End of project report 5228

November 2008

The effect of different levels of spring grass supply and stocking rate on the performance and intake of cows in early lactation

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1. Summary and Implications

- Approximately 0.8 to 1.0 t herbage per cow is required to offer the herd a diet of 80% grazed grass from February to mid April, with the remainder as concentrate
- Experiment I and II found that spring calved dairy cows in early lactation could be offered 13-16 kg DHA with 3 kg conc DM, such a grazing regime supported 2 – 2.1 kg milk solids cow/day.
- Only in a deficit grass supply scenario should >3 kg concentrate should be offered.
- Offering higher levels of herbage allowance >16 kg DM cow will result in lower levels of grass utilisation, this will impact on subsequent sward quality.
- Results from this study indicate that significant predictors of DM intake and milk production in the early lactation period for spring calving grazing dairy cows are DHA, concentrate level, DIM, parity, MY_{Pot}, BW and BCS.
- When these factors are known, GDMI, TDMI and milk production of grazing dairy cows can be predicted to a high level of accuracy in early lactation.
- At current grazing stocking rates in Ireland, dairy farmers have a huge capacity to reduce concentrate supplementation levels and increase milk performance with early spring grazing.

2. Introduction

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 the early spring period 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/supply (O'Donovan, 2000). Grazing pastures in early spring has previously been shown to increase herbage utilization and condition 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 and Peyraud et al., 1996). An increasing level of milk production has been reported when greater DHA's 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 should be offered to post parturient animals in early spring. In an early lactation study conducted by Kennedy et al. (2005) a reasonably high animal production performance was reported when a medium DHA of 15 kg DM/cow/d and 3 kg DM/cow/d of concentrate was offered. It is reported that under grazing conditions daily intakes of herbage can be as high as 3.6% in early lactation dairy cows (Kolver et al., 2002). As intake is at its lowest directly post partum a low DHA may be sufficient during the first grazing rotation, to attain a high level of milk production while simultaneously maintaining sward quality in subsequent rotations. 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. The main objective when supplementing dairy cows is to increase total DMI and energy intake relative to that achieved with pasture only diets (Stockdale, 2000; Delaby et al., 2001; Bargo et al., 2003). Dry matter intake (DMI) of dairy cows is at its lowest following parturition and does not peak until 8 – 14 weeks post-partum (Ingvartsen and Andersen, 2000; Kertz et al., 1991). This indicates that dairy cows do not consume enough feed to meet the energetic requirements of lactation and is substantiated when the studies of Roche et al. (2006) are examined. 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/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 which offers no concentrate in conjunction with an optimum DHA requires investigation.

Experiment I. The Effect of Early Lactation Feeding Strategy on the Lactation Performance of Spring Calving Dairy Cows

Introduction

Grazed herbage is one of the cheapest feeds available thus the objective of pasture-based systems must be to maximize the proportion of grazed grass in the diet of the dairy cow. 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. Previous studies have reported a high level of milk production and sward utilization when a medium DHA (15 kg DM/cow/day) and 3 kg DM of concentrate was allocated to spring calving dairy cows in early lactation. However, the optimum allowance that should be offered in early lactation needs to be quantified.

The objective of this study was to establish the influence of daily herbage allowance and concentrate supplementation level offered to spring calving dairy cows in early lactation on immediate, subsequent and total lactation performance, body weight and body condition score.

Materials and Methods

The experiment was a randomised block design with a 3 × 2 factorial arrangement of treatments. Sixty-six Holstein-Friesian dairy cows (30 primiparous and 36 pluriparous) were balanced on parity, calving date, pre-experimental milk yield, BW and BCS. They were then assigned to one of six experimental treatments consisting of three DHA's and two concentrate levels. The grazing treatment daily herbage allowances were set at 13 (L), 16 (M) and 19 (H) kg DM/cow/day, within each of the DHA treatments half of the animals (n = 11) were offered 0 kg DM/cow/day (0) concentrate while the remaining half were offered 4 kg DM/cow/day (4). The grazing and concentrate supplementation treatments were imposed for 11-weeks from 21 February to 8 May 2006 (P1). Concentrate composition, on a fresh weight basis was: molassed beet pulp, 48%; soybean meal, 25%; barley, 20%; vegetable fat, 3%; dicalcium phosphate (DCP), 1.6%; calcined magnesite, 1.3%; ground limestone, 0.6%; salt, 0.5%; and trace elements. The chemical analyses of the herbage and concentrate offered during P1 is presented in Table 1.

