AGRI-FOOD
& BIOSCIENCES
INSTITUTE

Impact of pasture allocation frequency on dairy cow performance

March 2020

Impact of pasture allocation frequency on dairy cow behaviour and performance

(Report prepared for AgriSearch by AFBI as part of AgriSearch Project: D95 -18)

Project team: Ms Jessica Pollock, Dr Debbie McConnell, Dr Kat Huson and Mr Alan Gordon

Agri-Food and BioSciences Institute
Livestock Production Systems Branch
Sustainable Agri-Food Sciences Division
Large Park
Hillsborough
County Down
BT26 6DR
Northern Ireland
Tel: (+44) 28 92 682484

Table of Contents

List of Tables

Table of Figures

1 Key messages

- The overall aim of this study was to assess the impact of frequency of fresh pasture allocation (12, 24 and 36 hour allocations) on the performance of lactating dairy cattle.

- Pasture allocation frequency had no significant impact on grass utilisation.

- Increasing pasture allocation frequency produced significantly lower milk fat plus protein yields with animals receiving 12 hour allocations exhibiting the poorest performance.

- Treatment differences were driven by parity 1 animals. Due a greater level of competition for resources within the 12h treatment, parity 1 animals in this treatment were considered to consume grass faster at grazing than their 24 and 36h counterparts, resulting in less grazing selectivity (and subsequently poorer ingested forage quality) and a higher rumination rate post grazing. This is thought to result in the lower overall milk fat plus protein output from this treatment.

- Pasture allocation frequency had limited impact on the performance of multiparous animals.

- Cows displayed a strong diurnal feeding pattern with a preference for daytime grazing which was evident regardless of grazing management.

2 Introduction

Efficient grassland utilisation is a key factor in the long-term sustainability of dairy production systems in temperate grassland environments across the globe (Dillon, 2007). Increasing the proportion of grazed grass in dairy cow diets has been associated with both environmental (O'Brien et al., 2012) and economic (Dillon et al., 2005) benefits meanwhile meeting a growing consumer demand for grass-fed produce (Schuppli et al., 2014). Whilst research has highlighted the potential of lactating dairy cows to consume up to 17kg DM cow-1 day-1 on pasture only diets (Kennedy et al., 2003), achieving this high level of grazed grass in the diet can be challenging and requires effective management of the plant, animal and climatic conditions. Within dairy cow grazing systems there are a number of factors which influence dry matter intake (DMI) and considerable research has been undertaken to develop appropriate sward and animal management strategies. For example, increasing pasture allocation per cow has been identified as a management strategy to increase animal DMI in both low and high feed supplementation scenarios (Kennedy et al., 2008, McEvoy et al., 2008, Bargo et al., 2002, Dale et al., 2018). However this management approach is often associated with a reduction in grass utilisation efficiency which can negatively impact longer-term grass DMI and consequently animal performance, limiting the use of this approach on commercial farms. Hence the development a grass allocation strategy which will achieve high levels of grass DMI whilst simultaneously maintaining grass utilisation is required.

Animal grouping strategy is another key component within the animals feeding environment, which can influence feeding behaviour and subsequently DMI (Grant and Albright, 2001). For example, Krohn and Konggaard (1979) found grouping subordinate primiparous animals separately within an indoor environment increased their DMI by 20% and subsequently increased milk production. Within their groups dairy cattle form a hierarchy through dominance establishment (Hussein et al., 2016). Dominance in dairy herds is predominately positively correlated to live weight and lactation number (Phillips and Rind, 2002, Sołtysiak and Nogalski, 2010, Hussein et al., 2016), therefore primiparous animals are generally classed as subordinate due to their lower live weight and lactation number. Although grouping primiparous animals separately from multiparous animals may support the performance and health of the primiparous animals (Krohn and Konggaard, 1979, Sniffen et al., 1993), limitations on labour and grazing infrastructure often make this impractical on commercial dairy farms. Therefore grazing herds regularly encompass animals of different parities and production levels, hence varying energy demands are common. Consequently strategies which meets these differing energy demands and minimise the negative impacts of dominance within grazing groups are required.

Pasture allocation frequency (PAF) is a management strategy which to date has received relatively little attention in grazing systems. This approach creates short-term differences in both grass availability and inter-animal competition for resources, potentially impacting grazing behaviour and grass DMI. Previous indoor studies have found reducing the feeding frequency of a total mixed ration (TMR) from five times to once daily (Mäntysaari et al., 2006) and from once daily to alternative day feeding (Phillips and Rind, 2001), resulted in an increase in DMI and subsequently animal performance. Previous literature on PAF has been inconsistent. Dalley et al. (2001) found reducing PAF from 6 daily allocations to once a day improved milk yield of lactating dairy cows. In contrast, Abrahamse et al. (2008) observed reduced animal performance through a lower milk yield when PAF was reduced from allocations daily to every 4 days. Within commercial intensive dairy grazing systems, fresh pasture is conventionally allocated either once or twice daily post milking. Although research has investigated very high frequency (Dalley et al., 2001) and low frequency (Abrahamse et al., 2008) allocations, conventional PAF's are seldom investigated in research trials. In addition, studies to date have offered high pasture allowances (> 40kg/cow/day) resulting in high post-grazing sward heights, limiting the inter-animal competition for resources often witnessed in intensive grazing systems on commercial farms and resulting in poor pasture utilisation rate. Previous research has highlighted the negative economic impact of reduced pasture utilisation on dairy farms in Northern Ireland (AFBI, 2017).

3 Aims and Objectives

The overall aim of this study was to assess the impact of frequency of fresh pasture allocation on the performance of lactating dairy cattle. A number of sub-objectives were identified, including:

1. To evaluate the impact of pasture allocation frequency on grass utilisation
2. To understand animal grazing behaviour within grazing systems of varying pasture allocation frequency
3. To determine the influence of pasture allocation frequency on animal performance and milk output
4. To investigate any interaction between pasture allocation frequency and animal parity group.

4 Materials and Methods

The experiment was conducted at the Agri-Food and Biosciences Institute, Hillsborough, Northern Ireland during 2018 (54°27'N; 06°04'W).

Experimental procedures in this study were conducted under an experimental license granted by the Department of Health, Social Services and Public Safety for Northern Ireland (DHSSPSNI) in accordance with the Animals Scientific Procedures Act 1986.

4.1 Experimental design

The experiment consisted of two experimental periods both lasting sixty days: period one (P1; 11 May - 10 July) and period two (P2; 11 August - 10 October). Experimental animals were housed full-time for 25 days (11 July – 5 August; non-experimental period) due to a prolonged period of low rainfall that resulted in a shortage of grass on the experimental areas. Mean monthly rainfall recorded at the experimental site was less than the five-year average (Table 4.1-1). During June and July 2018 at the experimental site average daily hours of sunshine were greater compared to the five-year average. Similarly, average temperature was higher in May, June, July and August during 2018 relative to the average for the previous five years. Contrastingly, average temperature was lower in 2018 in September and October compared to the five-year average between 2013 and 2017 (Table 4.1-1).

Table 4.1-1 Rainfall, sunshine hours and average temperature at the Hillsborough site during 2018 and during the previous five year period (2013 – 2017).

	May	June	July	August	September	October
Rainfall (mm)						
5 year average	67.9	69.3	75.7	110.4	55.7	108.2
2018	34.4	24.2	66.	72.4	34.4	50.0

Sunshine (hours)						
5 year average	6.4	5.4	5.9	5.2	4.3	3.4
2018	6.3	8.0	6.6	4.3	3.1	3.6
Temperature (ºC)						
5 year average	10.7	13.4	14.8	14.2	12.5	10.0
2018	11.8	14.8	15.8	14.4	11.5	9.2

Ninety spring calving dairy cows comprising of 66 Holstein cattle and 24 Holstein x Jersey crossbred animals were allocated to one of three treatment groups. Each treatment group (n=30) consisted of nine primiparous and 21 multiparous animals, with a mean calving date and lactation number of the 4th of February (s.d., 18.3 d) and of 2.4 (s.d., 1.31), respectively. Treatments were balanced for breed, pre-experimental milk yield [mean 37.2 kg cow^{-1} day^{-1}, (s.d., 7.87kg)], live weight [mean 606kg, (s.d. 62.1kg)], body condition score [mean 2.42, (s.d., 0.157)], milk predicted transmitting ability (PTA) [mean 200kg, (s.d. 141.9kg)] and kilograms of fat plus protein PTA [mean 26.3kg, (s.d. 7.09kg)].

Animals grazed part time from 12 April and commenced full time grazing on 22nd April. Animals were divided into their treatment groups on 4 May and had a 7 day adaption period observed prior to measurements starting.

Throughout the grazing periods animals were offered a grazing concentrate twice daily during milking via individual concentrate feeders, at a rate of 4.5 kg cow^{-1} day^{-1} fresh weight (FW) and 6 kg cow^{-1} day^{-1} FW for P1 and 5kg cow^{-1} day^{-1} (FW) and 6.5kg cow^{-1} day^{-1} FW for P2, for primiparous and multiparous animals, respectively (Table 4.1-2).

Table 4.1-2 Formulation of grazing concentrate offered during the study.

