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Providing fresh pasture in the afternoon for full-time grazing dairy cows increases energy-corrected milk yield

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ABSTRACT

High pasture allowance in the feed ration during the grazing season is an important resource, particularly for organic dairy farmers, as pasture intake directly affects the overall efficiency of these systems. The timing of fresh pasture provision to dairy cows could affect pasture utilisation, due to diurnal changes in herbage chemical composition and cows' motivation to graze. This study examined the effect of time of allocation of fresh pasture on milk production and behaviour in 60 dairy cows fitted with Nedap SmartTag neck sensors. The cows were offered strip grazing with a high herbage allowance (>40 kg DM/cow/d) after either morning milking (treatment AM; n = 30) or afternoon milking (treatment PM; n = 30). Cows were milked twice daily (0500 and 1500 h) and individually received 4 kg grain-mix per day. Adaptation to treatment was implemented for two weeks, followed by five days of recordings. The PM and AM pasture offered had on average a metabolisable energy content of 12.3 and 12.1 MJ/kg dry matter, respectively, and did not differ in herbage composition. Total grazing time was longer ($P < 0.001$) for PM than for AM cows (576 and 520 min/cow/d, respectively). Conversely, total rumination time was shorter ($P < 0.001$) for PM than for AM cows (409 and 469 min/cow/d, respectively). Cows in the PM group had higher ($P = 0.009$) energy-corrected milk (ECM) yield than cows in the AM group (28.6 and 26.0 kg ECM/cow/d; respectively). Even though both groups were on full-time grazing, a simple change in grazing management by providing access to fresh pasture in the afternoon resulted in more time spent grazing and increased ECM yield. Taking cows' grazing motivation into account when timing fresh pasture allocation can thus be beneficial in increasing efficiency on full-time pasture.

1. Introduction

High pasture intake during the grazing season is important for dairy production in general, and for organic dairy production in particular, as pasture usually makes up a substantial proportion of the forage ration. Well-managed pasture can be beneficial financially, as discussed by Wilkinson et al. (2020), and from an animal welfare perspective (Von Keyserlingk et al., 2017). However, it can be challenging to achieve a well-managed grazing system, since cows' motivation for seeking pasture varies (Charlton et al., 2013). One approach to overcome this is to take cows' diurnal behaviour into account and provide fresh pasture when the cows are most motivated to graze, thus promoting grazing behaviour. Several previous studies have found that grazing around dusk involves the longest and most intensive grazing events of the day (Gibb et al., 1998; Caram et al., 2021), and that allocation of new feed or pasture stimulates feeding behaviour and grazing activity (DeVries et al., 2003; Verdon et al., 2018). A study by Pollock et al. (2022) investigating pasture allocation frequency found that for multiparous cows, proving fresh herbage every 36 hours significantly increased their grazing activity compared with providing fresh herbage every 12 or 24 hours. Irrespective of pasture allocation frequency, cows in that study displayed a very distinct grazing pattern over the 24-hour period, with a

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major grazing peak after afternoon milking and a smaller peak after morning milking (Pollock et al., 2022), demonstrating the benefits of providing fresh herbage in the afternoon. Rumen fill may also affect grazing behaviour and serve as a meal-eating regulator. In an extensive review, Gregorini et al. (2008) assessed the influence of pasture herbage composition, i.e. total intake in combination with particle reduction size of the herbage, on rumen fill. Different herbage species undergo different particle size reductions and thereby differ in their impact on rumen fill. Conventional pasture in the Nordic region consists of a combination of grass and legumes, of which grass has a slower particle size reduction than legumes (review by Gregorini et al., 2008). An increase in milk yield and in fat and protein yield has been observed for cows with access to pasture in the afternoon compared with the morning, which is suggested to be due to a change in nutrient content of the pasture over the day (Orr et al., 2001; Gregorini et al., 2008; Vibart et al., 2017). In short, the DM and water-soluble carbohydrate (WSC) content increase during the day, while the content of structural carbohydrates and crude protein decreases due to a dilution effect. This suggests that the nutritional value of herbage is more favourable during afternoon compared with morning grazing, due to a better-balanced ratio between fermentable carbon and nitrogen. Feed rations with a balanced carbon:nitrogen ratio can improve intake, milk yield and nitrogen use efficiency (Cosgrove et al., 2007; Pozo et al., 2022). We hypothesize that offering to lactating dairy cows fresh pasture in the afternoon-early evening, rather than in the morning, will result in an increase milk yield. The present study aimed to study changes in grazing behaviour, milk yield and composition, and dietary nitrogen utilization when dairy cows were allowed to access their daily grazing strip either after the morning milking or after the afternoon milking on an organic dairy farm in southwest Sweden.

2. Material and methods

The grazing experiment was carried out from 5 May to 28 May 2022 on an organic farm with a herd of 98 lactating dairy cows in the Halland region, southwest Sweden. The farm was chosen for being a successful low-input pasture-based dairy farm, non-common among Swedish dairy farms. According to the Swedish Animal Welfare act (SFS: 2018:1192) animals on private farms can be enrolled in research studies without an ethical permission required if treatments are part of their normal daily routines and if there is no invasive handling of the animals included. As the trial complied with these regulations, no ethical approval was required for this study.