Table 1. Chemical Analysis of herbage and concentrate from 21 February to 8 May (P1)

	Herbage Allowance						
	Low	Medium	High	SED	Sig	Conc	S.D.
DM (%)	17.6	17.6	17.7	1.6	NS	82.8	18.28
DM Composition (%)							
OM digestibility	86.1	86.4	86.2	0.24	NS	-	-
Crude protein	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

DM = Dry matter; OM = Organic matter; ADF = Acid-detergent fiber; NDF = Neutral-detergent fiber; NS, not significant;

Following P1 all animals remained in their individual herds and were offered a DHA of 20 kg DM/cow/day and no concentrate for the following 4-wk period (P2; 9 May – 5 June). Subsequent to P2 all animals grazed as a single herd and were offered a DHA of 22 kg DM/cow/day and no concentrate for the remainder of lactation. Milk production data for P3 was from 6 June to 23 October, which coincided with the time that the first animal was dried off. Animals were dried off if yielding < 5 kg/cow/day or if within 2 months 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.

Herbage mass (> 4cm) was determined twice weekly on the low, medium and high herbage allowance areas by defoliating two strips (1.2 m × 10 m) per allowance with an Agria machine (Etesia UK Ltd., Warwick, UK.). The pre-grazing sward height was determined daily in each plot by recording 40 measurements across the two diagonals of the paddock, using the electronic plate meter described above. Pre-grazing values were recorded for the low, medium and high DHA treatments (n=3). The measured pre-grazing sward height, multiplied by the mean sward density, was used to calculate the DHA required for the three herbage allowances. Post-grazing sward height was measured immediately after grazing for each of the six individual treatments (n=6).

Milk yields were recorded daily while milk fat, protein and lactose concentrations were determined from one successive evening and morning sampling taken weekly. All cows were weighed weekly. Body condition score was recorded weekly during the lactation on a 1 to 5 scale (1=emaciated, 5=extremely fat) with 0.25 increments. Body weight and BCS change were calculated using values of BW and BCS from the first two and last two weeks of the study. Individual total dry matter intakes (TDMI) were estimated during P1 using the n-alkane technique.

The herbage samples selected weekly for each treatment were freeze dried and milled through a 1mm sieve. Samples were analyzed for DM, ash, ADF, NDF (Van Soest, 1963), CP (Leco FP-428; Leco Australia Pty Ltd.) 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.

Results

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

Table 2. Chemical analysis of herbage from 9 May – 5 June (P2; 28 days) and 6 June – 23 October (P3; 140 days)

	P2	SD	P3	S.D.
DM (%)	16.6	2.16	17.1	2.87
DM Composition (%)				
OM digestibility	84.4	1.17	80.6	1.34
Crude protein	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

DM = Dry matter; OM = Organic matter; ADF = Acid-detergent fiber; NDF = Neutral-detergent fiber
SD = Standard Deviation

The first grazing rotation was completed in 40 d while the second grazing rotation lasted 36 d. Pre-grazing sward height was identical between the grazing treatments during P1 (Table 3), while pre-grazing DM yield > 4cm (1,896 kg DM/ha) and sward density (235 kg DM/ha) were similar between treatments. 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 post-grazing sward heights (PGSSH) were recorded with decreasing herbage allowances, as 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 4 kg concentrate resulted in a higher PGSSH (+ 0.5 cm).

