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Effect of restricted access time to pasture on dairy cow milk production, grazing behavior, and dry matter intake

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ABSTRACT

The objective of this experiment was to investigate the effect of restricting pasture access time on milk production and composition, body weight and body condition score change, dry matter intake, and grazing behavior of autumn calving dairy cows in midlactation. Fifty-two (19 primiparous and 33 multiparous) Holstein-Friesian dairy cows (mean calving date, August 17 ± 91.2 d) were randomly assigned to a 4-treatment (n = 13) randomized block design grazing study. The 4 grazing treatments were: (i) full-time access to pasture (22H; control), (ii) 9-h access to pasture (9H), (iii) two 4.5-h periods of access to pasture after both milkings (2 × 4.5H), and (iv) two 3-h periods of access to pasture after both milkings (2 × 3H). Experimental treatments were imposed from March 7 to April 6, 2007 (31 d). The pregrazing herbage mass of swards offered to all treatments was 1,268 kg of dry matter/ha, and sward organic matter digestibility was 86.4%, indicating high-quality swards conducive to high dry matter intake. Swards where animals had 22H and 2 × 4.5H access to pasture had the lowest postgrazing sward heights (3.5 cm), reflecting the greatest levels of sward utilization. After the experimental period, there were no differences in milk production; however, the 2 × 3H animals tended to have lower milk protein concentration (−0.17%) compared with 22H animals. Furthermore, dry matter intake of the 9H animals was lower than 22H animals. Although restricting access time to pasture decreased grazing time, animals compensated by increasing their intake/minute and intake/bite. Restricting pasture access time resulted in much greater grazing efficiency, because the 9H, 2 × 4.5H, and 2 × 3H treatments spent a greater proportion of their time at pasture grazing (81, 81, and 96%, respectively) than 22H animals (42%). Results of this study indicate that allocating animals restricted access to pasture does not significantly affect milk production. This study also found that the total access time should be greater than 6 h and that perhaps needs to be divided into 2 periods.
Key words: restricted access, pasture, grazing behavior, milk production

INTRODUCTION

Grazed grass is reported as the cheapest feed available (O'Kiely, 1994) and is the fundamental component of the dairy cow diet for the majority of Irish milk production systems. Irish dairy farmers are now targeting a 300-d grazing season to increase the proportion of grazed grass in the diet of the dairy cow and optimize the economical efficiency of their business.

Two of the main obstacles when extending the grazing season are the availability of sufficient herbage in early spring and the climatic conditions during this period. However, through appropriate autumn grazing management (Roche et al., 1996), timely N application strategies (O'Donovan et al., 2004), and grass-budgeting techniques (Defrance et al., 2006), sufficient herbage can be made available to begin the grazing season in early spring. However, inclement weather conditions in early spring and late autumn can decrease the number of days at pasture for lactating animals. Traditionally, during these periods dairy cows generally remain indoors and are primarily offered grass silage. Allowing animals access to pasture for a few hours per day has previously been shown to increase milk production and milk protein concentration (Dillon et al., 2002) and may be a strategy that can be implemented during periods of inclement weather. Pérez-Ramírez et al. (2008) reported that restricting pasture access time to 4 h daily could be used as a tool to improve grazing efficiency.

The quantity of herbage consumed by grazing animals is typically regulated by grazing time, biting rate, and intake per bite (Holmes, 1989). Under grazing conditions, 2 main grazing bouts are normally observed, one in the a.m. and another in the p.m. (Rook et al., 1994; Linnane et al., 2001). However, grazing animals have the ability to alter their intake rate as a consequence of behavioral decisions (Newman et al., 1994a). Thus, if animals are removed from pasture and periods of fast-

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ing are imposed, it may induce a greater impulsion for the animal to graze. Several studies, conducted with sheep and cattle, have reported a relationship between duration of fasting and subsequent grazing behavior (Newman et al., 1994b; Patterson et al., 1998; Pérez-Ramírez et al., 2008). Greenwood and Demment (1988) found that steers fasted for 36 h grazed 27% faster than unfasted steers. Additionally, Pérez-Ramírez et al. (2008) stated that when pasture access was decreased from 8 to 4 h, for maize-supplemented animals, there were minimal effects on animal performance, due to the behavioral adaptation of the grazing dairy cow. Therefore, if unsupplemented animals are given restricted access to pasture, they may have a greater propensity to graze, thereby increasing their intake per bite, which may ultimately result in negligible differences in total DMI (**TDMI**) and subsequent milk production. The objective of this experiment was to investigate the effect of restricting pasture access time on milk production and composition, BW, BCS, DMI, and grazing behavior of autumn calving dairy cows in midlactation.

