Effects of daily herbage allowance and stage of lactation on the intake and performance of dairy cows in early summer

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The aim of this study was to investigate the relationship between daily herbage allowance (DHA) and the performance of dairy cows at two stages of lactation. Spring-calving (n=42, mean calving date 17 February) and autumn-calving (n=42, mean calving date 22 September) Friesian cows were divided into three equal groups and assigned to three levels of DHA (above a cutting height of 35 mm), 17 (L), 20 (M) and 23 (H) kg of dry matter (DM) per head, from late April to late June, 1996. The spring-calving cows grazed to sward heights (mm) of 47, 56 and 65 (s.e. 0.6) and residual herbage organic matter (OM) masses (above 35 mm) of 294, 408 and 528 (s.e. 12.1) kg/ha for L, M and H, respectively. The autumn-calving cows grazed to corresponding sward heights of 51, 60 and 69 (s.e. 1.1) mm and left residual herbage OM masses of 364, 445 and 555 (s.e. 12.9) kg/ha for L, M and H, respectively. Pastures were mechanically topped post grazing. Spring-calving cows consumed 13.3, 14.7 and 15.5 kg OM (s.e. 0.47) per day, and autumn-calving cows consumed 13.3, 13.8 and 14.9 kg OM (s.e. 0.43) per day for L, M and H, respectively. Mean daily solids-corrected milk yield was 23.1, 23.8 and 24.8 (s.e. 0.34) kg for the spring-calving cows, and 17.5, 18.4 and 18.7 (s.e. 0.35) kg for the autumn-calving cows, for L, M and H, respectively. Milk yield could be predicted from pre-experimental yield (PMY) and daily herbage organic matter allowance (DOMA, kg) according to the following equation: y = –1.13 + 0.76 (s.e. 0.030) × PMY + 0.22 (s.e. 0.057) × DOMA (r.s.d. 1.32, R^2 0.89). The results indicate that high individual cow and herd production levels can be achieved from high quality herbage alone

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during early summer at a DHA of 23 kg DM for spring-calving cows and 20 kg DM for autumn-calving cows.

Keywords: dairy cows; herbage allowance; intake; milk yield; stage of lactation

Introduction

Profitability of dairying in Ireland depends to a large extent on efficient use of grassland and high performance from grazing dairy cows. This is achieved by a high intake of high quality grass. Daily herbage allowance (DHA), defined as the quantity of herbage (above a specified height) offered daily per cow, is of major importance in determining daily herbage organic matter intake (OMI) and milk production. The relationships between DHA and both OMI and milk yield are generally curvilinear (Gordon *et al*., 1966; Greenhalgh *et al.,* 1966; Greeenhalgh, Reid and Aitken, 1967; Combellas and Hodgson, 1979; Le Du *et al.,* 1979; Peyraud *et al.,* 1996).

Intensive use of grassland for dairying is based on regular assessment of herbage supply and grazing severity in order to ensure adequate feed for the cows (O'Donovan *et al.,* 1997). This budgeting of feed supply is a function of herbage-supply targets for grazing and silage conservation (Stakelum and O'Donovan, 1998). Short-term feed budgeting is focused on DHA and grazing severity. Using DHA and herbage-supply targets to make decisions on grazing management is a realistic option with the use of a visual assessment technique to measure herbage supply (O'Donovan *et al*., 2002a, b).

When DHA is high, post-grazing sward height and residual herbage mass are also high. Stakelum and Dillon (2007a, b) highlighted the subsequent reduction in sward quality and cow performance that result from lax grazing in spring. Thus, a compromise must be achieved between an adequate DHA and avoidance of too high a post-grazing sward height.

It has been shown that higher yielding herds require higher DHA (Butler *et al*., 2003). However, daily milk production varies with lactation stage, and as lactation advances dairy cows partition more energy towards body reserves. The effect of DHA on milk yield may vary, therefore, with lactation stage. In practice, advancing lactation stage is confounded with seasonal changes in herbage quality and sward structure. No experiments have been conducted where lactation stage and DHA were varied concurrently.

The objectives of this experiment were (1) to study the relationships between DHA, cow performance and intake for a practical range of DHA levels, and (2) to investigate if these relationships depended on lactation stage. Mechanical topping of pastures to remove herbage residues was used to avoid confounding of DHA and herbage quality.

Materials and Methods

Two experiments, one with spring-calving, and one with autumn-calving, cows were carried out at Moorepark Research Centre in 1996. A permanent grassland site (20 ha) was used which was ryegrass (*Lolium perenne*) dominant, with minor proportions of *Agrostis* and *Poa* species and of *Trifolium repens.* Trace amounts of *Taraxacum officinale* and *Rumex obtusifolium* were also present. The soil type was a free-draining acid brown earth of sandy loam to loam texture.

