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RESEARCH ARTICLE

Changes in the milk response to different herbage mass of dairy cattle in a tropical climate

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ABSTRACT

The interaction between pasture and supplementation in dairy production systems constitutes a very important part of the efficiency of dairy. This study evaluated the effect of the herbage mass (HM) on the milk production and solid concentration. Twenty Holstein cows were distributed into two groups, 10 assigned 2200 kg DM ha^{-1} (low herbage mass, LHM) and 10 with 2800 kg DM ha^{-1} (medium herbage mass, MHM). Herbage mass was measured above 5 cm. The experiment lasted 8 wk. The variables evaluated were DM intake (DMI), milk production and composition (fat and protein concentration). Effects of treatments on variables were evaluated using a repeated measure analysis over time. The results showed nonsignificant differences in the pasture DMI between LHM and MHM for weeks 1, 2, 3 and 5 ($P > 0.05$). During week 4, pasture DMI was 3 kg greater for LHM than MHM ($P < 0.05$). The milk production did not differ between treatments per week, but the average was 2.4 kg greater for LHM compared to MHM ($P < 0.05$). In conclusion, changes in the pasture availability increased milk production at LHM, but not enough to cause changes in solids concentration. This clearly shows that, LHM can increase milk and solids production.

Key words: Intake, milk yield and composition, pasture allowances.

INTRODUCTION

The pasture-based dairy production systems have low operating costs compared to feedlot systems; nevertheless, the cost of land is expensive (Dillon et al., 2005; Ramsbottom et al., 2015). For this reason, it is essential to dilute the cost of the land in a higher milk production per hectare (Macdonald et al., 2017). However, in many tropical livestock regions, the low DM availability and poor nutritive value of pastures severely limit animal production. Different strategies have been adopted to improve pasture production and quality by changing the availability of resources such as water and fertilizers, soil structure and botanical composition, and controlling the intensity and frequency of grazing (Pulina et al., 2018).

Despite the limited DM intake (DMI) and milk production from pasture-based systems, grazing is the cheapest food source, therefore, it is important to evaluate strategies that maintain herbage as the main diet component (Beltrán et al., 2019) to take advantage of the genetic merit of animals that graze pastures with medium nutritive value. In this situation, supplementation with concentrate food takes importance, which is an effective strategy for satisfying seasonal deficiencies in pasture production (Schöbitz et al., 2013) and meeting the nutritive requirements of animals with high/medium genetic merit (Pulido et al., 2010).

However, despite obtaining good results in milk production, supplementation with concentrate food causes changes in the ingestive behaviour of grazing animals (Bargo et al., 2003), decreasing the pasture DMI (Beltrán et al., 2019), which generates a greater dependence on this type of supplement. The animal response (beef or milk) is sometimes also affected by using concentrates (Auldist et al., 2013). From the nutritional point of view, concentrate supplements can cover the nutritional requirements to complement metabolic energy (ME) levels that animals have not been able to intake from the pasture and which are essential to achieve productive dairy goals (Bargo et al., 2003).

Herbage mass has been considered a key factor in determining the herbage DMI and animal performance in response to its direct effect on grazing behaviour and herbage chemical composition (Pérez-Prieto and Delagarde, 2012). Normally, herbage mass (HM) is expressed in kg DM ha^{-1} and refers to the plant material above ground level (0 or 5 cm above ground level; according to methodology) and maintains a close relationship with the pasture height (Cárdenas et al., 2020). The HM is dynamic and changes permanently in growth rate, senescence, defoliation frequency and carbohydrate concentration (Calvache et al., 2020). For these reasons, the estimation is only valid at the determined moment.

Several studies (Pérez-Prieto and Delagarde, 2012; Beltrán et al., 2019) have reported that DMI and milk production increased with HM (measured at ground level), supporting that herbage is a management tool directly related to farming decisions (Pérez-Prieto and Delagarde, 2012) and profitability of the pasture-based dairy cattle systems.

However, the interaction between HM and supplementation does not consider many pasture-based dairy systems, especially under tropical conditions. This could be due mainly by the knowledge of HM and nutritive value, which can decrease the use of concentrates, reducing the production costs associated with a higher economic return rate for the system. To test the hypothesis that low HM does not affect DMI or milk production in tropical conditions, this study aimed to evaluate the changes in the DMI, and animal response (milk composition and production) of cows feeding with low herbage mass (LHM) *vs*. medium herbage mass (MHM) and supplemented with concentrate.