Concentrate Ingredient	g kg^{-1} FW
Soya Hulls	187
Maize Meal	160
Wheat	150
Hi-Pro Soya Bean Meal	125
Rape Seed Meal	90
Molaferm	70
Distillers Grain	60
Pollard	57
Citrus-pulp	40
Rumen Protected Fat	20
Minerals/Vitamins	41

During the non-experimental period animals were housed in their treatment groups and offered common levels of silage and concentrates. Animals remained in the same treatment groups during P2 however, one Holstein parity one animal was removed from each group (n=29) due to an ill health animal and to ensure treatment groups remained balanced. Treatments groups had a mean milk yield of 27.6 kg cow-1 day-1 (s.d., 7.40) and a mean of 2.5 lactations (s.d., 1.30d) prior to P2 commencing. Once full-time grazing occurred (5 August) all silage was removed from the diet.

Balanced groups were assigned to one of the three pasture allocation treatments; allocated fresh pasture every: 12 hours (12h), 24 hours (24h) or 36 hours (36h).

4.2 Grazing management

The primary experimental area consisted predominately of perennial ryegrass (Lolium perenne L.) swards with an average age of five years. The soil type was a slightly gleyed sandy clay-loam (48% sand, 31% silt and 21% clay) overlying Silurian shale (greywacke) till. Six primary grazing blocks and seven primary grazing blocks each 2.52 ha in size were established in P1 and P2, respectively. Each block consisted of three 0.72 ha plots with each plot comprising of either: six 12h paddocks (0.14ha each), three 24h paddocks (0.28ha each) or two 36h paddocks (0.42ha each; Figure 4.2-1). Plots were randomly allocated within the blocks and animals grazed in as close proximity as possible. Grass was allocated at a rate of 15 kg DM cow^{-1} day^{-1} throughout the study. Target pre and post grazing covers across all treatments were 3200kg DM ha^{-1} and 1700 kg DM ha^{-1}, respectively. Animals in the 24h treatment were offered fresh pasture after the afternoon milking. The 12h treatment were offered fresh pasture after both morning while fresh pasture was offered after alternating morning and afternoon milkings for the 36h treatment. There were four complete rotations in P1 and three in P2. Three primary blocks were topped in P1 after rotation 4 and four primary blocks were topped in P2 after rotation 1 using a disc mower (Lely, Splendimo 320) to a height of approximately 4.0cm to maintain sward quality, paddocks within blocks were topped successively. If post grazing targets were not met non-experimental animals were used to graze these areas in the immediate 24 hours following the grazing by experimental animals.

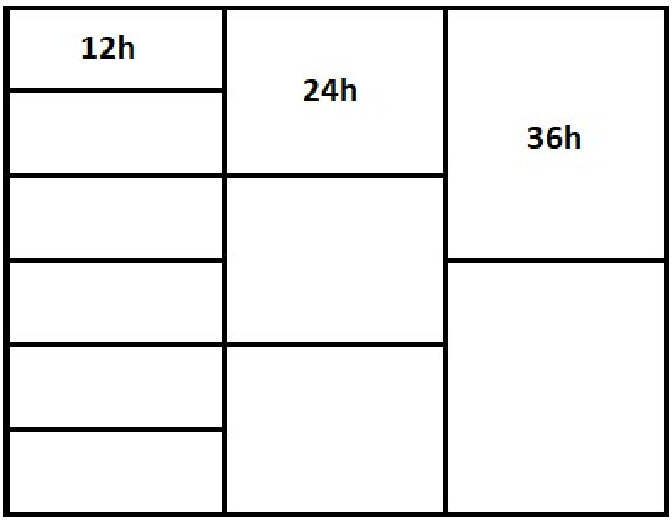

Figure 4.2-1 Diagram of 72 hour grazing block with six 12h (0.14 ha), three 24h (0.28 ha) and two 36h (0.42 ha) paddocks.

Swards were grazed prior to the experiment commencing and subsequently received 34.5kg of nitrogen (N) ha^{-1} as urea. Thereafter, fertiliser in the form of calcium ammonium nitrate (CAN) was applied after each grazing with 41 kg N ha^{-1} in rotation one, 35kg N ha^{-1} in rotation two, three and four, and 29kg N ha^{-1} in rotation five and six. Grazing blocks were sown on the same day with a total of 204 kg N ha^{-1} applied during experimental period, fertiliser was pre-weighed for each individual paddock prior to application by a tractor mounted fertiliser distributer (Vicon, UK).

4.3 Sward measurements

Pre- and post-grazing pasture heights were determined using rising plate meter (RPM; Jenquip EC10 Electronic Platemeter, Feilding, New Zealand) for each paddock. Measurements were taken in a 'W' formation across each paddock with 20, 40 and 60 measurements for the 12 h, 24 h and 36 h treatments, respectively. Pasture utilisation was expressed as the ratio of pasture consumed to pasture available (above 4.0 cm) calculated using the following equation:

$$\frac{Pre-grazing\ height\ (cm) - Post-grazing\ height\ (cm)}{Pre-grazing\ height\ (cm) - 4.0}$$

Additionally, a representative pasture sample was harvested twice a week from each treatment using electric hand shears (BOSCH, UK), cut to a height of 4cm. Samples were harvested from the appropriate paddocks immediately prior to grazing. Near infrared spectroscopy (NIRS) analysis determined DM content, crude protein (CP), water soluble concentrations (WSC), acid detergent fibre (ADF) and metabolisable energy (ME) of the sample using the methodology described by Park et al. (1998) for grass silage, with a fresh grass calibration equation. Concentrate samples were collected weekly and bulked for each two consecutive weeks. Bulked samples were oven dried at 60°C for 48 hours and subsequently analysed for ADF, neutral detergent fibre (NDF), ash, nitrogen (N), gross energy (GE) and starch concentration by standard wet chemistry analytical techniques.

4.4 Animal measurements

4.4.1 Animal performance measurements

Cows were milked twice daily, between 05.30 and 07.30, and 15.00 and 17.00. Individual cow milk yields (kg) were recorded at each milking. Milk fat, protein and lactose contents were determined weekly from milk samples collected during two consecutive milkings each week. Milk samples were analysed using an infrared milk analyser (Milkoscan Model 605; Foss Electric, Hillerod, Denmark). Weighted milk composition for the 24 hour period was determined using the average daily milk yield of the previous seven days. Milk energy concentrations (MJ kg^{-1}) were calculated using the equations of Tyrrell and Reid (1965).

Milk energy = (fat x 0.0384) + (protein x 0.0223) + (lactose x 0.0199) - 0.l08

∴ Milk energy output = milk energy content x average daily yield for previous 7 days

Individual animal liveweight (LW) was recorded after each milking using an automatic weighbridge (BioControl, Norway). Body-condition score (BCS) was estimated fortnightly using a five-point body condition scoring system (Edmonson et al., 1989). Change in LW and BCS over the course of the experiment were calculated as the difference between the final and initial value.

4.4.2 Animal behaviour measurements

A total of 42 animals were selected (n= 14 per treatment) and balanced according to initial parameters (pre-experimental yield, days in milk, live weight, PTA of milk, milk fat and protein). Each subset of 14 animals from each treatment consisted of four primiparous and ten multiparous animals. Animals were fitted with grazing and ruminating behaviour monitoring equipment (RumiWatch; ITIN + HOCH, Switzerland) for a period of 12 days (8 - 20th September). The equipment consisted of a halter equipped with an oil-filled tube with a built-in pressure sensor, a 3-axis accelerometer, data logger and two 3.6 V batteries. The oil-filled tube was placed over the bridge of the animal's nose with pressure in the oil-filled tube altering with jaw movements. These pressure signatures and acceleration patterns were collected at a frequency of 10 Hz resolution. Raw data was stored on 4GB SD memory card and downloaded after the 12 day recording period. As detailed and validated by Werner et al. (2018), specialist software (RumiWatch Converter version V0.7.4.5) was used to classify pressure and acceleration data into a range of grazing and ruminating variables, producing one-hour data summaries (Table 4.4-1). Halters were reviewed twice daily to ensure animals did not have any abrasions.

Table 4.4-1 Grazing behaviour parameters recorded using the Rumiwatch sensor

Behaviour variable	**Variable in Rumiwatch manager**	**Description**
Grazing time (min hr^{-1})	EAT1TIME	Prehension bites and mastication chews in the downward position
Ruminating time (min hr^{-1})	RUMINATETIME	Time spent ruminating per hour
Number of boli (n. hr^{-1})	BOLUS	Number of rumination boluses per hour
Chews per bolus (n. bolus^{-1})	CHEWSPERBOLUS	Number of chews per rumination bolus

4.5 Statistical analysis

Due to constraints on grazing infrastructure and animal numbers available for the experiment, it was not feasible to establish replicated groups within each grazing treatment. Therefore, individual animals were used as the experimental unit for statistical analysis, as has been the case for similar studies (Dale et al. 2018, Verdon et al. 2018). Although there is ongoing discussion around using individual animals as replicates in grazing experiments (Iason and Elston, 2002), it has also been demonstrated that the use of multiple smaller replicate groups may not be appropriate when study results are likely to be impacted by changes in grazing behaviours, as small groups of animals behave differently to larger groups which are found in the commercial systems for which the results of this study would apply (Rind and Phillips, 1999). During P2, data from one primiparous animal was excluded from the results due to a chronic illness. In addition, two primiparous animals were removed from their treatment groups during this period and replaced with animals of similar milk yield, parity and live weight in order to maintain balanced groups. Data was analysed using Genstat (Genstat Sixteenth Edition, Lawes Agricultural Trust, Rothamsted, UK). Data from each period was analysed separately. Mean weekly milk yields, fat concentrations, protein concentrations, fat plus protein yield and ECM yield were analysed using a linear mixed model methodology with a repeated measures design to take account of correlations in individual animal measurements made at the various time points (Purcell et al. 2016). The restricted maximum likelihood (REML) estimation method was used to fit all effects in each model and the correlation between time points assessed with an antedependence model of order 1. The individual animal was fitted as a random effect in the models with week of measurement fitted as the time factor. The individual effects of week, parity group and treatment together with their interactions were fitted as fixed effects in all models.