Treatments and experimental design

Three levels of DHA were compared. They were 17(L), 20(M) and 23(H) kg of herbage dry matter (DM) per cow above a cutting height of 35 mm. There were 14 cows per treatment arranged in a randomised block design. The two experiments were carried out simultaneously from 29 April to 23 June (8 weeks). Spring-calving cows with a mean calving date of February 17 (s.d. 13.1 days) were used in Experiment 1, and autumn-calving cows with a mean calving date of 22 September (s.d. 19.4 days) were used in Experiment 2. At the end of the experiments, all the treatment groups were grazed in separate plots at a DHA of 20 kg DM for three weeks to measure any carry-over effects of the treatments.

Animals

In each experiment, 42 Friesian dairy cows were blocked into groups of three on the basis of parity, calving date, milk yield and body weight for the 3 weeks prior to the start of the experiments, and from within block (BLK) they were randomly assigned to the three treatments (TRT). There were four first lactation animals in each treatment in Experiment 1 and none in Experiment 2. Average daily pre-experimental milk yield (PMY) was 28.4 (s.d. 3.78) kg and 19.2 (s.d. 3.09) kg for Experiments 1 and 2, respectively. The milk contained 42.3 g/kg (s.d. 4.88) and 46.4 g/kg (s.d. 4.96) fat, and 33.9 g/kg (s.d. 2.14) and 38.6 g/kg (s.d. 2.70) protein for Experiments 1 and 2, respectively. The cows had average parities of 3.4 (s.d. 2.05) and 3.8 (s.d. 1.89), and average pre-experimental body weights (PWT) of 546 (s.d. 69.6) kg and 562 (s.d. 69.7) kg for Experiments 1 and 2, respectively. They were at 71 (s.d. 13.1 days) and 219 (s.d. 19.4) days of lactation at the start of the respective experiments.

Likely milk yield (LMY) was calculated from PMY according to the expression: LMY = PMY $\times$ 0.98^t, where t is the interval in weeks from the mid-point of the PMY period to the mid-point of the experimental period (Delaby, Peyraud and Delagarde, 2001). This assumes a lactation persistency of 0.98 per week for cows (a value of 0.985 was used for heifers). The LMY can be compared to the observed (experimental) milk yield (EMY) in order to explain the effect of DHA on milk yield in relation to the production potential of the cows.

Pre-experimental procedures

Grazing by day commenced on 3 April and full time grazing commenced on 10 April. Concentrates were offered to each cow at 6 kg/day prior to full-time grazing and were reduced by 1 kg per day from the beginning of full time grazing. After a further 5 days, concentrates were replaced by 0.5 kg/day of calcined-magnesite pellets to prevent hypomagnesaemia. Grazing conditions deteriorated on 22 April due to heavy rain and concentrates were again offered at 4 kg/day per cow. This continued up to 27 April and was phased out before the beginning of the experiments. The post-grazing sward height during this time was 62 (s.d. 7.5) mm. The experimental area was grazed once during this period. Fields were dusted with calcined-magnesite at a rate of 17 kg/ha from May 3 at which time feeding of calcined-magnesite pellets ceased. This continued up to 8 June. Nitrogen fertiliser was applied at 85 kg/ha N in January and at 34 kg/ha N after grazing.

Grazing management during the experiments

During the experimental period and the carry-over periods, the cows were rotationally grazed on one-day plots with no run back to previously grazed areas. Grazing areas were based on herbage mass to 35 mm and each plot was fenced with double strands of electrified wire to prevent grazing outside the plots. New plots were allocated after the evening milking. Water was supplied in each plot. The residual herbage in all plots was mechanically topped to 60 mm after grazing each day.

Sward measurements

Before grazing, 4 strips (1.08 m × 6 m) of herbage, cut to 35 mm, were taken with an Agria Mower in each plot on 4 days each week. The herbage in each strip was weighed and sampled, and a sub-sample from each strip was dried at 95 °C for 16 h (overnight) in an oven with forced air circulation for DM determination. A composite sample from each plot (*ca*. 100 g) was freeze-dried and ground through a 1 mm screen. A weekly composite sample for each treatment was created from these samples and these were analysed for crude protein (CP) (Leco FP20000), neutral detergent fibre (NDF) (Van Soest, 1963), modified acid detergent fibre (ADF) (Clancy and Wilson, 1966), *in vitro* organic matter digestibility (OMD) (Morgan, Stakelum and Dwyer, 1989) and ash (Muffle furnace at 55 °C for 4 h).

The yield of pasture left after grazing was estimated on 4 days each week. Four strips (0.52 m × 9 m) of residual herbage, cut to 35 mm on each grazing plot, were taken using a lawnmower. The herbage in each strip was weighed and sampled, and a sub-sample from each strip was dried at 95 °C for 16 h for DM determination. The dried material was ground through a 1 mm screen and analysed for ash as described above.

The height of the sward before and after grazing and after mechanical topping was measured. Forty readings were taken (20 per diagonal) on 4 days each week using a HFRO sward stick (Hutchings, 1991).