MATERIALS AND METHODS

The experiment was conducted for 8 wk in 2014, between August and September. The first 3 wk corresponded to the adaptation period of the animals to the different herbage masses (HMs), and the remaining 5 wk were the sampling time. There is no ethics committee approval because the animals were not subjected to any invasive process and animal integrity was never affected, nevertheless the experimental protocol considered the three Rs and the five freedoms.

The study area of experiment was carried out at the La Esmeralda farm (4°48′34″ N; 74°06′09″ W; 2984 m a.s.l.), located in the municipality of La Calera, Colombia. The climate is considered tropical and fully humid according to Koppen-Geiger classification, presents mean annual temperature of 15 °C and annual rainfall of 1158 mm, with two cycles of rain (bimodal), concentrating rainfall during February to May and August to November.

Experiment design and treatments

Twenty Holstein cows with similar physiological conditions (540 ± 50 kg body weight, BW), (3.5 body condition score; BCS), days in milk (DIM; 85 ± 13) and production (25 ± 5 L milk d^{-1}) were randomly distributed into two treatments: Low herbage mass (LHM) 2200 kg DM ha^{-1} and medium herbage mass (MHM) 2800 kg DM ha^{-1}. Herbage mass (HM) was measured above 5 cm. The pasture allowance for both treatments was calculated at 6 kg DM 100 kg^{-1} BW d^{-1}, corresponding to 147 and 115 m^2 cow^{-1} d^{-1} for LHM and MHM, respectively.

Pasture and grazing management

The polyphytic pasture used in this study was established in 2013. It was composed of 80% ryegrass (*Lolium perenne* L.), 17% kikuyu (*Cenchrus clandestinus* (Hochst. ex Chiov.) Morrone) and 3% other species. Both HMs were calculated using the Rising Plate Meter (RPM F400, Farmworks Systems Ltd., Feilding, New Zealand), with the equation developed by Cárdenas et al. (2020) for mixed pastures in Colombia. The equation used is as follows:

$$\text{kg DM ha}^{-1} = 79.7(\text{CH}) + 319.7 \ (r^2 = 0.85)$$

where CH is the compressed height in cm.

The animals grazed in the same paddock, but each treatment was separated by 3 m of distance and with an electric fence. All cows had access to fresh pastures after morning milking and according to the assigned treatment. A new pasture break was allocated to LHM and MHM cows immediately after milking at 06:00 h. The strip was changed the next day after the morning milking; therefore, they returned to the same strip after the afternoon milking. Each estimation considered 50 compressed sward height measurements by walking through the herbage in a 'W' pattern.

To allow a difference of 600 kg DM ha^{-1} between treatments, 9 d before starting the experiment, all paddocks were grazed successively by non-experimental cows. Every time that herbage in the paddock grew up to 2200 kg DM ha^{-1}, 70% of each paddock was again grazed by non-experimental cows and then used for the LHM treatment. The remaining 30% of each paddock was again grazed when herbage grew to 2800 kg DM ha^{-1} and used for the MHM treatment.

Supplementation

The concentrate supply was calculated at the rate of 1 kg concentrate per 4 L milk. The corresponding quantity of concentrate for each cow was supplied at the milking time; thus, it was supplied twice a day, at 04:00 and 14:00 h.

The apparent intake of the concentrate was measured according to the following:

$$AIc = C_{offered} - (C_{residual} - C_{wasted})$$

where AIc is apparent intake in kg DM of concentrate; $C_{offered}$ is kg concentrate offered, $C_{residual}$ is kg concentrate left in the feeder and C_{wasted} is kg concentrate outside the feeder but belonging to the one offered.

Milk and pastures

Daily milk production was recorded with an automated system (MPC580; DeLaval, Tumba, Sweden). Milk samples were collected during morning and afternoon milking. The milk solids concentration was measured twice a week (Monday and Friday), taking a sample of the compound and homogenized milk from the morning and afternoon milking. Samples were transported to the Nutrition Laboratory at the University of La Salle, Bogotá, Colombia, where fat and protein concentrations were estimated by a LactoStar-milk analyzer (3500, Funke Gerber, Berlin, Germany). The kilograms of fat and protein produced were calculated with the percentages obtained in the composition analysis and multiplied by the volume produced per animal.

