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Effect of herbage allowance on grazing behavior and productive performance of early lactation primiparous Holstein cows

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ABSTRACT

Effects of daily herbage allowance (DHA) on milk production and composition, body condition score (BCS) and grazing behavior of primiparous Holstein cows during early lactation were investigated. Cows were blocked by body weight (BW), age and BCS, and randomly assigned within block to one of three grazing treatments ($n = 11$ cows each) being: high (HA, 30 kg DM/cow/d), medium (MA, 15 kg DM/cow/d) and low (LA, 7.5 kg DM/cow/d) DHA. Cows were grazed in 8 consecutive grazing paddocks (GP) of 7 d of occupation each. The experiment was a completely randomized block design and data were analyzed as repeated measurement in time. Milk production was higher in HA and MA groups than in LA (24.3 and 22.7 *vs.* 19.2 L, $P<0.01$ respectively). Milk response to extra DHA was 0.43 L of milk/kg DHA between LA and MA treatments, which dropped to 0.19 L of milk/kg between LA and HA treatments. Cows in the HA treatment had higher BCS than cows in MA and LA treatments (3.18 *vs.* 3.05 and 3.07; $P<0.05$). Cows on all treatments mobilized BCS during the first 3 weeks after calving but, while HA cows lost ~0.5 points of BCS, LA cows lost 1 point. The probability of a cow grazing at any time increased ($P<0.01$) as the experiment progressed, being 54.5, 61.3, 66.8 and 68.7 min/100 min for GP 3, 5, 7 and 8, respectively. Probability of grazing increased linearly for cows receiving HA (0.39 min/100 min/d) and MA (0.44 min/100 min/d) treatments at higher rate than cows receiving LA (0.22 min/100 min/d) treatment. A linear effect of days in milk (DIM) on bite rate as well as an interaction of DIM by treatment occurred. At DIM = 0, the mean value for bite rate was ~15 bites/min, and the slope relative to DIM was higher for HA and MA cows (0.54 and 0.69 bites/min/d, respectively) than for LA cows (0.29 bites/min/d). The result of the present experiment evidence the major role of DHA on milk production in primiparous dairy cows during early lactation, being more important at lower levels of DHA. The lack of response on milk production to higher levels of DHA might have been related to the low effective grazing time and bite rate exhibited by early lactation grazing primiparous cows.

1. Introduction

The quantity and quality of nutrients consumed by cows can be controlled and manipulated and relatively accurately predicted, in intensive milk production systems where TMR's are generally fed. However in extensive systems, where herbage

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Abbreviations: BCS, body condition score; BW, body weight; DHA, daily herbage allowance; DIM, days in milk; DM, dry matter; GP, grazing paddock; ME, metabolizable energy; NEB, negative energy balance.

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is the primary diet component, manipulation of nutrient availability, and its prediction, is more complex since it includes the quantitative uncertainties associated with grazing. Digestion and utilization of nutrients in dairy cows is an interaction of the animal, its diet and the ruminal microbial population. The most important aspects in this interaction, which determine productive efficiency under grazing conditions, are herbage characteristics and animal ingestive behavior (Chilibroste et al., 2005).

The gap between energy need and DMI by dairy cows during the transition from the non-lactating to lactating state generally results in a negative energy balance (NEB; Drackley, 1999) which, under grazing conditions, has been reported to be more severe in primiparous *vs.* multiparous cows (Meikle et al., 2004). A lower dry matter (DM) intake of grazing primiparous dairy cows in early lactation resulted in a higher NEB, and large mobilization of body reserves as lactation progressed, *vs.* multiparous cows (McEvoy et al., 2009). Thus, the grazing process places an extra constraint on primiparous cows attempting to achieving high herbage DM intake (Kolver and Muller, 1998), and ultimately to express their genetic potential for milk production. Daily herbage allowance (DHA) plays a major role in determining animal DM intake and productive performance, as well as residual herbage mass which influences grass growth and productivity. Assessment of the effect of DHA on milk production is critical to identify losses in animal performance in grazing dairy systems, as well as to develop feeding strategies to increase the efficiency of dairy systems which include grazing.

