The Effect of Early-Lactation Feeding Strategy on the Lactation Performance of Spring-Calving Dairy Cows

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ABSTRACT

The objective of this study was to establish the influence of daily herbage allowance (DHA) and supplementation level offered to spring-calving dairy cows in early lactation on animal performance throughout lactation. Sixty-six Holstein-Friesian dairy cows were randomly assigned to a 6-treatment grazing study. The treatments comprised 3 DHA levels (13, 16, and 19 kg of DM/cow; >4 cm) and 2 concentrate supplementation levels (0 and 4 kg of DM/cow per day). Treatments were imposed from February 21 to May 8 (period 1; P1). During the subsequent 4-wk (period 2; P2), animals were offered a DHA of 20 kg of DM/cow and no concentrate. Subsequently, all animals grazed as a single herd to the end of lactation. Sward quality was homogeneous throughout lactation. A low DHA increased sward utilization (+14%) but reduced milk, solids-corrected milk, protein, and lactose yields compared with a high DHA during P1. Concentrate supplementation significantly increased milk, solids-corrected milk, fat, protein, and lactose yields during P1. The positive effect of concentrate supplementation remained throughout P2. A total concentrate input of 380 kg of DM/cow increased total lactation milk (+432 kg), solids-corrected milk (+416 kg), fat (+18 kg), protein (+15 kg), and lactose (+23 kg) yields. Greater P1 body weights were recorded when a high DHA and concentrate were offered. The P1 treatment had no effect on body condition score throughout lactation. The results indicate that offering a low DHA in early spring does not adversely affect total milk production, body weight, or body condition score, and offering concentrate results in a greater total lactation milk production performance.

Key words: herbage allowance, concentrate, dairy cow, grazing

INTRODUCTION

Using grazed pasture as the primary diet source for spring-calving dairy cows in early lactation affords farmers the opportunity to reduce ever-increasing costs of production. Grazed herbage can supply nutrients to dairy cows at a lower cost than alternative feeds (Shalloo et al., 2004). Therefore, the objective of pasture-based systems must be to maximize the proportion of grazed grass in the diet of the dairy cow (Dillon et al., 2005). The extension of the grazing season into early spring can be facilitated by ceasing grazing of pastures earlier in autumn, which allows grass to accumulate, thereby ensuring an adequate herbage supply in early spring when animal demand exceeds grass growth and supply (O'Donovan, 2000). Grazing pastures in early spring has previously increased herbage utilization and conditioned swards for subsequent grazing rotations (O'Donovan et al., 2004; Kennedy et al., 2006).

Daily herbage allowance (**DHA**), defined as the quantity of herbage allocated per cow per day above a certain cutting height, is a key component in both animal performance and herbage utilization. There is a strong curvilinear relationship between DHA and milk yield (Combellas and Hodgson, 1979; Peyraud et al., 1996). An increasing level of milk production has been reported when greater DHA are allocated to dairy cows in mid lactation (Stockdale, 2000; Bargo et al., 2002; Maher et al., 2003). There is, however, limited information on the optimum quantity of herbage that postparturient animals should be offered in early spring. In an early lactation study conducted by Kennedy et al. (2005), reasonably high animal production performance was reported when a medium DHA of 15 kg of DM/cow and 3 kg of DM/cow of concentrate were offered. The question that now arises is: what is the optimum DHA that should be offered to dairy cows in early lactation?

Offering concentrate supplementation in conjunction with grazed pasture gives dairy farmers an opportunity to achieve high production per cow and per unit area (Peyraud et al., 2004). The main objective when supplementing dairy cows is to increase total DMI and energy

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intake relative to that achieved with pasture-only diets (Stockdale, 2000; Delaby et al., 2001; Bargo et al., 2003).

High response levels to concentrate have previously been reported (Delaby et al., 2001; Bargo et al., 2003; Horan et al., 2005) when animals in mid lactation were offered a grass and concentrate diet. Stockdale (1999) reported that milk production response to concentrate was lower in spring compared with summer, because of the greater energy content of spring herbage. With lower milk production response levels and greater herbage utilization, as well as greater sward quality during the spring period, a system that offers no concentrate in conjunction with an optimum DHA requires investigation.

The objective of this study was to establish the influence of DHA and concentrate supplementation level offered to spring calving dairy cows in early lactation on immediate, subsequent, and total lactation performance, BW, and BCS.

MATERIALS AND METHODS

The experiment was conducted at Moorepark Research Centre, Fermoy, Co. Cork, Ireland (50°07'N; 8°16'W) on an area of 24.1 ha from February to December 2005. The soil type was a free-draining, acid-brown earth with a sandy loam-to-loam texture. The experimental area was a permanent grassland site consisting of a predominantly perennial ryegrass sward (*Lolium perenne* L.); the swards were on average 3 yr old. A grass seed mixture of 3 late-heading diploid cultivars, Twystar, Cornwall, and Gilford, was initially sown. No clover was present in the sward.