Once per week during the experiment, botanical composition was measured by clipping and hand-sorting plants in each treatment. Due to the homogeneity of the pasture during the experiment, once during the experiment, at week 3 of sampling, a pasture sample and concentrate were taken to the Animal Nutrition Laboratory of La Salle University to determine nutritive value using wet chemistry according to AOAC (2016). The variables measured were crude protein (CP), non-structural carbohydrate (NSC), crude fiber (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF), metabolizable energy (ME) and total digestible nutrients (TDN).

Pasture intake

The apparent pasture intake (API) expressed in kg DM cow^{-1} d^{-1} was calculated using the pre- and post-grazing HM. Pre-grazing HM was measured the previous day to start the grazing for each event, and breaks were marked out based on post-grazing cover (above ground level) targets of 1200-1500 kg DM ha^{-1}. The apparent pasture intake (API) (kg cow^{-1} d^{-1}) was then calculated using the following equation:

$$API = \frac{(HMpre - HMpost) \times area\ (ha)}{(Nr\ cows)}$$

where HMpre is pre-grazing HM and HMpost is post-grazing HM.

Statistical analysis

Milk production, milk composition and DM intake were analyzed using the MIXED procedure of SAS (PROC MIXED; SAS Institute, Cary, North Carolina, USA). The model included the fixed effect of treatment, random effect of cows, day of sampling as a repeated measure and interaction between treatment and day of sampling. The covariance structure (Littell et al., 1998) was based on the probability test and the Akaike information criterion test according to (a) no structure, (b) compound symmetry (CS), (c) heterogeneity of compound symmetry (HCS), (d) Toeplitz (TOEP) and (e) Toeplitz heterogeneity (HTOEP). Botanical composition for each treatment during the experiment was analyzed as repeated measures too. Prior to analysis, all data were checked for normality and homogeneity of variances. When there were significant differences ($P < 0.05$), a multiple mean comparison test (LSMEANS) was performed with the PDIFF command. Results were considered significant at $P < 0.05$, and tendency at $P < 0.1$.

RESULTS

Botanical composition and nutritive value of the pasture and concentrate

The botanical composition (BC) of the pasture remained constant during the 5 wk of sampling (Figure. 1), with *L. perenne* being the species that predominated with an average of 83% of participation in the grassland, followed by *C. clandestinus*, with 10% participation and finally other species, with 7%. Considering that during the 5 wk of treatment, the balance in BC was maintained, and the pastures of LHM and MHM were kept in the same vegetative state, the nutrient concentration variation in the pasture remained constant during the experiment.

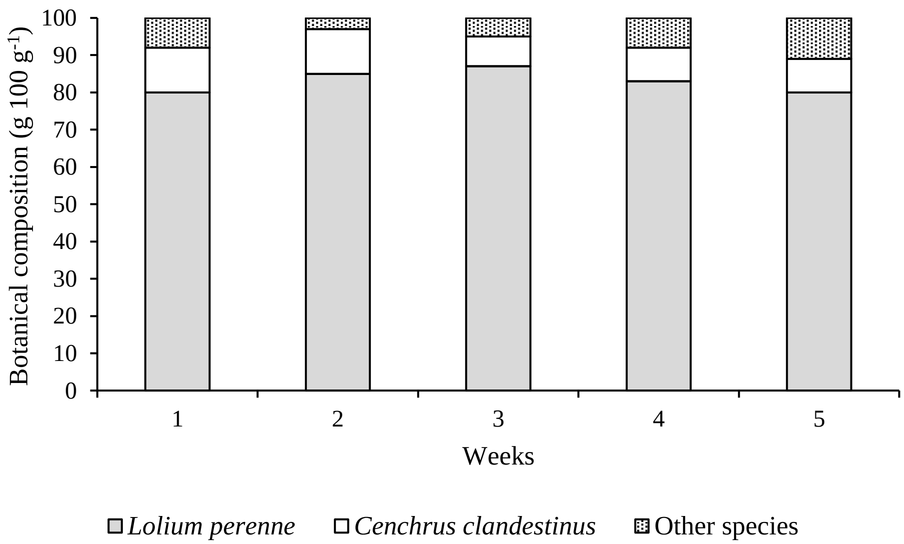

Figure 1. Changes in the botanical composition of the pasture during the experiment.

The nutritive value of pasture and concentrate results are presented in Table 1. Both HMs presented similar characteristics, specifically in NSC, NDF, ADF, DM, and TDN. The CP concentration was slightly higher in MHM, exceeding the CP of LHM by 5 percentage units. The opposite case happened with ME, with LHM presenting the highest concentration compared to MHM (+14%). The concentrate was the one with the best concentration of ME, exceeding LHM by 25% and MHM by 34%, while the CP concentration of the concentrate was slightly lower than both HMs. The common factor between LHM, MHM and the concentrate was the concentration of NSC, given that the values for these three ranged between 25.7 and 28 g kg^{-1} DM.

