
THE PROCEEDINGS OF THE
NEW ZEALAND SOCIETY
OF
ANIMAL PRODUCTION
VOLUME 62 2002

Performance and intake of high-yielding Holstein cows offered a TMR either alone or with access to grazing for six hours per day

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Abstract

Grazing of lactating cows is a decreasing practice in Europe despite numerous potential benefits. In parts of Europe, farmers are required to graze all dairy cows for at least six hours per day during summer, but little is known about the effect on the performance of high-yielding animals. A study was undertaken to investigate the effects of the following treatments on high-yielding Holstein cow performance: continuous housing (C; control) with a total mixed ration (TMR), a six-hour grazing period directly after morning milking with TMR offered *ad libitum* when housed (EG; early grazing), a six-hour grazing period following morning milking with 75% of *ad-libitum* TMR when housed (RT; restricted TMR), or TMR access for one hour following morning milking, followed by a six-hour grazing period (DG; delayed grazing) then housed with TMR offered *ad libitum*. Total dry matter intake (DMI) was similar in C, EG and DG but lower in RT (26.9, 26.0, 26.7 and 23.8 kg DM/cow/d; P <0.001; SED 0.524). Milk yield was also lowest in RT, with mean values of 45.7, 44.2, 44.9 and 41.7 kg/cow/d in C, EG, DG and RT respectively (P =0.001; SED 0.993). High-yielding cows can be grazed for a six-hour period during the day with little impact on milk production provided TMR is unrestricted when housed.

Keywords: Total mixed ration; grazing; pasture intake; milk production

Introduction

With increasing intensification of dairy farming in Europe, there is a decreasing emphasis on grazing the lactating cow and a movement towards greater use of summer housing with total mixed ration (TMR) feeding (March et al. 2014). However, there are potential economic, environmental, milk quality and animal welfare benefits of grazing. For example, an annual intake from grazing greater than 600 kg DM/cow is reported to be more profitable than summer feeding alone (Van den Pol-van Dasselaar et al. 2014), methane output can be reduced and the concentration of beneficial fatty acids in milk increased by grazing cows for part of the day (Mufungwe et al. 2014). In addition, when given a choice, cows can also exhibit motivation to be at pasture (Motupalli et al. 2014).

Certain farmers in the Netherlands and Germany are incentivised by milk companies to graze milking cows for a minimum of six hours per day, while in Scandinavia, legislation requires cows to have access to pasture for at least six hours during the summer months. Little is known about the effects of this grazing period on high-yielding cows. Previous research has reported that allocating high-yielding dairy cows to pasture between milkings in either the morning or evening (approximately 7-12 hours), reduced milk yield unless TMR was also provided in the field (Mufungwe et al. 2014). Providing access to a TMR in the field may not be a practical solution for the majority of dairy farmers. Lower yielding cows can adapt to maintain dry matter intake (DMI) in response to restricted periods of pasture access (Gregorini 2011). Therefore, limiting the time high-yielding cows have at pasture to six hours may allow them to graze and consume sufficient TMR to maintain milk yield.

Behavioural studies observed that cows rapidly consume a meal of TMR following milking before going out to grass – a strategy that was able to maintain milk yield, but limited pasture intake to less than 2 kg DM/cow/d on average (Charlton et al. 2011; Motupalli et al. 2014). The feeding behaviour of cows to consume feed around dawn/morning milking (Gregorini 2011) could also be used to increase the pasture intake of high-yielding cows if TMR access is removed at this time. Potentially, pasture intake could be further increased by restricting TMR intake prior to morning milking, amplifying diurnal changes in feed intake behaviour and subsequently reducing feed costs whilst maintaining milk yield. Our aim was, therefore, to determine the effects of a six-hour grazing period with various timings and restriction of access to a TMR prior to grazing on milk performance and intake in high-yielding dairy cows.

Materials and methods

The experiment was conducted at Harper Adams University, Newport, Shropshire, UK (52.780°N, 2.434°W), during summer 2015 from 12th May to 14th July. All procedures involving animals were conducted in accordance with the UK Animals (Scientific Procedures) Act 1986.