MATERIALS AND METHODS

The study was conducted at Moorepark Research Centre, Fermoy, Co. Cork, Ireland (50°07′N; 8°16′W) from March 7 to April 6, 2007 (31 d). The soil type was a free-draining, acid brown earth with a sandy loam-to-loam texture. The experimental area was a permanent grassland site containing greater than 80% perennial ryegrass. There was no clover present in the sward.

Animals and Experimental Design

The experiment was a randomized block design with 4 grazing treatments. Fifty-two Holstein-Friesian dairy cows were selected from the Moorepark autumn calving herd. Nineteen cows were primiparous, while the remaining 33 were pluriparous (18 cows in their second lactation and 15 cows in their third or greater lactation). Approximately 20% of the cows participating in the study were extended lactation cows [at the commencement of the experiment, cows were on average 202 (±12.7) DIM, 10 cows were greater than 345 DIM]. Animals were balanced on the basis of calving date (August 17; ±12.7 d), 4 wk pre-experimental milk yield (23.8 ± 0.53 kg), parity (2.1 ± 0.18), milk fat concentration (4.13 ± 0.096%), milk protein concentration (3.40 ± 0.036%), milk lactose concentration (4.57 ± 0.022%), BW (591 ± 8.6 kg), and BCS (3.00 ± 0.06).

Cows were balanced, blocked into groups of 4, and randomly assigned to 1 of the following 4 grazing treatments: (i) 22-h (full-time) access to pasture (22H; control), (ii) 9-h access to pasture (9H), (iii) two 4.5-h periods of access to pasture after both milkings (2 × 4.5H), and (iv) two 3-h periods of access to pasture after both milkings (2 × 3H). Before assignment to treatment, all cows were offered ad libitum pasture during the day and were housed at night and offered ad libitum grass silage and maize silage in a 50:50 ratio.

Description of Treatments and Grazing Management

All animals were allocated a daily herbage allowance (**DHA**) of 15.5 kg of DM/cow per day and 3 kg of DM/cow per day of concentrate, which was offered in 2 equal feeds at a.m. and p.m. milking in the milking parlor. Concentrate composition on a fresh weight basis was 50% citrus pulp and 50% corn gluten. All treatments were offered herbage in 24-h allocations after a.m. milking. No supplementary feed was offered when animals were removed from pasture and returned indoors.

The 22H treatment animals were given access to pasture on a full-time basis. The 9H treatment was allocated herbage after a.m. milking and remained outdoors until p.m. milking, after which they returned indoors until the following a.m. milking. The 2 × 3H animals were turned out to pasture for 3h after a.m. milking, and they then returned indoors until p.m. milking. After p.m. milking, the 2 × 3H animals returned to pasture for a further 3-h period, returning indoors once this time had elapsed. The 2 × 4.5H treatment was similar to the 2 × 3H treatment, the only difference being that animals had 4.5-h access to pasture after each milking rather than 3 h. Herds were housed individually when indoors, there were a sufficient number of cubicles for all cows, and all cubicles were cleaned and lined daily.

Within each paddock, the 4 treatments grazed as separate herds. All herds grazed adjacent to one another in their separate areas, defined using temporary electric fences. The position of each herd in relation to the other herds was retained throughout the experiment. The experiment was completed during the first grazing rotation.

Subsequent to the 31-d period when treatments were imposed, all animals grazed as a single herd. They were allocated 15 kg of DM/cow per day of herbage and 3 kg DM/cow per day of concentrate for a further 2-wk period (carryover period).

Sward Measurements

Herbage Mass Determination and Sampling. Paddock herbage mass (>4 cm) was determined twice weekly by harvesting 2 strips (1.2 m × 10 m) per allowance with an Agria machine (Etesia UK Ltd., Warwick, UK). Ten grass height measurements were recorded before and after cutting on each cut strip using an electronic plate meter (Urban and Caudal, 1990) with a plastic plate (30 cm × 30 cm and 4.5 kg/m; Agrosystèmes, Choiselle, France). This allowed the calculation of mass of herbage per centimeter [herbage mass (DM/ha)/(precutting height − postcutting height); kg of DM/cm per ha]. All mown herbage from each strip was collected. It was weighed and subsampled (0.3 kg). A subsample of approximately 0.1 kg was dried for 48 h at 40°C in a drying oven for determination of DM content.

Herbage, representative of that selected by the 22H, 9H, 2 × 3H, and 2 × 4.5H treatments, was sampled weekly with Gardena (Accu 60, Gardena International GmbH, Ulm, Germany) hand shears, taking cognizance of the previous defoliation height recorded from each treatment. A subsample was stored at −20°C before being freeze-dried and milled prior to chemical analysis.