Experimental Design, Treatments, and Herd Management

The experiment was a randomized block design with a 3 × 2 factorial arrangement of treatments. The 6 experimental treatments consisted of 3 DHA and 2 concentrate levels. Animals (n = 22 per group) were offered a low, medium, or high DHA; within each of the DHA treatments, half of the animals (n = 11) were offered 0 kg of DM/cow per day of concentrate, whereas the remaining half were offered 4 kg of DM/cow per day. To create severe, moderate, and lax grazing treatments, DHA were set at 13 (low), 16 (medium), and 19 (high) kg of DM/cow. The grazing and concentrate supplementation treatments were imposed for 11 wk from February 21 to May 8 (period 1; **P1**). Concentrate composition on a fresh weight basis was molasses beet pulp, 48%; soybean meal, 25%; barley, 20%; vegetable fat, 3%; dicalcium phosphate, 1.6%; calcined magnesite, 1.3%; ground limestone, 0.6%; salt, 0.5%; and trace elements.

The chemical analysis of the concentrate is presented in Table 1.

Following **P1**, all animals remained in their individual herds and were offered a DHA of 20 kg of DM/cow and no concentrate for the following 4-wk period from May 9 to June 5 (period 2; **P2**). Subsequent to **P2**, all animals grazed as a single herd and were offered a DHA of 22 kg DM/cow and no concentrate for the remainder of lactation. Milk production data for period 3 (**P3**) was from June 6 to October 23, which coincided with the time that the first animal was dried off. Animals were dried off if yielding <5 kg/cow per day or if within 2 mo of calving, whichever occurred first. Individual cumulative lactation figures (calving date to drying off date) were then calculated for each animal within each treatment and are reported. Figure 1 details the experimental design of the study.

Animals

Sixty-six Holstein-Friesian dairy cows were selected from the Moorepark spring calving herd. Thirty cows were primiparous and the remaining 36 were multiparous (16 cows in their second lactation and 20 cows in their third or greater lactation). All animals were balanced on the basis of calving date, previous lactation milk yield [dam's first-lactation milk yield (first 36 wk) in the case of the primiparous animals], milk yield during the first 10 d of the present lactation, BW, and BCS. The mean calving date of the herd (n = 66) was February 7 (SD 9.9 d), and previous lactation cumulative milk yield, daily milk yield of present lactation, mean parity number, preexperimental live weight, and preexperimental BCS were 5,123 (SD 1,002) kg, 22.3 (SD 4.4) kg, 2.2 (SD 1.66), 525 (SD 60.3) kg, and 3.2 (SD 0.32), respectively. The cows were blocked into groups of 6 and randomly assigned to 1 of 6 grazing treatments (n = 11).

From calving until treatment assignment, all cows were allowed access to pasture by day, but were housed at night and offered grass silage ad libitum. Each cow was supplemented with 5.3 kg of DM/cow per day of concentrate. All cows had calved for at least 10 d before allocation to their respective system.

Grazing Management

The experimental area was divided into 12 paddocks. Within each paddock, the 6 treatments grazed as 6 separate herds differentiated by DHA and concentrate supplementation level. All herds grazed adjacent to one another in their separate areas, defined using temporary electric fences. The position of each herd in relation to the other herds was retained throughout the experi-

Table 1. Chemical analysis of herbage and concentrate from February 21 to May 8 (period 1)

	Herbage allowance			SED	P <	Concentrate	SD
	Low	Medium	High				
DM (%)	17.6	17.6	17.7	1.6	NS	82.8	18.28
DM composition (%)							
Digestible OM	86.1	86.4	86.2	0.24	NS	—	—
CP	23.7	23.3	22.6	0.05	NS	20.6	0.22
Crude fiber	—	—	—	—	—	7.6	0.37
ADF	22.5	22.4	23.0	0.74	NS	—	—
NDF	39.4	39.4	39.8	0.84	NS	19.3	0.71
Ash	7.4	7.6	8.1	0.21	0.01	8.9	0.30

ment. Herds did not, however, regrazed the same area in the second grazing rotation as was grazed during the first grazing rotation.

Mechanical topping to 5.0 cm of the entire experimental area was completed during the second grazing rotation to create a homogeneous sward for P2 and P3.

The first nitrogen fertilizer application (urea; 46% N) was applied in mid-January at a rate of 40 kg of N/ha. Nitrogen (calcium ammonium nitrate; 26.6% N) was reapplied as paddocks were grazed until September. Total annual nitrogen application was 240 kg of N/ha. Phosphorus and potassium fertilizer were applied in April at a rate of 7 kg of P/ha and 31 kg of K/ha, respectively.

Sward Measurements

Herbage Mass Determination and Sampling. Herbage mass (>4cm) was determined twice weekly on

the low, medium, and high herbage allowance areas by defoliating 2 strips (1.2 m × 10 m) per allowance with an Agria machine (Etesia UK Ltd., Warwick, UK). Ten grass-height measurements were recorded before and after defoliation on each cut strip using an electronic plate meter (Urban and Caudal, 1990) with a plastic plate (30 cm × 30 cm and 4.5 kg/m; Agrosystèmes, Choiseille, France). This allowed the calculation of sward density [herbage mass (DM/ha)/(precutting height – postcutting height); kg of DM/cm per hectare]. All mown herbage from each strip was collected, weighed, and subsampled (0.3 kg). A subsample of approximately 0.1 kg of the herbage sample was dried for 24 h at 90°C in a drying oven for determination of DM content.