Animals

The cows were milked at 16/8 (night/day) hour intervals. Individual cow milk yield was recorded on three successive mornings and evenings, and milk composition was measured on one successive morning and evening each week. Body weight was measured weekly.

The intake of grazed grass by the cows was estimated on two occasions using the n-alkane technique of Mayes, Lamb and Colgrove (1986) as modified by Dillon and Stakelum (1989). The technique used the herbage C_{33} (n-tritriacontane)/dosed C_{32} (n-dotriacontane) ratio. Cows were dosed twice daily after milking with pellets containing 500 mg of C_{32} for a 12-day period. Rectal faecal samples were collected twice daily from each cow after milking for the last 6 days. These collection periods were from 13 to 18 May (RUN 1) and from 10 to 15 June (RUN 2). Faecal samples from each cow were wet bulked prior to analysis. Grass samples were obtained from each plot pre-grazing on days 6 to 11 of each measurement period. Samples were cut to the approximate post-grazing sward height of the particular treatment using a hand-held shears. The C_{32} and C_{33} concentrations of the pellets, faeces and herbage were analysed according to a modification of the method of Mayes *et al.* (1986) with direct saponification (Dillon, 1993).

Calculations and statistical analysis

All herbage mass and composition data, DHA and intake values are presented in organic matter terms so as to eliminate any problems associated with soil ash contamination of samples. The animal production data were reduced by averaging across weeks for each cow. The sward physical data were reduced by averaging across days within weeks. One cow in Experiment 2 had health problems and stopped lactating. She was removed and her data was not used in the analyses.

All sward and sward compositional data analyses were carried out using one-way analysis of variance with weekly values as the replicates. The animal production data were analysed as a randomised block using the following model:

$Y_{ij} = \text{mean} + TRT_i + BLK_j + b_1X_1 + b_2X_2 + e_{ij}$

where b_1X_1 and b_2X_2 were the values of the appropriate pre-experimental milk production or body weight variables and calving date, respectively. Intake was analysed according to the following model:

$Y_{ijk} = \text{mean} + TRT_i + BLK_j + (TRT \times BLK)_{ij} + RUN_k + (TRT \times RUN)_{ik} + e_{ijk}$, and the TRT effect was tested using the $TRT \times BLK$ term.

The relationship of the response (linear or quadratic) to herbage allowance was tested using orthogonal polynomial contrasts (Steel and Torrie, 1981). All analyses were carried out using the statistical procedures of SAS (SAS, 1991).

Results

Sward results

Pre-grazing herbage mass (HM), sward height (SH) and DHA for the experimental and the carry-over periods are shown in Table 1. Pre-grazing HM and SH were similar for the three treatments and between experiments. There were numerical differences in pre-grazing HM and SH between treatments for the carry-over period of both experiments but these were not significant.

The chemical composition of the swards was similar across the different herbage allowance treatments and experiments (Table 2). The swards were high in OMD and CP and low in fibre. The swards grazed during the carry-over period were slightly lower in OMD (28 g/kg) and crude protein (14 g/kg) and higher in NDF (42 g/kg) and

Table 1. Pre-grazing herbage mass organic matter (OM), sward height and daily herbage allowance for the low, medium and high daily herbage allowance treatment during the experimental and carry-over periods

Variable	Period by Experiment†	Herbage allowance‡			s.e.
		Low	Medium	High	
Herbage mass	E-1	1,729	1,807	1,781	65.5
(OM; kg/ha)	E-2	1,606	1,741	1,750	71.8
	C-1	2,259	1,569	1,998	268.4
	C-2	2,127	1,430	1,700	306.1
Sward height (cm)	E-1	17.7	17.2	17.5	1.08
	E-2	16.9	16.9	17.0	1.01
	C-1	18.6	15.4	17.5	1.74
	C-2	18.2	14.4	16.3	1.59
Herbage allowance	E-1	15.1	18.1	20.9	0.15
(OM; kg/cow)	E-2	15.3	18.0	20.9	0.16
	C-1	18.2	18.7	18.5	0.22
	C-2	18.1	18.9	18.6	0.20

† Where E represents the experimental period (8 weeks) and C represents the carry-over period (3 weeks); 1 = spring-calving cows and 2 = autumn-calving cows.
‡ The only significant effects were on herbage allowance ($P < 0.001$) in E-1 and E-2 (linear effect only).

