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Restricting dairy cow access time to pasture in autumn: The effects on milk production, grazing behaviour and DM intake of late lactation dairy cows

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ABSTRACT

Extending the grazing season in pasture based systems of dairy production can increase farm profitability; poor weather and soil conditions can reduce the number of grazing days. The study objectives were to (i) examine the effect of restricted access to pasture in the autumn on the milk production, grazing behaviour and DM intake (**DMI**) of late lactation spring-calving dairy cows and (ii) establish the effect of alternating restricted and continuous access to pasture on dairy cow production, DMI and grazing behaviour. Cows were randomly assigned to one of four grazing treatments: (i) 22 h (full-time) access to pasture (**22H**; control); (ii) Two 5-h periods of access to pasture (**2×5H**); (iii) Two 3-h periods of access to pasture (**2×3H**); and (iv) alternating between full-time and 3-h access to pasture with no more than three continuous days on any one regime, e.g. Monday – full-time access, Tuesday – 2x3H access, Wednesday – 2x3H access; Thursday – full-time access, etc. (**2×3HV**). Restricted access to pasture was offered after a.m. and p.m. milking. Swards of similar quality and pregrazing herbage mass were offered. Treatment had no effect on milk yield (13.2 kg/day), milk fat (48.2 g/kg), protein (39.0 g/kg) or lactose content (42.6 g/kg) and milk solid yield (1.15 kg/day). Similarly, there was no effect of treatment on final BW (483 kg) or final BCS (2.66). There was no significant difference in DMI (15.1 kg DM/cow/day) between treatments. There was an effect on daily grazing time, 22H cows (565 min/cow/day) grazed for longest time, however, when the 2x3HV treatment had full-time access to pasture, they had a similar grazing time (543 min/cow/day) to the 22H cows and were similar to the 2x3H treatment on days with restricted access to pasture (357 min/cow/day). The 22H and 2x5H animals had similar grass DMI/min (29.2 g/min), the 2x3HV were higher (33.9 g/min) but were similar to the comparable treatment when offered 2x3H access time (41.6 g/min) and when offered 22H access time (27.7 g/min). The results from this study show how when offered a grass only diet of autumn pasture grazing behaviour can be modified by restricting pasture access time without reducing dairy cow production in late lactation at low production levels. There was also no effect of alternating access time between 22H and 2x3H on milk production and DMI in the 2x3HV treatment. Restricted access time to pasture in autumn may be a strategy which farmers can use to extend the grazing season.

Implications

Farm profitability can be improved by increasing the number of grazing days. Wet weather and poor soil conditions can reduce the number of grazing days. By restricting cows' access to pasture during periods of poor weather and offering restricted access to pasture e.g. two 3-h periods per day high milk production, DM intake and grazing efficiency can be achieved. This practice also reduces damage to pasture. Cows can adapt to grazing management practices which vary from day-to-day suggesting that when weather permits cows can graze full time but restricted access can be offered on days with poor weather conditions.

Introduction

Global dairy production is constantly in a state of flux due to milk price volatility, international food markets, ever increasing environmental constraints and societal demands (Dillon et al.,

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2008). The efficient conversion of grazed grass into milk can ensure the competitiveness of pasture based dairy production (Hanrahan et al., 2018). Grazed grass, the cheapest feed available (Finneran et al., 2012), produces milk of a high product quality (O'Callaghan et al., 2016), is more environmentally sustainable (Peyraud et al., 2010) and can offer more welfare friendly conditions to the dairy cow (Olmos et al., 2009). Grass based system profitability is dependent on maximising the proportion of grazed grass in the diet of the dairy cow (Kennedy et al., 2005), which can be achieved by extending the length of the grazing season (Hanrahan et al., 2018). In Ireland, a 300-day grazing season is targeted; national farm survey data show actual grazing season length is on average 229 days (Teagasc, 2019).