Experimental design

Animals and treatments. Fifty-six Holstein cows that were (mean ± SE) 89 ± 5.3 days *post partum*, yielded 44.7 ± 0.42 kg/d of milk, weighed 644 ± 7.7 kg and with a body condition score (Ferguson et al. 1994) of 2.78 ± 0.029 were used. In each of two 28-day periods, 28 cows were randomly and equally allocated to one of four groups (Table 1) based on their milk yield, parity, live weight, feed

Table 1 Summary of grazing treatments imposed on 56 cows across two 28-day periods at Harper Adams University, Newport, Shropshire, UK in a study determining the effects of a six-hour grazing period, with various timings and restrictions on access to total mixed ration (TMR) prior to grazing, on intake and milk production in high-yielding Holstein cows.

Treatment	Description
C: Control	Cows continuously housed with TMR offered *ad libitum.*
EG: Early grazing	Cows at pasture for 6 h immediately following morning milking and then housed with TMR offered *ad libitum* while housed.
RT: Restricted TMR	Cows at pasture for 6 h immediately following morning milking and then housed with TMR intake restricted to 75% *ad-libitum* TMR intake.
DG: Delayed grazing	Cows housed with access to TMR for 1 h following morning milking, then at pasture for 6 h, then housed with TMR offered *ad libitum* while housed.

intake and milk-fat content measured in the week prior to allocation. Measurements were undertaken in the final week of each 28-day period.

Cows were milked twice per day at approximately 0630 and 1630 h. Immediately following morning milking, cows in treatments C (control) and DG (delayed grazing) were allowed to return to the cubicle housing and feeding area, while cows in EG (early grazing) and RT (restricted TMR) were separated as they exited the milking parlour and moved to the grazing area. After one hour, DG were separated and moved to the grazing area. After six hours at pasture, cows were gathered and returned inside; at approximately 1230 h for cows in EG and RT, and 1330 h for cows in DG. While housed, cows were offered TMR *ad libitum,* except for treatment RT, where each animal could eat up to 75% of *ad-libitum* intake. All cows had continual access to water when indoors and at grass.

Grazing and pasture allocation. The grazing area consisted of a 3-ha field, with pasture composed predominately of perennial ryegrass (*Lolium perenne*). The field could be accessed from both ends and subdivided with temporary electric fences to allow flexible rotational grazing. Daily fresh-pasture allowance was 6 kg DM/cow/d above a 4-cm base and was allocated in the following manner: on day one, cows were allocated a strip of 8 kg DM/cow; on day two, cows were allocated a fresh strip of 5 kg DM/cow plus the previous days un-grazed allowance; on day three, cows were allocated a fresh strip of 5 kg DM/cow plus the previous two days un-grazed allowance. Each daily grass strip was further split into three parts of equal area and treatment groups grazed independently. Grazing was counter balanced so that no group grazed the same area twice over a three day period. After three days, cows were no longer permitted access to the previous days grazing and the pattern was repeated. Pasture allowance was determined from herbage mass (HM), estimated daily prior to grazing using a rising-plate meter (Jenquip, Fielding, New Zealand) and the standard UK calibration equation:

$$HM = 120H + 640$$

where H was average compressed height in ½cm units. Post-grazing HM was also recorded daily for each group using the rising-plate meter. Target pre-grazing HM was 2700-3000 kg DM/ha and a group of non-lactating cows were used to graze residual herbage to 1500-1600 kg DM/ha. Mechanical topping was used to maintain pasture quality where necessary.

Housing and TMR feeding. Cows were housed together in the same portion of a free-stall building containing "Super Comfort cubicles" fitted with foam mattresses (IAE, Stoke-on-Trent, United Kingdom). Fresh TMR was delivered at approximately 0800 h daily, and was composed of maize silage, lucerne silage and concentrates, formulated to produce approximately 40 kg of milk per day using a Feed into Milk software package (Thomas 2004). The TMR was accessed via 30 electronic roughage intake bins (RIC bins; Insentec, Marknesse, The Netherlands). Cows were trained to use RIC bins at least one week prior to each study period and that week's mean TMR intake for each cow used as a baseline *ad-libitum* intake. Cows could access any RIC bin, with C, EG and DG cows permitted *ad-libitum* intake, while RT cows were restricted within the RIC system to a quantity 75% of the intake of their corresponding paired cow in treatment C with the most closely matching milk yield, live weight and feed intake measured in the week prior to allocation.

Experimental measurements

Milk yield and composition. Milk yield was automatically recorded at each milking for all cows throughout the study (GEA, Düsseldorf, Germany). Sub-samples were also taken on four separate occasions (2 x am and 2 x pm) during the final week of each treatment period for subsequent analysis of fat and protein content using a Milkoscan Minor (FOSS, Warrington, UK), calibrated according to AOAC (2012).