Table 2. Organic matter digestibility and chemical composition of herbage dry matter (DM) for the low, medium and high daily herbage allowance treatments during the experimental and carry-over periods

Variable	Period by Experiment†	Herbage allowance‡			s.e.
		Low	Medium	High	
Organic matter digestibility (g/kg)	E-1	857	855	852	4.4
	E-2	858	855	851	4.6
	C-1	829	831	820	4.3
	C-2	832	828	818	5.8
Neutral detergent fibre (g/kg DM)	E-1	363	372	372	10.5
	E-2	362	370	383	10.6
	C-1	399	412	419	8.2
	C-2	403	417	424	10.2
Acid detergent fibre (g/kg DM)	E-1	192	194	193	6.0
	E-2	191	191	199	6.6
	C-1	204	203	208	3.4
	C-2	199	211	212	3.8
Crude protein (g/kg DM)	E-1	220	229	214	9.7
	E-2	219	226	218	9.8
	C-1	196	216	210	8.5
	C-2	201	219	203	7.3

† See footnotes to Table 1.
‡ No significant differences were detected for any variable.

ADF (13 g/kg) then those grazed during the experimental period.

The post-grazing HM and SH, and the post-topping SH are shown in Table 3. Post grazing HM reflected the increasing levels of DHA in both experiments. The first increment of allowance significantly increased the post-grazing HM in both Experiments 1 ($P < 0.001$) and 2 ($P < 0.01$). The second increment of DHA also significantly increased post-grazing HM in both experiments

Table 3. Post-grazing herbage organic matter (OM), and sward height post grazing and post topping (SH) for the low, medium and high daily herbage allowance treatments during the experimental and carry-over periods

Variable	Period by Experiment†	Herbage allowance (HA)			s.e.	Significance‡	
		Low	Medium	High		HA	L
Herbage mass	E-1	295	404	525	33.5	***	***
(OM; kg/ha)	E-2	361	441	554	31.6	**	***
	C-1	700	480	603	111.9		
	C-2	726	518	592	106.1		
SH Post-grazing (cm)	E-1	4.7	5.6	6.5	0.24	***	***
	E-2	5.0	6.1	6.9	0.26	***	***
	C-1	5.4	5.3	5.5	0.33		
	C-2	5.8	5.6	5.6	0.32		
SH Post-topping (cm)	E-1	4.4	4.6	4.9	0.20		
	E-2	4.3	4.7	5.0	0.18	*	*
	C-1	5.3	4.8	5.3	0.34		
	C-2	5.6	5.2	5.2	0.24		

† See footnotes to Table 1.
‡ L = Linear effect of herbage allowance; there were no quadratic effects.

(P < 0.001). The SH showed a similar trend to the HM values. There were non-significant differences in post-grazing HM for the carry over period in both experiments that broadly reflected the pre-grazing HM values. The post-topping sward height tended to increase over the experimental period with increasing DHA and this was significant in Experiment 2.

Intake

The average OMI of the different DHA groups in both experiments are shown in Table 4. There was no quadratic component for the DHA effect. There was no RUN or RUN by DHA effect in either experiment. There was a significant linear increase in intake in both Experiment 1 (P < 0.001) and Experiment 2 (P < 0.05) with increased DHA. Using the 84 individual cow OMI values, OMI could be predicted from the following expression:

OMI = 0.48 (s.e. 2.22) + 0.30 (s.e. 0.074) × DHA + 0.14 (s.e. 0.039) × PMY(solids corrected) + 0.009 (s.e. 0.0027) × pre-experimental body weight, (r.s.d. 1.726, R^2 0.34).

The regression coefficients did not differ between the spring- and autumn-calving cows.

Animal performance

The milk production, milk composition and body weight values for the experimental period of Experiment 1 are shown in Table 5. There was no quadratic component for the effect of DHA for any variable. There were significant linear increases in milk yield (P < 0.01), solid-corrected milk yield (P < 0.001),

Table 4. The effect of daily herbage allowance on average herbage organic matter intake (kg/day) during the experimental period

Experiment[†]	Herbage allowance (HA)			s.e.	Significance[‡]	
	Low	Medium	High		HA	L
E-1	13.3	14.7	15.5	0.47	**	***
E-2	13.3	13.8	14.9	0.43	*	*

[†] See footnotes to Table 1.
[‡] See footnotes to Table 3.

Table 5. The effect of daily herbage allowance on milk yield, milk constituents yield, milk composition, body weight and body-weight gain for the experimental period: spring-calving cows

Variable	Herbage allowance (HA)			s.e.	Significance[†]	
	Low	Medium	High		HA	L
Milk yield (kg/day)	24.1	24.6	25.9	0.30	**	***
Solid-corrected milk yield (kg/day)	23.1	23.8	24.8	0.30	***	***
Fat-corrected milk yield (kg/day)	24.4	24.9	26.1	0.30	**	***
Milk fat yield (kg/day)	0.98	1.00	1.05	0.016	*	**
Milk protein yield (kg/day)	0.82	0.85	0.89	0.012	**	***
Milk lactose yield (kg/day)	1.14	1.18	1.24	0.017	**	**
Milk fat concentration (g/kg)	41.2	41.2	40.3	0.79		
Milk protein concentration (g/kg)	34.0	34.6	34.2	0.24		
Milk lactose concentration (g/kg)	47.4	48.0	47.8	0.20		
Body weight (kg)	557	563	556	3.2		
Body-weight gain (kg/day)	0.02	0.23	0.13	0.055		

[†] See footnotes to Table 3; there were no significant quadratic effects.

fat-corrected milk yield (P < 0.01), milk fat yield, (P < 0.05), milk protein yield (P < 0.01), and milk lactose yield (P < 0.01) with increases in DHA. There was a trend for increased body-weight gain with increases in DHA (P < 0.10) and the quadratic component approached significance (P < 0.10).