Pre- and Postgrazing Sward Heights. The pregrazing sward height was determined daily in each plot by recording 30 measurements across the 2 diagonals of the paddock, using the electronic plate meter described above. Pregrazing values were recorded for each of the 4 treatments. The measured pregrazing sward height, multiplied by the mean mass of herbage per centimeter, was used to calculate the DHA required. Postgrazing sward height was measured immediately after grazing for each of the 4 individual treatments.

Herbage Utilization. Herbage mass utilization was calculated using the method of Delaby and Peyraud (1998). It was further used to evaluate the herbage mass produced and removed.

Animal Measurements

Milk Production. Individual milk yields (kg) were recorded at each milking. Milk fat, protein, and lactose concentrations were determined from one successive a.m. and p.m. milk sample taken weekly. The concentrations of these constituents were determined using Milkoscan 203 (Foss Electric DK-3400, Hillerød, Denmark). Solids-corrected milk yield was calculated using the equation of Tyrrell and Reid (1965). All cows were weighed weekly. Body weight was recorded electronically using a portable weighing scale and Winweigh software package (Tru-Test Ltd., Auckland, New Zealand). Body condition score was recorded weekly during the study on a 1 to 5 scale (1 = emaciated; 5 = extremely fat) with 0.25 increments (Lowman et al., 1976) and was measured by 1 experienced independent observer throughout the study. Body weight and BCS change were calculated using values of BW and BCS from the first 2 and last 2 wk of the study.

Intake Estimation. Individual grass DMI (**GDMI**) and TDMI were estimated during the experimental period using the n-alkane technique (Mayes et al., 1986) as modified by Dillon and Stakelum (1989). All cows were dosed twice daily, before milking, for 12 consecutive days with a paper filter or bung (Carl Roth GmbH and Co. KG, Karlesruhe, Germany) containing 500 mg of dotriacontane (C32). From d 7 of dosing, fecal grab samples were collected from each cow twice daily for the remaining 6 d. The fecal grab samples were then bulked (12 g of each collected sample) and dried for 48 h in a 40°C oven in preparation for chemical analysis.

In conjunction with the fecal collection, the diet of the animals was also sampled. Herbage representative of that grazed (taking cognizance of the previous defoliation height recorded from each treatment) was manually collected from each paddock before a.m. grazing on d 6 to 11 (inclusive) of the intake measurement period. Two samples of approximately 25 individual grass snips were taken from each paddock with a Gardena hand shears. The ratio of herbage C33 (tritriacontane) to dosed C32 was used to estimate intake. The n-alkane concentration was determined as described by Dillon (1993).

Grazing Behavior. Grazing behavior data were collected on 2 occasions from 28 cows across each of the 4 grazing treatments during the intake measurement period. Animals were selected by randomization block, and to accurately reflect the age profile of the herd, parity was taken into consideration when the blocks were chosen. Data were collected over two 24-h periods. After a.m. milking, 7 cows from each grazing treatment were fitted with Institute of Grassland and Environmental Research behavior recorders (Rutter et al., 1997). If the data file collected from a cow was deemed unreadable after the 24-h period, the animal had a recorder fitted for a further 24 h. Fifty-six usable individual grazing behavior recordings were obtained. Recorded jaw movements were analyzed using the "Graze" analysis software (Rutter, 2000). Total grazing, ruminating, and idling times as well as the number of prehensions and mastications were measured using this software. The numbers of grazing and ruminating bouts were also counted, as well as the number of boli within each ruminating bout. Handling time was calculated as grazing time plus ruminating time, intake per minute was calculated as [GDMI (kg/d) × 1,000]/grazing time, and intake per bite was calculated as [GDMI (kg/d) × 1,000]/grazing prehensions per day.

Chemical Analyses

The herbage samples for each treatment were freeze-dried and milled through a 1-mm sieve. Samples were analyzed for DM, ash (AOAC, 1995; method 942.05), ADF and NDF (AOAC, 1995; method 973.18 using

Table 1. Chemical analysis of spring herbage offered to autumn calving dairy cows allocated restricted access to pasture during a 31-d period[1]

Item	22H	9H	2 × 4.5H	2 × 3H	SED	Significance
OM digestibility (%)	86.2	86.6	85.9	87.0	0.371	0.540
CP (%)	24.3	22.8	22.7	24.2	0.58	0.423
ADF (%)	22.2	22.9	21.0	20.7	1.17	0.761
NDF (%)	34.9	36.8	35.8	33.9	2.94	0.695
Ash (%)	7.4	7.3	7.0	7.6	0.83	0.858

[1]22H = 22-h access to pasture; 9H = 9-h access to pasture; 2 × 4.5H = two 4.5-h periods of access to pasture; 2 × 3H = two 3-h periods of access to pasture; SED = standard error of the difference.

sodium sulfate for the NDF; Ankom Technology, Macedon, NY), CP (Leco FP-428, Leco Australia Pty Ltd., Castle Hill), and OM digestibility (**OMD**). Organic matter digestibility was determined using the method described by Morgan et al. (1989; Fibertec Systems, Foss, Ballymount, Dublin, Ireland). The concentrate offered was analyzed for DM content, nitrogen, crude fiber, and ash concentrations.