Live weight and body condition score. Cow live weight (Lwt) was recorded (Trutest, Auckland, New Zealand) at the start and end of each treatment period at approximately 1630 h as cows exited the milking parlour. Body condition score (BCS; 1-5 scale where 1 = emaciated and 5 = obese; Ferguson et al. 1994), was recorded at the same time as Lwt by a single, trained observer.

Feed analysis and intake. Feed samples were collected during the final five days of each period. These consisted of a TMR sample collected within 10 minutes of feeding, and pasture samples taken as described by Smit et al. (2005), to represent the herbage in the grazed horizon at approximately 0730 and 1130 h. Feed samples were stored at -20°C until subsequent analysis. Prior to analysis, feed samples were bulked by period and a sub-sample freeze dried to a constant weight and analysed for DM and ash content (AOAC 2012). Crude protein (CP) concentration was measured by combustion using a LECO FP 528 N analyser (Leco Corporation, St. Joseph, MI), fibre content (Van Soest et al. 1991), and water-soluble carbohydrate (WSC) content (Thomas 1977) were determined. The metabolisable energy (ME) content in the pasture was predicted from the modified acid detergent fibre content (Givens et al. 1990) (Table 2).

Daily intake of TMR for each cow was automatically recorded via the RIC system, while individual pasture intakes were estimated using the *n*-alkane method based on Mayes et al. (1986). For the final 12 days of each period, a daily dose of C_{32} alkane (dotriacontane) was thoroughly incorporated in to the TMR at 2.0 g/cow/d. Total quantity of TMR fed and daily TMR intake were used to calculate the quantity of (C_{32}) *n*-alkane consumed by each cow. Faecal samples for each cow were collected in the final five days of each period between 0400 and 0600 h from naturally voided faecal deposits, frozen at -20°C and bulked within cow. A sub-sample was freeze dried for subsequent analysis. Pasture, TMR and faecal samples were analysed for *n*-alkanes and pasture intake for each cow calculated from the concentrations of a naturally occurring odd-chain (C_{33}) and dosed even-chain (C_{32}) *n*-alkane (Mayes et al. 1986).

Statistical analysis

Data were evaluated by ANOVA in Genstat v.17 (VSN International 2015). The model included the effect of treatment, block within period, and used the performance data collected in the week prior to commencing the study as a covariate where appropriate. Differences were considered significant at P <0.05 and the least significant difference test was conducted *post hoc*.

Results and discussion

Pasture quality was high during the study, with ME and CP content similar in both pasture and TMR (Table 2), and WSC content 121 g/kg DM higher in pasture than in the TMR. Pasture quality usually declines as summer progresses, however there was no effect of 28-day-period on the intake or milk production variables (P >0.05).

Total DMI was similar in cows receiving C, EG or DG (P >0.05; Table 3), with a mean value of 26.5 kg DM/cow/d, but was approximately 2.7 kg DM/cow/d lower (P <0.05) in RT. The mean ± SE pre-grazing HM was 2620 ± 13 kg DM/ha, and 210 ± 10 kg DM/ha was consumed. Allowing cows to consume TMR for an hour after milking (DG), or exposing them to pasture immediately following milking (EG) resulted in a pasture intake of approximately 2.2 kg DM/cow/d, only 8.2% of total DMI. A possible explanation for the similar total DM intake in C, EG and DG cows is that although cattle are often observed to have a diurnal grazing pattern, the early morning grazing bout is thought to be triggered by hunger, while evening bouts may be an adaptive strategy to maximise daily energy intake for release throughout the night (Gregorini 2011). Early grazing cows in the current study may have quickly reached satiety due to recent TMR intake and not achieved a higher pasture intake. When cows had TMR allowance restricted to 75% of ad-libitum (RT), pasture intake over six hours was higher (P <0.05), increasing to around 3.5 kg DM/d or 14.6% of total DMI. Although pasture intake was highest in cows with restricted TMR access, this was not sufficient to overcome the lower (P <0.05) TMR intake and subsequently lower total DMI of RT cows.