The milk production, milk composition and body weight values for the carry-over period of Experiment 1 are shown in Table 6. There was no effect of DHA except for milk protein concentration (P < 0.01).

The milk production, milk composition and body weight values for the experimental period of Experiment 2 are shown in Table 7. There was no quadratic component for DHA for any variable. There were significant linear increases in milk yield (P < 0.01), solid corrected milk yield (P < 0.01), fat-corrected milk yield (P < 0.01), milk fat yield (P < 0.05), milk protein yield (P < 0.01), milk lactose yield (P < 0.001), milk protein concentration (P < 0.05) and milk lactose concentration (P < 0.01) with increases in DHA.

Table 6. The effect of daily herbage allowance treatments on milk yield, milk constituents yield, milk composition, body weight (kg) and body-weight gain for the carry-over period: spring-calving cows

Variable	Herbage allowance†			s.e.
	Low	Medium	High	
Milk yield (kg/day)	20.7	21.3	21.6	0.44
Solids-corrected milk yield (kg/day)	19.9	20.8	20.5	0.45
Fat-corrected milk yield (kg/day)	20.9	21.8	21.7	0.47
Milk fat yield (kg/day)	0.84	0.88	0.87	0.022
Milk protein yield (kg/day)	0.72	0.74	0.72	0.015
Milk lactose yield (kg/day)	0.98	1.02	1.02	0.023
Milk fat concentration (g/kg)	41.2	41.7	40.0	0.93
Milk protein concentration (g/kg)	35.0	34.8	33.2	0.34
Milk lactose concentration (g/kg)	47.2	47.8	47.2	0.25
Body weight (kg)	564	567	560	4.1
Body-weight gain (kg/day)	0.20	0.18	0.18	0.152

† The only significant effect was a linear response in milk protein concentration (P < 0.01).

Table 7. The effect of daily herbage allowance on milk yield, milk constituents yield, milk composition, body weight and body-weight gain for the experimental period: autumn-calving cows

Variable	Herbage allowance (HA)			s.e.	Significance†	
	Low	Medium	High		HA	L
Milk yield (kg/day)	17.1	18.2	18.4	0.26	*	**
Solid-corrected milk yield (kg/day)	17.3	18.5	18.7	0.27	*	**
Fat-corrected milk yield (kg/day)	18.0	19.1	19.3	0.29	*	**
Milk fat yield (kg/day)	0.75	0.79	0.79	0.016		
Milk protein yield (kg/day)	0.64	0.69	0.69	0.011	**	**
Milk lactose yield (kg/day)	0.80	0.86	0.87	0.014	**	***
Milk fat concentration (g/kg)	43.9	43.2	43.3	0.81		
Milk protein concentration (g/kg)	37.3	37.6	37.8	0.16		*
Milk lactose concentration (g/kg)	46.4	47.1	47.4	0.22	*	**
Body weight (kg)	581	591	591	3.2		*
Body-weight gain (kg/day)	0.49	0.64	0.67	0.130		

† See footnotes to Table 3; there were no significant quadratic effects.

The milk production, milk composition and body weight values for the carry-over period of Experiment 2 are shown in Table 8. There was no quadratic component for DHA for any variable. There was a significant linear decrease in milk yield ($P < 0.05$) and a significant linear increase in milk lactose concentration ($P < 0.05$) with increasing DHA. There was a tendency ($P < 0.10$) for linear decreases in fat-corrected milk yield, milk protein yield, and body-weight gain with increasing DHA.

A selection of multiple regression equations is shown in Table 9. They relate

Table 8. The effect of daily herbage allowance treatments on milk yield, milk constituents yield, milk composition, body weight and body-weight gain for the carry-over period: autumn-calving cows

Variable	Herbage allowance†			s.e.
	Low	Medium	High	
Milk yield (kg/day)	14.7	14.8	13.4	0.42
Solid-corrected milk yield (kg/day)	15.2	15.3	14.2	0.39
Fat-corrected milk yield (kg/day)	16.0	15.8	14.6	0.41
Milk fat yield (kg/day)	0.66	0.66	0.62	0.020
Milk protein yield (kg/day)	0.57	0.57	0.52	0.015
Milk lactose yield (kg/day)	0.69	0.70	0.64	0.020
Milk fat concentration (g/kg)	44.5	44.9	46.0	1.20
Milk protein concentration (g/kg)	38.2	38.5	39.2	0.53
Milk lactose concentration (g/kg)	46.6	46.8	48.0	0.38
Body weight (kg)	607	614	615	5.2
Body-weight gain (kg/day)	1.19	0.85	0.61	0.201

† The only significant effects were for milk yield (linear, $P < 0.05$) and lactose concentration (linear, $P < 0.05$).