Table 3. Effect of daily herbage allowance and concentrate level on pre-grazing sward measurements (P1 and P2)

	Daily Herbage Allowance				
	Low	Medium	High	SED	Sig
P1					
DHA > 4cm (kg DM/cow/d)	13.3	15.9	19.0	0.09	***
DM yield > 4cm (kg/DM/ha)	1,905	1,900	1,884	26.3	NS
Pre grazing height (cm)	12.2	12.1	12.1	0.11	NS
Sward density> 4cm (kg DM/ha)	234	236	235	1.1	NS
Area (m^2/cow/d)	73	88	107	2.2	***
P 2					
DHA > 4cm (kg DM/cow/d)	20.1	20.2	20.2	0.14	NS
DM yield > 4cm (kg/DM/ha)	2,754	2,811	2,747	109.0	NS
Pre grazing height (cm)	15.7	16.0	15.7	0.45	NS
Sward density> 4cm (kg DM/ha)	236	236	236	3.8	NS
Area (m^2/cow/d)	74	72	74	3.1	NS

DHA = Daily Herbage Allowance; NS, not significant; ***, *P* < 0.001

Throughout P2 (one grazing rotation; 28-d) all animals were allocated a DHA of 20.2 kg DM/cow/d with an area allocation of 73 m^2/cow/d. Stocking rate during P2 was 5.3 cows/ha. Pre-grazing sward height (15.8 cm), DM yield > 4cm (2,771 kg DM/ha), sward density (236 kg DM/ha) and sward utilization (86%) were similar between treatments. During P3 rotation length ranged from 19 – 30 d (as the grazing season progressed rotation length increased). Pre-grazing height was 13.5 (s.d. 2.00) cm and pre grazing DM yield > 4 cm was 2,256 (s.d. 480.9) kg DM/cow/d. All animals were offered a DHA of 21.4 (s.d. 4.17) kg DM/cow/d which resulted in an area allocation of 100 (s.d. 36.1) m^2/cow/d. Average stocking rate ranged from 4.74 to 2.56 cows/ha. Animals grazed to a mean PGSSH of 5.8 (s.d. 0.63) cm which corresponded to a sward utilization level of 85% (s.d. 19.7).

Table 4. Effect of daily herbage allowance and concentrate level on post-grazing height and sward utilization (P1 and P2)

	Treatment						Significance		
	L0	L4	M0	M4	H0	H4	SED	DHA	Conc
P1									
Post-grazing height (cm)	3.3	3.7	4.0	4.5	4.7	5.2	0.08	***	***
Utilization (%)	109	104	101	94	92	86	1.0	***	***
P2									
Post-grazing height (cm)	5.6	5.3	5.7	5.7	5.9	5.6	0.24	*	0.10
Utilization (%)	86	88	86	85	84	86	2.1	NS	NS

L=Low herbage allowance; M=Medium herbage allowance; H=High herbage allowance; 0= no concentrate; 4 = 4 kg DM/cow/d concentrate; DHA=Daily herbage allowance; Conc=Concentrate
NS, not significant; ***, $P < 0.001$; *, $P < 0.05$

There was no significant interaction between daily herbage allowance and concentrate level offered, nor was there a quadratic response to DHA for any of the production variables investigated. 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. Animals offered a high DHA, during P1, had a greater TDMI (+ 1.4 kg/cow/d; Table 5) than animals offered a low DHA (15.2 kg DM/cow/d). The greater TDMI corresponded to greater milk yields as 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 to either the low or high DHA treatments.

A high DHA increased milk protein yield (P < 0.05; + 65.3 g/d) compared with animals offered a low DHA (839.4 g/d). There was no effect of DHA on milk fat concentration. Daily herbage allowance had no effect on milk protein concentration. All effects of DHA dissipated after P1.

The cumulative concentrate input, for supplemented animals, from calving until the end of the 11-wk experimental period was 382 kg DM/cow. Total dry matter intake was greater (+ 2.5 kg/cow/d; Table 5) for supplemented animals compared to their unsupplemented counterparts (14.9 kg/cow/d). Milk and SCM yields were significantly improved (+ 4.4 and + 3.9 kg/cow/d, respectively; P < 0.001) when animals were offered 4 kg DM/cow/d concentrate during P1 (Table 5). When concentrate was offered in conjunction with either a medium or high DHA however, milk yield was similar to that produced by animals offered a low DHA.