Table 2 Chemical composition (g/kg DM unless otherwise stated) of the pasture and total mixed ration (TMR) offered to dairy cows that were either, continuously housed and offered a total mixed ration (TMR) *ad libitum* (control; C), offered grazing for 6 h immediately after morning milking then housed and offered a TMR *ad libitum* (early grazing; EG), offered TMR for 1 h after morning milking then grazed for 6 h, housed and offered a TMR *ad libitum* (delayed grazing; DG), or offered grazing for 6 h immediately after morning milking, housed and offered a TMR at 75% of *ad-libitum* intake (restricted TMR; RT).

Chemical analysis	Pasture	TMR
Dry matter (DM), g/kg	206	482
Metabolisable energy (ME), MJ/kg DM	12.3	12.2
Organic matter (OM)	895	930
Crude protein (CP)	175	176
Water-soluble carbohydrate (WSC)	202	81
Neutral detergent fibre (NDF)	390	329
Acid detergent fibre (ADF)	210	196
Hemicellulose (HC)	180	133

Milk yield reflected the pattern of total DMI (Table 3), with a similar yield in C, EG and DG cows (P >0.05), with an overall mean value of 44.9 kg/d. Milk yield was lower (P <0.05) in cows fed RT compared to C or DG. Previous research has reported that cows fed exclusively TMR have a higher milk yield than cows receiving both grazing and TMR (Mufungwe et al. 2014; Bargo et al. 2002). However, these studies had a longer grazing period (7-12 hours), suggesting that six hours (used in this study), approaches the maximum length of grazing possible for housed TMR intake to compensate for a period without TMR access. For cows in later lactation, or cows yielding less than approximately 45 kg/d, a longer grazing period may be possible without affecting production. Milk fat and protein content were similar in all treatments. Liveweight gain was higher in continuously housed cows than in cows that were grazed and had restricted access to TMR (RT). Mufungwe et al. (2014) reported that when cows were unable to maintain DMI, Lwt loss was greater, although this did not fully compensate for the reduction in milk yield.

Assuming an annual grazing period of six months, a daily pasture intake of approximately 3.3 kg DM/cow

Table 3 Intake and performance means[1] of dairy cows that were continuously housed and offered a total mixed ration (TMR) *ad libitum* (control; C), offered grazing for 6 h immediately after morning milking then housed and offered a TMR *ad libitum* (early grazing; EG), offered TMR for 1 h after morning milking then grazed for 6 h, housed and offered a TMR *ad libitum* (delayed grazing; DG), or offered grazing for 6 h immediately after morning milking, housed and offered a TMR at 75% of *ad-libitum* intake (restricted TMR; RT).

	C	EG	DG	RT	SED	*P*-value
DM intake						
TMR, kg/d	26.9^{c}	23.6^{b}	24.7^{b}	20.3^{a}	0.698	<0.001
Pasture, kg/d	–	2.35^{a}	1.98^{a}	3.48^{b}	0.449	0.006
Total, kg/d	26.9^{b}	26.0^{b}	26.7^{b}	23.8^{a}	0.524	<0.001
Milk yield, kg/d	45.7^{b}	44.2^{ab}	44.9^{b}	41.7^{a}	0.993	<0.001
Milk fat, g/kg	30.6	32.7	31.3	33.7	0.175	0.293
Milk protein, g/kg	2.97	2.91	2.89	2.94	0.056	0.492
Live weight change, kg/d	0.86^{b}	0.31^{a}	0.41^{ab}	0.09^{a}	0.177	<0.001

[1]Means within a row with a different superscript differ P <0.05.

would be necessary to reach 600 kg DM/cow/yr. This is the yearly intake from grazing that has a determined economic benefit in Dutch dairy systems (Van den Pol-van Dasselaar et al. 2014). Given that only cows receiving RT achieved this level of pasture intake, implementing six-hour daily grazing periods may only provide limited economic benefit in high-yielding farms, aside from situations where grazing premiums are paid. However, if TMR allowance is unrestricted, and pasture is allocated at a sufficient quantity and quality, a daily six-hour grazing period is not detrimental to performance, and may actually provide health and welfare benefits to cows (Motupalli et al. 2014).

Conclusion

Our results suggested that in a TMR feeding system, high-yielding cows can be grazed for a six-hour period during the day without affecting milk production provided feed supply when housed is not limited. However, pasture intake was a minor component of the diet.

Acknowledgements

The authors acknowledge the assistance of the Harper Adams University farm staff, laboratory technicians and dairy PhD students. Also acknowledged is Dr. Bob Mayes (Hutton Institute, Aberdeen), for assistance with the *n*-alkane analysis, and funding support from ADHB Dairy.

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