2.1. Animals and experimental design

Sixty dairy cows were allocated to two treatment groups that were given access to a new strip of pasture after morning milking (treatment AM; n = 30) or after afternoon milking (treatment PM; n = 30). A period of pre-experimental recording started 10 days before starting the experiment and was used to record different metrics: 4 days of grazing behaviour, body weight (BW) and milk yield (MY) on two occasions, and animal information such as days in milk (DIM) and parity. This data was later used for grouping the cows into 2 homogenous groups and ensuring that no differences existed before start of the experiment in grazing behaviour between groups. Grazing time for cows later grouped into the AM group was 444 ± 62.8 min and grazing time for cows grouped into the PM group was 456 ± 67.5 min (P = 0.408), and milk yield was 29.0 ± 4.78 kg and 30.3 ± 5.09 kg, respectively (P = 0.355). The experimental cows were paired according to DIM, parity and milk yield, and within pair, randomly assigned to a treatment. For AM and PM cows, respectively, this resulted on average (± standard deviation, SD) in: body weight (BW) 637 ± 76.1 and 596 ± 134.5 kg; DIM 153 ± 58.3 and 155 ± 56.0; parity 1.6 ± 0.50 and 1.5 ± 0.50; and daily milk yield (MY) 29.0 ± 5.0 and 29.6 ± 5.4 kg. The remaining cows in the herd were allocated to either treatment, to create evenly distributed groups. In total, the experiment was run for three weeks of which the first two weeks were used to allow the cows to adapt to the new groups and to the grazing management system, and the last five days were used for data collection and sampling. Both groups spent all day on pasture except during milking. Milking took place in a 2 × 10 swing-over milking parlour (SAC, S.A. Christensen and Co. Ltd., Kolding, Denmark), starting at 0500 h and 1430 h each day, and cows went back to pasture straight after milking. The groups were always milked in the order PM followed by AM. The milking break from fetch until return to pasture took approximately 1.5–2 hours. Each group of cows was offered strip grazing with herbage allowance > 40 kg DM per cow per day (according to grazing management on the farm), on plots of average size 7500 m^2. In addition to pasture, all animals were offered a grain-mix (50 % barley, 25 % wheat, 15 % rye, 10 % oats) of 2 kg during each milking, i.e. in total 4 kg grain-mix per day. Nutrient composition of the pasture and grain-mix are presented in Table 1. Minerals were included in the grain-mix (Deltamin Bas Normal, Svenska foder, Lidköping, Sweden).

2.2. Grazing management and pasture characteristics

All cows were allowed one week of full-time grazing before the adaptation period began. Cows grazed on several pasture plots, following the farmer's normal routine, in a daily strip grazing system using temporary electric fencing. All cows had access to water on pasture throughout the experiment. The pasture used was established in 2021 using a seed mixture comprising 30 % perennial ryegrass (*Lolium perenne L.*), 26 % timothy (*Phleum pratense L.*), 17 % meadow fescue (*Festuca pratensis L.*), 13 % white clover (*Trifolium repens*), 6 % chicory (*Cichorium intybus*), 4 % plantago (*Plantago lanceolata*) and 4 % cumin (*Cuminum cyminum*). A new daily grazing strip was opened after milking, in morning or afternoon according to the treatment. In order to minimise differences between the daily grazing strips, cows in the two groups were offered bordering plots. The distance between the barn (milking parlour) and the grazing paddocks was approximately 1 km. Cows were fetched for milking morning and evening and herded back to the pasture after each milking.

Pre-grazing herbage mass was measured daily using a rising plate meter (Jenquip, Feilding, New Zealand; range 0–26 cm, plate area 0.1 m^2; weight 316 g). A total of 100 compressed heights were recorded while walking the pasture in a zig-zag pattern. To calculate the regression model of herbage mass (kg DM/ha; *dependent variable*) as a function of compressed sward height (cm; *independent variable*), herbage mass in 30 squares of 0.16 m^2 was measured with a Jenquip rising plate meter and the sward was immediately cut as close to ground level as possible (approx. 1–3 cm stubble height) with electric clippers (Bosch Iso Cordless Grass shears, Robert Bosch GmbH, Germany). The cut herbage samples were dried to constant weight at 60 °C. Sward surface height (SSH; n = 50) was recorded before and after grazing, using a sward stick similar in design of the HFRO sward stick (Barthram, 1984), but in which the contact area measured 15 mm x 35 mm.

Table 1
Nutritional content of hand plucked pasture samples (n = 10) and grain samples (n = 2), mean (SD) offered to lactating dairy cows receiving fresh pasture either after morning or afternoon milking.

Feed chemical composition	Pasture	Grain
DM, g/kg	163 (17.1)	880 (0.88)
ME, MJ/kg DM	12.1 (0.48)	-
Ash, g/kg DM	84 (6.6)	34 (4.4)
CP, g/kg DM	148 (24.1)	106 (0.3)
WSC, g/kg DM	131 (24.8)	-
Starch, g/kg DM	-	553 (2.0)
aNDF, g/kg DM	323.2 (33.1)	154 (0.4)

Abbreviations: DM: Dry matter; ME: metabolisable energy; CP: crude protein; WSC: water-soluble carbohydrates; aNDF: amylase neutral detergent fibre.

2.3. Botanical composition

Immediately before cows accessed the new grazing strip, the botanical composition of the sward was determined as described by Mannetje and Haydock (1963), but by taking 30 images per strip from a height of approximately 1 m using a mobile phone camera (3024 x 4032 pixels), while walking the plots in a zig-zag pattern. The images were then analysed visually in a procedure where each image was divided into 12 equally sized squares, within which the areal coverage of five classes of species (grasses, plantago, clover, chicory, and other –composed by cumin and weeds-) was ranked on an arbitrary scale of 1–5, with 1 being the most dominant plant species per square. A value of zero was used when a group of species was not present. The most frequently occurring number per rank and species was found by using the MODE function in Microsoft Excel (Microsoft® Excel® for Microsoft 365 MSO, Version 2308 Build 16.0.16731.20052).

2.4. Feed samples and analysis

During the five days of the sampling period, herbage was sampled immediately before the cows accessed their new strip, in the morning for the AM group and in the afternoon for the PM group. Samples of pasture were hand-picked at 30 sites while walking a zig-zag transect, pooled and dried at 60 °C to constant weight, ground to pass through a 1-mm Wiley mill sieve and stored at room temperature prior to chemical analysis. To evaluate diurnal variation in chemical composition, samples of grasses, plantago, chicory, and white clover were hand-picked separately at 0700 and 1700 h on all five days of the sampling period. These samples were immediately frozen in the field by submersion in liquid nitrogen (N), and then dried at 60 °C to constant weight, ground to pass through a 1-mm Wiley mill sieve and kept at room temperature until analysis. The grain-mix offered to the animals at milking was sampled on two occasions during the sampling period and the samples were stored in plastic bags in a dry place for later analysis.