Table 1. Pasture and concentrate nutritive value based on DM. LHM: Low herbage mass 2200 kg DM ha^{-1}; MHM: medium herbage mass 2800 kg DM ha^{-1}.

Nutrient	LHM	MHM	Concentrate
DM, g 100 g^{-1}	22.0	17.0	87.0
Crude protein, g 100 g^{-1}	19.0	24.0	18.0
Cellulose, g 100 g^{-1}	21.0	15.0	-
Hemicellulose, g 100 g^{-1}	18.4	26.8	-
Non-structural carbohydrate, g kg^{-1} DM	27.4	25.7	28.0
Crude fiber, g 100 g^{-1}	-	-	12.0
Neutral detergent fiber, g 100 g^{-1}	65.8	67.8	-
Acid detergent fiber, g 100 g^{-1}	32.0	38.0	-
Ash, g 100 g^{-1}	12.0	14.0	6.0
Metabolizable energy, Mcal kg^{-1} DM	2.4	2.1	3.2
Total digestible nutrients, g 100 g^{-1}	65.0	61.0	-

Herbage mass and DM intake

Results of CH and HM per week for each treatment are in Table 2. There were no differences (P > 0.05) between the weeks for any treatments for HM and CH (P > 0.05). However, it was observed that HM was lower for LHM (2155 kg DM ha^{-1}) than MHM (2798 kg DM ha^{-1}). Regarding the post-grazing residue, a difference was observed between treatments of 140.4 kg DM ha^{-1}, favouring the MHM treatment. Likewise, the CH measured with the RPM remained constant during the week, presenting minor treatment variations, but between LHM and MHM, the CH at the beginning of grazing was higher for the MHM with 8.3 cm more than the LHM.

Table 2. Compressed height (CH) and herbage mass (HM) per week for low herbage mass (LHM) and medium herbage mass (MHM) at the beginning and ending of grazing. Average ± standard error, average is the result of 50 replicates per treatment. LHM: Low herbage mass; MHM: medium herbage mass; CH: compressed height by rising plate meter.

	LHM				MHM			
	Pre-grazing		Post-grazing		Pre-grazing		Post-grazing	
Week	CH	HM	CH	HM	CH	HM	CH	HM
	cm	kg DM ha^{-1}	cm	kg DM ha^{-1}	cm	kg DM ha^{-1}	cm	kg DM ha^{-1}
1	23.1 ± 0.3	2160 ± 27.9	11.2 ± 0.5	1216 ± 44.6	30.8 ± 1.0	2769 ± 83.7	16.1 ± 0.2	1599 ± 16.7
2	23.1 ± 0.2	2220 ± 22.3	11.1 ± 0.9	1208 ± 78.2	31.2 ± 0.2	2875 ± 16.7	14.5 ± 1.2	1447 ± 90.0
3	22.7 ± 0.1	2125 ± 11.1	11.9 ± 0.3	1276 ± 27.9	30.1 ± 0.4	2686 ± 39.1	13.7 ± 1.1	1414 ± 89.3
4	21.9 ± 0.4	2066 ± 39.1	11.1 ± 0.9	1599 ± 16.7	31.4 ± 1.4	2816 ± 37.3	15.2 ± 0.1	1532 ± 11.1
5	23.1 ± 0.9	2208 ± 72.6	10.9 ± 0.7	1260 ± 72.6	31.8 ± 0.4	2848 ± 39.1	13.9 ± 0.3	1434 ± 27.9

The Figure 2 shows the pasture DMI for the experimental period. Cows on LHM treatment had a greater DMI of pasture (P < 0.05) than those on MHM treatment. There was an affect of the main factor week on DMI of pasture with LHM being greater than MHM on weeks 1, 3, 4, and 5. In fact, the average of DMI was major for the cows LHM *vs*. MHM, exceeding by 10.7% the intake.

The total DMI did not differ between treatments for weeks 1, 2, 3 and 5 (P > 0.05), except for week 4 (P < 0.05; Figure 3), surpassing the treatment of LHM in 4.8 kg DM cow^{-1} than MHM. Therefore, on average, during the 4 wk, cows grazing LHM pastures consumed approximately 1.54 kg DM cow^{-1} d^{-1} more than those that grazed MHM.