Farmers have identified soil conditions as the biggest factor limiting the extension of the grazing season (Creighton et al., 2011). Poor soil conditions can lead to treading damage resulting in reduced herbage production (Tuñon et al., 2014) and soil compaction (Phelan et al., 2013). Over the past number of years, there has been interest in restricted access to pasture on a longer-term basis to mitigate nitrogen leaching (Christensen et al., 2019) and to manage wet soils (Laurenson et al., 2017). Restricted access to pasture is also frequently used as a strategy to overcome short periods of inclement weather, where if left to graze full-time, cows would damage pastures (Gregorini et al., 2009; Kennedy et al., 2009 and 2011; Pérez-Ramírez et al., 2008; 2009). These studies have shown that cows can readily adapt their behaviour and adjust to reduced pasture access time, during continuous periods between 30 and 60 days in length. In reality, weather conditions are highly variable and it may be more appropriate to offer full-time access to cows when soil conditions and weather permit, only restricting their access to pasture during periods of inclement weather. Consequently, cows may have one to two days of restricted pasture access before returning to pasture on a full-time basis, resuming restricted access when weather conditions deteriorate again. Currently, there is a dearth of information examining access time to pasture when continually switching between full-time and restricted access.

Pasture quality changes throughout the grazing season, deteriorating in the autumn (McCarthy et al., 2016). Yet, including grazed herbage in the diet of lactating dairy cows in late autumn/winter maintains milk protein output due to the higher energy and CP concentrations of grass during this period compared with that of grass silage (Kennedy et al., 2015). Grazing pastures in autumn influences pasture quality the following spring (Claffey et al., 2020). To ensure high quality pasture is available in spring, paddocks with high pregrazing herbage mass need to be grazed to encourage over-winter tillering (Hennessy et al., 2008). Restricted access time to pasture in spring has been shown to have no effect on dairy cow production in several studies (Kennedy et al., 2009 and 2011). However, Kristensen et al. (2007) and Pérez-Ramírez et al. (2008 and 2009) reported that restricting access time to pasture reduced milk yield and composition during the spring/early summer. After peak lactation, DM intake (**DMI**) decreases as days in milk increase (NRC, 2001). Therefore, if access to pasture in late lactation is restricted in autumn, DMI of grazed grass may not be affected as the cow can meet their lower intake requirement in the restricted time allocation (Clark et al., 2010). Studies reporting the effects of restricted access to pasture during the autumn are, however, limited.

The objectives of this study were to (i) examine the effect of restricted access to pasture in the autumn on the milk production, grazing behaviour and DMI of late lactation spring-calving dairy cows and (ii) establish the effect of alternating restricted and continuous access to pasture on dairy cow production, DMI and grazing behaviour. Preliminary results of this study have previously been presented (Kennedy et al., 2014).

Material and methods

The study was conducted at Teagasc Moorepark Research Centre, Fermoy, Co. Cork, Ireland (50°07′N; 8°16′W) from 26 September to 4 November, 2012. Experiments were undertaken in accordance with the European Union (Protection of Animals Used for Scientific Purposes) Regulations 2012 (S.I. No. 543 of 2012).

The site used was the same as that reported in Kennedy et al. (2009 and 2011). The soil type was an acid brown earth with a sandy loam-to-loam texture. The experimental area was a permanent grassland site containing more than 80% perennial ryegrass (*Lolium perenne* L.) and the majority of the remaining 20% comprised annual meadow grass (*Poa annua* L.). Daily weather data were collected within one kilometre of the grazing area throughout the study.

Animals and experimental design

The experiment was a randomised block design with four grazing treatments. Forty-eight late lactation Holstein-Friesian dairy cows were selected from the Moorepark spring-calving dairy herd. Of these, 12 were primiparous, the remaining 36 were pluriparous (17 cows were in their second lactation and 19 cows were in their 3rd or greater lactation). All animals were balanced on calving date (11 March, s.d. 23.1 days), three weeks pre-experimental milk yield (13.3, s.d. 2.15 kg), parity (2.6, s.d. 1.20), milk fat (45.1, s.d. 4.61 g/kg), protein (36.7, s.d. 2.80 g/kg) and lactose concentrations (43.3, s.d. 1.41 g/kg) and BW (501, s.d. 60.0 kg). Body condition score at the start of the experiment was 2.75.