Grass data was analysed using linear mixed model methodology using REML as the estimation method with block and plot within block fitted as random effects. The individual effects of rotation and treatment and their interaction were fitted as fixed effects. In all cases if the overall model terms in the fixed effects were significant ($p < 0.05$) two-tailed post-hoc tests were conducted between individual effects using the Bonferroni method for multiple comparisons. The objective of this study was to determine the effect of altering the frequency of fresh pasture allocation on grass utilisation, the performance of high yielding dairy cows and the interaction effect of PAF and parity group. Other than imposing the three different frequencies of fresh pasture allocation, every effort was taken to ensure all groups were treated the same.

Data from the halter was recorded from 17:00 on 8 September to 17:00 on 20 September. This was split into four 72 hour grazing periods, each treated as a replicate grazing period. Within each 72 hour period, data was compressed into two hour intervals to assist with data handling. The calculated variables were analysed using Genstat (Genstat Sixteenth Edition, Lawes Agricultural Trust, Rothamsted, UK) with a repeated measures design using the REML estimation method with the correlation between time points assessed with an autoregressive model of order 1. Animal was fitted as the subject factor with two hour time period as the time factor. A factorial arrangement of Time, Parity Group and Treatment were fitted as fixed effects. If the overall model terms in the fixed effects were significant ($P<0.05$) then pairwise differences between individual effects were assessed using Fisher's Least Significant Difference test. For the purpose of this paper, day time was considered to be 05:00 to 21:00 and night time 21:00 to 05:00, these times were selected as they corresponded with dusk and early morning milking.

5 Results

5.1 Pasture quality and utilisation

Pre-grazing sward height was similar for all treatments, with an average pre-grazing height of 11.6 cm and 11.3 cm in P1 and P2, respectively (Table 5.1-1). In P1, pasture utilisation rate was 8% lower in the 12 h PAF vs. 36 h PAF ($p = 0.018$; Table 5.1-1). Correspondingly, there was a significant ($p = 0.046$) effect of PAF on post-grazing sward height, with the 12 h treatment exhibiting a post-grazing residual 0.8 cm higher relative to the 36 h treatment. However, no significant differences in pasture utilisation or post-grazing sward height were observed in P2. Frequency of fresh pasture allocation did not significantly influence mean pre-grazing chemical composition of the pasture in either period (Table 5.1-1).

Although data from P1 and P2 were not statistically compared there are a several notable differences between pasture quality in both periods. Average DM content was higher in P1 than P2, with an average DM of 200 g kg^{-1} and 160 g kg^{-1}, respectively. In addition, grass WSC and ME content were 56 g kg^{-1} DM and 5 MJ kg^{-1} DM lower respectively, in P2 compared to P1. Average CP and ADF contents were 178 g kg^{-1} DM and 193 g kg^{-1} DM respectively in P1. Both components were higher in P2 with average concentrations of 193 g kg^{-1} DM and 310 g kg^{-1} DM for CP and ADF, respectively (Table 5.1-1).

Table 5.1-1 Effect of frequency of fresh pasture allocation on the mean chemical composition of the pasture on offer, pre- and post-grazing height and pasture utilisation efficiency in P1 and P2.

	Period 1					**Period 2**				
	12H	**24H**	**36H**	**SED**	**Sig**	**12H**	**24H**	**36H**	**SED**	**Sig**
Pre-grazing sward height (cm)	12.0	11.7	11.1	0.58	NS	11.2	11.4	11.2	0.36	NS
Post-grazing sward height (cm)	5.5^{a}	5.2^{ab}	4.7^{b}	0.34	0.046	5.2	5.2	5.2	0.23	NS
Utilisation efficiency	0.83^{a}	0.85^{ab}	0.91^{b}	0.029	0.018	0.85	0.84	0.85	0.034	NS
Grass Quality:										
Dry matter (DM) (g kg-^{1})	205	196	199	5.2	NS	159	159	162	4.0	NS
Crude protein (g kg^{-1} DM^{-1})	175	177	182	4.9	NS	193	193	193	6.6	NS
ADF (g kg^{-1} DM^{-1})	276	280	276	4.8	NS	313	310	308	5.0	NS
WSC (g kg^{-1} DM^{-1})	156	152	152	4.2	NS	96	100	94	5.4	NS
ME (g kg^{-1} DM^{-1})	115	115	115	0.8	NS	109	110	110	0.9	NS

* Letters denote significant differences

5.2 Animal performance

Pasture allocation frequency had no effect on milk yield in either period, and average daily milk yield from all treatment groups was 28.8 and 22.2 kg cow^{-1} day^{-1} for P1 and P2, respectively (Table 5.2-1, Table 5.2-2). However, daily milk yield in primiparous animals was significantly lower than multiparous animals, with a mean milk yield of 24.3 kg cow^{-1} day^{-1} and 33.4 kg cow^{-1} day^{-1} in P1, respectively ($p < 0.001$). Similarly, in P2, daily milk yield of primiparous animals was significantly ($p < 0.001$) lower than multiparous animals, with a mean milk yield of 19.4 kg cow^{-1} day^{-1} and 25.1 kg cow^{-1} day^{-1}, respectively. Interaction effects of treatment and parity (PAF x PG) were not observed for milk yield in either period.

Table 5.2-1 Effect of frequency of fresh pasture allocation ond animal parity on milk production, milk composition and animal liveweight for P1.

	Primiparous			**Multiparous**			**SED**	**Treatment**	**Parity**	**Treatment x Parity**
	12H	**24H**	**36H**	**12H**	**24H**	**36H**				
Milk Yield (kg cow^{-1} day^{-1})	25.0	24.1	23.7	33.5	34.3	32.4	1.52	0.339	<0.001	0.733
Milk fat (g kg^{-1})	38.7	41.3	42.8	39.8	40.5	39.7	1.29	0.466	0.059	0.060
Milk protein (g kg^{-1})*	31.7^{a}	33.0^{b}	32.9^{ab}	32.8^{b}	32.5^{ab}	32.4^{ab}	0.54	0.708	0.762	0.041
Milk fat + protein yield (kg cow^{-1} day^{-1})	1.79	1.82	1.90	2.42	2.64	2.46	0.100	0.067	<0.001	0.126
Milk energy output (MJ cow^{-1} day^{-1})	82.2	82.4	84.1	101.9	102.8	100.8	3.3	0.843	<0.001	0.749
Change in live weight (kg cow^{-1})	-6.3	-15.7	-4.7	-10.7	-11.9	-1.7	5.71	0.023	0.816	0.541

* Letters denote significant differences

Significant treatment effects were not observed for milk fat or protein content as discrete measurements in either period (Table 5.2-1, Table 5.2-2). However, in P1 there was a tendency for a higher milk fat plus protein yield at higher PAF's ($p = 0.067$), with means being the lowest in the 12 h PAF treatment within each parity. Primiparous animals in the 12 h treatment produced a milk fat plus protein yield, 4% and 6% less yield than the 24 h and 36 h treatments, respectively in P1 (Table 5.2-1). In P2, these trends were replicated and the between treatment differences were significant ($p = 0.012$). The 12 h treatment similarly exhibiting the lowest milk fat plus protein yield, producing -0.11 kg cow^{-1} day^{-1} less than the 36h treatment and -0.09 kg cow^{-1} day^{-1} less than the 24 h treatment (Table 5.2-2). In both periods, multiparous animals produced significantly greater milk fat plus protein yield relative to primiparous animals ($p < 0.001$). In addition, PAF x PG interactions were not observed for both milk fat plus protein yield in either period. However, significant PAF x PG interactions for milk protein content were observed in P1 ($p = 0.043$; Table 5.2-1). Primiparous animals in the 12 h treatment produced milk with an average protein content 1.3 g kg cow^{-1} day^{-1} lower than primiparous animals in the 24 h treatment. Contrastingly, no significant PAF x PG interactions for milk fat or protein content were observed in P2, although both milk fat and protein content were lowest for the primiparous animals in the 12 h treatment, mirroring trends evident in P1 (Table 5.2-2). Treatment effects were not observed for milk energy output in period one and two. However, in P2 PAF x PG interactions showed that milk energy output was significantly higher for primiparous animals in the 36 h treatment group producing on average 10.9 MJ cow^{-1} day^{-1} more than the other two treatments ($p < 0.001$). Multiparous animals in the 24 h treatment group exhibited the highest milk energy output producing on average 4.7 MJ cow^{-1} day^{-1} more relative to the 12 h and 36 h treatments, but this was not significantly different to the other treatment groups. Although these significant interactions were not observed in P1, similar trends did exist, with primiparous animals in the 36 h PAF and multiparous animals in the 24 h treatments both exhibiting the highest milk energy output.

Animals in the 24 h treatment lost significantly more weight than animals in the 36 h treatment in P1, by an average of 10.2 kg cow^{-1} ($p = 0.023$; Table 3), this significance was not observed in P2. However, in P2, multiparous animals lost significantly more live weight relative to primiparous animals ($p = 0.002$). Interactions of treatment x parity group were not observed for change in animal live weight in either period, values for the primiparous and multiparous animals were -8.8 kg cow^{-1} and -8.1 kg cow^{-1} respectively for P1, and 4.8 kg cow^{-1} and -8.4 kg cow^{-1} respectively for P2.