The effect of DHA on DM intake and milk production has been extensively investigated in mid lactation dairy cows (Peyraud et al., 1996; Wales et al., 1999; Bargo et al., 2002). In contrast, there is limited information on effects of DHA on productive performance of early lactation dairy cows. Kennedy et al. (2005) concluded that medium DHA of 15 kg of DM/cow and 3 kg of DM/cow of concentrate were enough to support a reasonably high level of milk production. However Kennedy et al. (2007) later found that when cows were offered a low DHA, milk yield was not compromised *vs.* a medium DHA (13 *vs.* 16 kg DM/cow respectively), but a higher DHA of 19 kg/DM/cow increased milk yield while reducing herbage utilization. McEvoy et al. (2009) developed an equation to predict DM intake and milk performance of grazing cows, where effects of parity and DHA were estimated. However, we are not aware of any study which determined the impact of DHA on productive performance of primiparous grazing dairy cows. Moreover, previous studies investigating the effects of DHA on productive performance in early lactation (Kennedy et al., 2005, 2007; McEvoy et al., 2008) did not include measures of grazing behavior.

Regardless of the production system, cows tend to consume discrete meals, and animal selectivity and searching compete with grazing time, which is directly related to DM intake (Newman et al., 1994). We studied adaptive changes in grazing behavior of lactating dairy cows relative to contrasting feeding strategies (Chilibroste et al., 2007), involving groups of primiparous and multiparous dairy cows that were past peak milk production (*i.e.*, over 60 days in milk [DIM]). However, effects of DHA on productive performance and feeding behavior in early lactation primiparous cows has been hardly investigated, and this is a critical deficiency due to the impact of DM intake during early lactation on animal performance and metabolism (Meikle et al., 2004).

The objective of this research is to establish the influence of DHA on milk production and composition, body condition score (BCS) as well as the underlying adaptative mechanisms, such as grazing behavior, in primiparous Holstein dairy cows during early lactation. The hypothesis was that the level of DHA during early lactation in primiparous cows affects grazing behavior and milk yield.

2. Materials and methods

The experiment was completed at the EEMAC Research Station Paysandu (Uruguay). Pregnant heifers ($n = 33$, age at calving = 2.96 ± 0.113 years, body weight (BW) = 595 ± 41.4 kg and BCS = 3.7 ± 0.267 (both 20 d prior to expected calving date) calving between March 25 and April 15 (*i.e.*, autumn) were selected from the experimental herd. Cows were blocked by BW, age and BCS, and randomly assigned within block to 1 of 3 treatments ($n = 11$ each) being: high (HA, 30 kg DM/cow/d), medium (MA, 15 kg DM/cow/d) and low (LA, 7.5 kg DM/cow/d) DHA. Research was compliant with regulations of the Ethical Committee of the University of Uruguay (Montevideo, Uruguay).

2.1. Management and feeding

Cows were milked at 5:00 and 16:00 h and daily allowed to graze between 8:00 and 15:00 h on a mix sward composed by Tall fescue (*Festuca arundinacea*), Birds foot trefoil (*Lotus corniculatus*) and White clover (*Trifolium repens*). Pasture was sown during April 2004 with 10 kg/ha of seed for Tall Fescue and Birdsfoot trefoil and 2 kg/ha for White clover. At the time of sowing it was fertilized with 18 kg of N and 46 kg of P/ha and, on the second year, 7 kg of N and 40 kg of P/ha were added. Cows grazed in a 7 d rotational system wherein the three treatments were moved weekly to a new set of adjacent independent grazing paddocks (GP) separated by electric fences. No GP was re-grazed during the experiment. To achieve targeted herbage allowances, the 11 cows/treatment grazed paddocks of 1, 0.5 and 0.25 ha for HA, MA and LA, respectively. In this experimental design, time and GP were deliberately confounded since cows grazed paddocks 1–8 from calving to 56 DIM. Since determination of herbage characteristics and depletion dynamics, as well as milk components, were determined within each GP at days 3 and 4 of occupation, GP was used as a repeated unit in time and average DIM of the cows for each treatment within each GP is reported.

Cows were individually supplemented at 18:00 h with corn silage (10 kg), a commercial concentrated (4.8 kg) and grass hay (0.4 kg), on a fresh weight basis, designed to meet maintenance metabolizable energy (ME) needs plus 8–10 L/d of milk (NRC, 2001), leaving any difference in performance to effects of the DHA treatments. Samples of each feed were collected on days 1, 3 and 6 of occupation of each GP, composited, oven dried at 60 °C for 48 h and then ground at 1 mm for chemical analysis.