Herbage representative of that selected by the low, medium, and high allowance treatments was sampled weekly with a Gardena (Accu 60, Gardena Interna-

		Low		Medium		High	
P1	Daily herbage allowance (kg of DM/cow per d)	13.3		15.9		19.0	
	Concentrate level (kg of DM/cow per d)	0	4	0	4	0	4
P2	Daily herbage allowance (kg of DM/cow per d)	20.1		20.2		20.2	
	Concentrate level (kg of DM/cow per d)	0	0	0	0	0	0
P3	Daily herbage allowance (kg of DM/cow per d)	21.4					
	Concentrate level (kg of DM/cow per d)	0					

Figure 1. Experimental design of an experiment investigating the effect of daily herbage allowance (low, medium, and high) and concentrate level offered to spring-calving dairy cows in early lactation on immediate, subsequent, and total lactation performance. Period 1 (P1) = February 21 to May 8; period 2 (P2) = May 9 to June 5; period 3 (P3) = June 6 to October 23.

tional GmbH, Ulm, Germany) hand shears, following close observation of the grazing cows' previous defoliation height. A subsample was stored at -20°C before being freeze-dried and milled before chemical analysis.

Pre- and Postgrazing Sward Heights. The pregrazing sward height was determined daily in each plot by recording 40 measurements across the 2 diagonals of the paddock, using the electronic plate meter described above. Pregrazing values were recorded for the low, medium, and high DHA treatments ($n = 3$). The measured pregrazing sward height, multiplied by the mean sward density, was used to calculate the DHA required for the 3 herbage allowances. Postgrazing sward height was measured immediately after grazing for each of the 6 individual treatments ($n = 6$).

Herbage Utilization. Herbage mass utilization was calculated using the method of Delaby and Peyraud (1998). It was further used to evaluate the herbage mass produced and removed. Herbage removed (kg of DM/cow per day) was calculated using the following equation: herbage removed = (pregrazing height – postgrazing height) $\times$ sward density $\times$ (area grazed/cow per day).

Animal Measurements

Milk Production. Milking took place at 0730 and 1630 h daily. Individual milk yields (kg) were recorded at each milking. Milk fat, protein, and lactose concentrations were determined from one successive morning and evening milking sample taken weekly. The concentrations of these constituents were determined using MilkoScan 203 (DK-3400, Foss Electric, Hillerød, Denmark). Solids-corrected milk yield was calculated using the equation of Tyrell and Reid (1965). All cows were weighed weekly. Body weight was recorded electronically using a portable weighing scale and Winweigh software package (Tru-Test Limited, Auckland, New Zealand). Body condition score was recorded weekly during the lactation on a 1 to 5 scale (1 = emaciated, 5 = extremely fat) with 0.25 increments (Lowman et al., 1976). Body weight and BCS change were calculated using values of BW and BCS from the first 2 and last 2 wk of the study.

Intake Estimation. Individual total DM intakes (TDMI) were estimated during P1 using the n-alkane technique (Mayes et al., 1986) as modified by Dillon and Stakelum (1989). All cows were dosed twice daily before milking for 12 consecutive days with a paper filter or bung (Carl Roth, GmbH, Karlesruhe, Germany) containing 500 mg of dotriacontane (C32). From d 7 of dosing, fecal grab samples were collected from each cow twice daily for the remaining 6 d. The fecal grab samples were then bulked (10 g of each collected sample) and

dried for 48 h in a 40°C oven in preparation for chemical analysis.

In conjunction with fecal collection, the diet of the animals was also sampled. Herbage representative of that grazed (following close observation of the grazing animals' previous defoliation) was manually collected from each paddock before morning grazing on d 6 to 11 (inclusive) of the intake measurement period. Two samples of approximately 25 individual grass snips were taken from each paddock with a Gardena hand shears. The ratio of herbage C33 (tritriacontane) to dosed C32 was used to estimate intake. The n-alkane concentration was determined as described by Dillon (1993).

Chemical Analyses

The herbage samples selected weekly for each treatment were freeze dried and milled through a 1-mm sieve. Samples were analyzed for DM, ash, ADF, NDF (Van Soest, 1963), CP (Leco FP-428; Leco Australia Pty Ltd., Baulkham Hills, New South Wales, Australia) and organic matter digestibility (OMD; Morgan et al., 1989). The concentrate offered was sampled weekly, bulked over the 11 wk, and analyzed for DM content, CP, crude fiber, NDF, and ash concentrations.

Statistical Analysis

All statistical analysis was conducted using SAS (SAS Institute, 2002). Herbage data from P1 and P2 were analyzed using the following model:

$$Y_{ijk} = \mu + A_i + C_j + R_k + W_k(R_j) + A_i \times C_j + e_{ijkl}$$

where μ = mean, A_i = DHA ($i = 1$ to 3); C_j = concentrate level ($j = 1$ to 2); R_k = rotation ($k = 1$ to 2), $W_k(R_j)$ = week within rotation ($k = 1$ to 6); $A_i \times C_j$ = the interaction between DHA and concentrate level, and e_{ijkl} = residual error term.