Statistical Analyses

All statistical analyses were carried out using SAS (SAS Institute, 2002).

All the herbage data were analyzed using the following model:

$$Y_{ijk} = \mu + T_i + W_j + e_{ijk}$$

where μ = mean; T_i = treatment (i = 1 to 4); W_j = week (j = 1 to 4); and e_{ijk} = residual error term.

All animal variables were analyzed as 52 individual variables. To improve the accuracy of the model, pre-experimental milk yield, milk composition, BW, and BCS were used as covariates specific to the parameters being analyzed. Daily milk yield, milk constituent yield, milk composition, BW, and BCS were analyzed with the following model:

$$Y_{ijk} = \mu + P_i + T_j + P_i \times T_j + b_1X_{ijk} + b_2DIM_{ijk} + e_{ijk}$$

where Y_{ijk} = the response of the animal in parity i to treatment j; μ = mean; P_i = parity (i = 1 to 2); T_j = treatment (j = 1 to 4); $P_i \times T_j$ = the interaction between parity and treatment; b_1X_{ijk} = the respective pre-experimental milk output or live weight-BCS variable; b_2DIM_{ijk} = DIM; and e_{ijk} = residual error term. Dry matter intake and grazing behavior were analyzed using the same model as above; however, values for pre-experimental milk yield and BW were included as covariate values in the model. For comparison purposes, only 2 levels of parity were used (i.e., primiparous animals were compared with animals that were in their second or greater lactation).

Due to differences in parity, in terms of pre-experimental values, these covariates were centered within parity before inclusion. That is, the deviations from the parity mean were used as covariates. The incorporation of individual animal covariates within the model decreased the residual error term, therefore explaining more variation within parity.

RESULTS

Weather

Rainfall during March was 21% greater than the 10-yr average (77 mm), whereas mean air temperature was 0.33°C lower than the 10-yr average (7°C). Total sunshine hours were 24% greater than the 10-yr average during the month of March (99.4 h). The weather for the first 6 d of April was typical of the average values recorded during the previous 10 yr. Total grass growth during the month of March was 500 kg of DM/ha less than the 10-yr average (846 kg of DM/ha). Grass growth during the first week in April was 130 kg of DM/ha less than the preceding 10 yr (348 kg of DM/ha).

Chemical Analyses

There was no difference in the herbage offered to all 4 herds. Chemical composition of the sward is presented in Table 1. The chemical composition of the concentrate was ash 11.0% (±0.136), CP 14.9% (±0.305), NDF 26.7% (±0.544), and crude fiber 9.8% (±0.148).

Grazing Management

There was no difference in DHA allocated; all herds received the target herbage allocation of 15.5 kg of DM/cow per day (Table 2). Because grazing management was controlled for each of the 4 herds and all cows grazed in separate areas within the same paddock, there was no difference in the DM yield >4 cm (1,268

Table 2. Effect of restricted access to pasture on sward measurements over a 31-d period[1]

Item	22H	9H	2 × 4.5H	2 × 3H	SED	Significance
DHA (kg of DM/cow per d)	15.5	15.5	15.4	15.4	0.22	0.770
DM yield >4 cm (kg of DM/ha)	1,221	1,223	1,306	1,320	180.1	0.734
Pregrazing sward height (cm)	8.6	8.6	9.0	8.9	0.73	0.768
Mass of herbage/cm (kg of DM/ha)	270	271	270	269	10.7	0.988
Area (m^2/cow per d)	151	160	140	140	18.1	0.275
Postgrazing sward height (cm)	3.5[a]	3.8[bc]	3.6[ac]	3.9[b]	0.156	0.001
Herbage utilization (%)	1.13[a]	1.05[b]	1.07[b]	1.01[b]	0.050	0.001

[a–c]Values in the same row not sharing a common superscript are significantly different.

[1]22H = 22-h access to pasture; 9H = 9-h access to pasture; 2 × 4.5H = two 4.5-h periods of access to pasture; 2 × 3H = two 3-h periods of access to pasture; SED = standard error of the difference; DHA = daily herbage allowance

kg of DM/ha), pregrazing sward height (8.8 cm), mass of herbage per centimeter (270 kg of DM/ha), or the quantity of area allocated per cow per day (148 m^2/cow per d).