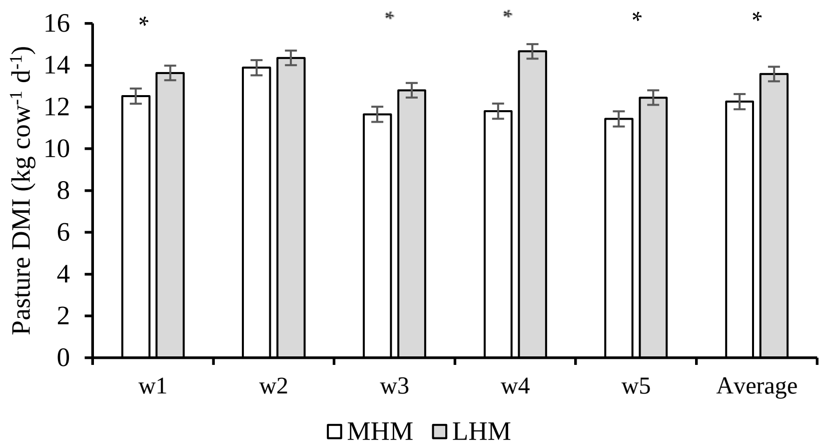

Figure 2. Pasture DM intake (DMI) of cow with medium herbage mass (MHM, 2800 kg DM ha^{-1}) and low herbage mass (LHM, 2200 kg DM ha^{-1}). Bars: Standard error; w: week; *significant difference between treatments in week (w).

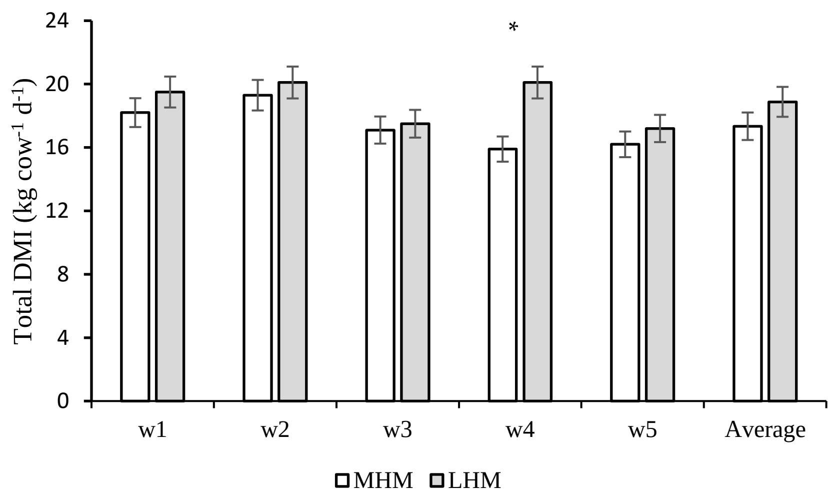

Figure 3. Total DM intake (DMI) of cows with different allowance of grass; medium herbage mass (MHM, 2800 kg DM ha^{-1}); low herbage mass (LHM, 2200 kg DM ha^{-1}). Bars: Standard error; *significant difference between treatments in week (w).

Energy and protein intake

Figures 4 and 5 show the ME and CP intake, respectively. Both figures are directly related to the total DMI, where it can be observed that ME intake did not differ among treatments ($P > 0.05$) for weeks 1, 2, 3 and 5. However, during week 4, there was a significant difference ($P < 0.05$), with the highest ME intake for LHM ($P < 0.05$). The MHM presented the numerically highest CP intake in weeks 1, 2, 3 and 5, being significantly higher with the LHM only in weeks 2 and 3, and exceeding CP intake in the MHM in 0.64 and 0.6 kg cow^{-1} d^{-1}, respectively. On average, the LHM consumed 50.3 Mcal ME and 3.6 kg CP d^{-1}, whereas the MHM consumed 43 Mcal ME and 4.0 kg CP d^{-1}.