Table 5.2-2 Effect of frequency of fresh pasture allocation and animal parity on milk production, milk composition and animal live weight for P2.

	Primiparous			**Multiparous**			**SED**	**Treatment**	**Parity**	**Treatment x Parity**
	12H	**24H**	**36H**	**12H**	**24H**	**36H**				
Milk Yield (kg cow^{-1} day^{-1})	19.1	19.2	19.7	24.5	26.5	24.4	1.51	0.123	<0.001	0.733
Milk fat (g kg^{-1})	43.7	46.0	48.0	46.1	46.2	46.8	2.04	0.105	0.059	0.060
Milk protein (g kg^{-1})	36.5	36.6	37.7	38.3	37.3	38.4	1.14	0.630	0.762	0.041
Milk fat + protein yield (kg cow^{-1} day^{-1})	1.55^{a}	1.58^{a}	1.69^{b}	2.08^{c}	2.22^{d}	2.16^{cd}	0.036	0.012	<0.001	0.407
Milk energy output (MJ cow^{-1} day^{-1})	71.2^{a}	71.8^{a}	82.4^{b}	82.6^{a}	86.8^{b}	81.6^{a}	2.98	0.120	<0.001	<0.001

Change in live weight (kg cow^{-1})	8.9	-5.2	10.6	-8.0	-8.6	-8.7	5.02	0.549	0.002	0.242

* Letters denote significant differences

5.3 Animal behaviour

5.3.1 Diurnal feeding patterns

All treatments exhibited strong diurnal feeding patterns with over 90% of grazing occurring during the day and 70% of ruminating time occurring during night time (2100 to 0500). However grazing patterns varied between treatments. The main grazing sessions observed in the 12h treatment were closely aligned to the two daily allocations of fresh pasture, exhibiting on average a two fold increase in grazing time post fresh pasture allocation (Figure 5.3.1). Similarly, in the 24h treatment the main grazing session corresponded with the allocation of fresh pasture (Figure 5.3.1). However, grazing time was 16 minutes longer in the afternoon grazing session for animals in the 24h PAF relative to the 12h PAF. In addition animals in the 24h treatment had an additional grazing session prior to dusk (Figure 5.3.1). Contrastingly, the grazing pattern of animals in the 36h didn't correspond with fresh pasture allocation. Animals in the 36h treatment had similar grazing pattern as the 12h treatment with two main grazing sessions however one additional grazing session was witnessed between 11am and 1pm, grazing during this time was significantly ($P<0.001$) greater than the 12h and 24h PAF (Figure 5.3.1).

The strong diurnal rumination pattern highlighted the preference for all animals to concentrate the majority of their rumination time during the night. With the greatest period of rumination evident between 9pm and 3am (Figure 5.3.1). Rumination time decreased with decreasing frequency of fresh pasture allocation with rumination times of 15.0, 13.7 and 12.6 min cow-1 hr-1 for the 12h, 24h and 36h treatments, respectively (Table 3). Diurnal rumination patterns were evident between treatments (Figure 5.3.1). Animals in the 12h treatment displayed a trend for longer rumination times during the night relative to the 24h and 36h treatment. Contrastingly, animals in the 24h treatments exhibited the greatest rumination during the day. Animals in the 36h treatment exhibited a significantly lower grazing time at 11am each day corresponding with the extra grazing session witnessed.

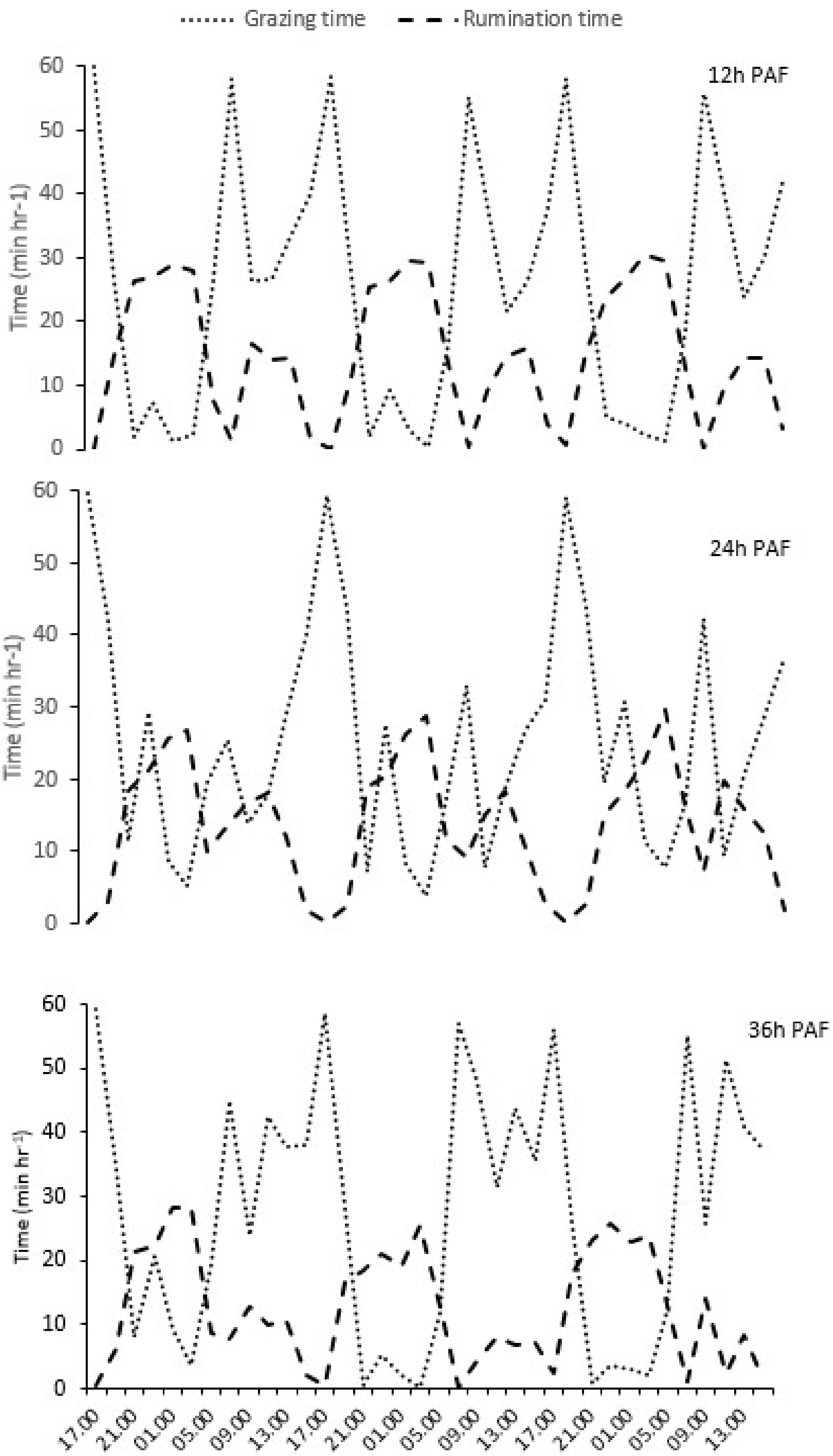

Figure 5.3-1 Grazing (dotted line) and rumination (dashed line) time per hour over a 72 hour period as influenced by 12h, 24h, or 36h pasture allocation frequencies

5.3.1

Primiparous animals

Feeding time was greater for primiparous animals in the 12h PAF compared to the 24h PAF however similar to that of the 36h PAF (P<0.001). Grazing time for primiparous animals decreased with decreasing frequency of fresh pasture allocation. Primiparous animals in the 12h treatment had the longest grazing time, grazing for 48 minutes cow-1 day-1 longer (P<0.001) relative to the 24h and 36h treatments (Table 5.3-1).

Rumination time followed the same trend as grazing time for primiparous animals decreasing with decreasing PAF; animals in the 12h PAF ruminated for significantly (P<0.001) longer compared to primiparous animals in the 24h and 36h PAF (Table 5.3-1). The longer rumination time observed is a consequence of a significantly longer rumination during the night between 9pm and 3am (Figure 5.3-2). Rumination chews were greatest for the 12h PAF with 232 chews cow-1 hr-1 greater (P<0.001) than the 24h and 36h PAF (Table 5.3-1). Similarly, chews per bolus observed the same effect; 12h primiparous animals chewed each bolus on average 5 times more relative to primiparous animals in the 24h and 36h treatments (P=0.002) (Table 5.3-1). Primiparous animals in the 12h treatment regurgitated the greatest number of boli, with animals in the 36h treatments the fewest number, the 24h treatment was significantly different form both (P=0.002).