Description of treatments and grazing management

Cows were randomly assigned to one of the following four grazing treatments: (i) 22 h (full-time) access to pasture (**22H**; control); (ii) Two 5-h periods of access to pasture after a.m. and p.m. milking (**2×5H**); (iii) Two 3-h periods of access to pasture after a.m. and p.m. milking (**2×3H**); and (iv) alternating between full-time and 3-h access to pasture after a.m. and p.m. milking, with no more than three continuous days on any one, e.g. Monday – full-time access, Tuesday – 2x3H access, Wednesday – 2x3H access; Thursday – full-time access etc. (**2×3HV**). Pasture access time was defined prior to the start of the experiment and did not depend on weather conditions. The 2x3HV treatment had an equal number of days where pasture access was restricted and where they had full-time access to pasture. All animals were allocated a common daily herbage allowance (**DHA**) of 17 kg DM/cow/day (>4 cm). No supplementary feed was offered to the treatments when they were removed from pasture and returned indoors. All treatments were offered herbage in 24-h allocations after a.m. milking. While at pasture, the four treatments grazed as separate herds, within the same paddock, with temporary fences erected to keep treatments separated. The position of each treatment in relation to the others was random during the period of the study. Calcium magnesite was dusted on the paddocks daily. A total grazing area of 19.3 ha was used during the study to give an effective stocking rate of 2.49 cows/ha. The experiment was undertaken during the penultimate and final grazing rotations of the season; thus, a number of paddocks were grazed on two occasions during the study.

When cows returned indoors, the 2x5H, 2x3H and 2x3HV treatments were grouped separately, in a cubicle house, with adequate individual lying space. Subsequent to the 26-d period when treatments were imposed, all animals grazed together as a single herd. Cows were offered a common DHA (18 kg DM/cow/day) for a further 2-wk period (carryover period).

Sward measurements

Herbage mass determination and sampling

For consistency and comparison between studies, grazing management practices were similar between this study and other experiments undertaken as part of this project (Kennedy et al., 2009 and 2011). Paddock herbage mass (>4 cm) was determined twice weekly by harvesting a representative strip (1.2 m × 1.5 m) with an Agria machine (Etesia UK Ltd., Warwick, UK). Ten grass height measurements were recorded before and after cutting on each strip using a rising pasture plate meter with a steel plate (diameter 355 mm and 3.2 kg/m; Jenquip, Fielding, New Zealand). Herbage mass was determined using the following equation:

$$\frac{\text{Weight of mown pasture (kg)}}{\text{(Length of cut (m)} \times \text{mower width (m)} \times 10\,000}$$

All mown herbage from each strip was collected, weighed and sampled. A sub-sample 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 each of the treatments was sampled weekly using a Gardena (Accu 60, Gardena International GmbH, Germany) hand shears using the previous defoliation height recorded for each of the treatments as a guide. A sub-sample was stored at −20 °C before being freeze-dried and milled before chemical analysis.

Pre- and postgrazing sward height and herbage utilisation

The pregrazing sward height was determined daily by recording 30 measurements across the two diagonals of the paddock, using the rising plate metre described above. Pregrazing values were recorded for each of the four treatments.

The DHA for the treatments was calculated by using the pregrazing HM and the daily herd requirement. Postgrazing sward height was measured daily for each of the four treatments.

Animal measurements

Milk production, BW and body condition score

Individual milk yields (kg) were recorded at each milking (Dairymaster, Causeway, Co. Kerry, Ireland). Milk composition was determined weekly from one successive a.m. and p.m. milking sample. The concentrations of fat, protein and lactose were determined using Milkoscan 203 (Foss Electric DK-3400, Hillerød, Denmark). Milk solid yield (MSY; kg) was calculated by summing milk fat and protein yields. BW was recorded weekly using a portable weighing scale and Winweigh software package. (Tru-test Limited, Auckland, New Zealand). Body condition score was recorded weekly during the study on a 1–5-point scale (1 = emaciated, 5 = extremely fat), with 0.25 increments (Edmonson et al., 1989) and was measured by the same experienced independent observer throughout the study.

Intake estimation

Individual grass DMI was estimated during the third week of the experimental period using the n-alkane technique (Mayes et al., 1986) as modified by Dillon and Stakelum (1989). To estimate DM intake methodology as previously outlined by Kennedy et al. (2009 and 2011) was used. In short, all cows were dosed twice daily, before milking, for 12 consecutive days with a paper filter (Carl Roth, Gmbh and Co. KG, Karlesruhe, Germany) containing 500 mg of dotriacontane (C32). From day 7 of dosing, faecal grab samples were collected from each cow twice daily for the remaining 6 days. The faecal 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 faecal collection, the diet of the animals was also sampled. Herbage representative of that grazed (taking cognisance of the previous defoliation height recorded from each treatment) was collected from each paddock before a.m. grazing on days 6–11 (inclusive) of the intake measurement period. Two samples of approximately 25 individual grass snips were taken from each paddock with Gardena hand shears. Herbage samples were frozen at −20 °C following collection. The ratio of herbage C_{33} to dosed C_{32} was used to estimate intake. The n-alkane concentration of the dosed pellets, faeces and herbage were determined as described by Dillon (1993).