2.2. *Analytical methods*

Herbage and supplementary feeds were analyzed by DM, ash and N, according to AOAC (1990) methods numbered 167.03, 942.05 and 984.13, respectively. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were measured sequentially (Van Soest et al., 1991; without sodium sulfite in the neutral detergent solution) using an ANKOM200 Fiber Analyzer (ANKOM Technology Corp., Fairport, NY, USA). Neutral detergent fiber assayed without a heat stable amylase. Fiber contents were expressed inclusive of residual ash.

2.3. *Measurements and calculations*

2.3.1. *Sward features*

Pre and post grazing sward mass was estimated with a rising plate meter (Ashgrove Co., Palmerston North, New Zealand), using the double sampling technique of Haydock and Shaw (1975). Botanical composition pre and post grazing herbage mass was assessed by visual observations in a quadrant of 0.3 m × 0.3 m randomly distributed within each GP (12, 6 and 4 replicates in pre and 18, 12 and 8 replicates in post grazed for HA, MA and LA, GP respectively). At each of these observation points, the area occupied by grasses, legumes and weeds was determined.

Herbage mass depletion on GP 2, 4, 6, 7 and 8 was estimated measuring herbage height daily with the rising plate meter for each treatment every hour during the grazing session.

2.3.2. *Grazing behavior*

On GP 3, 5, 7 and 8, the cows of each treatment were observed every 15 min on 3 alternate days and the animals ruminating or engaged in other activities were recorded. In the same paddocks during three alternate days, 4 individual cows from the same block of each treatment were observed to determine bite rate. During three grazing sessions of 1 h each, bite rate (*i.e.*, bites/min) was counted for each cow every 15 min. The grazing session started at 8:00 h (INITIAL), 10:30 h (MIDDLE) and 13:30 h (FINAL).

2.3.3. *Animal*

Daily milk yield was recorded during the experimental period for all cows. Milk samples were collected from 4 consecutive milking within each GP and composited to a single weekly milk sample for analysis of crude protein (CP), fat and lactose by midinfrared spectrophotometry (Milko-Scan, Foss Electric, Hillerød, Denmark). Body condition score was determined every 15 d by the same person from 2 months before until the 3rd months after parturition on a scale from 1 (emaciated) to 5 (fat) to the nearest quarter point according to Edmonson et al. (1989). Body weight was determined after morning milking at the same time as BCS.

2.4. *Statistical design and statistical analysis*

The experiment was statistically analyzed as a completely randomized block design. Milk and milk composition, as well as grazing behavior variables, were regressed against GP (the 7 d grazing unit) since they were determined at fixed days within each GP. The BCS data was statistically analyzed with DIM as the time variable since it was determined every 15 d, and BCS values were regressed against DIM.

The probability of cows grazing, ruminating or engaging in other activities in the GP was analyzed with GLM as repeated measurements in time (GENMOD; SAS, 2002) as:

$$\ln\left(\frac{P_{ijklm}}{1-P_{ijklm}}\right)=\mu+\tau_i+\beta_j+\lambda_k+\delta_l(\lambda_k)+\eta_m+(\eta\tau)_{im}+\tau_i\delta_l(\lambda_k)+\delta_l\eta_m(\lambda_k)$$

where P_{ijklm} = probability of each activity, μ = overall mean, τ_i = effect of herbage allowance (I = 1–3), β_j = effect of block (j = 1–11), λ_k = effect of GP (k = 1–8), $\delta_l(\lambda_k)$ = effect of day l within GP$_k$, $(\lambda\tau)_{ik}$ = interaction between treatment and GP, η_m = effect of grazing session (m = 1–3), $(\eta\tau)_{im}$ = interaction between treatment and grazing session, $\tau_i\delta_l(\lambda_k)$ = day effect by treatment within GP and $\delta_l\eta_m(\lambda_k)$ = day effect within grazing session and GP. Dependent variables were evaluated for linear and quadratic effects of DIM and differences in slope heterogeneity estimated.

Bite rates of individual cows were analyzed as repeated measurements in time (MIXED; SAS), with the model:

$$Y_{ijklm}=\mu+\tau_i+\beta_j+\varepsilon_{ij}+\lambda_k+\varepsilon_{ijk}+\delta_l(\lambda_k)+\tau_i\delta_l(\lambda_k)+\rho_{ijkl}+\eta_m+(\eta t)_{im}+\delta_l\eta_m(\lambda_k)+\varepsilon_{ijklm}$$

Table 1
Weather conditions during the experiment.