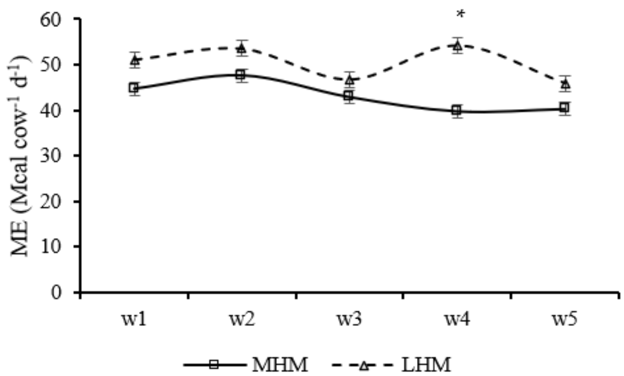

Figure 4. Metabolizable energy intake for cows with medium herbage mass (MHM, 2800 kg DM ha^{-1}) and low herbage mass (LHM, 2200 kg DM ha^{-1}). Bars: Standard error; *significant difference between treatments in week (w).

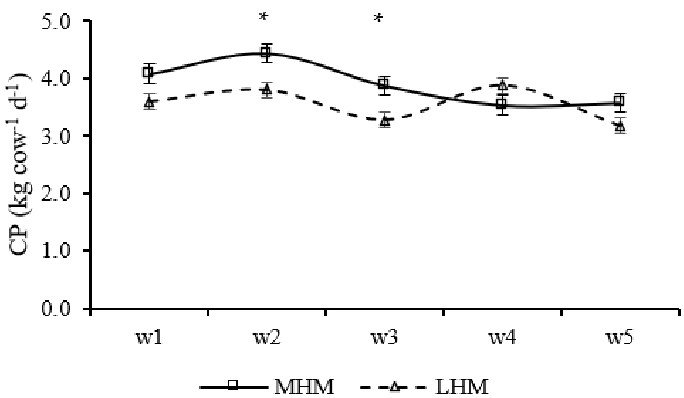

Figure 5. Crude protein (CP) intake for cows with medium herbage mass (MHM, 2800 kg DM ha^{-1}) and low herbage mass (LHM, 2200 kg DM ha^{-1}). Bars: Standard error; *significant difference between treatments in week (w).

Milk production and composition

Milk production did not differ between LHM and MHM throughout the weeks (P > 0.05, Table 3). However, the average production for the measurement period was the statistical difference between HM (P < 0.05, Table 3), where it was observed that the low supply of pasture (LHM) was exceeded by approximately 2.4 L cow^{-1} d^{-1}. The interaction between time (weeks) and HM did not have significant effects (P > 0.05).

The concentration of fat in milk was similar between treatments for all weeks (P > 0.05, Table 4), but on week 4, there was a statistical trend (P = 0.077) higher for the LHM (+0.25) than the MHM. Otherwise, fat production was expressed in kg cow^{-1} d^{-1}. In week 4, there was a significant difference (P < 0.05) in favour of the LHM overcoming 17% compared to MHM. Weeks two and five presented a significant trend (P = 0.08 and 0.07, respectively) favouring LHM. The average concentration and production were significant between HM (P < 0.05, Table 4), surpassing by 0.25 percentage units the LHM to the MHM for fat concentration. Fat production was better in LHM, with 160 g cow^{-1} d^{-1} more than in MHM.

In contrast to fat production and concentration, the milk protein did not present differences or statistical trends (P > 0.05, Table 5) between the treatments for any of the evaluated weeks. Only milk protein had a significantly different average (P < 0.05, Table 5), with the highest in LHM treatment by 150 g cow^{-1} d^{-1} compared to the MHM.

Table 3. Milk production of cows with low herbage mass (LHM) and medium herbage mass (MHM). Daily average ± standard error, the average is the result of 10 replicates per treatment each week. *7 d considered per week.

Week*	LHM	MHM	P-value
	$L\ d^{-1}\ wk^{-1}$		
1	31.8 ± 6.3	30.2 ± 5.8	0.55
2	32.8 ± 5.8	29.9 ± 6.1	0.30
3	32.7 ± 5.7	30.1 ± 7.0	0.38
4	32.9± 5.5	29.1 ± 5.9	0.29
5	30.7 ± 5.7	28.5 ± 4.1	0.35
Average	31.1 ± 0.7	28.7 ± 0.75	0.04

Table 4. Fat concentration and production of cows with low herbage mass (LHM) and high herbage mass (MHM). Daily average ± standard error, the average is the result of 10 replicates per treatment each week; *2 d considered per week (Monday and Thursday).