Grazing behaviour

Grazing behaviour data were collected on two separate 24 h periods from 24 cows across the 22H, 2x5H and 2x3H treatments during the third and fourth week of the study. The 2x3HV treatments had four 24 h periods of data collected from eight cows; two periods while on full-time access to pasture and two periods while access time to pasture was restricted. Animals were selected by randomisation block taking cognisance of lactation number. Methodology, similar to that outlined by Kennedy et al. (2009 and 2011), was used. Briefly, following a.m. milking, eight cows from each grazing treatment were fitted with IGER (Institute of Grassland and Environmental Research) behaviour recorders (Rutter et al., 1997). If the data obtained from a cow were deemed unreadable following a 24-h period, the animal had a recorder fitted for a further 24 h. Seventy-six usable individual grazing behavioural recordings were obtained. Recorded jaw movements were analysed using the analysis software 'Graze' (Rutter, 2000). Total grazing, ruminating and idling times, as well as the number of bites and mastications, were measured using this software. The number of grazing and ruminating bouts, as well as the number of boli within each ruminating bout, was also counted. Handling time was calculated as eating time plus ruminating time; intake/min was calculated as (DMI (kg/day) × 1 000)/grazing time; and intake/bite was calculated as (DMI (kg/day) × 1 000)/number of grazing bites/day. Individual DMI values of the cows from which grazing behaviour measurements were recorded were used to calculate intake/min and intake /bite.

Chemical analyses

Herbage samples were freeze-dried and milled through a 1-mm sieve for each of the treatments. Similar to previous experiments in this project (Kennedy et al., 2009 and 2011) samples were analysed for DM, ash (Association of Official Analytical Chemists, method 942.05), ADF and NDF (determined using the procedures of AOAC, (1995) method 973.18; using sodium sulphate for the NDF and; ANKOM™ technology, Macedon, NY, USA), CP (Leco FP-428; Leco Australia Pty Ltd, Baulkham Hills B.C. NSW, Australia) and organic matter digestibility (OMD; using the method described by, Fibertec™ Systems, FOSS, Ballymount, Dublin 12, Ireland).

Statistical analyses

All data were analysed using SAS (v9.4; SAS Institute). All variables were first tested for normality (UNIVARIATE procedure).

Grazing management variables (DHA, pregrazing DM yield > 4 cm, area offered per treatment per day, pre- and postgrazing sward height) and chemical analyses of the pasture were analysed using a mixed model (PROC MIXED) in SAS, the model included treatment (n = 1–4) and week of experiment (n = 1–4).

One cow was excluded from the analysis due to a health issue, which was unrelated to the experiment. Milk production, milk composition, BW and BCS were analysed using a mixed procedure (PROC MIXED) in SAS. Week of experiment was included as a repeated measure with cow as the subject; randomisation block was included as a random effect. The following model was used

$$Y_{ij} = \mu + T_i + W_j + T_i x W_j + eijk$$

where μ is mean, T_i is treatment (i = 1–4), W_j is week of treatment (i = 1–4), $T_i \times W_j$ is the interaction between treatment and week of treatment, and e_{ij} is the residual error term. Tukey's test was used to determine differences between treatment means. Significance was declared at $P < 0.05$.

DM intake and grazing behaviour were analysed with the following model

$$Y_{ij} = \mu + P_i + T_j + P_i x T_j + b_1 X1_{ij} + b_1 X2_{ij} + b_2 DIM_{ij} + e_{ij}$$

where Y_{ij} represents the response of animal in parity i to treatment j, μ = mean, P_i = parity (i = 1–2), T_j = treatment (j = 1–4), b_1X1_{ij} and b_1X2_{ijk} = the pre-experimental milk output and BW variables, b_2DIM_{ijk} = the days in milk and e_{ijk} is the residual error term. Tukey's test was used to determine differences between treatment means. Significance was declared at $P < 0.05$. Grazing behaviour data were divided for the 2x3HV treatment into days when cows had full-time access to pasture and days when pasture access was restricted to identify if differences existed in their behaviour when provided with different access times. See Supplementary Material S1 for further information.