All animal variables were analyzed as 66 individual variables to improve the accuracy of the model; pre-experimental milk yield, milk composition, BW, and BCS were used as covariates specific to the traits being analyzed. Daily milk yield, milk constituent yield, milk composition, BW, and BCS ($n = 66$) were analyzed with the following model:

$$Y_{ijkl} = \mu + P_i + A_j + C_k + A_j \times C_k + b_1 X_{ijkl} + b_2 \text{DIM}_{ijkl} + e_{ijkl}$$

where Y_{ijkl} represents the response of the animal l in parity i offered DHA j and concentrate level k ; μ = mean; P_i = parity ($i = 1$ to 2); A_j = DHA ($j = 1$ to 3);

Table 2. Chemical analysis of herbage from May 9 to June 5 (period 2; 28 d) and June 6 to October 23 (period 3; 140 d)

	Period 2	SED	Period 3	SED
DM (%)	16.6	2.16	17.1	2.87
DM composition (%)				
Digestible OM	84.4	1.17	80.6	1.34
CP	18.6	1.18	23.2	2.49
ADF	25.0	1.37	30.3	1.79
NDF	40.6	2.69	46.0	4.20
Ash	10.1	0.51	10.2	1.92

C_k = concentrate level ($k = 1$ to 2); $A_j \times C_k$ = interaction of DHA $\times$ concentrate level; b_1X_{ijkl} = the respective pre-experimental milk output or BW or BCS variable; b_2DIM_{ijkl} = DIM, and e_{ijkl} = residual error term.

Due to the differences in parity, in terms of preexperimental values, these covariates were centered within parity before inclusion. That is, the deviations from the parity mean were used as covariates. The incorporation of individual animal covariates within the model reduced the residual error term, therefore explaining more variation within parity.

RESULTS AND DISCUSSION

Maintaining a balance between optimizing dairy cow performance and maximizing herbage utilization is a key objective of efficient grassland management. This is attainable by including herbage in the diet of spring-calving dairy cows immediately postcalving as this practice has been shown to have beneficial effects on both the animal (Kennedy et al., 2005) and the sward (Kennedy et al., 2006).

Grass and Grazing Management

The chemical analysis of the herbage offered in P1 is presented in Table 1 and in P2 and P3 in Table 2. The herbage offered to each herd was similar for all parameters measured.

The first grazing rotation was completed in 40 d, and the second grazing rotation lasted 36 d. Pregrazing sward height was identical between the grazing treatments during P1 (Table 3), and pregrazing DM yield >4 cm (1,896 kg of DM/ha) and sward density (235 kg of DM/ha) were similar between treatments. Because of treatment imposed, the quantity of herbage allocated to the low, medium and high herbage allowance treatments (13.3, 15.9, and 19.0 kg of DM/cow per day, respectively) was significantly different ($P < 0.001$). Because of this, animals offered a high and a medium DHA were allocated 46 and 20% more area ($P < 0.001$), respectively, than animals offered a low DHA (73 m²/cow per day; Table 3). The mean stocking rates during

P1 were 3.8, 3.2, and 2.7 cows/ha for animals offered a low, medium, and high DHA, respectively.

Characteristic of swards grazed early in spring with a greater stocking density, lower postgrazing sward heights (PGSSH) have been recorded with decreasing herbage allowances (O'Donovan et al., 2004; Kennedy et al., 2006), and PGSSH for the 6 individual treatments during P1 ranged from 3.3 to 5.2 cm ($P < 0.001$; Table 4). Moreover, supplementing animals with concentrate resulted in a higher PGSSH (+0.5 cm). The differences, however, between postgrazing sward heights were not large enough to create differences in the chemical composition of the diet selected by the animals, which was similar to that reported by Maher et al. (2003). Combellas and Hodgson (1979) and Maher et al. (2003) stated that DHA generally has limited effects on diet composition.

As a result of higher PGSSH, supplemented animals utilized ($P < 0.001$) less pasture (−0.06%; Table 4) than their unsupplemented counterparts. Sward utilization was highest ($P < 0.001$) on the low DHA swards compared with the swards where a medium (−9%) and high (−18%) DHA were allocated.

Throughout P2 (one grazing rotation; 28 d) all animals were allocated a DHA of 20.2 kg of DM/cow with an area allocation of 73 m²/cow per day. Stocking rate during P2 was 5.3 cows/ha. Pregrazing sward height (15.8 cm), DM yield >4cm (2,771 kg of DM/ha), sward density (236 kg of DM/ha), and sward utilization (86%) were similar among treatments.

During P3, rotation length ranged from 19 to 30 d (as the grazing season progressed, rotation length increased). Pregrazing height was 13.5 (SD 2.00) cm and pregrazing DM yield >4 cm was 2,256 (SD 480.9) kg of DM/cow per day. All animals were offered a DHA of 21.4 (SD 4.17) kg of DM/cow, which resulted in an area allocation of 100 (SD 36.1) m²/cow per day. Average stocking rate ranged from 4.74 to 2.56 cows/ha. Animals grazed to a mean PGSSH of 5.8 (SD 0.63) cm, which corresponded to a sward utilization level of 85% (SD 19.7).