Postgrazing sward height was lower ($P < 0.001$; 3.5 cm) on the 22H swards compared with the 9H and 2 × 3H swards (3.9 cm). Postgrazing sward heights of the 2 × 4.5H were not different to the 22H and 9H treatments (3.7 cm), but they were lower ($P < 0.001$) than the 2 × 3H treatment (3.9 cm). Greater proportions of sward utilization ($P < 0.001$) were recorded on the swards grazed by animals from the 22H treatment (1.13), and this value was greater than that of the other 3 treatments (1.04).

Animal Production

Milk Production. There was no treatment × parity interaction for any of the milk production variables analyzed. Access time to pasture did not affect milk or SCM yield (21.7 and 20.5 kg/cow, respectively). There were no differences between treatments in milk fat concentration (4.11%), fat yield (882.5 g/d), and lactose yield (977.4 g/d; Table 3). Milk protein concentration tended to be lower ($P = 0.1$; 3.34%) for the 2 × 3H animals when compared with the 22H animals (3.51%). There was no difference in milk protein concentration between the 22H, 9H, and 2 × 4.5H (3.44%) or the 3 restricted treatments (3.39%). Milk lactose concentration was lower for the 2 × 4.5H treatment ($P < 0.05$; 4.44%) compared with all other treatments (4.54%). Milk protein yield tended ($P = 0.1$) to be lower for the 2 × 3H (694.2 g/d) compared with 22H and 9H (761 g/d) but was not different to the 2 × 4.5H treatment (731 g/d). Body weight and BCS were not affected by access time to pasture during the study period.

Average BW was lower ($P < 0.001$; 502 kg/cow) for primiparous animals compared with pluriparous (566 kg/cow), yet BCS was greater ($P < 0.001$) for primiparous animals. There was no significant effect of parity on BW and BCS change throughout the experimental period. During the 2 wk after the experimental period, there were no differences between treatments in any of the milk production variables measured.

DMI. Allowing cows access to pasture for one single period of 9H decreased ($P < 0.05$; −1.7 kg/cow per d; Table 4) GDMI and TDMI compared with 22H (13.8 and 16.8 kg/cow per d, respectively). There was no

Table 3. Effect of restricted access to pasture on milk production over a 31-d period[1]

Item	22H	9H	2 × 4.5H	2 × 3H	SED	Significance
Milk yield (kg/d)	21.8	22.4	21.5	20.9	0.778	0.310
Milk fat content (%)	4.10	4.20	4.01	4.14	0.159	0.710
Milk protein content (%)	3.51[a]	3.41[ab]	3.41[ab]	3.34[b]	0.075	0.177
Milk lactose content (%)	4.55[a]	4.54[a]	4.44[b]	4.53[a]	0.038	0.036
Milk fat yield (g/d)	892.4	926.6	860.0	850.9	44.38	0.385
Milk protein yield (g/d)	762.7[a]	759.1[a]	731.0[ab]	694.2[b]	28.94	0.115
Milk lactose yield (g/d)	994.9	1,018.7	953.8	942.2	40.71	0.273
SCM yield (kg/d)	20.8	21.4	20.0	19.7	0.853	0.250
Average BW (kg)	540	531	535	531	4.7	0.269
BW change/d (kg)	−1.31	−1.26	−1.18	−1.27	0.160	0.891
Average BCS	3.05	2.98	2.96	3.07	0.058	0.221
BCS change over period	0.007	0.072	−0.074	0.063	0.076	0.264

[a,b]Values in the same row not sharing a common superscript are significantly different.

[1]22H = 22-h access to pasture; 9H = 9-h access to pasture; 2 × 4.5H = two 4.5-h periods of access to pasture; 2 × 3H = two 3-h periods of access to pasture; SED = standard error of the difference.

Table 4. Effect of restricted access to pasture on DMI and grazing behavior over a 31-d period[1]