Results

Weather

Rainfall for the months of September and October was 23.8 and 99.3 mm, respectively, which was 0.28 and 0.98 of the 50-year average. Mean air temperature was 12.4 °C and 9.1 °C, respectively, which was 0.94 and 0.88 of the 50-year average.

Chemical analyses

There was no difference in the herbage offered to all treatments during the duration of the trial. Chemical composition of the herbage is shown in Table 1. Mean grass DM was 15.7 (1.78)% during the study.

Grazing management

There was no significant difference in DHA allocated to each of the treatments (16.8 kg DM/cow/day; Table 2), pregrazing DM yield > 4 cm (1 544 kg DM/ha), pregrazing sward height (9.4 cm), or area offered per treatment per day (1 400 m^2/treatment per day). The 2x3H had a significantly higher postgrazing sward height (4.6 cm) than all other treatments. The lowest postgrazing heights were measured from the 22H and 2x3HV swards (4.2 cm) while the 2x5H swards were grazed to an intermediate height (4.3 cm). Postgrazing height was similar for the 2x3HV on both restricted access and full-time access to pasture days.

Animal production

There was an interaction between treatment and week for milk yield; by the final week of the study, the 2x3H had a lower milk yield than the 22H treatment. There was no interaction between treatment and week in terms of milk fat, protein and lactose content and milk solid yield. There was a significant effect of week but values are not reported as differences between weeks were in line with stage of lactation.

Treatment had no effect on milk yield (13.2 kg/day; Table 3), milk fat content (48.2 g/kg), milk protein content (39.0 g/kg), milk lactose content (42.6 g/kg) or milk solid yield (1.15 kg/day). Similarly, there was no effect of treatment on end BW (483 kg) or end BCS (2.66). There were no differences in milk production variables measured between treatments during the two-week postexperimental period.

Grass DM intake

There was no significant interaction between treatment and parity. Parity tended to have an effect on DMI; primiparous cows ate 0.8 kg DM/cow/day less than multiparous cows (15.6 kg DM/cow/day). There was no significant difference between any of the treatments for DM intake (15.1 kg DM/cow/day; Table 4).

Grazing behaviour

There was no interaction between treatment and parity; there was also no effect of parity on any grazing behaviour variables. There was an effect of treatment on daily grazing time; the 22H cows (565 min/cow/day; Table 4) grazed for longer than all other treatments. However, when the 2x3HV treatment had full-time access to pasture, they had a similar grazing time (543 min/cow/day) to the 22H cows. The 2x3H cows had the shortest grazing time (358 min/cow/day) and when the 2x3HV cows had restricted access to pasture, they grazed for a similar length of time (357 min/cow/day) as the 2x3H treatment. The grazing time of the 2x5H cows was intermediate (487 min/cow/day). The 2x3H had the lowest number of grazing bites per day (22 315 grazing bites/cow/day) when compared to the other treatments (30 438 grazing bites/cow/day). The 2x3HV cows had 32 736 grazing bites/cow/day when offered full-time access to pasture and 22 987 grazing bites/cow/day when on restricted access time, which was similar to the 22H and 2x3H treatments, respectively. There was no difference between treatments in the number of bites per minute (61.2 bites/minute).

Grazing bouts was highest for the 22H treatment (5.8 bouts/day) with the 2x5H cows and 2x3H cows having significantly fewer grazing bouts at 3.4 and 2.0 bouts/day, respectively, while the 2x3HV cows had 4.5 grazing bouts/day, which was similar to all the treatments. The 2x3HV had 2.4 grazing bouts per day on 2x3H access days and 6.3 grazing bouts per day on days when offered 22H access.

Table 1
Chemical analysis of autumn herbage offered to cows grazing pasture on a full-time basis or offered restricted access time to pasture.

Item	22H	2x3HV	2x5H	2x3H	SED	*P*-value
OMD (%)	84.8	83.9	83.9	83.9	3.49	0.595
CP (%)	25.1	24.2	24.3	25.3	4.29	0.531
ADF (%)	34.4	34.3	35.7	32.5	11.29	0.594
NDF (%)	44.1	46.5	47.9	46.5	13.74	0.603
Ash (%)	8.0	7.5	8.0	7.5	2.15	0.450

22H = 22 h access to pasture; 2x3HV = Alternating between full-time and two 3-h periods of access to pasture, with no more than 3 continuous days on any one regime; 2x5H = Two 5-h periods of access to pasture; 2x3H = Two 3-h periods of access time to pasture.
OMD = Organic Matter Digestibility.