Feed analyses were performed by the laboratory at the Department of Applied Animal Science and Welfare, Swedish University of Agricultural Sciences, Uppsala, Sweden. The hand-plucked pasture samples and grain-mix samples were analysed by conventional chemical analyses, using standard methods for determination of DM, crude protein, neutral detergent fibre (NDF, assayed with a heat-stable amylase and expressed exclusive of residual ash; Chai and Udén, 1998), WSC, ash, *in vitro* organic matter digestibility (VOS) (from which metabolisable energy (ME) was calculated), as described by Bertilsson and Murphy (2003) and Volden (2011). Starch (including maltodextrin) in concentrate samples was analysed enzymatically according to Larsson and Bengtsson (1983). CP was analysed using the automated Kjeldahl procedure (Foss, Hillerød, Denmark).

2.5. Animal measurements

Milk yield of all experimental cows was recorded manually using a Tru-Test sampler (Tru-Test Datamars, Auckland, New Zealand) at each milking during the sampling period. Samples for milk composition were collected during the last four milkings of the sampling period, preserved with bronopol and then refrigerated. Body weight of each animal was recorded using a portable cattle scale after morning milking on the first two days of the study period and on the last two days of the sampling period. For the behaviour data, 53 cows (AM n = 26, PM n = 27) were equipped with Nedap SmartTag neck sensors (Nedap Livestock Management, DC Groenlo, The Netherlands), which automatically recorded four different behavioural states (eating during grazing, ruminating, idling and other) (Rue et al., 2020). For one cow (PM), only eating during grazing was recorded by the sensor. The behaviour information was obtained in datasets containing observations for each cow at 1-min intervals. For ease of reading, the behaviour "eating during grazing" is referred to hereafter simply as "grazing".

Data in one-minute bins were summarised within experimental days for each cow. If one cow lacked more than 10 % data points per day, all values for that day were set as "missing". One cow from the AM treatment was eliminated from the dataset, due to missing more than two full days of data (2880 data points or minutes). Outliers for each behaviour were identified in the dataset for experimental days and removed according to the ± 1.5 inter-quarter range (IQR) method. Before statistical analysis, data for each experimental cow day were averaged over the whole sampling period. Hourly durations of grazing, ruminating, and idling were computed using the arithmetic mean, and averaged over the day (24 h) using data from the whole sampling period.

2.6. Animal behaviour

Event duration for grazing and ruminating was calculated for group comparison only, by extracting stop and start times for each event and calculating the difference. Events were counted as unique events independent of length of time in between. For example, if a cow was recorded as ruminating for 24 minutes, interrupted by idling behaviour for one minute and then back to ruminating, this was counted as two separate ruminating events. The duration of each event, the maximum duration of events and the number of events were calculated per day and averaged over the sampling period. Events were defined as belonging to one experimental day depending on start time and were allowed to continue over a day shift. Grazing data were also aggregated into 2, 4 and 6 h post-milking for each group, in an attempt to separate the effect of fresh pasture from simply returning from milking.

2.7. Weather data

Outdoor temperature (C°), precipitation (mm), wind speed (m/s) and relative humidity (RH, proportion) were recorded 2 m above ground level every 15 min by a weather station located in close proximity to the grazing area (<1 km). The data were aggregated into hourly mean, min and max before being transmitted to cloud-based data storage (Lantmet, VPE/SLU Fältforsk, Sweden), and later downloaded for further analysis (https://www.ffe.slu.se/lm/LMHome.cfm, Lantmet, VPE/SLU Fältforsk, Sweden, 1 June 2022).

Temperature humidity index (THI) was calculated as (NOAA, 1976):

$$THI = F^{\circ} - (0.55 \quad (1 - RH)) * \quad (F^{\circ} - 58)$$

In order to use this equation for calculation on THI, temperature measurements in Celsius were converted to Fahrenheit (F°) according to:

$$F^{\circ} = C^{\circ} \times \frac{9}{5} + 32$$

Temperature, THI and precipitation were averaged for daytime (0700–1700 h) and night-time (1800–0600 h) for the whole sampling period.

2.8. Herbage intake

With the assumption that all cows consumed the 2 kg grain-mix offered at each milking, DMI was estimated by the NASEM (National Academies of Sciences, Engineering, and Medicine, 2021) and NEL20 (Norfor, 2011) approaches. NEL20 provides a feed value for net energy standardised at 20 kg of DMI. Since the cows in this study likely consumed close to 20 kg DM, we used NEL20 to estimate herbage intake. The NorFor model was used to estimate NEL20 of the feeds, and the animals' intake capacity and energy requirement (NorFor version 6.34, FST revision 2.10, FRC revision 2.15). All models were compared based on outcome for rumen fill and supply of energy requirement for each cow (data not shown). After this comparison, NASEM was chosen as being the best performing, as the model resulted in close to 100 % of intake capacity and energy requirement according to NorFor (2011), where mean rumen fill was 103 ± 3.7 % of intake capacity and energy supply was 101 ± 6.6 % of energy requirement. The NASEM equation takes the form:

$$DMI\left(\frac{kg}{d}\right) = [((3.7 + parity * 5.7) + 0.305 * MilkE + 0.022 * BW + (-0.689 + parity * -1.87) * BSC] * [1 - (0.212 + parity * 0.136) * e^{(-0.053 * DIM)}]$$

where DMI is estimated dry matter intake in kg per day, BSC is body condition score (set to 3.5 for all cows), parity was set to 0 for primiparous cows and 1 for multiparous cows, BW is body weight of the cow in kg, MilkE is the energy needed for daily milk production in Megacalories (Mcal; 1 litre of milk requiring 1.39 Mcal) and DIM is the number of days in milk since last calving.

2.9. Milk composition

Milk samples were analysed using MIR spectroscopy (CombiScope FTIR 300HP, Delta Instruments B. V., Drachten, the Netherlands) for milk fat, protein, lactose, total solids and milk urea nitrogen (MUN), calculated according to Delta Instruments (2007).