Table 5. Effect of daily herbage allowance and concentrate level on milk yield and dry matter intake from 21 Feb – 8 May (P1; 76 days)

	Treatment							Significance		
	L0	L4	M0	M4	H0	H4	SED	DHA	Conc	Lin
Milk Yield (kg/d)	23.0	28.3	24.7	28.6	25.1	29.2	0.87	*	***	**
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	**	NS
SCM yield (kg/d)	21.0	26.0	23.4	26.5	23.0	26.4	0.86	*	***	*
BW at end of P1 (kg)	486	497	497	511	501	526	8.9	**	**	***
BW change (kg/d)	-0.26	-0.17	-0.30	0.08	-0.29	0.23	0.175	NS	**	NS
BCS at end of P1	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	*	NS	*
TDMI (kg DM/cow/d)	14.1	16.3	15.4	17.8	15.1	18.1	0.573	**	***	**

L=Low herbage allowance; M=Medium herbage allowance; H=High herbage allowance; 0= no concentrate; 4 = 4 kg DM/cow/d concentrate; DHA=Daily herbage allowance; Conc=Concentrate; Lin=Linear (response to DHA); SCM=Solids-corrected milk yield; BW=Body weight; BCS=Body condition score; TDMI=Total dry matter intake

NS, not significant; ***, $P < 0.001$; **, $P < 0.01$; *, $P < 0.05$

During P2, when all animals were allocated 20 kg DM/cow/d, 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 DM/cow/d), SCM (+ 2.3 kg/cow/d), 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).

Table 6. Effect of daily herbage allowance and concentrate level on milk yield from 9 May – 5 June (P2; 28 days) and 6 June – 23 October (P3; 140 days)

	Treatment							Significance		
	L0	L4	M0	M4	H0	H4	SED	DHA	Conc	Lin
P2										
Milk Yield (kg/d)	19.5	22.0	20.1	23.1	20.5	22.8	0.86	NS	***	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	***	*
SCM yield (kg/d)	17.9	19.6	18.6	21.5	18.6	20.9	0.83	0.08	***	0.10
Average BW (kg)	516	512	523	524	516	534	10.6	NS	NS	NS
BW at end of P2 (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	*	0.06	**
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	*	NS	**
P3										
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
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 P3 (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

L=Low herbage allowance; M=Medium herbage allowance; H=High herbage allowance; 0= no concentrate; 4 = 4 kg DM/cow/d concentrate; DHA=Daily herbage allowance; Conc=Concentrate; Lin=Linear (response to DHA); SCM=Solids-corrected milk yield; BW=Body weight; BCS=Body condition score
NS, not significant; ***, $P < 0.001$; **, $P < 0.01$; *, $P < 0.05$

When complete lactation data was analyzed for all animals, from calving until drying off, there was no significant effect of DHA offered from 21 February to 8 May 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/y; P < 0.01) compared with cows that were unsupplemented throughout the year (5,168 kg/cow/yr). 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/yr).

Table 7. Effect of daily herbage allowance and concentrate level on total lactation milk yield, body weight and body condition score

	Treatment							Significance		
	L0	L4	M0	M4	H0	H4	SED	DHA	Conc	Lin
Milk Yield (kg)	5,077	5,346	5,262	5,746	5,167	5,711	257.9	NS	**	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
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
Body condition score	2.65	2.78	2.75	2.77	2.69	2.76	0.088	NS	NS	NS

L=Low herbage allowance; M=Medium herbage allowance; H=High herbage allowance; 0= no concentrate; 4 = 4 kg DM/cow/d concentrate; DHA=Daily herbage allowance; Conc=Concentrate; Lin=Linear (response to DHA); SCM=Solids-corrected milk yield; BW=Body weight; BCS=Body condition score
NS, not significant; **, $P < 0.01$; *, $P < 0.05$

Milk production response to concentrate or extra herbage offered was expressed as kg milk/kg concentrate/herbage DM and was defined as the overall increase in kg of milk/kg concentrate/herbage DM. During P1, when supplemented animals from each of the three herbage allowance treatments were compared with unsupplemented animals the mean milk production response was 1.1 kg milk/kg concentrate DM offered. Increasing DHA from a medium to a high level produced a milk yield response of 0.13 kg milk/kg 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 milk/ kg herbage DM. In order to achieve an increase in milk yield similar to that obtained with 1 kg concentrate DM, an additional herbage allowance of 1.3 and 2.6 kg DM/cow/d at the medium and high DHA levels, respectively, would have to be offered.

