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Sward structural characteristics and ingestive behaviour of beef heifers in a Pearl Millet pasture

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ABSTRACT - Ingestive behaviour of beef heifers and sward structural characteristics of Pearl Millet (*Pennisetum americanum* (L.) Leeke) were evaluated. The experiment was carried out in a randomized complete design following a repeated measure arrangement (three experimental periods) with three replications of two leaf blade masses (600 and 1,000 kg/ha DM), which were maintained using continuous grazing with variable stocking rate. The variables measured were sward height, herbage mass, leaf blade and stem bulk density in sward vertical strata (sward structural characteristics), grazing, idling, rumination time and bite rate of heifers (ingestive behaviour). Bite rate was modified by pasture management and was lower when the leaf blade mass was 1,000 kg/ha DM. The daily grazing, rumination and idling time of beef heifers were similar for both leaf blade masses. Structural variation of the sward, during the experimental period, altered the grazing, rumination and idling time of heifers, and affected the bite rate. In Southern Brazil, the beef heifers concentrate their grazing activities in the 12 p.m. to 6:00 p.m. period, decreasing the grazing between 12 a.m. and 6:00 a.m., even in the hottest season of the year.

Key Words: bite rate, grazing time, leaf blade bulk density, *Pennisetum americanum*, rumination time

Características estruturais do pasto e comportamento ingestivo de novilhas de corte em pastagem de milheto

RESUMO - Foi avaliado o comportamento ingestivo de novilhas de corte e as características estruturais do milheto (*Pennisetum americanum* (L.) Leeke). Utilizou-se o delineamento inteiramente casualizado com medidas repetidas no tempo (três períodos), duas massas de lâmina foliar (600 e 1.000 kg/ha de MS), mantidas por lotação contínua e com ajuste de carga, e três repetições. Avaliaram-se a altura do dossel, a massa de forragem, a densidade de lâminas foliares e colmos nos estratos verticais do pasto (características estruturais do dossel), os tempos de pastejo, ruminação e ócio e a taxa de bocados das novilhas (comportamento ingestivo). A taxa de bocados foi influenciada pelo manejo do pasto e foi menor quando a massa de lâmina foliar foi de 1.000 kg/ha de MS. Os tempos diários de pastejo, ruminação e ócio de novilhas de corte foram semelhantes entre as massas de lâmina foliar. As variações estruturais do pasto ao longo do tempo de utilização promoveram modificações nos tempos de pastejo, ruminação e ócio das novilhas e afetaram a taxa de bocados. Na Região Sul do Brasil, as novilhas concentram suas atividades de pastejo no período das 12 h às 18 h, diminuindo entre 24 h e 6 h, mesmo na estação mais quente do ano.

Palavras-chave: densidade de lâminas foliares, *Pennisetum americanum*, taxa de bocado, tempo de pastejo, tempo de ruminação

Introduction

Sward structural changes may be relevant to determine variations in forage intake and on animal grazing performance. The degree of animal selective grazing is influenced by the sward structural characteristics and the grazing efficiency determines the quantity of nutrients ingested (Carvalho et al., 2007).

The structure of the sward is defined as the result of the growing dynamic of the plants components in space (Carvalho et al., 2001). Forage mass, sward height and bulk density are structural characteristics that directly influence bite mass (Reis & Da Silva, 2006). When bite mass decreases, cattle are able to adjust their behaviour pattern in order to keep the level of intake compatible with their nutritional demands by increasing bite rate and grazing time in both

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temperate (Jamieson & Hodgson, 1979) and tropical pastures (Palhano et al., 2007).

A herbage mass is used in order to determine the pasture management, but the concept herbage mass does not have any relation with its components, such as the proportion of stems and leaves (Heringer & Carvalho, 2002), which vary immensely throughout the pasture cycle. Green leaf blade mass, more than forage mass, is the adequate indicator for forage species management (Maraschin, 2000). This statement can have more influence on grasses that, under favorable environmental circumstances, present high herbage accumulation in a short period of time such as Pearl Millet (*Pennisetum americanum* (L.) Leeke). Leaf dispersion along the sward, since leaves are preferred by grazing animals, will determine the mass of each bite and how easily each bite will be taken (Hodgson, 1990). Knowledge of the interaction between plants and animals helps management decisions because the grazing behaviour is modified by sward structure, which is also altered by the grazing process (Carvalho et al., 2001), and it may result in changes in tiller density and persistency (Hodgson, 1990).