Milk constituent concentrations were calculated as a weighted mean of the combined afternoon and morning milk yields. Daily ECM yield was calculated according to Sjaunja et al. (1990).

2.10. Statistical analysis

All data handling and figure design prior to statistical analysis were conducted using the R software (R 265 Core Team., 2021), unless specifically stated otherwise.Statistics were computed on the sampling period mean per cow for productive variables and behaviour. All variables were checked, and criteria met, for normality through the Shapiro-Wilks test using the univariate procedure (SAS 9.4 2016; Cary, NC, USA) in addition to visual inspection of the QQ plots. Homogeneity was checked through visual inspection of the residual plots. The effects of the treatments on behaviour, feed intake, body weight change, milk yield and milk composition were analysed in a generalized linear mixed model (SAS 9.4 2016; Cary, NC, USA). Variables included in the model as fixed effects were treatment (AM and PM; class variable), parity (primiparous and multiparous; class variable), DIM (continuous variable) and the interaction of treatment x parity. Pre-experimental milk yield was used as a covariate in the analyses for milk yield. The number of degrees of freedom was estimated by the Kenward-Roger approximation procedure. Unless otherwise stated, the values presented are least square means (LSM ± SE). Differences between treatments were considered significant at $P \leq 0.05$.

3. Results

3.1. Weather conditions

Mean (± SD) temperature, THI and precipitation for the region and the whole study period was 11.3 ± 3.74 °C, 52.6 ± 5.92 and 0.1 ± 0.49 mm, respectively, and for the sampling period 11.0 ± 2.95 °C, 52.1 ± 5.07 and 0.1 ± 0.45 mm, respectively. Temperature and THI at night (1800–0600h) during the sampling period was 9.3 ± 2.58 °C and 49.3 ± 4.62, respectively, while temperature and THI during the day (0700–1700 h) was 12.9 ± 2.05 °C and 55.4 ± 3.30, respectively. During the sampling week, the sun rose at 0430 h and set at 2140 h, dawn occurred at around 0330 h and dusk at around 2240 h. At this latitude and time of the year there is only civil and nautical twilight, with no true darkness (astronomical twilight), during the night.

3.2. Pasture and feed quality characteristics

Pasture characteristics and chemical composition of the herbage were similar between the two treatments (Table 2). Herbage mass (on average, 2860 kg DM/ha), pre- and post- grazing SSH (on average 25.6 and 11.2 cm, respectively), as well as herbage allowance (on average, 64.7 kg DM/cow/d) were almost identical in the two treatments. The ME content per kg DM in the offered strips was also very similar for the AM and PM pasture (Table 2). The CP:WSC ratio in hand plucked samples, as well as in samples of plantago and chicory were similar between the strips (Table 2). The CP:WSC ratio was, however, higher in AM than in PM grass ($P = 0.031$; $F_{1,5}=12.5$), and lower in AM than in PM clover ($P = 0.012$; $F_{1,5}=21.4$). The botanical composition did not differ between the two treatments for all the species ($P \geq 0.05$), except for chicory which its proportion was higher ($P = 0.006$; $F_{1,3}=322$) in AM than in PM treatment (Table 2). Grass and plantago were the most common species in both treatments. Other species, comprising cumin and weeds, represented less than 1 % of the total dry herbage mass (Table 2).

3.3. Behaviour, intake and body weight

Daily duration of grazing was higher ($P < 0.001$; $F_{1,48}=14.0$) and daily duration of rumination was lower ($P < 0.001$; $F_{1,47}=14.7$) in the PM group of cows compared with the AM group. There was no difference in idling time between cows in the two treatments ($P = 0.13$; $F_{1,47}=2.42$) (Fig. 1).

Irrespective of treatment, grazing and rumination both showed peaks in activity after milkings and at dusk (Fig. 2). There was a clear shift in behaviour around dawn, with cows switching from rumination to grazing (Fig. 2). The PM group spent numerically more time grazing (min/h) around dusk, while grazing by the AM group was more evenly distributed throughout the day (Fig. 2). Cows in the AM group spent slightly more time (min/h) ruminating during the night compared with cows in the PM group (Fig. 2).

There was a significant difference in grazing time (min/h) between the two treatments for each time interval studied (2, 4 and 6 h), where

Table 2
Pasture characteristics, and chemical and botanical composition of herbage in the strips offered to cows in the two treatments groups: access to new strip after morning milking (AM) or after afternoon milking (PM).

	AM	PM	SEM	P-value
Pasture characteristics				
Pre-grazing surface height, cm	25.1	26.1	1.83	0.553
Post-grazing surface height, cm	11.4	10.9	1.65	0.460
Herbage mass, kg DM/ha	2802	2918	194.5	0.539
Herbage allowance per strip, kg DM/cow	64.5	64.8	5.10	0.787
Herbage				
DM, g/kg	158	167	9.52	0.333
Crude protein, g/kg DM	162	164	13.2	0.900
WSC, g/kg DM	142	146	12.8	0.990
aNDF, g/kg DM	369	338	18.2	0.276
Ash, g/kg DM	90.3	95.4	4.30	0.112
ME, MJ/kg DM	12.0	12.2	0.29	0.305
CP:WSC ratio				
Hand plucking	0.91	0.93	0.130	0.799
Grass	1.85	1.48	0.523	0.031
Plantago	0.71	0.83	0.076	0.717
Clover	0.36	0.38	0.027	0.012
Chicory	0.89	1.09	0.210	0.562
Botanical composition (% Dry weight)				
Grass	38	31	7.04	0.181
Plantago	25.2	31.6	6.12	0.107
Clover	20.7	12.4	3.78	0.676
Chicory	14.2	13.1	2.67	0.006
Others	0.13	0.74	0.50	0.063

Abbreviations: Abbreviation: SEM: standard error of means. DM: Dry matter; ME: metabolisable energy; CP: crude protein; WSC: water-soluble carbohydrates; aNDF: amylase neutral detergent fibre.