Animal Performance

Milk Production. There was no significant interaction between DHA and concentrate level offered, nor was there a quadratic response to DHA for any of the production variables investigated; this was probably due to the high quality of herbage offered to all treatment groups (Table 2). A linear increase in milk ($P < 0.01$), SCM ($P < 0.01$), protein ($P < 0.01$), and lactose ($P < 0.05$) yields was measured when extra DHA was offered. Maher et al. (2003) reported similar findings

Table 3. Effect of daily herbage allowance (DHA) and concentrate level on pregrazing sward measurements in period 1 and period 2

	Daily herbage allowance			SED	<i>P</i> <
	Low	Medium	High		
Period 1					
DHA >4cm (kg of DM/cow per d)	13.3	15.9	19.0	0.09	0.001
DM yield >4cm (kg/DM per ha)	1,905	1,900	1,884	26.3	NS
Pregrazing height (cm)	12.2	12.1	12.1	0.11	NS
Sward density >4cm (kg of DM/ha)	234	236	235	1.1	NS
Area (m ² /cow per day)	73	88	107	2.2	0.001
Period 2					
DHA >4cm (kg of DM/cow per d)	20.1	20.2	20.2	0.14	NS
DM yield >4cm (kg/DM per ha)	2,754	2,811	2,747	109.0	NS
Pregrazing height (cm)	15.7	16.0	15.7	0.45	NS
Sward density >4cm (kg of DM/ha)	236	236	236	3.8	NS
Area (m ² /cow per day)	74	72	74	3.1	NS

in an experiment investigating the effect of DHA level on animals in midlactation.

Similar to that reported by Wales et al. (1999), animals offered a high DHA during P1 had a greater TDMI (+1.4 kg/cow per day; Table 5) than animals offered a low DHA (15.2 kg of DM/cow per day). The greater TDMI corresponded to greater milk yields because animals offered a high DHA produced 6.25% (1.6 kg/cow; $P < 0.05$) more milk than those offered a low DHA (25.6 kg/cow). Allocating a medium DHA resulted in an intermediate level of production (26.6 kg/cow) that was not significantly different from either the low or high DHA treatments. Delaby et al. (2001) found an increase in the milk yield of mid lactation cows when DHA was increased from 12 to 16 kg of DM/cow. This was similar to the findings of Bargo et al. (2002) who also found an increase in milk yield when pasture allowance offered to unsupplemented cows was increased from 27 to 49 kg of DM/cow. However, in an additional experiment there was no effect on milk yield when DHA was increased by 6 kg to 22 kg of DM/cow (Delaby et al., 2001); this was similar to the results of the present study when DHA was increased from 16 to 19 kg of DM/cow.

Apportioning a high DHA increased milk protein yield ($P < 0.05$; +65.3 g/d) compared with animals of-

fered a low DHA (839.4 g/d). Milk protein yield of animals offered a medium DHA (877.8 g/d) did not differ significantly from other treatments. The greater milk protein yield of the high DHA treatment was a product of the greater milk yields recorded and was similar to results reported by Maher et al. (2003). There was no effect of DHA on milk fat concentration in this experiment, which is similar to that reported by Dillon et al. (1997) and Maher et al. (2003). Daily herbage allowance had no effect on milk protein concentration, which was in contrast to that reported by Maher et al. (2003). All effects of DHA dissipated after P1, and thus it can be concluded that the level of DHA offered has an immediate, yet ephemeral, effect. Robaina et al. (1998) also found that diet had no effect on milk composition, although these animals were in mid to late lactation.

The cumulative concentrate input for supplemented animals from calving until the end of the 11-wk experimental period was 382 kg of DM/cow. Similar to that reported by several authors (Stockdale, 2000; Delaby et al., 2001; Bargo et al., 2003), TDMI was greater (+2.5 kg/cow per day; Table 5) for supplemented animals compared with their unsupplemented counterparts (14.9 kg/cow/d). Milk and SCM yields were significantly improved (+4.4 and +3.9 kg/cow per day, respectively; P

Table 4. Effect of daily herbage allowance (DHA) and concentrate level on postgrazing height and sward utilization in period 1 and period 2

	Treatment ¹						SED	<i>P</i> <	
	L0	L4	M0	M4	H0	H4		DHA	Conc.
Period 1									
Postgrazing height (cm)	3.3	3.7	4.0	4.5	4.7	5.2	0.08	0.001	0.001
Utilization (%)	109	104	101	94	92	86	1.0	0.001	0.001
Period 2									
Postgrazing height (cm)	5.6	5.3	5.7	5.7	5.9	5.6	0.24	0.05	0.10
Utilization (%)	86	88	86	85	84	86	2.1	NS	NS

¹L = low herbage allowance; M = medium herbage allowance; H = high herbage allowance; 0 = no concentrate; 4 = 4 kg of concentrate (Conc.) DM/cow per day.

Table 5. Effect of daily herbage allowance (DHA) and concentrate level (Conc.) on milk yield and DM intake from February 21 to May 8 (period 1; 76 d)