Grazing Paddock	Mean temperature (°C)	Relative humidity (%)	Precipitation (mm)
1	20	73	114
2	18	76	63
3	17	71	1
4	16	67	0
5	18	75	41
6	17	85	145
7	13	74	0
8	15	74	0

where Y_{ijk} = response variable, μ = overall mean, τ_i = effect of treatment (i = 1–3), β_j = effect of block (j = 1–11), ε_{ij} = experimental error within experimental units, λ_k = effect of GP (k = 1–8), ε_{ijk} = error of repeated measurement (within experimental units between weeks), $\delta_l(\lambda_k)$ = effect of day l within GP$_k$, $\tau_i\delta_l(\lambda_k)$ = day effect by treatment within GP, ε_{ijkl} = error of repeated measurement (within experimental units between days), η_m = effect of grazing session (m = 1–3), $(\eta\tau)_{im}$ = interaction between treatment and grazing session, $\delta_l\eta_m(\lambda_k)$ = day effect by treatment within GP and ε_{ijklm} = error of repeated measurement (within experimental units between grazing sessions). For both models (*i.e.*, grazing behavior and bite rate) a first order autoregressive covariance structure was selected.

Milk production and composition was analyzed as repeated measurements in time using MIXED (SAS, 2002) with block, treatment and GP as fixed effects and cows as the repeated unit.

Variation of BCS was analyzed by a heterogeneity slope test regressing BCS on DIM within periods of 20 d from calving (period I: 0–20; period II: 21–40; period III: 41–60 DIM). This approach allowed quantification and comparison of rapid changes in BCS in the periods of lactation where major changes in metabolic status would be expected.

3. Results

The dominant weather conditions during the experiment are in Table 1. Rain ranged from 0 mm in GP 3, 4, 7 and 8 to 145 mm in GP 6.

3.1. Milk production and composition

Average milk production differed (P<0.01) among treatments being higher in HA (24.3 L/d) and MA groups (22.7 L/d) than in LA (19.2 L/d). There was an interaction between treatment and GP (P<0.01). The evolution of milk and milk component production throughout the GP are shown in Table 2. Differences in milk yield due to treatments occurred in GP 3 through 8 with HA cows having higher milk yields than LA cows, but not from MA cows.

Neither crude protein nor fat content in milk differed among treatments, but an interaction among GP and treatment occurred (Table 2). Milk fat content values were extremely high during the first two weeks of lactation. Differences in fat content only occurred in GP 2, where LA cows had fat contents higher than MA cows (P<0.05) while MA cows did not differ from HA. A linear decline on milk fat content through lactation with no differences between treatments was observed (Table 2). Protein content only differed in GP 2, where LA cows had lower milk protein levels (P<0.05) than the other treatments.

Table 2
Change in milk production and composition throughout experimental grazing paddocks.

Variable	Herbage allowance	Grazing paddocks							Effect
		2	3	4	5	6	7	8	
Milk (L/d)	LA	19.1	21.4	19.8	19.6	16.7	18.6	19.3	Trt P<0.01
	MA	19.1	22.0	23.1	24.5	20.1	23.0	24.8	Trt × GP
	HA	22.5	24.1	24.7	26.0	22.1	23.9	25.4	P<0.05
Milk fat (g/kg)	LA	9.93	5.53	5.51	4.28	4.77	3.97	3.84	Trt NS
	MA	6.48	6.33	4.45	4.08	4.31	3.70	3.70	Trt × GP
	HA	8.62	6.20	4.21	4.10	4.58	3.84	3.79	P<0.01
Milk crude protein (g/kg)	LA	3.19	3.13	2.95	2.92	2.93	2.92	2.87	Trt NS
	MA	3.60	3.02	2.96	2.93	3.03	2.92	2.87	Trt × GP
	HA	3.66	3.10	3.08	2.97	3.09	3.01	2.95	P<0.01
DIM days	LA	6.9	13.8	20.8	27.8	34.8	41.7	48.7	Trt NS
	MA	7.7	14.5	21.5	28.6	35.4	42.5	49.6	Trt × GP
	HA	6.3	13.3	20.2	27.2	34.2	41.2	48.2	NS

Trt = treatments; GP = grazing paddock; DIM = days in milk.