Item	22H	9H	2 × 4.5H	2 × 3H	SED	Significance
GDMI (kg of DM/d)	13.8[a]	12.1[b]	12.9[ab]	13.0[ab]	0.42	0.05
TDMI (kg of DM/d)	16.8[a]	15.1[b]	15.9[ab]	16.0[ab]	0.42	0.05
Grazing time (min/d)	549[a]	437[b]	436[b]	346[c]	19.8	0.001
Grazing mastications (d)	5,638[a]	4,795[ab]	3,993[b]	4,161[b]	631.0	0.06
Grazing prehensions (d)	31,654[a]	25,157[b]	25,586[b]	19,312[c]	1,578.8	0.001
Grazing bites/min	57.1	57.7	58.7	55.9	2.45	0.744
Grazing bouts (d)	9.56[a]	5.70[b]	5.20[bc]	4.05[c]	0.803	0.001
Grazing bout duration (min/d)	63.0[a]	87.0[b]	92.9[b]	100.4[b]	12.59	0.03
GDMI/min (g)	25.9[a]	27.9[ac]	30.1[c]	37.6[b]	0.039	0.001
GDMI/bite (g)	0.47[a]	0.48[a]	0.52[a]	0.69[b]	1.329	0.001
Ruminating time (min/d)	401[ac]	363[ab]	438[c]	344[b]	26.6	0.009
Ruminating mastications (d)	25,207[a]	20,691[b]	25,966[a]	18,481[b]	1,865.2	0.001
Ruminating boli (d)	470[a]	386[a]	575[b]	466[a]	58.0	0.03
Ruminating bouts (d)	10.9[a]	11.7[a]	11.2[a]	13.6[b]	0.93	0.02
Ruminating bout duration (min/d)	38.4[ac]	31.8[ab]	42.8[c]	26.7[b]	3.60	0.001
Boli/ruminating bout	43.5[a]	34.1[a]	55.3[b]	35.4[a]	6.07	0.02
Handling time (min/d)	950[a]	800[b]	874[c]	690[d]	32.2	0.001
Idling time (min/d)	490[a]	640[b]	566[b]	750[c]	32.2	0.001
Idling mastications (d)	1,086[ac]	1,439[ab]	943[c]	1,548[b]	229.0	0.05
Total mastications (d)	31,931[a]	26,925[b]	30,901[a]	24,190[b]	1789.9	0.001

[a–d]Values in the same row not sharing a common superscript are significantly different.

[1]22H = 22-h access to pasture; 9H = 9-h access to pasture; 2 × 4.5H = two 4.5-h periods of access to pasture; 2 × 3H = two 3-h periods of access to pasture; SED = standard error of the difference; GDMI = grass DMI; TDMI = total DMI.

difference in GDMI and TDMI between the 9H, 2 × 4.5H, and 2 × 3H treatments (12.7 and 15.7 kg/cow per d, respectively). The 9H, 2 × 4.5H, and 2 × 3H treatments achieved 88, 93, and 94% of the TDMI of the 22H, respectively.

Grass DMI per minute was lowest ($P < 0.001$) for 22H cows (25.9 g/min) and greatest for the 2 × 3H herd (37.6 g/min), whereas the 9H and 2 × 4.5H herds had intermediate levels of GDMI per minute (29.0 g/min). The 2 × 3H animals had a significantly greater ($P < 0.001$) GDMI per bite (0.69 g/bite) compared with all other treatments (0.49 g/bite).

Grazing Behavior. The 22H grazed for 549 min (9.2 h), which was greater ($P < 0.001$; Table 4) than all other treatments. The 2 × 3H animals had a lower grazing time (346 min; 5.8 h) than all other treatments, whereas the 9H and 2 × 4.5H were intermediate (437 min; 7.3 h). Cows from the 22H treatment had the greatest number of grazing bouts ($P < 0.001$; 9.6 bouts), which resulted in a greater number of grazing prehensions ($P < 0.001$; 31,654 prehensions) than all other treatments. Conversely, the 2 × 3H animals had the least number of grazing bouts (4.1 bouts) compared with 22H and 9H treatments and less ($P < 0.001$) grazing prehensions (19,312 prehensions) than all other treatments. The grazing bout duration of the 22H animals was lower ($P < 0.05$; 63.0 min/d) than all other treatments (93.4 min/d).

Although the 2 × 4.5H treatment had the greatest ruminating time (438 min; 7.3 h), it did not differ from the 9H (363 min; 6.1 h) but was greater ($P < 0.01$) than that of 22H and 2 × 3H animals (373 min; 6.2 h). Ruminating mastications did not differ between the 9H and 2 × 3H animals (19,586 mastications), yet this was lower ($P < 0.001$) than the values recorded by the 22H and 2 × 4.5H animals (25,587 mastications). The 2 × 4.5H treatment had a greater ($P < 0.05$; 575 boli/d) number of ruminating boli than all other treatments (441 boli/d), whereas the 2 × 3H animals had a greater number ($P < 0.05$; 13.6 bouts/d) of ruminating bouts than all other treatments (11.3 bouts/d). Ruminating bout duration was shorter ($P < 0.001$) for 2 × 3H and 9H compared with 2 × 4.5H (42.8 min/d), and there was no difference between the 22H and 9H treatments (35.1 min/d). The number of boli per ruminating bout was greater for the 2 × 4.5H ($P < 0.05$; 55.3 boli) compared with all other treatments (37.7 boli).