	Treatment ¹						SED	<i>P</i> <		
	L0	L4	M0	M4	H0	H4		DHA	Conc.	Lin ²
Milk yield (kg/d)	23.0	28.3	24.7	28.6	25.1	29.2	0.87	0.05	0.001	0.01
Milk fat content (%)	3.83	3.81	3.89	3.77	3.70	3.64	0.155	NS	NS	NS
Milk protein content (%)	3.20	3.32	3.34	3.33	3.29	3.30	0.064	NS	NS	NS
Milk lactose content (%)	4.77	4.87	4.79	4.88	4.79	4.89	0.051	NS	0.01	NS
Milk fat yield (g/d)	874.9	1,077.0	965.1	1,056.5	931.9	1,071.8	53.97	NS	0.001	NS
Milk protein yield (g/d)	738.5	940.3	815.9	939.7	845.2	964.3	33.33	0.05	0.001	NS
Milk lactose yield (g/d)	1,089.8	1,379.0	1,174.9	1,391.8	1,206.4	1,431.1	49.30	0.05	0.001	0.01
SCM yield (kg/d)	21.0	26.0	23.4	26.5	23.0	26.4	0.86	0.05	0.001	0.05
BW at end of period 1 (kg)	486	497	497	511	501	526	8.9	0.01	0.01	0.001
BW change (kg/d)	-0.26	-0.17	-0.30	0.08	-0.29	0.23	0.175	NS	0.01	NS
BCS at end of period 1	2.70	2.78	2.81	2.89	2.78	2.86	0.098	NS	NS	NS
BCS change/d	-0.009	-0.008	-0.006	-0.004	-0.006	-0.004	0.0020	0.05	NS	0.05
Total DMI (kg of DM/cow per day)	14.1	16.3	15.4	17.8	15.1	18.1	0.573	0.01	0.001	0.01

¹L = low herbage allowance; M = medium herbage allowance; H = high herbage allowance; 0 = no concentrate; 4 = 4 kg of concentrate DM/cow per day.

²Lin = linear (response to DHA).

< 0.001) when animals were offered 4 kg of DM/cow per day concentrate during P1 (Table 5). When concentrate was offered in conjunction with either a medium or high DHA, milk yield was similar to that produced by animals offered a low DHA. This concurs with Bargo et al. (2002) who reported no difference in milk yield between treatments when cows in mid lactation were supplemented with concentrate regardless of quantity of herbage allowance allocated. Conversely, Delaby et al. (2001) reported an increase in milk yield when animals were supplemented with up to 4 kg of DM/cow per day in conjunction with extra herbage. Similar to the present study, Robaina et al. (1998) found greater milk yields when supplemented cows were offered a high pasture allowance as opposed to a low DHA. The similarity in milk yield between the treatments in the present study may have been influenced by the sward quality, as the herbage offered to all animals was of high quality (86.2% OMD, 23.2% CP, and 39.5% NDF; Table 1). In contrast, the herbage offered in the experiment reported by Delaby et al. (2001) was of lower quality (81.2% OMD, 16.5% CP, and 49.3% NDF). Additionally, the age profile of the herd may have influenced the results, as 4 kg of DM/cow per day may have been excessive for a herd containing 45% primiparous animals.

Supplementation ($P < 0.001$) increased milk fat and protein yields (+144.4 and +148.2 g/d, respectively) compared with unsupplemented animals (924.0 and 799.9 g/d, respectively). The increase in milk protein yield with supplemented animals in this experiment was because of a greater milk yield rather than greater protein concentration. This may have been because of the greater total energy intake by the supplemented cows.

Unlike other studies (Delaby et al., 2001; Bargo et al., 2002) where animals were supplemented with greater than 5 kg/cow per day, milk fat concentration was not influenced by concentrate supplementation in this study, similar to that previously reported by Dillon et al. (2002).

During P2, when all animals were allocated 20 kg of DM/cow per day, there was no carryover effect of DHA offered during the 11-wk treatment period (P1) on any milk production variables (Table 6). There was, however, a significant ($P < 0.001$) carryover effect of concentrate supplementation on milk (+2.6 kg of DM/cow per day), SCM (+2.3 kg/cow per day), fat (+91.1 g/d), protein (+71.9 g/d), and lactose (+150.0 g/d) yields and lactose concentration (+0.12%; $P < 0.01$). Daily herbage allowance and concentrate level offered during P1 had no residual effect on milk yield and milk composition during P3 (Table 6).

Complete Lactation Analysis. When complete lactation data were analyzed for all animals from calving until drying off, there was no significant effect of DHA offered from February 21 to May 8 on milk, SCM, fat, protein, or lactose yields (5,385, 5,144, 219, 189, and 246 kg, respectively; Table 7). Similarly, there was no effect of DHA on milk fat, protein, and lactose concentrations over the entire lactation. There was no effect of DHA on lactation length (291 d).

The total lactation milk yield of cows offered concentrate during P1 was increased (+432 kg/cow per year; $P < 0.01$) compared with cows that were unsupplemented throughout the year (5,168 kg/cow per year). A greater ($P < 0.01$) SCM yield was also produced by supplemented animals (+416 kg/cow) when compared with their unsupplemented counterparts (4,936 kg/cow per

Table 6. Effect of daily herbage allowance (DHA) and concentrate level (Conc.) on milk yield from May 9 to June 5 (period 2; 28 d) and June 6 to October 23 (period 3; 140 d)