	Concentration			Production		
Week*	LHM	MHM	P-value	LHM	MHM	P-value
	$g\ 100\ g^{-1}$			$kg\ d^{-1}$		
1	3.79 ± 0.32	3.55 ± 0.32	0.12	1.16 ± 0.22	1.03 ± 0.20	0.20
2	3.76 ± 0.38	3.50 ± .039	0.16	1.19 ± 0.24	1.00 ± 0.21	0.08
3	3.78 ± 0.36	3.54 ± 0.35	0.16	1.19 ± 0.20	1.03 ± 0.25	0.14
4	3.90 ± 0.30	3.65 ± 0.29	0.07	1.2 ± 0.16	1.02 ± 0.16	0.03
5	3.88 ± 0.40	3.63 ± 0.40	0.19	1.15 ± 2.12	1.00 ± 0.14	0.07
Average	3.82 ± 0.05	3.57 ± 0.05	0.01	1.18 ± 0.02	1.02 ± 0.03	0.01

Table 5. Protein concentration and production of cows with low herbage mass (LHM) and high herbage mass (MHM). Daily average ± standard error, the average is the result of 10 replicates per treatment each week; *2 d considered per week (Monday and Thursday).

	Concentration			Production		
Week*	LHM	MHM	P-value	LHM	MHM	P-value
	$g\ 100\ g^{-1}$			$kg\ d^{-1}$		
1	3.3 ± 0.15	3.1 ± 0.14	0.62	0.96 ± 0.19	0.91 ± 0.18	0.50
2	3.1 ± 0.18	3.1 ± 0.12	0.81	0.99 ± 0.17	0.90 ± 0.17	0.25
3	3.2 ± 0.27	3.2 ± 0.20	0.94	1.01 ± 0.15	0.93 ± 0.20	0.36
4	3.3 ± 0.37	3.3 ± 0.35	0.96	1.02 ± 0.16	0.92 ± 0.13	0.16
5	3.2 ± 0.53	3.2 ± 0.38	0.79	0.96 ± 0.18	0.88 ± 0.15	0.33
Average	3.2 ± 0.06	3.19 ± 0.06	0.73	0.99 ± 0.02	0.91 ± 0.02	0.03

DISCUSSION

Dry matter intake

In the current experiment, the lack of differences in the pasture DMI between low and medium HM can be related to the deeper grazing for LHM compared to MHM (5.6 *vs*. 7.3 cm post-grazing height, respectively), suggesting that cows in LHM were able to graze more intensely the lower herbage fraction (Beltrán et al., 2019), resulting in a different pasture DMI average. Our results are supported by Pérez-Prieto et al. (2011), who found that herbage intake is reduced by 0.65 kg DM as herbage is increased by 1000 kg DM ha^{-1} HM (measured at 5 cm).

Regarding total DMI, there were nonsignificant differences; this could have occurred due to the little difference (600 kg DM ha^{-1}) between HM. Similar results were reported by Chilibroste et al. (2015), where an HM difference of 1000 kg DM ha^{-1} plus supplementation was not enough to modify the total DMI. Piña et al. (2020) evaluated the DMI by different grazing sessions, with a difference between treatments of 600 kg DM ha^{-1}, the same as in the present study, but with different heights and HM. They reported nonsignificant differences in the total DMI regardless of the height. However, a meta-analysis by Pérez-Prieto and Delagarde (2013) found that pasture DMI was increased by 0.65 kg t^{-1}, measured above 4-5 cm, supporting that a 600 kg DM difference was not enough to modify total DMI.

On average, the difference in the HM was given by 8.4 cm CH calculated with the RPM. Height is not enough to cause a modification in grazing time, alter the ingestive behaviour and modify the total DMI (Chilibroste et al., 2015). Generally, a difference in total DMI requires an HM over 3200 kg DM ha^{-1} or below 2200 kg DM ha^{-1} (Mezzalira et al., 2014). These values (that also modify the pasture architecture) have a noticeable effect on nutritive value (Keim et al., 2015), given that pastures can be excessively mature or in an early vegetative state.

The differences found for the total DMI in week 4 (Figure 3) were more influenced by pasture intake than by supplement intake due to the supplement intake remaining stable between weeks (Figure 2). This was unlikely for week 4, where the LHM presented a higher DMI. It could probably be influenced by the fact that when they entered the paddock at week 4, in the LHM strip, the pasture was lower than other weeks (Table 2). This increased the area offered to animals, increasing the herbage fraction available to cows (2.5-5.0 cm) and increasing the pasture DMI (Pérez-Prieto and Delagarde, 2013).