This experiment was carried out to evaluate the effects of sward structural characteristics on the ingestive behaviour of beef heifers on Pearl Millet pasture managed at two leaf blade masses (600 and 1,000 kg/ha of DM).

Material and Methods

This study was carried out at the Departamento de Zootecnia of the Universidade Federal de Santa Maria (UFSM), Rio Grande do Sul, Brazil, in the Central Depression geographical region of Rio Grande do Sul state, Brazil (29º43'S, 53º42'W and altitude of 95m). The experimental period lasted from 12/31/2001 to 4/04/2002, totaling 94 days of pasture use.

The region has a humid subtropical climate (Cfa) according to the Köppen classification. Rainfall, global radiation and minimum, average and maximum temperature data during the experimental period were recorded at the Estação Metereológica do Departamento de Fitotecnia da UFSM (Figure 1).

The experimental area was divided up into six paddocks totalizing 6.0 ha. A contiguous 1.8 ha area was used as a grazing paddock for additional heifers added to or removed from the paddocks as required. The soil in the experimental area is classified as a Paleaudalf soil (EMBRAPA, 1999) and Pearl Millet (*Pennisetum americanum* L. Leeke) was sowed on 11/28/2001 by no till with 35 kg seeds/ha. Paddocks received 250 kg/ha fertilizer (5-20-20) and nitrogen (N) fertilization was 130 kg/ha, subdivided in three applications.

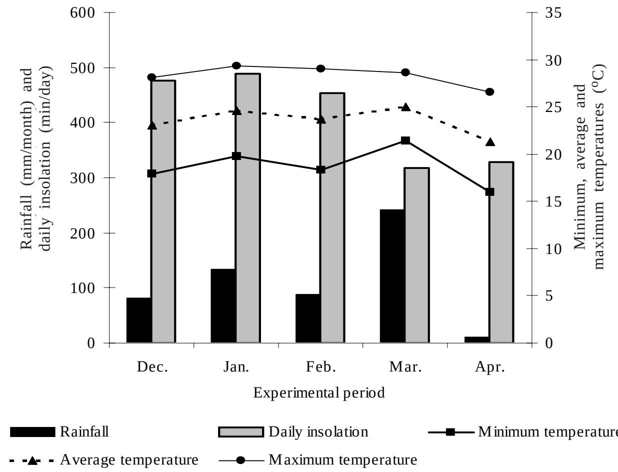

Figure 1 - Average monthly rainfall (mm), daily solar incidence (minutes), minimum, average and maximum temperature (°C) during the experimental period from December 2001 to April 2002

Treatments corresponded to two leaf blade masses (LBM): 600 and 1,000 kg/ha estimated at 15 days interval with equations for each treatment and period based on the double sampling technique ('t Mannetje, 2000) at 20 measurement points. Samples for these calibrations were cut as close as possible to the soil surface. Samples collected were separated into leaf blade, stems + sheath and dead material components and dried at 65º C, to determine the leaf blade expressed as sward percentage and LBM. Sward height (cm) was measured on the same measurement dates.

In order to maintain the intended leaf blade mass, grazing was carried out using Charolais and crossbred Nellore × Charolais heifers, approximately 14 months of age with 230 kg average initial body weight. The grazing method used was continuous with variable stocking rate (Mott & Lucas, 1952), with three testers per paddock and a variable number of additional heifers. The stocking rate was adjusted weekly, through visual assessments of herbage mass, and every fifteen days after double sampling technical evaluation. Experimental heifers had free access to water and mineral salt.

The herbage bulk density (kg/ha/cm DM) was evaluated (Stobbs, 1975b) on three areas of the sward per experimental unit that were representative of the intended leaf blade masses on 12/31/2001, 1/25, 2/21 and 4/4/2002, considering individual numbers to describe the sward condition. Leaf blade and stem bulk density were evaluated using the same methodology. Sampling was carried out using 1m^2 squares. In each square the herbage was cut considering four strata:

ground level to 15 cm; 15 to 30 cm; 30 to 45 cm; and above 45 cm from the ground. The evaluations were made from the top to bottom of the sward. All forage mass within the same strata were cut and weighed and, in the same experimental unit, samples were taken by strata which were separated into stems and leaf sheath, leaf blade and dead material components. The components were then dried in a forced air oven and weighed to calculate the bulk density of the components.