	Treatment ¹						SED	P <		
	L0	L4	M0	M4	H0	H4		DHA	Conc.	Lin ²
Period 2										
Milk yield (kg/d)	19.5	22.0	20.1	23.1	20.5	22.8	0.86	NS	0.001	NS
Milk fat content (%)	3.86	3.69	3.86	3.84	3.66	3.78	0.167	NS	NS	NS
Milk protein content (%)	3.20	3.30	3.35	3.34	3.29	3.31	0.070	NS	NS	NS
Milk lactose content (%)	4.63	4.69	4.63	4.79	4.67	4.79	0.052	0.12	0.001	0.05
Milk fat yield (g/d)	749.2	807.2	767.3	873.5	760.7	869.8	44.94	NS	0.01	NS
Milk protein yield (g/d)	652.1	730.6	676.6	756.9	683.6	740.3	31.66	NS	0.001	NS
Milk lactose yield (g/d)	897.5	1,028.2	922.1	1,107.0	960.8	1,095.4	45.87	0.11	0.001	0.05
SCM yield (kg/d)	17.9	19.6	18.6	21.5	18.6	20.9	0.83	0.08	0.001	0.10
Average BW (kg)	516	512	523	524	516	534	10.6	NS	NS	NS
BW at end of period 2 (kg)	502	505	508	516	506	524	10.2	NS	0.12	0.13
BW change (kg/d)	0.08	0.06	-0.40	-0.03	-0.65	-0.18	0.249	0.05	0.06	0.01
BCS at end of P2	2.66	2.73	2.78	2.85	2.63	2.75	0.106	NS	NS	NS
BCS change/d	-0.004	0.000	-0.001	-0.004	-0.007	-0.006	0.0026	0.05	NS	0.01
Period 3										
Milk yield (kg/d)	14.6	14.3	15.4	16.0	14.4	15.8	0.82	NS	NS	NS
Milk fat content (%)	4.32	4.20	4.13	4.12	3.92	4.16	0.177	NS	NS	NS
Milk protein content (%)	3.62	3.69	3.64	3.63	3.50	3.60	0.080	NS	NS	NS
Milk lactose content (%)	4.50	4.40	4.48	4.58	4.50	4.56	0.067	NS	NS	NS
Milk fat yield (g/d)	626.3	601.6	616.9	645.4	568.4	669.2	41.67	NS	NS	NS
Milk protein yield (g/d)	530.8	525.8	553.1	570.0	515.0	568.2	29.25	NS	NS	NS
Milk lactose yield (g/d)	657.8	629.8	687.3	727.2	648.7	721.3	41.78	NS	NS	NS
SCM yield (kg/d)	14.4	13.8	14.7	15.4	13.5	15.4	0.82	NS	NS	NS
Average BW (kg)	529	526	539	535	528	545	11.8	NS	NS	NS
BW at end of period 3 (kg)	545	548	558	550	547	562	13.8	NS	NS	NS
BW change (kg/d)	0.25	0.52	-0.27	0.40	0.25	0.29	0.388	NS	NS	NS
BCS at end of P3	2.55	2.76	2.76	2.65	2.56	2.70	0.109	NS	NS	NS
BCS change/d	-0.001	0.001	-0.004	-0.001	0.000	0.000	0.0022	NS	NS	NS

¹L = low herbage allowance; M = medium herbage allowance; H = high herbage allowance; 0 = no concentrate; 4 = 4 kg of concentrate DM/cow per day.

²Lin = linear (response to DHA).

year). Cumulative milk fat, protein, and lactose yields were greater ($P < 0.01$) for animals supplemented during the treatment period (+18, +15, and +23 kg/cow, respectively) compared with those that received herbage alone (210, 182, and 235 kg/cow per year, respec-

tively). There was no effect of concentrate on milk fat, protein, and lactose concentrations over the entire lactation period. Lactation length did not differ significantly between supplemented (287 d) and unsupplemented (295 d) treatments.

Table 7. Effect of daily herbage allowance (DHA) and concentrate level (Conc.) on total lactation milk yield, BW, and BCS

	Treatment ¹						SED	P <		
	L0	L4	M0	M4	H0	H4		DHA	Conc	Lin ²
Milk yield (kg)	5,077	5,346	5,262	5,746	5,167	5,711	257.9	NS	0.01	NS
Milk fat content (%)	4.23	4.07	4.11	4.07	3.89	4.06	0.159	NS	NS	NS
Milk protein content (%)	3.51	3.56	3.55	3.54	3.44	3.52	0.070	NS	NS	NS
Milk lactose content (%)	4.55	4.54	4.55	4.64	4.56	4.64	0.058	NS	0.11	NS
Milk fat yield (kg)	190	196	190	209	181	213	136.5	NS	0.05	NS
Milk protein yield (kg)	160	171	165	182	163	181	92.1	NS	0.01	NS
Milk lactose yield (kg)	206	218	213	242	211	239	127.9	0.19	0.01	0.14
SCM yield (kg)	4,922	5,047	5,041	5,516	4,846	5,495	271.4	NS	0.01	NS
BW (kg)	517	516	525	527	522	538	10.1	0.15	NS	0.06
BW change (kg/d)	0.30	0.25	0.29	0.29	0.29	0.32	0.092	NS	NS	NS
BCS	2.65	2.78	2.75	2.77	2.69	2.76	0.088	NS	NS	NS
BCS change/d	-0.003	-0.002	-0.003	-0.003	-0.002	-0.002	0.0060	NS	NS	NS

¹L = low herbage allowance; M = medium herbage allowance; H = high herbage allowance; 0 = no concentrate; 4 = 4 kg of concentrate DM/cow per day.

²Lin = linear (response to DHA).