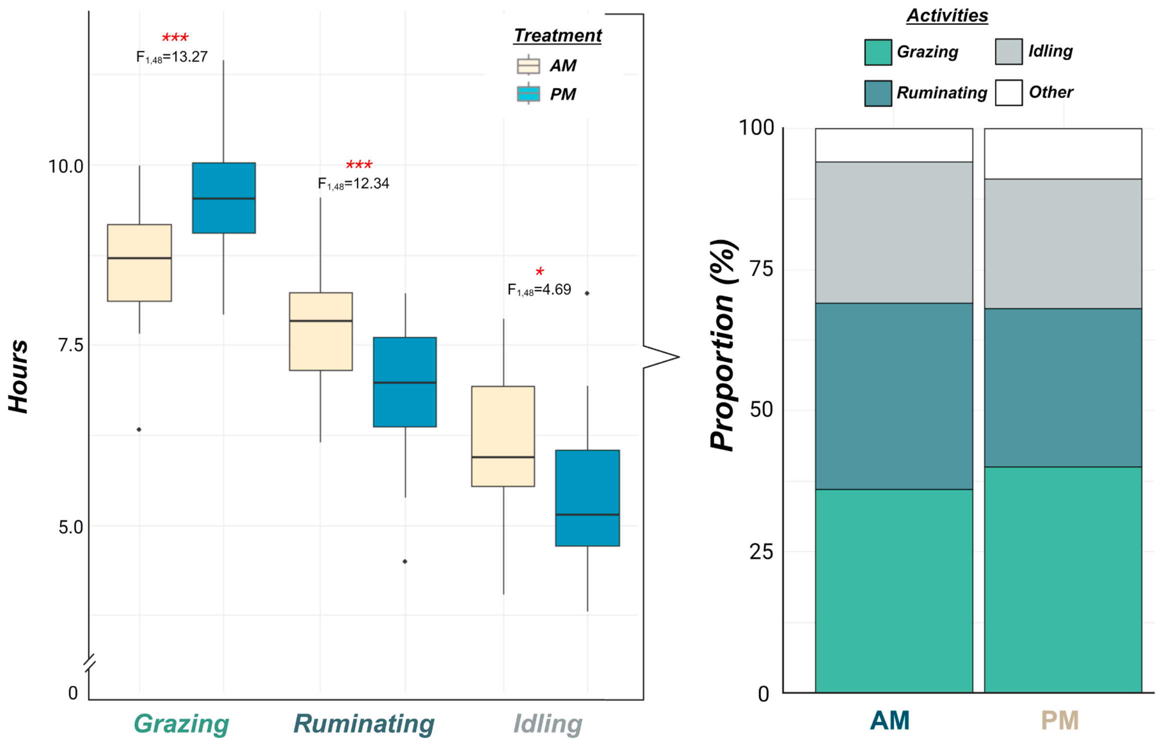

Fig. 1. Average time spent idling, ruminating and grazing by lactating dairy cows in the two different treatments, access to new pasture after morning milking (AM) or access to new pasture after afternoon milking (PM). P-value indicates treatment differences.

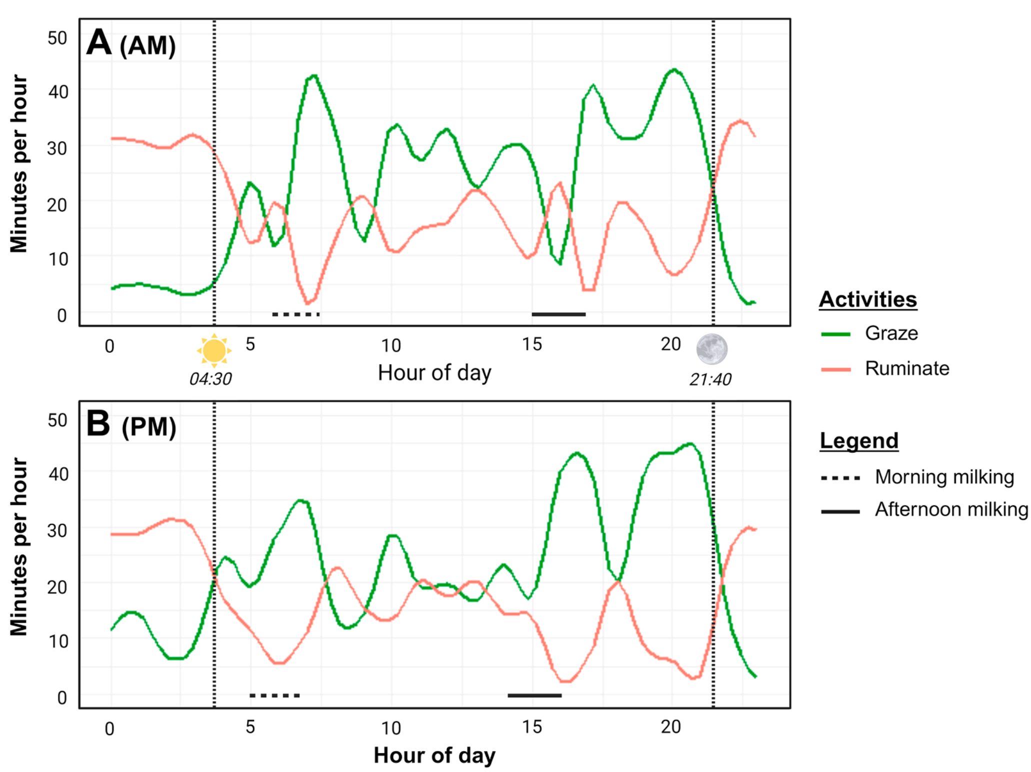

Fig. 2. Diurnal behaviour pattern of lactating dairy cows as percentage of minutes spent per activity in the treatments (A) access to new pasture after morning milking (AM) and (B) access to new pasture after afternoon milking (PM).

the cows receiving fresh pasture spent more time grazing than the cows which were let out on old pasture (Fig. 3). There was also a numerical increased cumulative effect for the PM cows, which after 6 h on fresh pasture had spent 228 min grazing, compared with the AM cows, which only spent 146 min out of 6 h grazing on fresh pasture (Fig. 3). Estimated pasture intake and body weight did not differ between the treatments.