Ingestive behaviour was assessed by visual observation (Jamieson & Hodgson, 1979), at 10 minutes intervals in three continuous 48-hour periods (1/18-1/19; 2/15-2/16 and 3/15-3/16/2002). Three testers were observed in each paddock and their activities were classified as grazing, idling or ruminating. Bite rates (bite/minute) were evaluated in the same heifers throughout the grazing activity time by measuring the time taken by the animals to take twenty bites (Hodgson, 1982). Grazing frequency was calculated based on the numbers of animals grazing in each hour of evaluation, considering 100% when all animals present on each paddock were grazing.

A randomized complete design following a repeated measure arrangement was used (grazing periods), with two treatments (leaf blade mass) and three replications (paddocks). The total experimental period was subdivided into three periods, from 12/31/2001 to 1/25/2002 (1-26 days); from 1/26/2002 to 2/23/2002 (27-54 days) and from 2/24/2002 to 4/4/2002 (55-94 days). The following mathematical model was used to analyze pasture parameters:

$$Yijk = \mu + LBMi + Pj + Rk(LBM)i + (LBM*P)ij + \Sigma ijk$$

where Yijk = dependent variables; μ= mean of all observations; LBMi = effect of ith blade leaf mass; Pj = effect of jth period; Rk (LBM)i = effect of kth replicate within the ith leaf blade mass (error A); LBM*Pij = effect of ith leaf blade mass × jth period interaction; Σijk = experimental error (error B).

For animal behaviour related variables, the animals were also inserted in the model. Data were submitted to analyses of variance at the level of 5% significance by the F test and when differences were detected, means were compared by the Student t test (PDIFF). The analyses were carried out using SAS Mixed PROC (SAS, 1996).

Results and Discussion

There was leaf blade mass (LBM) × days of use interaction for sward height and herbage mass (P<0.05). Management with 1,000 kg/ha leaf blade DM, throughout the experimental period, resulted on the highest sward height and, within the 55-94 days of experimental period also the greatest herbage mass (Table 1). These interactions showed that the use of herbage mass or sward height values as a criteria in order to keep the intended LBM value might not be adequate because of changes in the leaf/stem ratio during the Pearl Millet cycle, which changed from 1.6 (1-26 days) to 0.6 (55-94 days). Increase in the sward stem contribution as growing season progressed was also reported in tropical grasses by Sbrissia & Da Silva (2001).

Herbage offer was similar in both leaf blade masses, with values of 12.4 and 14.5 kg of DM/100 kg LW, respectively, for leaf blade masses of 600 and 1,000 kg/ha DM. According to Hodgson (1982) the highest levels of intake and animal performance are related to forage offer values around twice or three times the herbivore´s daily DM nominal intake value. From available data, it appears that forage offer in both leaf blade masses probably did not limit DM intake by grazing animals.

In tropical forage grasses, in order to understand the forage grazing and intake process, in addition to the sward height, the mass and forage offer, plant component distribution along the sward vertical structure should also be considered (Carvalho et al., 2001; Roman et al., 2008). For leaf blade bulk density there was strata × leaf blade mass interaction (Table 2) and the 15 to 30 cm stratum showed the highest leaf blade bulk density (P<0.05) in both leaf blade masses evaluated.

The lowest leaf blade bulk density (P<0.05) occurred in both the upper and lower strata, regardless of the leaf blade

Table 1 - Sward height and herbage mass of Pearl Millet pasture managed at two leaf blade masses

Leaf blade mass (kg/ha DM)	Days after starting pasture utilization		
	1-26	27-54	55-94
		Sward height (cm)	
600	37.5b	27.5c	26.9c
1,000	49.2a	40.0ab	47.7a
		Herbage mass (kg/ha DM)	
600	1,367.8c	1,419.9c	1,574.1bc
1,000	1,836.0bc	2,299.9b	3,359.9a

Means with different lower case letters represent treatment × grazing cycle interaction by the PDIFF test (P<0.05)

Table 2 - Vertical strata × leaf blade mass interaction on leaf blade mass bulk density in Pearl Millet pasture managed at two leaf blade masses

Strata (cm)	Leaf blade mass	
	600	1,000
	Leaf blade bulk density (kg/ha/cm of DM)	
+ 45	-	19.6bc
30-45	18.4bc	26.3ab
15-30	22.9ab	29.1a
0-15	18.8bc	13.4c