Table 2
Effect of offering spring-calving cow's full-time or restricted access time to pasture in autumn on sward measurements.

Item	22H	2x3 HV	2x5H	2x3H	SED	*P*-value
DHA (kg DM/cow/day)	16.7	16.9	16.8	16.9	0.36	0.912
DM yield > 4 cm (kg DM/ha)	1 601	1 527	1 510	1 538	130.2	0.765
Pregrazing sward height (cm)	9.4	9.4	9.4	9.4	0.50	0.996
Area (m^2/cow)	114	119	119	116	8.9	0.803
Postgrazing sward height (cm)	4.2[a]	4.2[a]	4.3[b]	4.6[c]	0.12	0.001

22H = 22 h access to pasture; 2x3HV = Alternating between full-time and two 3-h periods of access to pasture, with no more than 3 continuous days on any one regime; 2x5H = Two 5-h periods of access to pasture; 2x3H = Two 3-h periods of access time to pasture
DHA = Daily Herbage Allowance
[abc]Values in the same row not sharing a common superscript are significantly different.

Table 3
Effect of offering spring-calving cow's full-time or restricted access time to pasture in autumn on milk production.

Item	22H	2x3HV	2x5H	2x3H	SED	*P*-value
Milk yield (kg/day)	13.2	13.3	13.7	12.6	0.55	0.197
Milk fat content (g/kg)	48.4	47.8	47.4	49.1	0.13	0.577
Milk protein content (g/kg)	40.1	38.6	38.8	38.6	0.12	0.563
Milk lactose content (g/kg)	42.7	42.2	42.4	42.9	0.42	0.291
MSY (kg/day)	1.17	1.14	1.18	1.09	0.051	0.238
End BW (kg)	501	478	481	472	19.7	0.542
End BCS	2.72	2.70	2.61	2.61	0.062	0.321

22H = 22 h access to pasture; 2x3HV = Alternating between full-time and two 3-h periods of access to pasture, with no more than 3 continuous days on any one regime; 2x5H = Two 5-h periods of access to pasture; 2x3H = Two 3-h periods of access time to pasture.
MSY = Milk Solid Yield (kg fat + kg protein); BCS = Body Condition Score.

Table 4
Effect of offering spring-calving cow's full-time or restricted access time to pasture in autumn on DM intake and grazing behaviour.

Item	22H	2x3 HV	2x5H	2x3H	SED	*P*-value
DMI (kg DM/day)	15.5	15.1	15.0	14.9	0.53	0.850
Grazing time (min/day)	565[a]	460[b]	487[b]	358[c]	32.7	0.001
Grazing bites (day)	32 274[a]	28 358[a]	30 684[a]	22 315[b]	2 294.4	0.005
Grazing bites (bites/min)	57.0	62.3	63.0	62.3	3.00	0.174
Grazing bouts (day)	5.8[a]	4.5[ab]	3.4[b]	2.0[b]	0.73	0.001
Grazing bout duration (min/day)	114[a]	124[a]	151[b]	177[b]	17.0	0.002
DMI/min (g)	27.6[a]	33.9[b]	30.8[a]	41.3[c]	2.66	0.001
DMI/bite (g)	0.49[a]	0.54[a]	0.50[a]	0.68[b]	0.051	0.001
Ruminating time (min/day)	391	347	379	369	22.4	0.237
Ruminating boli (day)	465	502	482	423	43.6	0.324
Ruminating bouts (day)	11.5	17.7	13.6	14.3	2.29	0.062
Ruminating bout duration (min/bout)	33.9[a]	23.2[b]	32.0[a]	26.2[ab]	2.96	0.002
Boli/ruminating bout (n)	40.2[a]	31.4[b]	39.3[a]	29.4[b]	3.47	0.004
Handling time (min/day)	956[a]	806[b]	866[b]	729[c]	44.5	0.001
Idling time (min/day)	484[a]	634[bc]	574[b]	711[c]	44.5	0.001

22H = 22 h access to pasture; 2x3HV = Alternating between full-time and two 3-h periods of access to pasture, with no more than 3 continuous days on any one regime; 2x5H = Two 5-h periods of access to pasture; 2x3H = Two 3-h periods of access time to pasture.
DMI = DM intake; Handling time = ruminating + grazing time.
[abc]Values in the same row not sharing a common superscript are significantly different.