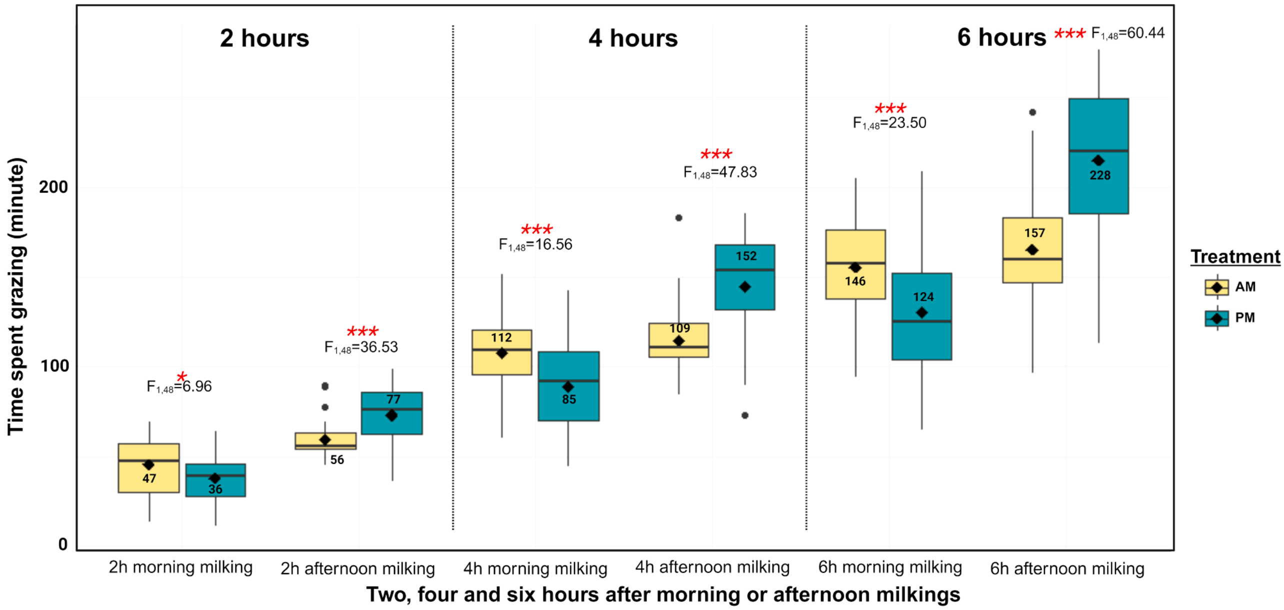

Fig. 3. Mean, standard error, F-value and statistical significance (*<0.05 and ***<0.001) of difference in minutes spent on eating during grazing in the 2, 4 and 6 hours after morning and evening milking for lactating dairy cows receiving new pasture after morning milking (AM) or after afternoon milking (PM).

3.4. Milk yield and composition

Allocation time of a new strip did not affect milk yield (kg/d; P = 0.10; $F_{1,53}$=2.74) or milk composition. However, cows in the PM group had higher ECM (P < 0.01; $F_{1,55}$=7.24) and milk protein yield (P < 0.05; $F_{1,55}$=5.80) than cows in the AM group (Table 4). Milk fat (P = 0.08; $F_{1,55}$=3.15) and lactose (P = 0.09; $F_{1,55}$=3.02) production per day tended to be higher in the PM group than the AM group, but concentration of MUN tended (P = 0.08; $F_{1,55}$=3.24) to be lower in the PM group than the AM group. There was an effect of DIM on all variables except estimated DMI, milk protein yield per day and urea in milk (Table 4). The net energy for lactation requirement for the two treatments was 128 MJ/cow/day for the AM and 138 MJ/cow/day for the PM.

Table 3
Effect of time of access to new pasture, after morning milking (AM) or after afternoon milking (PM), on grazing, ruminating and idling behaviour in lactating dairy cows.

	AM	PM	SEM	P-value	P-value trt*parity	P-value DIM
Grazing behaviour (per 24 h)						
Total time grazing, min	520	576	14.9	0.001	0.396	0.202
Mean bouts duration, min	25.2	30.5	1.60	0.002	0.347	0.202
Number of bouts, number	22	19	0.9	0.018	0.632	0.456
Max bout duration, min	97.7	110.7	6.65	0.058	0.522	0.827
Ruminating behaviour (per 24 h)						
Total time ruminating, min	468	409	15.3	0.001	0.166	0.232
Mean bouts duration, min	28.4	25.7	1.69	0.118	0.091	0.213
Number of bouts, number	17	16	0.7	0.172	0.572	0.344
Idling behaviour (per 24 h)						
Total time idling, min	359	330	18.3	0.125	0.103	0.467

Abbreviation: SEM: standard error of mean; trt: treatment; DIM: days in milk.