Table 5.3-1 Impact of parity and pasture allocation frequency on grazing behaviour of dairy cows

	Primiparous			Multiparous			Parity	PAF	Parity x PAF	
	12H	24H	36H	12H	24H	36H			SED	Sig
Feeding time (min cow^{-1} hr^{-1})	26.6^{c}	24.8^{ab}	26.1^{bc}	24.1^{a}	25.9^{bc}	28.2^{d}	Ns	<0.001	0.66	<0.001
Grazing time (min cow^{-1} hr^{-1})	24.3^{c}	22.4^{b}	22.3^{b}	20.3^{a}	21.4^{b}	24.3^{c}	0.004	<0.001	0.61	<0.001
Bite Rate	52.1^{b}	54.8^{b}	48.2^{a}	53.0^{b}	53.5^{b}	55.2^{b}				
Rumination time (min cow^{-1} hr^{-1})	15.8^{c}	13.2^{a}	12.4^{a}	14.2^{b}	14.2^{b}	12.8^{a}	Ns	<0.001	0.47	<0.001
Rumination chews (no. cow^{-1} hr^{-1})	1058^{a}	859^{b}	793^{b}	839^{b}	846^{b}	801^{b}	<0.001	<0.001	33.1	<0.001
Number of boli (no. cow^{-1} hr^{-1})	17.2^{e}	14.3^{bc}	13.0^{a}	15.7^{d}	15.4^{cd}	13.9^{ab}	Ns	<0.001	0.55	0.002
Chews per bolus (no $bolus^{-1}$)	37.7^{c}	32.0^{ab}	33.4^{b}	31.5^{ab}	31.7^{b}	29.9^{a}	0.006	0.006	1.15	0.002

5.3.1 Multiparous animals

Feeding time and grazing time in multiparous animals increased with decreasing PAF (P<0.001), dissimilar to the behaviour observed in primiparous animals (Table 5.3-1). The longer grazing time observed in the 36h treatment may be a consequence of the extra grazing session exhibited between 11am and 1pm, when animals in the other two treatments tended to be ruminating (Figure 5.3.1). Furthermore, within treatment difference were also observed, primiparous animals in the 12h treatment had a significantly (P<0.001) longer grazing time compared to multiparous animals (Table 5.3-1). Contrastingly, the 36h PAF exhibited the opposite effect as multiparous animals grazed longer (P<0.001) than primiparous animals. Grazing time in the 24h PAF was similar for both parity groups.

Similarly, within treatment significances were evident for rumination time (Table 5.3-1). Rumination time was significantly (P<0.001) greater for primiparous animals compared to multiparous animals in the 12h PAF. Contrarily, multiparous animals ruminated for 24 mins cow-1 day-1 longer (P<0.001) in the 24h PAF relative to primiparous animals. Both parity groups in the 36h PAF displayed similar rumination times (Table 5.3-1). Multiparous animals in the 36h PAF displayed a rumination time 1.4 mins cow-1 hr-1 shorter (P<0.001) than multiparous animals in the 12h and 24h PAF (Table 5.3-1). The number of boli regurgitated during rumination decreased with decreasing PAF, multiparous animals in the 12h and 24h treatments regurgitated on average 12% (P=0.002) more boli a day compared significantly to multiparous animals in the 36h treatment. However, multiparous animals in the 24h PAF exhibited the 1.8 chews per bolus more than multiparous animals in the 36h PAF (P=0.002). In addition, chews per a bolus were greater for all primiparous animals relative to multiparous animals in their treatment. Although this effect was significant (P=0.002) for both the 12h and 36h PAF however the difference between parity groups was much greater in the 12h treatment. It is evident that chews per a bolus were greater for primiparous animals in the 12h PAF following the two main grazing sessions (Figure 5.3-3).

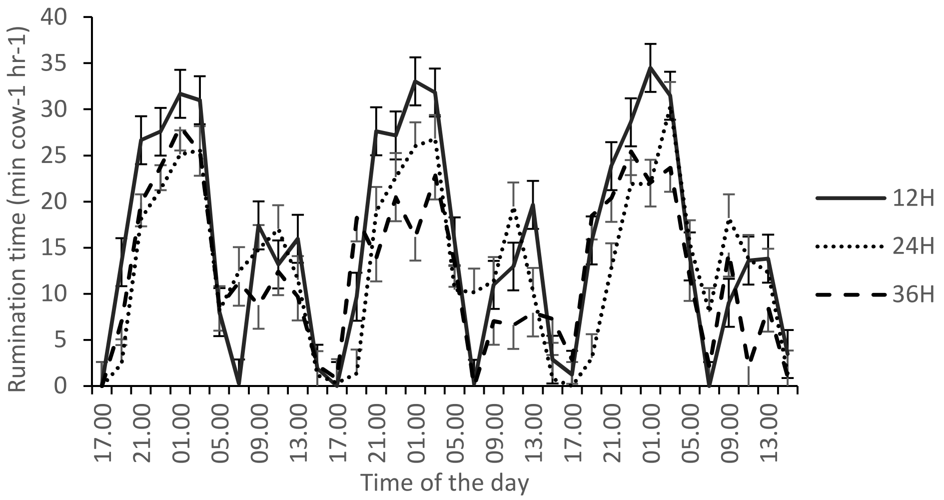

Figure 5.3-2 Rumination behaviour patterns as influenced by PAF in parity 1 animals

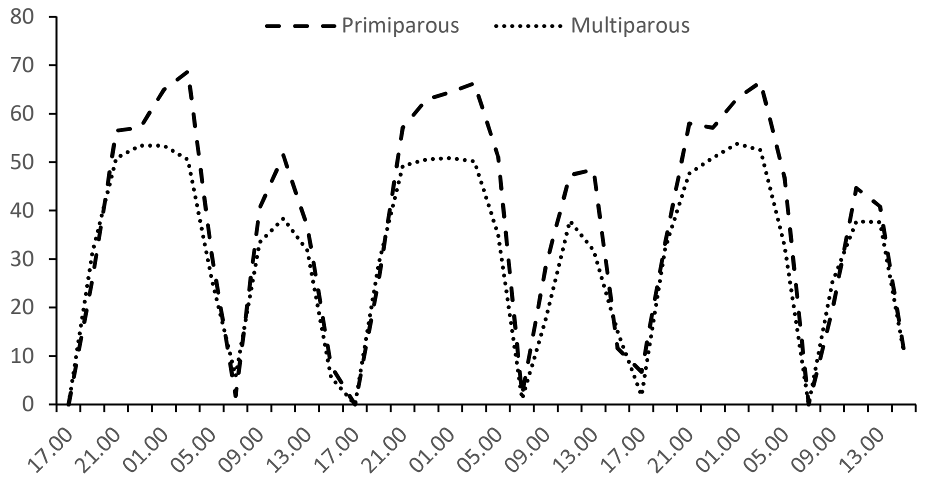

Figure 5.3-3 Chews per bolus recorded from primiparous and multiparous animals in the 12h PAF

6 Discussion

6.1 Pasture utilisation and quality

The high pasture utilisation efficiency (86%) observed during both periods of this experiment is reflective of an intensive grazing system, comparable to that of other studies offering similar herbage allowances (McEvoy et al., 2008, Kennedy et al., 2008) and in commercial practice. In the present study the significantly higher pasture utilisation rate (8%) observed in the 36 h treatment in P1 was a direct consequence of the lower post-grazing residual achieved with 36 h allocations (4.7 cm) relative to 12 h allocations (5.5 cm). As all treatment groups received an identical herbage allocation on a per-day basis, it is assumed that a higher DMI within the 36 h treatment caused the decrease in post-grazing sward height. It is postulated that the higher relative pasture allowance offered in the first and second feed of the 36 h treatment facilitated an increased DMI within these feeds, resulting in a higher overall DMI compared to the 12 h treatment. This hypothesis is supported by previous studies that have observed increases in DMI when high pasture allowances were offered (Kennedy et al., 2008, McEvoy et al., 2008, Curran et al., 2010). Although no significant difference in pasture utilisation was observed in P2, animals had a reduced energy demand during this time due to their later stage of lactation, corresponding with lower milk yield and likely lower DMI (Dale et al., 2018).

Differences in PAF were not found to impact on pasture quality throughout the experiment, this is consistent with results from previous grazing studies that investigated lower (Abrahamse et al., 2008) and higher (Dalley et al., 2001) frequencies of fresh pasture allocation relative to the present study. The numerically lower nutritional value of the sward during P2 relative to P1, as indicated by lower ME content and higher NDF content, reflects deteriorating sward quality over the grazing season. This common trend is linked to plant physiology and seasonal growth patterns that have been previously described by a number of authors (McCarthy et al., 2016, Earle et al., 2018).

6.2 Animal performance

Average milk production (25.5 kg cow^{-1} day^{-1}) throughout the experiment was reflective of high production dairy cows in intensive grazing systems (Bargo et al., 2002, Roche et al., 2006). The decreased performance at more frequent PAF observed in the 12 h treatment within the current experiment is comparable to a number of other studies, although most existing research has focussed on very intensive levels of PAF. For example, Dalley et al. (2001) observed that reducing the frequency of fresh pasture from six to one daily allocations improved animal performance, by a 1.0 litre cow^{-1} day^{-1} increase in milk yield ($p < 0.05$). Similarly, Verdon et al. (2018) observed improved animal performance when PAF was reduced from seven to two allocations per day resulting in an increase in fat and protein corrected milk yield (+0.9 kg cow^{-1} day^{-1}, $p < 0.03$) and daily milk yield (+1.2 L cow^{-1} day^{-1}, $p < 0.001$). This response has also been evident in indoor environments. For example, Phillips and Rind (2001) observed a significant increase in milk yield (+0.66 g cow^{-1} day^{-1}) and milk fat yield (44 g cow^{-1} day^{-1}) when frequency of TMR feeding was reduced from daily to alternate day feeding. Both Verdon et al (2018) and Phillips and Rind (2001) attributed the reduction in animal performance at higher feeding frequencies to reduced fibre digestion rates due to disturbances in the animals natural feeding pattern. This disturbance likely affects rumen function, impacting on grazing behaviour and ingestion rates. Whilst the disturbance to natural feeding patterns may be smaller for the current study due to the lower PAF imposed relative to the studies of Dalley et al. (2001) and Verdon et al. (2018) this may still have contributed to the lower animal performance witnessed in the 12 h treatment. Previous research has observed milking disrupts animal grazing behaviour with twice daily milking resulting in shorter grazing bouts for animals in the afternoon relative to animals milked once daily (O'Driscoll et al., 2010). As all treatments were offered fresh pasture after milking it is likely the disruption of the milking process on animals' natural grazing behaviour, would have impacted all treatments equally. In addition, behaviour studies have observed that lactating dairy cows have several distinct main grazing bouts, with the longest feeding bouts occurring at dusk and dawn (Gibb et al., 1998, Gregorini et al., 2006). Within the 12 h treatment, (relative to the 24 h and 36 h groups) restriction of herbage mass every morning at dawn (before morning milking) may have limited the animal's ability to graze, therefore impacting the animals' natural grazing behaviour.