Means with different lower case letters represent the strata × treatment interaction by the PDIFF test (P<0.05).

mass evaluated. However, the lowest leaf blade density in the upper stratum (Table 2) occurred due to the dispersion of emergent leaf blades and to the animal's selective intake, since grazing is done by stratum and the upper stratum is preferred because it is where the best quality forage is found (Carvalho et al., 2001). The lowest leaf blade density, found at the lower stratum of the canopy, from 0 to 15 cm, is the result of stem and dead material accumulation that normally occurs due to low luminosity and to the growth habit of the plant, which were also reported by Palhano et al. (2007b) and Roman et al. (2008).

Considering the leaf blade density, there was interaction between the vertical strata and evaluation dates of the pasture canopy structure in Pearl Millet managed at two leaf blade masses (Table 3).

The highest leaf blade density was observed in the 15-30 cm stratum on 12/30/2001, and the lowest densities were observed in the lower stratum (0-15) and at evaluations made on 3/21 and 4/4/2002 (Table 3). The average leaf blade mass observed in the lower stratum was 241.2 kg/ha DM, as a consequence of the arrangement of the leaves along the sward, which are distributed mainly in the upper stratum because they are the main photosynthetic apparatus of the plants, responsible for incident light absorption (Taiz & Zeiger, 2004). The highest leaf blade bulk density observed on 12/30/2001 reflected the initial pasture structure that grew without the influence of herbivores, and changed to a structure in which grazing was present. Selective grazing reduced leaf blade bulk density in all strata, in the following evaluations. Due to the short period of time planned for Pearl Millet pasture use, the specified targets for leaf blade mass were accomplished in the first evaluation period, and the structure was ready at the end of 21 days. Grazing caused the removal of most of the leaf blade available in the first evaluation, because animals prioritize grazing this component (Hodgson, 1990), which modified component distribution along the canopy. These densities, however, were all inferior to the ones observed in the 15 cm to 30 cm stratum on 12/30/2001, because plants not affected by grazing can have a larger number of leaves and the size of these leaves can be bigger in comparison to plants which are grazed frequently, and this exemplifies plant tolerance to herbivory mechanisms (Briske, 1991).

In the evaluation on 4/4/2002, the leaf blade bulk density was similar in all the strata, because of the considerable increase in the canopy with the advance of the Pearl Millet cycle and subsequent increase in dead material and stem participation, especially in the lower stratum (Roman et al., 2008). These changes reduced the leaf blade contribution (Table 2) due to flowering apex differentiation, when leaf blade/stem rates naturally decrease with stem elongation and decrease in leaf appearance and elongation rates (Skinner & Nelson, 1995).

Regarding the stem bulk density, there was interaction among vertical strata, leaf blade mass and evaluation dates (Table 4). The highest stem density (P<0.05) was observed from 0 to 30 cm at the end of experimental period on pasture managed with 1,000 kg/ha DM leaf blade mass (Table 4) and the lowest, in the stratum from 15 to 30cm in the first period of use on pasture managed with 600 kg/ha DM leaf blade mass.

Pearl Millet management with 600 kg/ha DM leaf blade mass promoted lower stem bulk density in the 0-45 cm stratum, throughout the whole experimental period (Table 4). When sward was managed with 1,000 kg/ha DM leaf blade mass, an increase in the stem bulk density above 15 to 30 cm (Table 4) was observed from March onwards. The increase in the stem bulk density makes it more difficult for animals

Table 3 - Strata × dates of evaluation interaction on leaf blade bulk density in the vertical strata in Pearl Millet (average of two leaf blade masses)

Strata (cm)	Date of evaluation				
	12/30/2001	1/25/2002	2/21/2002	3/21/2002	4/4/2002
	Leaf blade bulk density (kg/ha/cm of DM)				
+ 45	-	19.6bcd	-	-	-
30-45	34.1ab	23.8bc	22.6bc	17.5bcd	12.3d
15-30	44.1a	26.6bc	28.5b	19.1bcd	11.5d
0-15	19.2bcd	15.3cd	17.4bcd	12.1d	16.5cd

Means with different lower case letters represent the interaction between strata × dates of evaluation by the PDIFF test (P<0.05).

to reach leaf blades, which can modify bite depth and forage intake (Da Silva, 2006).