4. Discussion

This study was conducted on a commercial organic dairy farm characterised as a low-input production system in which the aim of the farmer is to optimise use of pasture as the main feed resource during the grazing season. It is worth noticing, that the grazing routine used was daily strip grazing with relatively high forage allowance, and therefore results of this study shouldnt be generalized to different grazing managements. Weather conditions during the sampling period can be considered to lie within the temperature-neutral zone for lactating dairy cows (reviewed by Kadzere et al., 2002), with mean THI of 52.3. During the experiment, the farmer made all decisions on grazing management, e.g. pastures to be grazed and forage allowance. The only pre-set conditions were that both groups of cows should graze on similar pastures, which was fulfilled by allowing both groups of cows to graze neighbouring strips of the same cultivated ley throughout the study. Thus, as intended, pasture characteristics such as herbage mass, botanical and chemical composition of the herbage and SSH did not differ between the treatments (Table 2). In relation to the second pre-set condition, the herbage mass and allowance, herbage ME content, and the pre- and post-grazing surface heights suggest that the offered pasture did not limit herbage and energy intake in either of the treatments (Johansen and Höglind, 2007; Perez-Prieto and Delagarde, 2012; Mezzalira et al., 2014; Kunrath et al., 2020). The total grazing time recorded (Table 3) also supports the assumption that there were no restrictions on herbage intake. According to Pérez-Prieto and Delagarde (2012), average daily grazing duration under strip or rotational grazing management typically lies within the range 450–550 min/d, indicating that the cows in our study were motivated to graze as both groups were closer to the higher end of that range. However, in a study by Wales at el. (1999) herbage intake in lactating dairy cows increased linearly without reaching a plateau as the herbage allowance increased from 20 to 70 kg DM per cow and day on pasture of ryegrass and white clover, and as the herbage allowance increased from 25 to 50 kg DM per cow and day on pasture dominated by paspalum. The pre-grazing SSH of the pastures used by Wales et al. (1999) was rather low (7–9 cm), which may have been a limiting factor for high intake rate at any allowance quantity, as discussed by Mezzalira et al. (2014).

The most significant findings in the present study were the observed increased grazing time, reduction in rumination time and increased ECM yield when cows were allowed to access the fresh grazing daily strip after afternoon milking (PM group) rather than after morning milking (AM group) (Tables 3 and 4). The increased grazing time in PM cows (Table 3) differ to the findings by Vibart et al. (2017), who in a similar experimental setting did not observe any differences in grazing time when late-lactation dairy cows were allowed fresh ryegrass-based pasture either after the morning or afternoon milking. It is worth noting that in the present study and in the study by Vibart et al. (2017), grazing time refers to eating time during grazing, i.e. it does not include other activities such as searching for feed during grazing. While there is no apparent explanation for the conflicting results obtained in the studies, the more prolonged grazing time in PM cows may be a consequence of cows displaying more intense grazing during dusk, as part of their natural diurnal rhythm, as shown in other studies (Gibb et al., 1998; Taweel et al., 2004; Gregorini et al., 2008; Kismul et al., 2019). Changes in chemical composition of the herbage during the day, i.e. increased content of WSC owing to ongoing photosynthesis resulting in increased digestibility and higher WSC:CP ratio in late afternoon-early evening, may be a motivation for more intense grazing around dusk (Provenza et al., 1998; Taweel et al., 2004; Gregorini et al., 2007). However, in our study, WSC and CP contents, as well as CP:WSC ratio did not follow a clear pattern, as seen by others (Delagarde et al., 2000; Orr et al., 2001; Gregorini et al., 2008; Vibart et al., 2017).

In ruminants, the main eating bouts are concentrated during the day and the main rumination bouts during the night (Rook and Huckle, 1997). Gibb et al. (1998) observed peaks in grazing behaviour at sunrise and sunset, but also the occurrence of multiple smaller meals between sunrise and evening milking, interspersed with intervals of ruminating and resting. In line with that, and irrespective of treatment, cows in our study displayed most of their grazing events during daytime (Fig. 2), as also observed by Iqbal et al. (2023). In addition, the grazing pattern displayed in our study was affected by both milking routine and the time of allocation of a new daily grazing strip, with a greater cumulative effect on grazing duration for cows receiving fresh pasture in the afternoon (Fig. 3). This demonstrates the positive effect of offering fresh pasture, independent of time of day, on cows' motivation to graze, and

Table 4
Effect of time of access to new pasture, after morning milking (AM) or after afternoon milking (PM), on milk production, milk composition, milk urea and body weight change in lactating dairy cows.

	AM	PM	SEM	P-value	P-value trt*parity	p-value DIM
Animal metrics						
Estimated DMI, kg DM/day	20.1	20.4	0.43	0.581	0.923	0.710
Milk yield, kg/day	25.8	27.7	0.62	0.104	0.638	< 0.001
ECM, kg/day	26.0	28.6	0.96	0.009	0.767	0.010
BW change, kg/day	−0.71	−0.59	0.198	0.561	0.933	0.001
Milk composition						
Fat%	4.50	4.49	0.153	0.953	0.414	0.036
Protein, %	3.49	3.50	0.065	0.933	0.084	< 0.001
Lactose, %	4.82	4.78	0.032	0.295	0.865	0.006
Fat, kg/day	1.15	1.23	0.047	0.082	0.882	0.026
Protein, kg/day	0.89	0.96	0.029	0.019	0.796	0.069
Lactose, kg/day	1.24	1.33	0.048	0.088	0.550	< 0.001
Total solids, kg/day	3.47	3.73	0.116	0.029	0.798	0.001
Total solids, g/kg milk	13.6	13.5	0.18	0.988	0.166	0.003
Urea in milk, mg/dL	12.6	10.9	0.01	0.077	0.019	0.596

Abbreviations: SEM: standard error of means; trt: treatment; DIM: days in milk; DMI: dry matter intake; ECM: energy-corrected milk; BW: body weight.

indicates that appropriate timing of fresh pasture allocation may increase this motivation even further. Interestingly, this slightly differ compared to the findings by Vibart et al. (2017), who only observed a positive impact on grazing when fresh pasture was offered in the morning. In our study, after receiving fresh pasture the PM cows spent 64, 63 and 63 % of their time grazing in the 2, 4 and 6 h windows, respectively. In contrast, the cows in the AM group spent 39, 47 and 40 % of their time grazing in the 2, 4 and 6 h windows respectively. In addition, cows receiving fresh pasture in the afternoon showed a reduction in number of grazing bouts but an increase in the duration of these bouts (Table 3), as also reported by Gregorini et al. (2008,2011), Abrahamse et al. (2009) and Vibart et al. (2017). As a consequence, evening allocation of fresh pasture was significantly more efficient in terms of grazing time in this study.