Response to Concentrate and Herbage. Milk production response to concentrate or extra herbage offered was defined as the overall increase in kilograms of milk per kilogram of concentrate or herbage DM. During P1, when supplemented animals from each of the 3 herbage allowance treatments were compared with unsupplemented animals, the mean milk production response was 1.1 kg of milk/kg of concentrate DM offered. This was similar to that reported by Horan et al. (2005; 1.00 kg of milk/kg of concentrate DM) and Bargo et al. (2002; 0.96 kg of milk/kg of concentrate at a high pasture allowance and 1.36 kg of milk/kg of concentrate at a low pasture allowance), but greater than that reported by Kennedy et al. (2002; 0.66 kg of milk/kg of concentrate DM). The restriction of pasture allowance coupled with the increased energy intake from concentrate resulted in animals achieving a greater response to concentrate.

When DHA was increased from a low to a medium level, the milk production response of unsupplemented cows (0.65 kg of milk/kg of DM DHA) was greater than that reported by other authors (Delaby et al., 2001; Maher et al., 2003). Increasing DHA from a medium to a high level produced a milk yield response of 0.13 kg of milk/kg of DM of extra herbage offered. Yet, when DHA was increased from a low to high herbage allowance, the milk production response of unsupplemented cows was 0.37 kg of milk/kg of herbage DM, which was similar to the increase of 0.33 kg of milk/kg of herbage DM reported by Delaby et al. (2001) and Maher et al. (2003); however, Delaby et al. (1999) reported a response of 0.25 kg of milk/kg of herbage DM. The greater response to herbage of the animals offered a low DHA indicates that these animals may have been restricted and may have had to mobilize more body reserves. To achieve an increase in milk yield similar to that obtained with 1 kg of concentrate DM, an additional herbage allowance of 1.3 and 2.6 kg of DM/cow per day at the medium and high DHA levels, respectively, would have to be offered.

BW and BCS. There was a linear response in BW at the end of P1 ($P < 0.001$) to the extra DHA offered. Animals offered a low DHA had the lowest BW at the end of P1 (486 kg/cow), and the high DHA animals had the highest end of P1 BW (526 kg/cow). Although a low herbage allowance and no supplementation may have restricted milk production to some extent, BW was not affected; P1 BW loss equated to -0.26 kg/cow per day. According to Dillon et al. (1999) a BW loss of 0.5 kg/d for the first 8 wk of lactation is acceptable. There was no effect of DHA on BW change in this experiment, which was similar to that reported by Delaby et al. (2001). Following P2, all effects of DHA on BW had

dissipated; there was no effect of initial treatment on overall BW.

Following P2 there was a linear response in BW change to DHA because animals initially offered a low DHA gained 0.07 kg/cow per day ($P < 0.05$) compared with animals offered a medium and high DHA whose BW change was -0.21 and -0.41 kg/cow per day, respectively. There was no difference in BW change between treatments following P3 or in overall BW change.

Similar to studies conducted by Dillon et al. (2002), Delaby et al. (2003), and Horan et al. (2005), supplementing animals with concentrate increased BW ($+16$ kg/cow; $P < 0.01$) during P1. Delaby et al. (2003) reported that BW increased with the level of concentrate supplementation on both lax and severe grazing treatments. The positive BW change of the supplemented animals in this experiment equated to 0.02, 0.10, and 0.13 kg/cow per kg of concentrate DM during P1 for the low, medium, and high herbage allowance treatments, respectively. There was no effect of initial concentrate supplementation on BW following both P2 and P3 or on overall BW. Animals supplemented during P1, however, gained 0.23 kg/cow per day ($P < 0.01$) more than their unsupplemented counterparts.

Daily herbage allowance offered during P1 did not affect BCS during P1, P2, or P3 or on overall BCS. However, supplemented animals tended ($P = 0.13$) to have a greater BCS ($+0.08$) than their unsupplemented counterparts (2.87). The effect of P1 supplementation tended ($P = 0.17$) to influence BCS in P2, with animals initially supplemented having a greater BCS ($+0.09$) than unsupplemented animals (2.71). Concentrate supplementation had no effect on BCS in P3. The BCS loss ($P < 0.05$) of the animals offered a high and medium DHA during P1 was half of that lost by animals offered a low DHA (-0.008). Following P2, however, the inverse of this was true, because animals offered a low DHA during P1 lost 0.004 less condition score per day than animals initially offered a high DHA (-0.006 ; $P < 0.05$). There was no effect of DHA on BCS change during P3 or on overall values.

CONCLUSIONS

When animals were offered a low DHA in early lactation (P1), milk yield was not compromised compared with the medium DHA level. However, offering a high DHA level increased milk yield but significantly reduced sward utilization. Body weight was reduced by offering a low DHA; however, there was no effect on BCS. The effect of DHA offered during P1 was transient, because there were no effects on milk production parameters for the remainder of lactation.

Conversely, supplementing animals with 4 kg of DM/cow per day of concentrate during P1 significantly increased milk yield. This positive effect remained for the duration of P2 and culminated in a greater total lactation milk yield and milk constituent yield. There was a high response to concentrate during P1; however, milk yield was similar for all supplemented treatments regardless of DHA offered. Additionally, concentrate supplementation only affected BW during P1. The results from this study indicate that offering animals a low DHA and 4 kg of DM/cow per day of concentrate during the first 9 to 13 wk of lactation did not significantly affect total lactation performance and resulted in increased sward utilization.

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