Similar results were reported by Curran et al. (2010). They demonstrated that pasture intake increases when the availability of pasture is low for grazing dairy cows, with a difference between treatments of approximately 800 kg DM ha^{-1}. The same difference occurred for week 4 in the present study. Another explanation for the difference in pasture DMI is that pastures in an early phenological stage have higher ME content, better digestibility and CP and low concentration of NDF and ADF (Calvache et al., 2020). These factors make grazing this type of pasture increase the DMI (Fulkerson and Donaghy, 2001). Therefore, the effect of HM (measured above 5 cm) on pasture DMI depends on differences in the HM between treatments and the chemical composition of the pasture.

The total DMI for LHM and MHM was an average of 18 kg cow^{-1} d^{-1}. This is a relatively regular intake for the kind of animals studied in the experiment and their milk production level, agreeing with the majority of authors who have measured total DMI of dairy cows with different HMs (Bargo et al., 2003; Pulido et al., 2010). However, it should be noted that the intake reported in this manuscript is an "apparent" intake based on the methodology used. However, with more precise methodologies, the intake value could vary.

This study shows that the DMI of cows fed under different, non-contrasting pasture availabilities (i.e., 600 kg DM ha^{-1}). This result can be related to the numerically greater pasture DMI for LHM compared to MHM, which is expected in studies measuring HM above 5 cm, where pasture DMI is increased as HM is reduced (Pérez-Prieto and Delagarde, 2013).

Milk production and fat and protein concentration

On average, the treatment that received LHM had higher milk production than the MHM, but this difference was insignificant for any of the weeks. This was coherent with the DMI from the pasture, with nonsignificant differences. Hence, the cows in the LHM had a greater ME intake, like NSC did, which is directly associated with milk production (Reis and Combs, 2000; Muñoz et al., 2016). Generally, pastures with higher compressed height are associated with lower nutritive value because they are in a more advanced phenological stage (Lee et al., 2008). Similar results were reported by Pérez-Prieto et al. (2011), where cows receiving an LHM had greater milk production and milk protein compared to high HM (measured at 5 cm), which could be explained by the greater pasture DMI. Nevertheless, this small difference in favour of the LHM could become important when it is considered at the herd level and per unit area since, in this case, the economic return is greater (Loughrey et al., 2015; O'Sullivan et al., 2020).

Average milk fat and protein production expressed in kg d^{-1} showed a significant difference in favour of LHM, which could be associated with consumption since cows that grazed LHM pastures consumed more DM than those with MHM, for which they produced more milk and therefore more kilograms of fat and protein. Pérez-Prieto and Delagarde (2012) explain that cows grazing in pastures with LHM have a greater option of a surface with pastures in an early phenological state, increasing the digestible fraction of the pasture and allowing the cows to consume more food of better quality.

Despite differences in fat and protein production in milk, their concentrations did not differ between treatments. Milk protein concentration is a complex variable to modify (Walker et al., 2004), which occurred in this study, where changes in the HM could not cause a high difference in ME intake, which has been positively related to the milk protein concentration (Walker et al., 2004). Although ME intake was greater for LHM, it was not enough to modify the milk protein, given that it is a variable that, besides being measured by the genetic merit (Scholtens et al., 2020), needs large amounts of non-structural carbohydrates to increase its concentration in milk (Mordenti et al., 2021). Nevertheless, a slight raise in milk protein concentration can positively affect economic profitability, given that it is the most expensive nutrient paid by the dairy industry.

CONCLUSIONS

When herbage mass (HM) is measured at 5 cm, low herbage mass (LHM) can increase milk and solids production (protein and fat, expressed as kg d^{-1}), despite pasture and total DM intake not being modified, suggesting that LHM increased energy intake. Therefore, HM can be used as a grazing management strategy to improve milk and solid production in grazing dairy cows under tropical conditions. The total DMI was not affected by the differences between the HMs, although pasture DMI did present significant differences on average between the HMs.

Author contribution

Conceptualization: I.C., O.B., A.N. Methodology: I.C., I.B., O.B., R.P. Software: I.C., L-A.V., A.N. Validation: O.B., R.P. Formal analysis: I.C., I.B., O.B., R.P. Investigation: I.C. Resources: A.N., L-A.V. Data curation: I.C., I.B., O.B. Writing-original draft: I.C., I.B. Writing-review & editing: O.B., R.P., L-A.V., A.N. Visualization: I.C., I.B., O.B., R.P., L-A.V., A.N. Supervision: I.C., I.B., O.B., R.P., L-A.V., A.N. Project administration: I.C. Funding acquisition: I.C. All co-authors reviewed the final version and approved the manuscript before submission.

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