The ratio of shorter and longer wavelengths when the sun is close to the horizon has been suggested to have a stimulatory effect on appetite (Gregorini et al., 2006). In accordance with this, we observed a shift in activity from ruminating to grazing at sunrise and a major peak in grazing before sunset for both groups. The peaks, seen around 0730 h and 1830 h, could also have been triggered by the milking routine (short-term fasting), as found in other studies (Orr et al., 2001; Iqbal et al., 2023). The high motivation of the cows to graze during the afternoon-early evening, irrespective of fresh pasture allocation time, is in line with findings by Vibart et al. (2017) and Caram et al. (2021). Cows in the AM group spent a similar amount of time grazing during a 4-hour period in morning and afternoon in that study (196 vs 189 min; Vibart et al., 2017) and in our study (109 vs 112 min). When herbivores graze the same area, whether in the wild or in intensive pasture management systems, they often commence grazing collectively at specific times (Molle et al., 2022). However, they generally stop grazing at different times, depending on their different individual needs and/or hunger levels. We observed this pattern (Fig. 3), with low within-group variation in grazing times during the first 2 h after fresh pasture allocation. This variation increased substantially with increasing cumulative time (4 and 6 h), regardless of treatment or milking.

Differences in grazing and rumination behaviours have been associated previously with stage of lactation and parity, due to the different energy requirements in the various physiological states (Iqbal et al., 2023). However, stage of lactation and parity did not influence grazing or rumination duration in our study, although we found an effect of stage of lactation on production parameters and parity is known to impact the time budget of dairy cows (Grant and Albright, 2001). The cows on the study farm have been carefully bred to cope with an intense full-time grazing system and were acclimatised to grazing for more than a month before our sampling, which could possibly explain the lack of parity effect.

Despite the greater total grazing time for cows in the PM group compared with the AM group, estimated intake did not differ significantly between the treatments. However, it is worth noting that herbage intake was estimated using equations based on several assumptions and whether there was a real difference in intake, or not, cannot be exclusively determined by this method.

The total daily rumination time of cows in the PM and AM groups was within the range (387–530 min) reported by Pérez-Prieto and Delagarde (2012). In both groups of cows, most of the rumination took place at night, between dusk and dawn. In addition, there was an increase in rumination activity after each main grazing event, both in the morning and evening (Fig. 2). Interestingly, cows in the PM group showed shorter total daily rumination time than cows in the AM group. This could be a consequence of greater digestibility (Ciavarella et al., 2000; Linnane et al., 2001) and palatability (Provenza et al., 1998), or to more selective grazing behaviour by the PM group, selecting for certain species in the pasture. In line with increased digestibility, Gregorini et al. (2009) reported a decrease in toughness of meadow fescue, and an increase of particle size reduction, from early morning to evening as a consequence of a relative decrease in fibre concentration in the herbage and an increase in DM and WSC content during the day. Grant et al. (1990) found that a reduction in particle size resulted in shorter rumination time.

Milk yield and daily fat yield were numerically greater in cows in the PM treatment than in AM cows. This numerical increase, in combination with a significant increase in daily protein yield, had a significant effect on ECM, with PM cows producing 10 % more kg ECM than AM cows. Similarly, Vibart et al. (2017) observed a tendency for increased milk fat, milk protein and milk solids yield when the time of allocation to fresh pasture was in the afternoon rather than in the morning.

While a single, simple and easy to adopt change in grazing management appears to be an effective way of increasing milk protein content and ECM yield, results should be considered with caution. Many factors can affect herbage intake and animal performance, such as herbage quality and allowance, sward structure and grazing management, among others. In the present study, the grazing strategy applied by the farmer, similar to a ́rotatinuous ́grazing management (Schons et al., 2021), resulted in herbage allowances and pre- and post-grazing sward heights (Table 2) capable of providing the conditions for a maximized herbage intake for both groups of cows.

Assuming that herbage intake was similar for the two groups of cows in our study, the higher yields of ECM and protein may have been due to changes in the chemical composition of the herbage as the day progressed. Better utilisation of dietary N, it is suggested by the tendency ($P < 0.08$) for a lower concentration of urea-N in milk from the PM group than in milk from the AM group. In lactating dairy cows, urea-N in milk can be used as an index of a more optimal balance of energy:protein ratio (Oltner and Wiktorsson, 1983), and of the efficiency of utilisation of dietary N (Gustafsson and Palmquist, 1993; Gonda, Lindberg, 1994; Jonker et al., 1998). Based on the high correlation between MUN and urinary excretion of urea-N (Gonda, Lindberg, 1994; Jonker et al., 1998), a small adjustment in grazing management, would result in a lower environmental impact by reducing excretion of N to the environment (Pozo et al., 2022). However, the fact that in the present study MUN concentrations only tended ($p < 0.08$) to differ between treatments, and dietary-N utilization was not quantified, doesn't allow to draw a clear conclusion on a better efficiency of utilization of N as a result of changing the time of allocation of the daily grazing strip from morning to afternoon as seen by Pozo et al. (2022).

5. Conclusions

Lactating dairy cows allowed to access their fresh daily grazing strip later in the day devoted more time to grazing and less time to ruminating than cows accessing the fresh pasture early in the morning. This simple change in grazing management from giving access to fresh pasture in the afternoon, rather than the morning, resulted in increased ECM yield, as a result of increased milk protein and total solids yield.

However, before advising the adoption of this simple practice to dairy farmers, more research is needed in order to elucidate how the response in animal performance could be affected by location, seasonality and weather conditions –e.g., photoperiod, heat stress-, pasture characteristics -e.g., botanical composition, phenological stage, herbage mass, sward structure-, and grazing management –e.g., herbage allowance, pre- and post-grazing pasture heights-, among other factors.

CRediT authorship contribution statement

E. Ternman: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Q. Lardy:** Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. **R. Danielsson:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **H. Gonda:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Ethical considerations

Not applicable. Treatments and handling of animals were part of the everyday farm routine and did not require ethical approval.

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Declaration of Competing Interest

Authors declare that there is no conflict of interest

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Data availability

None of the data have been deposited in an official repository, but all are available on request by contacting the corresponding author.

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