The 2x3H and 2x5H (164 min/bout) had a significantly longer grazing bout duration than the 22H (114 min/bout) and 2x3HV (124 min/bout). The 2x3HV had a grazing bout length of 160 minutes when offered 2x3H access time and 93 minutes when offered 22H access time.

The 22H and 2x5H animals had similar DMI/min (29.2 g/min), the 2x3HV were higher (33.9 g/min). The 2x3H treatment had the highest DMI/min (41.3 g/min). The 22H, 2x3HV and 2x5H had similar DMI/bite (51.0 g/bite) but were lower than 2x3H (0.68 g/bite).

There was no difference in ruminating time (372 mins/day), the number of ruminating boli (468 boli) or the number of ruminating bouts (14.3 bouts/day) between any of the treatments. Ruminating bout duration was significantly shorter for the 2x3HV (23.2 min) compared to the 22H and 2x5H treatments (33.0 min) with the 2x3H (26.2 min) being similar to both treatments.

Handling time was significantly longer for 22H (956 min/cow/day) when compared to all other treatments. The 2x3HV and 2x5H had similar handling times (836 min/cow/day) while the 2x3H were intermediate (729 min/cow/day). The 2x3HV had similar values for handling time to the 22H and 2x3H when allocated full-time and restricted access time to pasture (904 min/cow per day and 687 min/cow per day, respectively).

Discussion

Technologies, such as restricted access to pasture, can help extend the grazing season (Kennedy et al., 2009 and 2011) which may have a positive influence on farm profitability (Hanrahan et al. 2018). Deteriorating pasture quality in autumn (McCarthy et al., 2016) and unpredictable weather conditions often result in cows alternating between full-time and restricted access to pasture, the effects of which together have not been investigated prior to this study.

Effect of restricted access to pasture on animal production and grazing behaviour

The imposed restriction on daily access time to pasture, when cows were in late lactation, did not have a treatment effect on the animal's production performance, which concurs with Kennedy et al. (2009 and 2011) who also found no effect of restricting pasture access time on DMI or production when investigating cows in early lactation. Previous studies by Pérez-Ramírez et al. (2008) and Mattiauda et al. (2013) have shown that restricting access time to pasture led to a reduction in DMI (1.8 kg DM/cow/day and 1.7 kg DM/cow/day, respectively) and milk yield (1.1 kg/cow/day and 1.3 kg/cow/day, respectively). In these experiments, supplementary feeds were in excess of 0.50 of the total DMI, with only one period at pasture. It was hypothesised that the loss in production was due to the lower DMI, caused by the restricted access time. Kennedy et al. (2009) previously showed that by dividing access time into two distinct periods rather than one distinct grazing period, DMI can be increased. In our study, there was no effect on DMI when pasture was offered in two distinct periods. Although the *n*-alkane technique is only an estimate of DMI, a lot of work has been completed at Teagasc Moorepark to ensure the accuracy of the technique (Wright et al., 2019), consequently, we are confident in the estimates obtained.

Cows in the present study with 6 h pasture access per day (2x3H) had a lower total number of grazing bites per day, presumably due to shorter pasture access time. They did however have higher DMI per bite and higher DMI per min (albeit obtained from calculated rather than measured values) which enabled them to have a similar intake to cows allocated 22H access to pasture resulting in no effect on milk production. It is unusual however that the postgrazing height of the 2x3H cows was higher than all other treatments, normally this would suggest a lower DMI, but this was not the case in the present study. It may be because the 2x3H spent a shorter period in the paddock and consequently had less time to trample the pasture resulting in a higher postgrazing height compared to the other treatments. It may also suggest that two 3-h periods are the minimum pasture access time that unsupplemented late lactation cows should be offered in autumn, however, this requires further investigation. It is worth considering that without supplementation, and if continued for an extended period of time (i.e. >28 days), the 2x3H treatment may have resulted in lower DMI and production losses, and may not be sustainable as a longer-term strategy to retain cows at pasture in autumn. An interaction between treatment and week of experiment showed that milk yield was reducing at a greater rate for the 2x3H when compared to 22H by the end of the study. No supplementary feedstuffs were included in the diet of the cows that would affect appetite in the present study, giving a true reflection of how cows behaved in response to the treatments imposed on a grass only diet. Pérez-Ramírez et al. (2008) stated that cows showed a stronger motivation for grazing when receiving a low-supplement feeding regime. Kennedy et al. (2011) have shown that offering supplementary forage in the form of grass silage (4 kg DM/cow) resulted in no benefits to milk production, as it reduced the animals' appetite when grazing, which resulted in a 2.3 kg reduction in DMI. In our experiment, all animals grazed intensively as bite rate and DMI/bite were relatively high and similar to that reported in other studies offering a grass only diet (Werner et al., 2019; 31 267 bites/day and 62.3 bites/min). Patterson et al. (1998) found that as time of fasting increased, the animals responded by increasing their grazing bites/min and DMI/bite. In the present study, the 2x5H had a similar DMI/min and DMI/bite when compared with the 22H treatment, while reducing pasture access time to two 3-h periods (2x3H) increased both parameters. This indicates that the 2x5H had sufficient time at pasture to consume their full DMI requirement without adjusting their grazing behaviour. The 2x5H grazed for 81% of their time at pasture, ensuring efficient grazing and less time to potentially damage paddocks during inclement weather (Kennedy et al., 2009; Tuñon et al., 2014), especially when compared to the 22H treatment which only grazed for 43% of their time at pasture. The grazing time of the 22H (565 min/day) was similar to that reported in other studies where a grass only diet was offered (500 min/day; Werner et al., 2019).