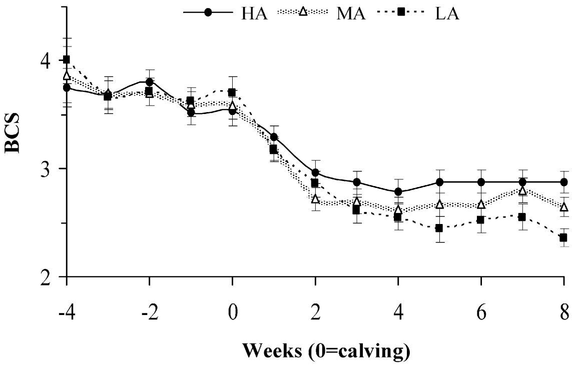


Fig. 1. Body condition score (BCS) throughout the study for cows receiving high (HA), medium (HM) and low (LA) herbage allowances. Dots = observed values; continued lines = fitted curves.

3.2. Body condition score

Changes in BCS over time is presented in Fig. 1. Cows receiving treatment HA had a higher ($P<0.05$) average BCS (3.18 units) than MA and LA cows (3.05 and 3.07, respectively). Cows in all treatments mobilized body reserves during the first 20 DIM but, while HA cows lost ~0.5 BCS points, LA cows lost 1 point of BCS in addition to having lower milk production. During the first 20 DIM, cows lost BCS at a rate of 0.038 BCS units/d with no differences among treatments. From day 21 to 40, HA cows moved to a positive balance (0.0088 BCS units/d) while MA and LA remained in a negative balance (−0.001 and −0.004 BCS units/d). From 41 to 60 DIM the HA cows remained in a positive BCS positive while MA and LA cows increased the negative slope compared with the previous period (*i.e.*, −0.008 and −0.015 BCS units/d).

3.3. Herbage: mass, allowance and depletion dynamics

Mean herbage availability pre grazing during the whole experiment was 2750 ± 275.5 kg DM with no differences among GP. Actual DHA were 36.5, 17.2 and 9.1 kg DM cow/d for HA, MA and LA, respectively, values which were within the target range.

The experiment was designed such that herbage height and mass at the end of paddock occupation differed among treatments covering a range from restricted condition for grazing (*i.e.*, herbage height below 5–7 cm; LA) to non restricted conditions for grazing (*i.e.*, herbage height over 10–12 cm; HA). Average botanical composition of the herbage on offer before grazing was 240 g/kg DM Tall fescue, 300 Birdsfoot trefoil and 380 White clover. The proportion of ground not occupied by productive species was due to uncovered soil ($50\,m^2/1000\,m^2$) and annual weeds ($30\,m^2/1000\,m^2$). Chemical composition of herbage samples collected during calibration according to Haydock and Shaw (1975) varied between 135 and 172 g CP/kg DM, 440–482 g NDF/kg DM and 292–305 g ADF/kg DM.

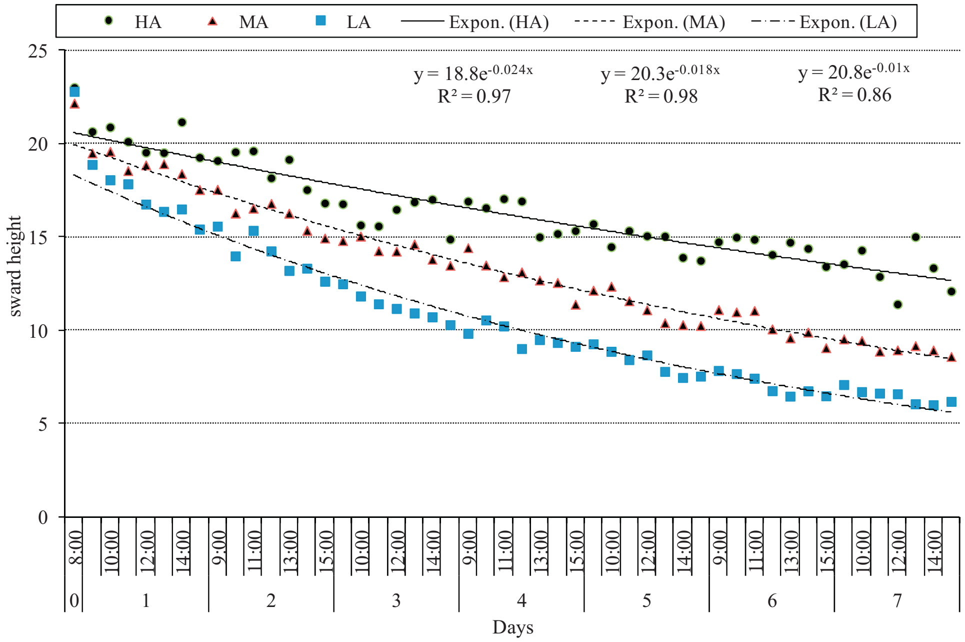
Changes in herbage height during the 7 d of occupation within GP is in Fig. 2. Mean herbage height depletion for the three treatments was exponential with a fractional rate of −0.01, −0.018 and −0.024 cm/h for HA, MA and LA swards, respectively. Mean herbage utilization (*i.e.*, the difference between herbage mass pre and post r grazing) was 470, 610 and 730 g/kg DM of initial herbage mass for HA, MA and LA swards, respectively.