Maintaining 600 kg/ha DM leaf blade mass proved to be more efficient to control stem growth than management with a greater leaf blade mass. However, pasture management with lesser leaf blade mass could have forced the heifers to ingest more stem components while heifers on pastures with a bigger leaf blade mass had a better opportunity to select leaves instead of stems. Progress in Pearl Millet development and increase in of the stem elongation rate as a consequence of flowering (Skinner & Nelson, 1995) were also important as causes of higher stem bulk density on pasture managed with 1,000 kg/ha DM, which was observed from 3/21/2002 onwards.

Heifers kept on pastures with 1,000 kg/ha DM leaf blade mass showed the lowest (P<0.05) bite rate (Table 5). The leaf blade masses evaluated resulted in distinct sward structures, which were verified by the canopy heights, forage mass (Table 1), leaf blade bulk density (Table 2 and 3) and stems (Table 4). These differences caused different intake behaviours, since lower bite rates, such as those observed in animals kept on pastures managed with 1,000 kg/ha DM LBM are associated with heavier bites which require a longer time of apprehension and manipulation for each bite (Da Silva & Sarmento, 2005; Carvalho et al., 2007).

There was no difference (P>0.05) in grazing, rumination and idling time for heifers grazing Pearl Millet managed at the two evaluated leaf blade masses. Time dedicated daily to grazing was 490.2 and 483.7 minutes/day for leaf blade masses of 600 and 1,000 kg/ha DM, respectively. Changes in the ingestive behaviour, with higher bite rates at 600 kg/ha DM LBM (Table 5) were probably enough to compensate lower bite mass so there was no need to modify grazing time in the different sward structures (Tables 2, 3 and 4).

Daily grazing, rumination and idling time and heifer bite rate changed during Pearl Millet pasture use (Table 6), which was also reported by Carvalho et al. (2007). Changes in sward structure over time, according to these authors, also need to be considered in order to understand variables that rule the grazing process and forage intake. Horizontal (distribution of patches) and vertical (strata) structure variations could interfere and cause variation in animal grazing behaviour, even in single species pastures.

Interactions between leaf blade mass and days of pasture use for grazing, rumination and idling time and bite rate (P>0.05) were not observed. The longer time dedicated to grazing (P<0.05) in the first period (1-26 days) of pasture use is a reflex of the initial sward structure, as discussed, since the canopy was more open, with longer leaves, forcing the animals to apprehend them one by one, which results in more time needed to take the bites (Carvalho et al., 2001; Palhano et al., 2007). The lower bite rate observed during this period (Table 6) indicated that the animals needed more time to apprehend and manipulate the forage due to the leaf blade distribution in the vertical sward structure (Carvalho et al., 2001; Da Silva & Sarmento, 2005). The rumination time, longer in the 1-26 days period, was also affected by forage manipulation and apprehension activities, which are the factors that cause the major impact on the bite rate and mass and are basically determined by the grazed plant architecture (Carvalho, 1997), because, the longer the rumination time is, the larger will the bites taken by the grazing animal (Stobbs, 1975a).

Time dedicated to social interactions (idling) is inversely related to the grazing animal's need to keep up forage intake rates. Longer grazing and rumination times reduced time dedicated to idling (P<0.05), because they were excluding activities.

The average grazing frequency was 32.7 and 30.2%, respectively, for leaf blade mass of 600 and 1,000 kg/ha DM (Figure 2).

Three important grazing times peaks are usually observed: the first in the early morning, the second one at sunset and the third, generally shorter, at night (Bremm et al., 2005). The collected data (Figure 2) confirmed the observation that the first meal of the day of a grazing animal normally begins

Table 4 - Strata × sward structure × evaluation date interaction on stem bulk density in the vertical strata of Pearl Millet pasture managed at two leaf blade masses

Strata (cm)	Leaf blade mass (kg/ha of DM)									
	600					1,000				
	Date of evaluation									
	12/30/2001	1/25/2002	2/21/2002	3/21/2002	4/4/2002	12/30/2001	1/25/2002	2/21/2002	3/21/2002	4/4/2002
+ 45	-	-	-	-	-	-	-	-	-	-
30-45	-	10.4ghij	-	-	-	3.3ijk	7.2ghij	9.2ghij	24.8cdefghi	49,7bc
15-30	0.66j	33.4cde	3.5ijk	8.4ghij	7.4ghij	2.5hjk	16.4efghij	16.8efghij	22.6cdefghi	66,3a
0-15	13.0fghi	41.8bc	11.8ghij	23.7cdefghi	31.8cdef	15.3efghij	26.5cdefg	17.6defghij	36.0cd	57,4ab

Different lower case letters represent the treatment × evaluation date × strata interaction by the PDIFF test (P<0.05).