Handling time was least ($P < 0.001$) for the 2 × 3H treatment animals (690 min; 11.5 h) and greatest for the 22H animals (950 min; 15.8 h). Animals from the 9H and 2 × 4.5H treatments recorded intermediate values (837 min; 14 h). Idling time was greatest ($P < 0.001$) for the 2 × 3H treatment (750 min; 12.5 h) and least for the 22H treatment (490 min; 8.2 h), whereas 9H and 2 × 4.5H treatments were intermediate (603 min; 10.1 h). Idling mastications were greatest ($P < 0.05$) for the 2 × 3H treatment (1,548 mastications). There was no difference in the number of idling mastications between the 22H and 9H treatments (1,263 mastications), and 2 × 4.5H animals had less idling mastications ($P < 0.05$; 551 mastications) than 9H and 2 × 3H animals (1,494 mastications). A greater ($P < 0.001$) number of total mastications (31,416 mastications) were recorded from 22H and 2 × 4.5H animals than 9H and 2 × 3H animals (25,558 mastications).

DISCUSSION

This study provides a valuable insight into the effect of restricting pasture access time of lactating dairy cows in midlactation on production performance. Furthermore, it permits an enhanced understanding of the mechanisms that govern an animal's adjustment to restrictions imposed through the documentation of DMI and grazing behavior.

Effect of Restricted Pasture Access Time on Animal Production Performance

Restricting pasture access time did not affect milk production of midlactation dairy cows (21.7 kg/cow) in the present study, which contrasts with the findings of Mattiauda et al. (2003) and Pérez-Ramírez et al. (2008). Several factors may have influenced the disparity between results achieved in different studies. The aforementioned studies demonstrated that decreasing pasture access time from 8 to 4 h/d decreased milk yield by 5 and 8%, respectively. The minimum pasture access time in the present study was 6 h, and this was allocated in 2 distinct periods. Previous studies (Rook et al., 1994) reported that when dairy cows are allocated unrestricted access to pasture, grazing time ranges between 9 and 11 h. Rook et al. (1994) and Linnane et al. (2001) recorded an increase in grazing intensity in the a.m. and p.m., whereas Taweel et al. (2004) reported that time spent grazing at dusk constituted approximately 40% of the daily total grazing time. Although animals can modify their grazing behavior as a consequence of a behavioral decision (Newman et al., 1994a), it appears from the results of Mattiauda et al. (2003) and Pérez-Ramírez et al. (2008) that allowing dairy cows access to pasture for one single 4-h period is too restrictive and may also indicate that access time should be split into 2 periods. This requires further investigation.

In previous studies, animals were supplemented with additional feed when they were removed from pasture (Chilibroste et al., 2007; Pérez-Ramírez et al., 2008), resulting in a decreased period of fasting, which in turn decreased their motivation to graze. O'Donovan et al. (2005) showed that offering an all-grass diet resulted in a greater milk yield when compared with cows that were removed from pasture for a short period and supplemented with forage crops. This may indicate that when animals are removed from pasture, they should not be supplemented with additional forage.

Additionally, Chilibroste et al. (2007) reported that greater-yielding cows may be affected to a greater extent by length of grazing time allowed. The experimental animals used in the study of Pérez-Ramírez et al. (2008) were earlier in lactation and had greater pre-experimental milk yields (166 ± 38 DIM and 29.6 ± 3.7 kg/cow, respectively) compared with animals used in the present study. There is little published data on the effect of restricting pasture access time on milk production of dairy cows in the first half of their lactation. It may transpire that animals that are earlier in lactation, and greater-yielding animals, may be under a greater degree of stress and may not be able to sufficiently alter their grazing behavior to adjust to such a situation. Kennedy et al. (2008) found that when the diet of early lactation animals was restricted for 11 wk, milk production tended to remain at a lower level throughout lactation even when all animals were offered a greater DHA.

One of the most critical factors when explaining differences in milk production is the quality of the diet offered. In the present study, animals were offered a high-quality early spring pasture (86.4% OMD and 23.5% CP) with a pregrazing yield of 1,268 kg of DM/ha (>4 cm). This was in contrast to the midsummer pasture offered by Pérez-Ramírez et al. (2008), which was composed of 77.0% OMD and 22.5% CP with a pregrazing yield of 1,397 kg of DM/ha (>5 cm). The present study was conducted during the first grazing rotation when the plant was in a vegetative state and when high levels of sward utilization were achieved, whereas the study of Pérez-Ramírez et al. (2008) was carried out later in the grazing season when the grass plant was in a reproductive growth stage and there would be a greater concentration of dung pads, which can affect sward quality and utilization.