The supplement individually fed at 18:00 h to each cow (*i.e.*, a mixture of 10 kg corn silage plus 4.8 kg of a compound feed plus 0.4 kg of grass hay (fresh weight) was totally consumed by the cows. Ash, CP, NDF and ADF content for corn silage were 78 ± 5.1, 81 ± 8.0, 628 ± 102.0 and 349 ± 73.3 g/kg DM, respectively, while those for hay were 100 ± 4.4, 78 ± 8.2, 722 ± 20.6 and 413 ± 17.7 g/kg DM, respectively. The compound feed had 243 ± 13.1 g CP/kg DM, 241 ± 11.3 g NDF/kg DM and 83 ± 8.4 g ADF/kg DM.

3.4. Grazing behavior

The probability of finding cows grazing when the group was observed was affected ($P<0.01$) by GP and day within GP, but there were no treatment or treatment by GP interactions. The probability of a cow grazing was 619, 638 and 632 min/1000 min for cows receiving the HA, MA and LA treatment, respectively. Grazing probability increased ($P<0.01$) as the experiment progressed being 545, 613, 668 and 687 min/1000 min for GP 3, 5, 7 and 8, respectively. Cows in all treatments increased ($P<0.01$) grazing activity during the 7 d of GP occupation (Fig. 3), although there was no treatment by day interaction within GP.

The probability of cows grazing at each individual grazing session (*i.e.*, INITIAL, MIDDLE, FINAL) showed that grazing in the INITIAL grazing session was higher ($P<0.01$) than in the MIDDLE and FINAL sessions, although it did not differ among treatments (910, 860 and 920 min/1000 min for HA, MA and LA cows, respectively). At the end of the grazing session (FINAL), grazing probability tended to be higher ($P<0.07$) for LA (620) than for HA (520) and MA (530 min/1000 min) cows.



Dots=observed values; continued lines=fitted curves.

Fig. 2. Herbage height change for cows receiving high (HA), medium (HM) and low (LA) treatments. Fitted exponential equations for each treatment are shown within the figure under the series identification.

Along with the change in grazing time, bite rate of individual cows was determined. All fixed effects in the model differed (P<0.01), except the interaction of grazing session by treatment, which tended (P<0.067) to differ. Mean bite rates were 46.6, 49.5 and 43.4 bites/min (P<0.01) for HA, MA and LA cows, respectively. Similar to the probability of grazing, bite rate increased during the experiment with the lowest values in GP 3 (39.8 bites/min) and the highest in GP 8 (60 bites/min). Cows grazed at higher (P<0.01) bite rates in the INITIAL grazing bout (50.1 bites/min) than in the MIDDLE and FINAL bouts (46.6 and 42.7 bites/min, respectively).

4. Discussion

Mean temperature and humidity were relatively high for the autumn although, based upon previous experimentalist experience, but were not judged to be limiting milk production. Rainfall ranged from 145 mm in GP 6 to zero in GP 3, 4, 7

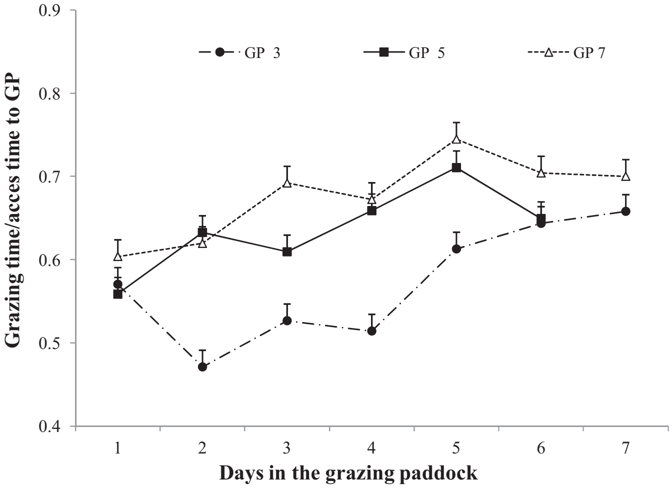


Fig. 3. Actual grazing time over total access time throughout days within grazing paddocks 3, 5 and 7.

and 8. The wet conditions of GP 6 appeared to affect milk production of the groups (Table 2; $P<0.01$), without observable effects in other GP.