As previously discussed, increasing pasture availability through a high pasture allowance has been found to improve DMI and consequently animal performance (Kennedy et al., 2008, McEvoy et al. 2008, Bargo et al. 2002). Curran et al. (2010) observed a significant increase ($p < 0.001$) in pasture DMI and subsequently animal performance when pasture allowance was increased by 5 kg DM cow^{-1} day^{-1}. However, high allocation rates (>20 kg DM cow^{-1} day^{-1}) are not commercially viable because they inevitably lead to higher post-grazing sward heights and consequently poor utilisation of the available pasture. In addition, higher post-grazing residuals are associated with deteriorating sward quality throughout the grazing season (Mayne et al., 1987). Within the present study, the 24 h and 36 h treatments offered a relatively higher pasture allowance in the first feed of each allocation offering 15 kg cow^{-1} and 22.5 kg cow^{-1}, respectively. In contrast, 12 h allocations resulted in every feed having less pasture available (7.5 kg DM cow^{-1}) due to the incremental delivery of fresh pasture after every milking. In addition, because a limited quantity of pasture is available in each feed within the 12 h treatment animals were forced to graze to low post-grazing sward heights in every feed, this may have resulted in an increased difficulty in harvesting pasture, thus increasing the time and energy expended per bite. Therefore the benefits in animal performance from a reduced PAF are likely because of the combined effects of reduced disturbance to natural feeding behaviour, ease of harvesting and high pasture allowance encouraging DMI during the first (24 h and 36 h) and second (36 h) feed. The absence of a significant effect on the performance of primiparous animals in the 36 h treatment in P1 may be a consequence of the lower post-grazing residual in this treatment, potentially impacting both milk production and composition. This response of reduced animal performance linked to lower post-grazing residuals is reinforced by the results of Mayne et al. (1987) who observed a reduction in milk yield of 2.3 kg cow^{-1} day^{-1} and milk protein yield of 66 g cow^{-1} day^{-1} when post-grazing sward height was reduced from 6 cm to 5 cm ($p < 0.001$). Hence maintaining a post-grazing residual greater than 5 cm throughout the grazing season may allow for improved animal performance under the 36 h PAF management however further studies are required to identify the optimal level of pasture allocation for this treatment. Animals in the 36 h treatment displayed the lowest live weight losses in P1, however the live-weight losses experienced were all comparable to those observed with dairy cows in other studies throughout their lactation (Roche et al., 2006). In addition, no significant change in live weight was associated with the PAF treatment were observed in P2, nor were there any significant changes in the animals BCS (data not shown).

Similar to the present study, Peyraud et al. (1996) reported milk yields in primiparous animals are 20 to 30% lower relative to multiparous animals. In the present study, reducing PAF from 12 h or 24 h to 36 h improved the milk energy output of primiparous animals, PAF was not found to significantly impact the milk energy output of multiparous animals. The improved performance of primiparous animals may have been a result of reduced competition for resources, given the lower stocking density (71 livestock units (LU) ha^{-1}) in the 36 h grazing paddocks compared to the 24 h (107 LU ha^{-1}) and 12 h (214 LU ha^{-1}) paddocks. This effect has been observed in indoor environments by DeVries et al. (2005) who identified that increasing feed availability through offering TMR at an increased frequency (once vs. twice daily and twice vs. four times daily), both decreased the displacement of subordinate animals at the feed fence and reduced feed sorting. Feed sorting occurs within both indoor (Devries et al., 2005) and outdoor (Abrahamse et al., 2008) feeding environments, where the NDF content is higher in the remaining forage compared to the forage offered as a result of animals preferentially consuming the highest quality forage available. Although feed sorting is inevitable, Phillips and Rind (2002) suggested dominant animals may have priority access to the best grazing sites allowing these animals to ingest higher quality pasture. Through a combined effect of a larger grazing area and higher pasture allowance within 36 h treatment during the first two allocations, lower ranking animals would likely experience less competition for high quality grazing sites, and hence increased options for dietary selection across the grazing area. This in turn, is likely to have resulted in the better performance in these animals compared with those on more frequent pasture allocation. These effects are likely to be further exacerbated in swards with greater species diversity than those employed in this current study due to the broader range in sward nutritive value and palatability. However, further investigation of animal grazing behaviour, and associated parity differences, within multi-species swards is required.

In contrast, although all treatments were offered the same pasture allowance over the 72 h grazing block, as previously mentioned animals in the 12 h treatment and to a lesser extent in the 24 h treatment, had a limited quantity of pasture at each allocation due to the phased delivery of feed, limiting opportunities for feed sorting and requiring cows to graze to the target post-grazing residual within each feeding period in order to achieve this intake. Prache and Peyraud (2001) have shown animals respond to restricted pasture available through increasing bite mass. In the current study, this response may have presented a further competitive advantage to older heavier multiparous animals within the 12 h and 24 h PAF due to their larger mouth size (Verdon et al. 2018) leading to multiparous animals eating a greater quantities of high quality pasture in comparison with primiparous animals.

6.3 Grazing behaviour

6.3.1 Diurnal variation

Average daily grazing time and ruminating time in the present study is representative of high production Holstein-Friesian dairy cows within full-time grazing systems and is comparable with that noted by others (Vance et al. 2012, Bargo et al. 2002), highlighting the significant energy and time requirements for of nutrient capture within grazing systems. The concentration of grazing during the day has been widely reported with grazing from dusk to dawn typically accounting for less than 15% of total grazing time and thus contributing minimally to total DMI (Stockdale et al. 1983, Stobbs, 1970). Linnane et al. (2001) suggested low levels of grazing during the night may reflect the greater difficulty of animal selectivity in the dark. Additionally, the preference for animals in the present study to concentrate the majority of their rumination activity during the night is in agreement with previous indoor (Schirmann et al. 2012) and grazing (Gregorini et al. 2012) studies on lactating dairy cows. Furthermore, the occurrence of these feeding patterns across all three treatments confirms diurnal feeding behaviour exists in pasture systems irrespective of the management method imposed. Previous literature has similarly observed circadian feeding patterns under a number of different management methods including; restricted pasture (Gregorini et al. 2012) and timing of pasture allocation (Vibart et al. 2017).

6.3.2 Influence of pasture allocation frequency on animal feeding behaviour

Contrary to the present experiment, previous studies have reported no effect of PAF on grazing time (Abrahamse et al. 2008, Verdon et al. 2018). This may be due to the relatively low (Abrahamse et al. 2008) and high (Verdon et al. 2018) frequencies of pasture allocation investigated compared to the current study. The discrepancy in results may be due to the and the relatively high pasture allowances offered by Abrahamse et al. (2008) and Verdon et al. (2018) relative to the present study. Offering a high pasture allowance may have had a greater impact on grazing time than the frequency of fresh pasture allocation. However similar to the studies mentioned, PAF in the present study had a significant impact on the pattern of grazing activity throughout a 24 hour period.

Literature has widely acknowledged allocation of fresh feed motivates animals to eat, thus the greatest proportion of time attributed to this activity often occurs immediately after the delivery of fresh feed, as observed in studies offering TMR (DeVries et al. 2003) and pasture (Verdon et al., 2018). This effect was observed in both the 12h and 24h PAF with the longest grazing period(s) occurring shortly after the one (24h) or two (12h) daily allocations of fresh pasture.

Animals in the 24h PAF spent a longer proportion of time grazing when offered fresh pasture in the afternoon compared to animals in the 12h PAF. An indoor study offering dairy cows TMR similarly witnessed reducing allocations from twice to once daily resulted in more animals eating for longer when TMR was offered once daily (DeVries et al. 2005). However, this concentration of feeding activity during certain periods of the day may have a greater effect in pasture based systems compared to indoor systems as pasture nutritive value varies throughout the day. Orr et al. (1997) reported pasture offered in the evening (19:30h) displayed a greater nutritive value with an increase in DM (9%), WSC (2.7%) and starch (1.1%) concentrations compared to pasture offered in the morning (07:30h). Subsequently evening allocations have been associated with improved performance of beef (Gregorini et al. 2006) and dairy (Philips and Rind, 2001) cows. The increase of milk energy output (+4.2 MJ cow^{-1} day^{-1}) observed by multiparous animals in the 24h PAF relative to the 12h PAF in the current study is likely a result of a greater proportion of the total time spent grazing occurring in the evening at the time of highest pasture quality.

In addition to improved nutritive value, pasture biochemical properties alter throughout the day. Plant toughness reduces from dawn to dusk and this is thought to increase the rate of particle breakdown during digestion, subsequently impacting on animal grazing behaviour with a more rapid particle breakdown increasing rumen throughput and encouraging further grazing activity (Gregorini et al. 2009). Despite similar grazing times, the lower average rumination time observed by multiparous animals in the 24h treatment in comparison to the 12h PAF, is likely a function of the 24h animals ingesting a larger proportion of their total daily pasture intake in the evening when nutritive value is higher and pasture toughness reduced.