Table 9. Regression equations for predicting daily solid-corrected milk yield (kg) using pre-experimental solid-corrected milk yield (PMY, kg) and either daily herbage organic matter allowance (DHA, kg), daily herbage organic matter intake (OMI, kg), post-grazing sward height (PGSH, cm) or post-grazing herbage organic matter mass (PGHM, t/ha)

Item	Equation			
	1	2	3	4
Intercept	–1.13	0.84	–1.73	–0.20
	(1.250)†	(1.152)	(1.366)	(1.094)
Regression coefficient for				
PMY	0.76***	0.73***	0.78***	0.78***
	(0.030)†	(0.033)	(0.030)	(0.030)
DHA	0.22***			
	(0.057)			
OMI		0.19*		
		(0.078)		
PGSH			0.70***	
			(0.175)	
PGHM				5.8***
				(1.52)
R^2	0.89	0.88	0.89	0.89
r.s.d.	1.323	1.397	1.321	1.331

† ( ) = s.e.

experimental daily EMY to PMY and a number of other variables, including DHA, OMI, post-grazing HM and post-grazing SH. The equations were derived using all the data (n = 84) from both experiments. All equations explained similar proportions of total variation but equations 2, which used OMI, had a somewhat higher residual standard deviation than the others (1.4 v 1.3). The regression coefficients for DHA, OMI, and post-grazing HM and SH were not different between spring- and autumn-calving cows.

Average EMY was related to LMY according to the expression:

EMY = −1.16 + 0.85 (s.e. 0.027) × LMY + 0.25 (s.e. 0.055) × DHA organic matter, (r.s.d. 1.275, R^2 0.93).

Differences between intercepts for season of calving were close to significance ($P < 0.10$) but when the heifers in Experiment 2 were omitted from the analysis, the difference were not close to significance. There was no evidence that the slopes for LMY or DHA were affected by season of calving. The relationship between EMY and LMY is shown in Figure 1.

Discussion

Mechanical topping after each grazing was successful in maintaining similar swards for the same DHA levels in both experiments. Stakelum and Dillon (2007a) showed that mechanical topping, to 60 mm, of under-grazed fields in the April to June period was successful in avoiding subsequent deterioration in herbage quality. If the herbage remaining after grazing on the H allowance treatment was not mechanically topped in May, when the post-grazing sward height was close to 70 mm, there would likely have been some decline in OMD later on. Also, other sward structural differences between the swards would have developed due to the different grazing heights if the swards were not topped.

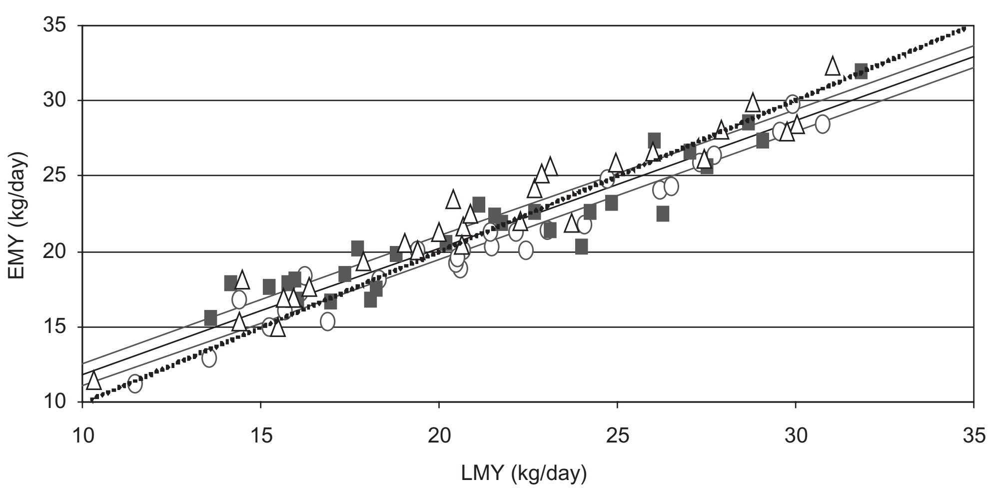

Figure 1. Relationship between likely milk yield (LMY) and experimental milk yield (EMY) for cows grazing pasture over 8 weeks during May and June at low (○), medium (■) or high (△) daily herbage allowances.