Table 5 - Pearl Millet leaf blade mass and bite rate of grazing beef heifers

Variables	Target leaf blade mass (kg/ha DM)		CV (%)
	600	1,000	
Actual leaf blade mass (kg/ha of DM)	641.7b	1,023.8a	26.0
Bite rate (bite/minute)	41.1a	37.0b	15.7

Means followed by the same lower case letters on the line are not different (P>0.05) by the PDIFF test.

minutes after sunrise, around 6 a.m (Carvalho et al.. 2005) after the animals have been through a long period of grazing inactivity during the night, when the rumination process prevails as activity and the rumen empties what had been previously ingested. At both leaf blade masses, a higher grazing frequency occurred between 6 am and 7 pm (26% between 6 a.m. and 12 p.m and 32% between 12 p.m and 6 p.m) and decreased progressively with the beginning of the night, restarting between 11 p.m. and 1 a.m. (16% of the total grazing time), in a similar way to that observed by Bremm et al. (2005) in Italian ryegrass pasture. The highest temperature was 28.3°C during the experimental period (Figure 1) and it seems that this did not affect the grazing activity of the animals on pasture, because decrease in the grazing frequency during the hottest hours of the day, from 10 a.m. to 4 p.m., was not observed.

Table 6 - Grazing, rumination and idling daily times, in minutes/day and beef heifers bite rate (bites/minute) during the period of use of Pearl Millet pasture (average of two leaf blade masses)

Variable	Days after the start of pasture use			CV (%)
	1-26	27-54	55-94	
Grazing	549a	456b	457b	18.5
Rumination	547a	479b	480b	10.5
Idling	282b	442a	443a	16.5
Bite rate	24.9b	46.5a	46.7a	15.7

Means followed by the same lower case letters on the line are not different (P>0.05) by the PDIFF test.

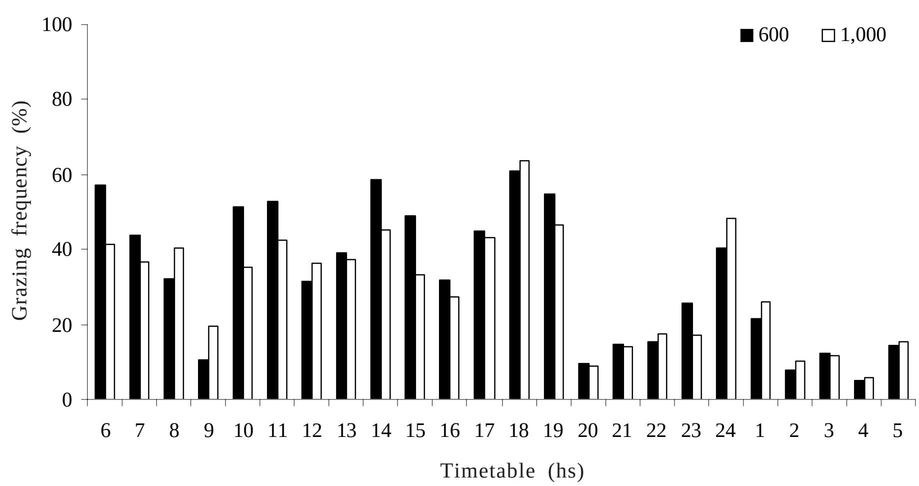

Figure 2 - Grazing frequency (% of grazing heifers) on Pearl Millet managed at two leaf blade masses.

Conclusions

The instantaneous structure of Pearl Millet sward, represented by leaf blade mass, influenced grazing animals´ bite rate. Bite rates were higher in the lower sward leaf blade masses evaluated. Beef heifer grazing, rumination and idling time did not change when the value of the leaf blade mass varied from 600 to 1,000 kg/ha DM. Bite rate modifications are enough to establish the same level of dry matter intake for grazing animals, even with different sward structure, promoted by differences in sward height, leaf blade mass and vertical distribution of the sward components. The structural variations over time (pasture cycle) modify animal grazing and rumination time and affect bite rates.

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