Contrastingly, to the 12h and 24h PAF the greatest proportion of time spent grazing in the 36h PAF did not always correspond with fresh pasture allocation. Although peak grazing time was observed daily between 17:00 and 19:00, this only coincided with fresh pasture allocation once every three days. Hence this trend was evident daily over the 72 hour grazing block regardless of time of pasture allocation. Phillips and Rind (2001) observed this similar effect with dairy cows offered TMR indoors on alternate days with animals displaying similar feeding behaviour on feeding and non-feeding days. The authors in this study suggested animals fed at intervals greater than 26 hours could not anticipate delivery of fresh feed. Consequently the increase in TMR intake and milk yield was a result of reduced disturbance of the animal feeding behaviour which can be caused by periods of feed restriction and shorter feed intervals. In the present study, animals in 36h PAF displayed a greater distribution of daily grazing activity, more representative of that of set stocking (Philips and Leaver, 1986). The greater distribution of grazing behaviour and lack of grazing peaks observed when fresh pasture was offered is likely a result of the animals' inability to anticipate delivery of fresh pasture.

A greater distribution of grazing behavior throughout a 24 hour period has also been witnessed at high PAF. Verdon et al. (2018) noted more even hourly grazing behaviour and a subsequent decrease in ruminating time ($P<0.001$) relative to twice daily offerings when pasture was offered over seven daily allocations compared to two daily allocations. This suggests, very high or low PAF's may impact significantly on animal grazing behaviour. However, the subsequent relationship between this behavioural change and animal performance is less clear. Whilst Verdon et al. (2018) observed lower milk yields from cows allocated seven grass allocations per day compared to those offered grass twice daily, Dalley et al. (2001), suggested a more consistent distribution of grazing activity provides a more consistent supply of metabolites increase the efficiency of milk synthesis. Pollock et al. (2020) in the complimentary paper noted improved performance from the 36h treatment however this was mainly driven by greater performance from parity one animals alone. This suggests the behavioural responses to changing pasture management are multifactorial and cannot be considered in isolation.

6.3.3 Interaction between PAF and parity group

Primiparous animals are often classed as subordinate animals due to their lower live weight, lactation number and milk production (Hussein et al. 2016). Philips and Rind (2002) observed grazing time in lactating dairy cows was negatively correlated to dominance value thus lower ranking animals in the herd such as primiparous animals tend to graze for longer. Similarly Bach et al. (2006) observed feeding time of TMR was 30 mins cow^{-1} day^{-1} longer for primiparous animals housed with multiparous animals compared to primiparous animals housed alone. The authors attributed this time to longer periods spent sorting feedstuffs in search of higher quality forage. It is hypothesised that similar behaviours were evident in the current study with longer grazing time of primiparous animals in the 12h PAF relative to multiparous animals. The smaller grazing area and lower pasture availability immediately after allocation of fresh pasture in the 12h treatment, relative to the 24h and 36h treatment, likely resulted in greater competition for resources. Wales et al. (1998) reported lactating cows grazing perennial ryegrass pastures consistently selected a diet significantly higher ($P<0.001$) in CP and lower in NDF than the average pasture on offer, this is achieved through the selection of specific grazing sites. It is likely that multiparous animals displaced primiparous animals from preferential grazing sites within the pasture, and hence were able to achieve satiety sooner due to the selection of higher quality pasture compared to their younger counterparts. In contrast, it is considered that primiparous animals expended a greater amount of time browsing and selecting herbage suitable for consumption as evidenced by the greater grazing time. Coupled with a likely intake of less preferential, poorer quality pasture, this would have resulted in a reduction in potential energy intake, increased energy expenditure and consequently the poorer milk yields described in Pollock et al. (2020).

In contrast, the similar (24h) and lower (36h) grazing time of primiparous animals relative to multiparous animals in these treatments suggests reduced competition for resources (space, grazing sites and pasture availability) within these treatments. Multiple indoor studies have highlighted reduced space allowance of dairy cattle results in an increase in aggressive interactions between animals (Kondo et al. 1989; DeVries et al. 2004). Although grazing systems provide a much larger space allowance for each individual animal relative to indoor systems, reducing space allowance in grazing paddocks may create competition for grazing sites. Although pasture is generally allocated in kilograms of dry matter per cow, in practice pasture is allocated on a herd basis rather than to an individual animal, consequently animals within herds compete for resources (Werner et al. 2019). Offering a high pasture allowance in the first 12 hour period (24h and 36h) and second 12 hour period (36h) of the 12h and 24h PAF results in an increased pasture availability and a greater number of grazing sites available within these allocations, increasing access to high quality pasture for lower ranking animals. Within the 12h treatment limited pasture was available in each feed. Kennedy et al. (2009) observed dairy cows with restricted access to pasture employed two strategies; increased bite mass and decreased handling time in order to consume feed more rapidly during grazing. Furthermore, Olofsson (1999) reported increasing competition for feed within indoor environments resulted in animals consuming feed more rapidly compared to when there was ample access to feed hence the findings of this study are in line with other studies.

Increased requirement for rumination activity is a result of larger particle sizes entering the rumen (Grant et al. 1990). In the present study ruminating time and number of boli regurgitated increased with increasing PAF in primiparous animals. This is likely a result of greater competition for resources leading to higher intake rates and reduced mastication similar to that observed by Kennedy et al (2009), consequently leading to larger particle size entering the rumen. The temporary restriction of grazing sites and pasture availability, further limit the ability of lower social ranking animals to select the highest quality pasture subsequently reducing their milk production (Hill et al. 2015). This was observed within the 12h treatment as primiparous animals exhibited a greater number chews per a bolus after two main grazing sessions relative to multiparous animals further indicating rapid intake rate and selection of more fibrous pasture.

Previous literature has also noted dairy cows with longer feeding times tend to have shorter ruminating times (Schirmann, et al. 2012; Dado et al. 1994). Contrary to this, both grazing and ruminating time was greatest for primiparous animals in the 12h treatment compared to primiparous animals in the 24h and 36h treatments. This suggests competition for resources may have a strong impact on overall time budget for these animals, this ultimately resulting in increased energy expenditure on feeding activities and less energy available for milk production as witnessed in the corresponding paper (Pollock et al., 2020). Primiparous animals in the 24h PAF exhibited a similar grazing time however reduced ruminating activity compared to the 36h treatment. As previously discussed, the greater distribution in daily grazing activity in the 36h PAF likely facilitated rumination activity resulting in lower overall ruminating time for animals in the 36h PAF. The reduction in energy expenditure on feeding behaviour in primiparous animals in the 36h PAF subsequently would have increased energy available for productive purposes. This coupled with the more consistent supply of metabolites for milk synthesis resulted in primiparous animals in the 36h PAF having a milk energy output was on average 10.9MJ cow^{-1} day^{-1} more than primiparous animals in the 12h and 24h PAF (P<0.001; Pollock et al, 2020).

Contrastingly, multiparous animals in the 24h PAF produced a significantly greater milk energy output (5.2 MJ cow^{-1} day^{-1}) than multiparous animals in the 36h PAF (Pollock et al., 2020). This suggests the concentration of grazing activity in the evening corresponding with pasture at its highest nutritive had a greater effect on multiparous animals than distribution of grazing time.

The contrasting effect of PAF on grazing time in primi- and multi-parous highlights the need to examine sub-groups or individual animal behaviours relative to the whole herd to observe a truer picture and fully understand the grazing dynamics within the herd. Previously studies investigating the effect of management methods on animals behaviour have looked at the behaviour of the whole herd, likely masking behavioural differences that may have been present between parity groups (Abrahamse et al. 2008, Kennedy et al. 2009).

7 Conclusions

Reducing the frequency of fresh pasture allocation from a typical 12 h or 24 h allocations seen on many commercial farms to 36 h pasture allocations was seen to improve the performance of primiparous animals grazing in mixed-parity herds, relative to 12 h and 24 h allocations. These findings highlight the effect of competition for resources within intensive pasture grazing systems where mixed-parity herds are common. Primiparous animals are most likely to fall lower in the herd hierarchy, and therefore would not gain preferential access to prime grazing areas of swards in highly-competitive grazing environments. Overall, reducing the frequency of fresh pasture allocation from 12 h or

24 h to 36 h allocations created a balance between offering a higher pasture allowance to support animal performance whilst achieving low post-grazing residuals and high levels of grass utilisation, which is a key factor underpinning efficient and economically viable grazing systems. The optimal PAF within individual commercial dairy grazing herds is likely to depend on the herd composition and proportion of primiparous grazing animals. The reduced PAF treatments studied here present a viable method for addressing within herd variation in animal nutritional requirements in grazing systems, to improve animal performance but maintain high pasture utilisation relative to that observed under a typical 12 h or 24 h allocation frequency.

This study highlights the complex nature of animal feeding behaviour decisions and the multiple factors influencing this activity. In the present study all animals irrespective of parity or treatment displayed diurnal grazing and ruminating patterns. The lack of a grazing peak when fresh pasture was allocated in the 36h treatment and the more even distribution of grazing activity throughout a 24 hour period highlights the animals' inability to anticipate delivery of fresh pasture. Grazing and ruminating time was greatest for primiparous animals in the 12h PAF, resulting in greater overall energy expenditure on feeding behaviour. This is due to the lower ranking of primiparous animals within a herd and the greater competition for resources in the 12h PAF relative to the 36h. The results show that management strategies can have a significant effect on animal feeding behaviour but further exploration is required to develop optimum strategies to manage the complex interactions present within a grazing herd to facilitate individual animals to express optimal feeding behaviour and ultimately animal performance.