The cows did not graze below the post-topping height for any DHA treatment indicating that the grazed horizon was regrowth following the previous defoliation. This indicates that the composition of the herbage selected would be similar across defoliations. In a previous experiment (Maher, Stakelum and Rath, 2003) using similar techniques, the composition of selected herbage was found to be similar despite differences in grazing height. A difference between topping height and the resultant sward height after topping can occur, where some of the pasture is shorter than the cutting height. This will result in an average height of the resultant sward that is shorter than the cutting height. The differences in post-topping sward height between the DHA groups in the present study were smaller than those found in the study of Maher *et al*. (2003). Therefore, similar composition of selected herbage was likely to have been achieved in the present experiment.

Estimates of energy requirements and supply

It is difficult to validate estimates of intake because there is no reference method. One approach is to compare net energy (NE) intake and requirements for observed cow performance (Peyraud *et al*., 1996). The NE concentration of herbage was estimated using a value of 1.05 UFL (Unite Fourragere Lait) for an OMD value of 0.85. A UFL is defined as the NE value for lactation of 1 kg of air-dried standard barley. Estimates of NE requirements for maintenance and milk yield were calculated according to the INRA system of Jarrige (1989). The overall differences between requirements and supply were +0.83 (s.d. 2.04) and +2.88 (s.d. 2.07) UFL for Experiments 1 and 2, respectively. If an allowance of 1 UFL/day is assigned to grazing energy expenditure (Langlands *et al*., 1963), then the differences were –0.17 UFL and +1.88 UFL for Experiments 1 and 2, respectively. According to the INRA system this would result in a daily body-weight loss of 0.08 (s.d. 0.55) kg in Experiment 1 and a daily body-weight gain of 0.41 kg (s.d. 0.48) in Experiment 2. The observed daily body-weight changes were +0.12 (s.d. 0.25) and +0.60 (s.d. 0.39) kg for Experiments 1 and 2, respectively. These data suggest good accuracy of estimates of OMI.

Daily herbage intake

The increase in OMI with increased DHA was slightly higher than that found by Maher *et al*. (2003). The relationship between DHA and OMI depends on the levels of DHA being compared, the cutting height of the herbage and the level of production of the experimental animals and, hence, comparisons across different experiments can be difficult. Peyraud *et al*. (1996) found that OMI increased by 0.32 kg/kg of DHA within the DHA range of 11 to 16 kg above 5 cm. They also reported an increase in OMI of 0.36 kg/kg of DHA within the DHA range 12.6 to 19 kg in a companion experiment. Meijs and Hoekstra (1984) found increases of 0.46 and 0.32 kg/kg within the ranges 15 to 20 kg and 20 to 25 kg for DHA above 4 cm, respectively. The present result of 0.30 kg/kg broadly agrees with these values. Most strip grazing experiments have shown a curvilinear relationship between OMI and DHA (Greenhalgh *et al*., 1966, 1967; Greenhalgh, 1970; Combellas and Hodgson, 1979; Le Du *et al.,* 1979; Peyraud *et al*., 1996). A curvilinear effect of DHA on intake was not found in the present experiment. The probable explanation is that a much narrower range of DHA was used in the present study than in the others mentioned.

The regression analyses showed that OMI could be predicted using some measure of cow performance and DHA. According to the relationship found here, intake increased by 0.14 kg/kg pre-experimental solids-corrected milk yield. This value is identical to that reported by Maher *et al*. (2003) but is lower than those of Greenhalgh *et al*. (1966), Curran and Holmes (1970) and Peyraud *et al*. (1996) who reported values of between 0.25 and 0.27. Values of 0.17 to 0.33 were recorded by Caird and Holmes (1986) while Delagarde, Peyraud and Delaby (2000), Butler *et al*. (2003) and Kennedy *et al*. (2003) reported values of 0.19 to 0.23 which are similar to the value found here. PMY in this experiment was the yield achieved, with little supplementation, by grazing cows in April. The partial regression coefficient may be larger if higher feeding levels were used which would have increased the reference yield.

The partial regression coefficient for PWT (0.9 kg per 100 kg) is similar to those of Butler *et al*. (2003), Kennedy *et al*. (2003) and Maher *et al*. (2003) who reported corresponding values of 1.3, 0.7 and 0.5, respectively. Other reports indicated similar effects of body weight on intake (Greenhalgh *et al*., 1966; Caird and Holmes, 1986; Peyraud *et al*., 1996). The absence of a significant effect due to stage of lactation is consistent with the finding of Caird and Holmes (1986) that OMI is poorly related to stage of lactation after the second month. Peyraud *et al*. (1996) also found that stage of lactation was not significant in any of their intake equations.

Milk yield

Milk yield can be viewed as a direct function of PMY and the OMI achieved during the experiment. The R^2 value for the relationship between milk yield and PMY along with DHA is similar to the value reported by Maher *et al.* (2003) for similar levels of DHA applied from May to August. The coefficient for DHA of 0.20 reported by Delaby *et al*. (2001) also compares well with the present value. The finding that the four equations in Table 9 have similar R^2 values reflects the fact that post-grazing HM and post-grazing SH, DHA and OMI are all highly correlated, and so were equally effective as predictors of milk yield.