When access time to pasture was restricted to two 3-h periods in the present study, milk protein concentration was decreased compared with the control treatment. Pérez-Ramírez et al. (2008) also found a reduction in milk protein concentration when pasture access time was restricted from 8 to 4 h/d and cows were supplemented with 10 kg of DM supplement. Low milk protein concentration is generally associated with decreased DMI and energy supply (Coulon and Rémond, 1991). This may not have been the case in the present study, because when offered the same sward, there was no difference in TDMI between the 2 × 3H and 22H treatments; the extended periods of time when animals were not grazing may, however, have affected the rate of protein turnover in the rumen, thereby causing deficiencies in absorption by altering relative rates of synthesis (Oldham, 1984).

Friggens et al. (1998) stated that depending on the quality of the diet, DMI may either be the result of a constraint imposed by the diet or a consequence of the cow meeting its requirements. It is clear in this study that pasture access time imposed a constraint on DMI, because allocating cows one 9-h period decreased TDMI when compared with control treatment. Mattiauda et al. (2003) reported a 1.8-kg reduction in DMI when pasture access time was restricted. In the present study when the 9-h period was split into 2 distinct periods (i.e., 2 × 4.5H treatment), TDMI increased by 0.8 kg DM/cow per day, suggesting that total access time to pasture should be split into 2 periods.

Smith et al. (2006) reported no effect of pasture access time on BW. This is in contrast to the study of Garcia-Rodriguez and Oregui (2003), who found that restricting pasture access time decreased the BW of milking ewes by 3%. Given the short duration of the present study and minimal differences in TDMI, it is not surprising that there was no effect on BW.

Effect of Restricted Pasture Access Time on Grazing Behavior

A strong association between grazing behavior, herbage intake, and milk production has previously been reported (Pulido and Leaver, 2003). Several studies, conducted with sheep and cattle, have reported a relationship between fasting duration and subsequent grazing behavior (Newman et al., 1994b; Patterson et al., 1998).

Similar to that reported by Chilibroste et al. (1997), the current study found that the longest grazing time was recorded in animals with the greatest access to pasture (22H). Although the grazing time of 9H, 2 × 4.5H, and 2 × 3H treatments was less than that of animals from the control treatment (22H), restricting pasture access time resulted in much greater grazing efficiency, because these animals spent a greater proportion of their time at pasture grazing (81, 81, and 96%, respectively) than control animals (42%). Pérez-Ramírez et al. (2008) reported that cows increased the proportion of time spent grazing from 68% with 8-h to 87% with 4-h access.

The increased grazing efficiency of animals in the present study was associated with greater periods of fasting similar to that reported by Chilibroste et al. (2007) and lower ruminating time of the 2 × 3H animals. Greenwood and Demment (1988) previously showed that fasted animals compromise rumination to sustain high instantaneous intake rate. In addition, a lower ruminating time indicates less material in the rumen to digest. Chilibroste et al. (1998) reported that although a period of fasting increased grazing time, the magnitude of increase tended to vary depending on whether inert rumen bulk was in the rumen.

In concurrence with the present study, Newman et al. (1994b) also found that when periods of fasting were induced (restricting pasture access), intake rate increased, and this was largely due to an increase in bite mass. Patterson et al. (1998) has shown that dairy cows grazing good quality swards may be able to compensate for an increased degree of hunger by increasing biting rate and DMI per bite. Chilibroste et al. (1997) reported no difference between treatments in the number of bites per minute. In the present study, restricting pasture access time resulted in increased DMI per bite. Animals from the 2 × 3H treatment who fasted for 18 h/d had a DMI per bite 0.23 g greater than the control treatment. Intake rate (DMI/min) increased dramatically when access time to pasture was restricted. Pérez-Ramírez et al. (2008) reported a greater intake rate when pasture access time was limited. Taweel et al. (2004) reported that bite rate, bite mass, and hence intake rate increased later in the day (i.e., p.m.), thus reinforcing the suggestion that if access time to pasture is restricted, total grazing time should be split into 2 distinct periods.

CONCLUSIONS

Maximizing dairy cow performance from grazed pasture remains a key objective of pasture-based systems of dairy production. This study has shown that there is no effect of restricting access time to pasture on milk yield of midlactation animals yielding approximately 22 kg/cow per day. Milk protein concentration tended to be decreased when pasture access time was restricted to 2 × 3 h periods. Offering animals access to pasture for one 9-h period decreased TDMI. However, animals from the other treatments had similar TDMI as they adjusted their grazing behavior to compensate for decreased grazing time by increasing intake per minute and intake per bite. This study concludes that if access time to pasture is restricted, then the total access time should be greater than 6 h and that perhaps needs to be split into 2 distinct periods.

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