8 Acknowledgements

The authors gratefully acknowledge funding from AgriSearchNI for this study. The authors thank farm and laboratory staff at the Agri-Food and Biosciences Institute (AFBI) Hillsborough for their assistance with cow management, sampling and chemical analysis of feed samples.

9 References

Abrahamse, P.; Dijkstra, J.; Vlaeminck, B.; Tamminga, S. Frequent Allocation of Rotationally Grazed Dairy Cows Changes Grazing Behavior and Improves Productivity. J. Dairy Sci. **2008**, 91, 2033–2045. [CrossRef]

Bargo, F.; Muller, L.; Delahoy, J.; Cassidy, T. Milk Response to Concentrate Supplementation of High Producing Dairy Cows Grazing at Two Pasture Allowances. J. Dairy Sci. **2002**, 85, 1777–1792. [CrossRef]

Concentrate Supplementation on Grass Intake and Milk Production with Holstein Friesian Dairy Cows. J. Dairy Sci. **2003**, 86, 610–621. [CrossRef]

Curran, J.; Delaby, L.; Kennedy, E.; Murphy, J.; Boland, T.M.; O'Donovan, M. Sward characteristics, grass dry matter intake and milk production performance are affected by pre-grazing herbage mass and pasture allowance. Livest. Sci. **2010**, 127, 144–154. [CrossRef]

Dale, A.J.; Laidlaw, A.S.; McGettrick, S.; Gordon, A.; Ferris, C.P. The effect of grazing intensity on the performance of high-yielding dairy cows. Grass Forage Sci. **2018**, 73, 798–810. [CrossRef]

Dalley, D.E.; Roche, J.R.; Moate, P.J.; Grainger, C. More frequent allocation of herbage does not improve the milk production of dairy cows in early lactation. Aust. J. Exp. Agric. **2001**, 41, 593. [CrossRef]

Devries, T.; Von Keyserlingk, M.; Beauchemin, K. Frequency of Feed Delivery Affects the Behavior of Lactating Dairy Cows. J. Dairy Sci. **2005**, 88, 3553–3562. [CrossRef] [PubMed]
Dillon, P. Achieving high dry-matter intake from pasture with grazing dairy cows. Frontis **2007**, 18, 1–26.
Dillon, P.; Roche, J.R.; Shalloo, L.; Horan, B. Optimising financial return from grazing in temperate pastures. In Proceedings of the Satellite Workshop of the International Grassland Congress, Cork, Ireland, July 2005; pp. 131–147.
Earle, E.; McHugh, N.; Boland, T.M.; Creighton, P. Evaluation of the effects of ewe prolificacy potential and stocking rate on herbage production, utilization, quality and sward morphology in a temperate grazing system. Grass Forage Sci. **2018**, 73, 247–256. [CrossRef]
Edmonson, A.; Lean, I.; Weaver, L.; Farver, T.; Webster, G. A Body Condition Scoring Chart for Holstein Dairy Cows. J. Dairy Sci. **1989**, 72, 68–78. [CrossRef]
Gibb, M.J.; Huckle, C.A.; Nuthall, R. Effect of time of day on grazing behaviour by lactating dairy cows. Grass Forage Sci. **1998**, 53, 41–46. [CrossRef]
Grant, R.; Albright, J. Effect of Animal Grouping on Feeding Behavior and Intake of Dairy Cattle. J. Dairy Sci. **2001**, 84, E156–E163. [CrossRef]
Gregorini, P.; A Gunter, S.; Beck, P.A. Matching plant and animal processes to alter nutrient supply in strip-grazed cattle: Timing of herbage and fasting allocation1. J. Anim. Sci. **2008**, 86, 1006–1020. [CrossRef] [PubMed]
Hussein, A.N.; Al-Marashdeh, O.; Bryant, R.H.; Edwards, G.R. Relationship between social dominance and milk production of dairy cows grazing pasture. Proc. N. Z. Soc. Anim. Prod. **2016**, 76, 69–72.
Iason, G.; Elston, D.A. Groups, individuals, e_ciency and validity of statistical analyses. Appl. Anim. Behav. Sci. **2002**, 75, 261–265. [CrossRef]
Kennedy, E.; O'Donovan, M.; Delaby, L.; O'Mara, F. Effect of herbage allowance and concentrate
Kennedy, J.; Dillon, P.; Delaby, L.; Faverdin, P.; Stakelum, G.; Rath, M. Effect of Genetic Merit and
Krohn, C.; Konggaard, S. E_ects of isolating first-lactation cows from older cows. Livest. Prod. Sci. **1979**, 6, 137–146. [CrossRef]
Mäntysaari, P.; Khalili, H.; Sariola, J. E_ect of Feeding Frequency of a Total Mixed Ration on the Performance of High-Yielding Dairy Cows. J. Dairy Sci. **2006**, 89, 4312–4320. [CrossRef] [PubMed]
Mayne, C.S.; Newberry, R.D.;Woodcock, S.C.F.;Wilkins, R.J. Effect of grazing severity on grass utilization and milk production of rotationally grazed dairy cows. Grass Forage Sci. **1987**, 42, 59–72. [CrossRef]
McCarthy, B.; Delaby, L.; Pierce, K.; Fleming, C.; Brennan, A.; Horan, B. The multi-year cumulative effects of alternative stocking rate and grazing management practices on pasture productivity and utilization efficiency. J. Dairy Sci. **2016**, 99, 3784–3797. [CrossRef]
McEvoy, M.; Kennedy, E.; Murphy, J.; Boland, T.; Delaby, L.; O'Donovan, M. The Effect of Herbage Allowance and Concentrate Supplementation on Milk Production Performance and Dry Matter Intake of Spring-Calving Dairy Cows in Early Lactation. J. Dairy Sci. **2008**, 91, 1258–1269. [CrossRef]
O'Brien, D.; Shalloo, L.; Patton, J.; Buckley, F.; Grainger, C.;Wallace, M. A life cycle assessment of seasonal grass-based and confinement dairy farms. Agric. Syst. **2012**, 107, 33–46.
O'Driscoll, K.; O'Brien, B.; Gleeson, D.; Boyle, L. Milking frequency and nutritional level affect grazing behaviour of dairy cows: A case study. Appl. Anim. Behav. Sci. **2010**, 122, 77–83. [CrossRef]
Park, R.; Agnew, R.; Gordon, F.; Steen, R. The use of near infrared reflectance spectroscopy (NIRS) on undried samples of grass silage to predict chemical composition and digestibility parameters. Anim. Feed. Sci. Technol. **1998**, 72, 155–167. [CrossRef]
Peyraud, J.; Comeron, E.;Wade, M.; Lemaire, G. The effect of daily herbage allowance, herbage mass and animal factors upon herbage intake by grazing dairy cows. Anim. Res. **1996**, 45, 201–217. [CrossRef]
Phillips, C.; Rind, M. The Effects of Frequency of Feeding a Total Mixed Ration on the Production and Behavior of Dairy Cows. J. Dairy Sci. **2001**, 84, 1979–1987. [CrossRef]
Phillips, C.; Rind, M. The Effects of Social Dominance on the Production and Behavior of Grazing Dairy Cows Offered Forage Supplements. J. Dairy Sci. **2002**, 85, 51–59. [CrossRef] [PubMed]
Prache, S.; Peyraud, J. Foraging behaviour and intake in temperate cultivated grasslands. In Proceedings of the International Grassland Congress, Sao Paulo, Brazil, 11–21 February 2001.
Purcell, P.; Law, R.; Gordon, A.; McGettrick, S.; Ferris, C. E_ect of concentrate feeding method on the performance of dairy cows in early to mid lactation. J. Dairy Sci. **2016**, 99, 2811–2824. [CrossRef] [PubMed]
Rind, M.I.; Phillips, C.C. The e_ects of group size on the ingestive and social behaviour of grazing dairy cows. Anim. Sci. **1999**, 68, 589–596. [CrossRef]
Roche, J.; Berry, D.; Kolver, E. Holstein-Friesian Strain and Feed Effects on Milk Production, BodyWeight, and Body Condition Score Profiles in Grazing Dairy Cows. J. Dairy Sci. **2006**, 89, 3532–3543. [CrossRef]

Schuppli, C.A.; Von Keyserlingk, M.A.G.; Weary, D.M. Access to pasture for dairy cows: Responses from an online engagement. J. Anim. Sci. **2014**, 92, 5185–5192. [CrossRef] [PubMed]
Sniffen, C.; Beverly, R.; Mooney, C.; Roe, M.; Skidmore, A.; Black, J. Nutrient Requirements Versus Supply in the Dairy Cow: Strategies to Account for Variability. J. Dairy Sci. **1993**, 76, 3160–3178. [CrossRef]
Sołtysiak, T.; Nogalski, Z. The Effects of Social Hierarchy in a Dairy Cattle Herd on Milk Yield. Pol. J. Nat. Sci. **2010**, 25, 22–30. [CrossRef]
supplementation on dry matter intake, milk production and energy balance of early lactating dairy cows. Livest. Sci. **2008**, 117, 275–286. [CrossRef]

Tyrrell, H.F.; Reid, J.T. Prediction of the Energy Value of Cow's Milk. J. Dairy Sci. **1965**, 48, 1215–1223.

Verdon, M.; Rawnsley, R.P.; Raedts, P.J.M.; Freeman, M. The Behaviour and Productivity of Mid-Lactation dairy Cows Provided Daily Pasture Allowance over 2 or 7 Intensively Grazed Strips. Animals **2018**, 8, 115.[CrossRef]