4.1. Milk production and composition

The evolution of milk production differed among treatments. While MA and HA cows increased milk production with time, milk yield of LA cows remained stable after GP 3, with the exception of GP 6 when all treatments had lower milk yield due to high rainfall (Table 1). The relatively stable milk production of around 19 L/d throughout the experiment of cows receiving treatment LA suggests that a limited nutrient availability and/or energy balance in this group limited milk production. While differences in milk production between HA and MA cows remained relatively stable throughout the experiment (*i.e.*, 1–2 L/cow/d), the difference between HA and LA cows increased from 2.5 to 6 L/cow/d. Milk response to extra DHA was 0.43 L of milk/kg extra DHA between LA and MA treatments. This response dropped to 0.19 L of milk/kg extra DHA between HA and LA treatments. The response between HA and MA was close to zero (*i.e.*, 0.08 L of milk/kg extra DHA). The high response in milk to extra DHA at low DHA concurs with Kennedy et al. (2007) and McEvoy et al. (2008) with spring calving early lactation mixed parity dairy cows. However, the result of the present experiment are over than values reported by Delaby et al. (2001) with mid lactation mixed parity cows. The high responses in milk from LA to MA indicates that LA may have been restricting DM intake resulting in higher mobilization of body reserves. However the relevance of results of Kennedy et al. (2007) and McEvoy et al. (2008) to our data is unclear, as their data refer to DHA over 4 cm while those in our study are values at ground level.

The low milk CP level of LA cows in GP 2 (3.19 *vs.* 3.66 and 3.59 for LA, HA and MA, respectively) might be evidence of faster body protein mobilization and consequent depletion of body protein reserves in LA cows. Tamminga et al. (1997) determined that the largest portion of body protein mobilization was during the first week after parturition (579 g of protein/kg of tissue mobilized), reaching a plateau at week 4 of lactation; which is consistent with results reported by Komaragiri et al. (1998), who found a limited capacity for protein mobilization during the first 5 week postpartum. Milk protein production was higher for HA (0.75 kg/d) than LA (0.57 kg/d) cows, but it did not differ from MA cows (0.68 kg/d). The same trend occurred for milk fat production, which was higher for HA (1.16 kg/d) than LA (1.0 kg/d) cows, although neither differed from MA cows.

4.2. Body condition score

The MA cows lost BCS at a higher rate in the first 2 wks of lactation, but remained stable thereafter (Fig. 1). The main trends in BCS changes are consistent with McEvoy et al. (2009), Kennedy et al. (2007) and Delaby et al. (2001), although availability of published information relating DHA and BCS change is very limited. Differences in the rate of BCS change among treatments were evident, with HA cows mobilizing body reserves during the first 20 DIM in contrast to HA and LA cows which remained in NEB during the whole experiment, but with a higher rate of mobilization during the first 20 DIM. During the last 40 d of the experiment, MA cows sustained 23.1 L/d while LA cows only produced 18.8 L/d. Data suggest that MA cows overcame DHA limitations to sustain high milk production with a similar rate of body reserve mobilization compared to cows receiving LA treatment.

4.3. Grazing behavior

Although the treatment groups did not differ in mean grazing time during the experiment, the change over time of this variable suggests that all treatment had less grazing activity during the first weeks of lactation than have been reported previously by Chilibroste et al. (2007). The reduction in grazing time associated with low bite rate suggests that actual DM intake relies mainly on bite mass which ultimately is determined by herbage mass, structure and allowance (McEvoy et al., 2009; Chilibroste et al., 2005). Although grazing behavior variables were not measured during GP 1 and 2, according to the trend in Fig. 3, low grazing probability values would be expected.