The relationship between LMY and EMY makes it possible to examine the adequacy of the different levels of DHA in achieving a theoretical lactation persistency of 0.98 per week (Delaby *et al*., 2001). As can be seen in Figure 1, the DHA allowances were adequate for cows in late lactation but inadequate for cows in earlier lactation. The H allowance was more than adequate for later lactation cows with EMY exceeding LMY by 1.0 kg for LMY of 20 kg. At this level of allowance EMY was 0.6 kg less than LMY for earlier lactation cows at a LMY of 30 kg. The LMY levels of 20 and 30 kg are equivalent to 22.4 and 33.5 kg of milk from grazed herbage plus *ca.* 1.8 kg/day concentrate in April when grazing to a residual sward height of 60 mm.

Delaby *et al*. (2001) used LMY as a measure of cow milk production potential. Their reference milk yield was PMY at turnout in April when cows were offered *ad libitum* maize silage, grazed grass and concentrates. The PMY period in the present experiments is different in that cows grazed to 60 mm and received 0.5 kg of supplementary concentrates per day except for the final week when they were offered 4 kg/day due to inclement weather.

The similarity of the response to DHA in both experiments occurred despite the higher partitioning of ingested energy to body-weight gain by the cows in later lactation (0.13 versus 0.60 kg/day body-weight gain in Experiments 1 and 2, respectively). An explanation for this is the absence of any effect of DHA on body-weight gain. The extra energy consumed was used for milk production in both experiments despite the fact that the later lactation cows were gaining more body weight than the earlier lactation cows.

Milk composition

Contrary to the observations of Greenhalgh *et al.* (1966), Greenhalgh, Reid and Atkin (1967) and Le Du *et al.* (1979), there was no effect of DHA on milk fat concentration. These results are similar to those of Maher *et al*. (2003) who also found no effect for similar levels of DHA. Combellas and Hodgson (1979) and Greenhalgh *et al.* (1966) found no significant effect of DHA on milk protein concentration in short-term experiments. This is in agreement with the results found here. In the experiment of Greenhalgh *et al*. (1966) there was an increase from 29.8 to 32.2 g/kg in milk protein concentration from the lowest to the highest level of DHA, but the differences were not significant. Maher *et al*. (2003) found that milk protein concentration increased linearly with increasing DHA. It is difficult to reconcile the absence of an effect of DHA on milk protein concentration in the present study for either season of calving. Milk protein concentration was 34.3 and 37.6 g/kg for Experiments 1 and 2, respectively. These values are high compared to those normally found for cows on spring grass. This is especially true for the cows in Experiment 1. The milk protein concentration for the cows used by Maher *et al.* (2003) was 32.9 g/kg. It is possible that in the present study the potential of the cows for milk protein production was already reached and so could not respond to increased DHA.

Residual effects

The residual effect of indoor feeding levels in early lactation on spring-calving dairy cows on pasture are small (Gordon, 1977; Le Du *et al.*, 1979; Butler, Gleeson and Morgan, 1983; Clements, Mayne and Wilkins, 1988). Even in a situation where grass intake was reduced by proportionately 0.48 and daily milk yield was reduced by proportionately 0.40 during the first 6 weeks of lactation compared to a control group of monozygous twins, the effect had disappeared after 6 weeks of improved feeding (Bryant and Trigg, 1979). Delaby and Peyraud (2002) found no residual effect of different turnout scenarios to spring pasture. The pattern of under-feeding in early lactation can influence the magnitude of any residual effect (Grainger and Wilhelms, 1979). The work of Le Du *et al.* (1979) suggests that the residual effect of indoor feeding level prior to turnout to pasture depends on the level of DHA applied thereafter.

In this experiment the carry-over period was short and all groups were offered the medium herbage allowance. Differences in milk yield persisted in Experiment 1 but they were not significant. It is not clear why milk protein concentration was lower for H compared to L and M in Experiment 1, despite a higher milk yield for this treatment during the carry-over period. It is also not clear why milk yield was lower for H compared to M and L in Experiment 2. While the pre-grazing herbage mass was more variable between treatments during the carry-over period compared to the experimental period, the differences were not considered large enough to affect production (Stockdale, 1985; Peyraud *et al.*, 1996; Stakelum and Dillon, 2004).

Practical implications

Good performance can be achieved in early summer with both spring- and autumn-calving dairy cows on good quality pasture. A daily herbage allowance of 23 kg herbage DM permitted spring-calving cows to achieve their production potential. An allowance of 20 kg was sufficient for autumn-calving cows. These levels of daily herbage allowance are recommended where milk quota is limiting on dairy farms and producers wish to achieve good individual cow performance from grazed pasture. The low allowance would be applicable to a situation where a dairy farmer wanted to maximise output of milk per hectare.

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