Effect of variable restricted access time to pasture on animal performance

Mimicking actual on-farm practice is essential to underpin the applicability of new grazing management technologies. While restricted access to pasture for a continuous period (between 30 and 60 days) has been investigated and has shown that cows can readily adapt their behaviour and adjust to reduced pasture access time during continuous periods (Gregorini et al., 2009; Kennedy et al., 2009 and 2011; Mattiauda et al., 2013; Pérez-Ramírez et al., 2008; 2009), some farmers are likely to practise restricted access to pasture for shorter periods of time based on the prevailing weather conditions. When the grazing behaviour of the 2x3HV was examined on a daily basis, taking cognisance of cow's access time to pasture the previous day, it was evident that cows immediately adjusted their grazing behaviour to reflect their access time. For example when morning grazing time was calculated for the 2x3HV on a day of restricted access, following a day of full-time access, grazing time was 172 mins while it was 176 for the cows in the 2x3H treatment, who were continually offered two 3-h periods of access to pasture. Similarly, when the 2x3HV were offered full-time access following a day of restricted access, their morning grazing time was 316 mins, which was similar to the 22H cows' morning grazing time of 323 mins. This is probably due to the morning grazing bout being one of the major grazing bouts of the day and according to Abrahamse et al. (2009), the rate of bites and chews is greater immediately after moving to fresh pasture. Furthermore, as pasture was allocated on a daily basis and cows consumed their daily allocation (postgrazing height of 4.2 cm) overnight fasting probably occurred; Patterson et al. (1998) found that intake rate increased significantly when animals were fasted for up to 6 h in comparison to a 1 h fast.

The rapid adjustment to their pasture access time explains why the performance/behaviour of these cows reflects the access time provided on a given day. Furthermore, the results of our experiment indicate that given cows' flexibility and readiness to adjust to their given circumstances, restricted access to pasture can be used as a strategy to retain cows at pasture for short periods of time, e.g. one to two days. Also, based on the findings of longer-term restricted access treatments both in the present study and previous studies (Gregorini et al., 2009; Kennedy et al., 2009 and 2011; Mattiauda et al., 2013; Pérez-Ramírez et al., 2008; 2009), it offers the possibility to use restricted access to pasture as a strategy to retain cows at pasture on a longer-term basis, for example where poor soil conditions prevail and full-time access would increase the risk of treading damage.

Conclusion

The results from this study show how grazing behaviour can be modified by restricting access time to pasture with no reduction in milk production or DMI in spring-calving dairy cows in late lactation with a production level in the range of 10–15 kg milk/day. There was also no effect of alternating access time between 22H and 2x3H on milk production and DMI in the 2x3HV treatment.

Therefore, it is possible for restricted access time to pasture to be implemented on dairy farms in autumn with no effect on animal performance.

Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.animal.2021.100335.

Ethics approval

Experiments were undertaken in accordance with the European Union (Protection of Animals Used for Scientific Purposes) Regulations 2012 (S.I. No. 543 of 2012).

Data and model availability statement

None of the data were deposited in an official repository. The data that support the study findings are available upon request.

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Declaration of interest

None.

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