Since GP and DIM followed the same tend as dictated by the experimental design (Table 2), an alternative model was used to study effects of DIM on grazing behavior. Using this approach, grazing activity on a continuous basis (*i.e.*, DIM) was examined with calving fixed as day 0. Heterogeneity of slopes in time among treatments was examined and the probability of a cow grazing did not differ between treatments. A significant linear increase in the probability of a cow being grazing with DIM was detected with a significant interaction ($P<0.05$) treatment × DIM. While the probability of a cow grazing at the beginning of lactation (Fig. 4A) did not differ among treatments (338, 325, 350 min/1000 min for HA, MA and LA cows, respectively) the slopes for HA (0.39 min/1000 min/d) and MA (0.44 min/1000 min/d) cows were higher than for LA cows (0.22 min/1000 min/d). The same approach was used to estimate effects of DIM on bite rate (Fig. 4) where a linear effect of DIM on bite rate, as well as a treatment × DIM interaction, occurred. While at DIM = 0 the mean value for bite rate was ~25 bites/min with no differences between treatments, the slope differed for HA and MA cows (0.54 and 0.69 bites/min/DIM, respectively) from LA cows (0.29 bites/min/DIM).

Based upon our findings as a whole, it is clear that these early lactation primiparous cows faced severe restrictions in fulfilling their ME needs under grazing conditions reported. The cows grazed a very low proportion of allowed grazing time (*i.e.*, <35%) and grazed at a very low rate (*i.e.*, <25 bites/min) which suggests a slow and selective grazing down process. It

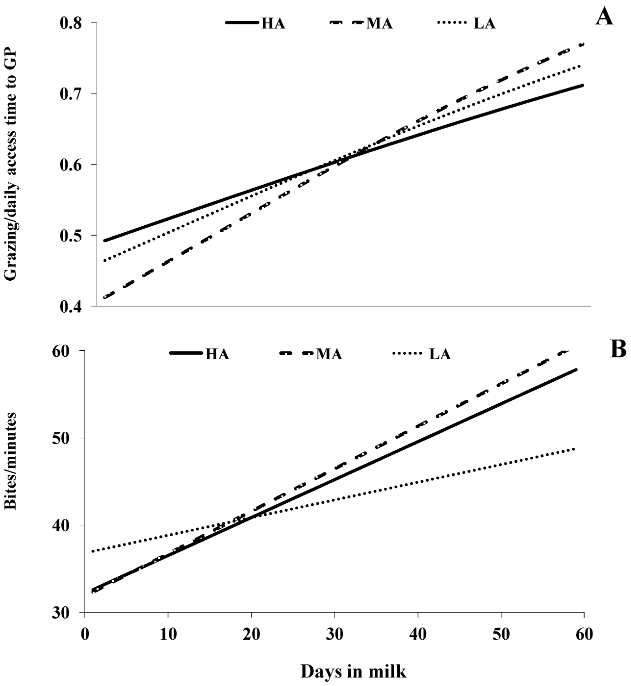


Fig. 4. Actual grazing time over total access time (A), and bite rates (B) of cows grazing paddocks with high (HA), medium (MA) and low (LA) herbage allowance.

seems that it takes at least 3 weeks after calving for primiparous dairy cows to achieve values for grazing time and bite rate comparable with those reported by others for mixed parity cows over 60 DIM (Chilibroste et al., 2005; Gibb, 2006). Nevertheless it is noteworthy that for all the DHA treatments, cows always grazed actively at the INITIAL grazing session but reduced activity during the MIDDLE and FINAL grazing bouts thereby highlighting the importance of behavioral changes of cows as adaptations to changes in sward conditions (Gibb, 2006). This also suggests that differences in herbage DM intake between DHA levels must be mainly relative to mean bite mass rather than to grazing time and/or bite rate since the cows exhibited a similar grazing pattern after calving among DHA treatments. Recent research (*e.g.*, Kennedy et al., 2007; McEvoy et al., 2008) suggests that low to medium herbage allowances would be enough to meet the ME requirements of early lactation dairy cows on herbage supplemented with 3–4 kg of concentrate. However our findings do not support this suggestion since the lack of responses in milk production to higher levels of herbage allowance might have been related to low adaptation capability of early lactation grazing primiparous dairy cow to the grazing harvest process.

5. Conclusions

Daily herbage allowance plays a major role on milk production of primiparous dairy cows with high response in milk and component yields with an increase from low to medium DHA. In contrast, increases from medium to high DHA result in lower milk production responses, but with changes in BCS suggesting effects of higher DHA on metabolic status of early lactation dairy cows.

Early lactation primiparous cows faced severe restrictions in fulfilling their ME needs under grazing conditions. Primiparous cows grazed a very low proportion of allowed grazing time (*i.e.*, <35%) and grazed at a very low rate (*i.e.*, <25 bites/min) which suggests a slow and selective grazing down process. Mean bite mass is determinant of herbage DMI during the first three weeks of lactation.

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