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) while the high DHA animals had the highest BW (526 kg/cow). Although a low herbage allowance and no supplementation may have restricted milk production to some extent, BW was not affected as following P1 BW loss equated to - 0.26 kg/cow/d. 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 as animals initially offered a low DHA gained 0.07 kg/cow/d ($P < 0.05$) compared with animals offered a medium and high DHA whose BW change was - 0.21 and - 0.41 kg/cow/d, respectively. There was no difference in BW change between treatments following P3 or in overall BW change. The positive BW change of the supplemented animals in this experiment equated to 0.02, 0.10 and 0.13 kg/cow per kg DM of concentrate, 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/d ($P < 0.01$) more than their unsupplemented counterparts.

Daily herbage allowance offered during P1 did not impact on BCS during P1, P2 and P3 or overall BCS. However, supplemented animals tended ($P=0.13$) to have a greater BCS (+ 0.08) than their unsupplemented counterparts (2.87).

Conclusions

When animals were offered a low DHA in early lactation (P1) milk yield was not compromised when 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 as there were no effects on milk production parameters for the remainder of lactation.

Conversely supplementing animals with 4 kg DM/cow/d 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 DM/cow/d of concentrate during the first 9

– 13-wk of lactation did not significantly affect total lactation performance and resulted in increased sward utilization.

Experiment II. An investigation into the effect of herbage allowance and concentrate supplementation on milk production performance and dry matter intake of spring-calving dairy cows in early lactation

Introduction

Targeting the early lactation period for increased grass input in the diet eliminates the requirement to offer grass silage to animals in early lactation. Depending on the DHA offered, concentrate supplementation level may be reduced. In Ireland grass growth is seasonal with little net growth in the November to January period. Therefore, in early spring grass supply is generally not sufficient to meet the cow's demand. As a result it is necessary to supplement a grass based diet with concentrate, firstly, to ensure the cow is offered adequate feed allowance in early lactation, secondly to maximise milk output per cow and thirdly, to budget the available feed to ensure the first grazing rotation is not completed before early-April. Supplementing animals with concentrate has been shown to increase total DMI and therefore, total energy intake. Concentrate supplementation will allow the animal to express a greater proportion of her milk production potential with minimal bodyweight losses, especially in high producing dairy cows.

Substitution rate (kg/kg) is the decrease in pasture DM intake per kg of supplement feed offered. Substitution rate is greater at higher DHA's but is affected by other factors such as cow genetic merit, concentrate allowance, pasture quality, parity and stage of lactation. Milk response to concentrate supplementation, which is the increase in milk yield per kg of concentrate offered, is reportedly lower in spring compared to summer, due to the higher energy content of spring grass. Low substitution rates will result in greater milk responses to the supplement offered, thus making it more economical to offer the supplement to the animals. When pasture constitutes a large proportion of the diet what is the optimum concentrate level to offer dairy cows in early lactation?

The objective of this study was to investigate the effect of concentrate level and DHA on milk production and dry matter intake (DMI) of spring calving dairy cows in early lactation.

Materials and Methods

The experiment was a randomised block design with a 2 × 3 factorial arrangement of treatments and investigated the effect of offering three levels of concentrate (0, 3kg or 6kg DM) and two levels of daily herbage allowance (13kg or 17kg herbage DM/cow/day) - six grazing treatments. Treatments were imposed for an 11-week period from 20 February to 7 May 2006 (PI). Seventy-two Holstein Friesian dairy cows (24 primiparous and 48 multiparous) were balanced on calving date, lactation number, first 10 days milk yield of the present lactation, BW and BCS. Animals were divided into two herds (n=36) and were offered one of two DHA's: 13 kg DM/cow/day (Low – L) or 17 kg DM/cow/day (High – H) (>4 cm). These two herds were further sub-divided into three herds (n=12) and were offered no concentrate (0), 3 kg (3) or 6 kg (6) DM/cow/day of concentrate. Concentrate was offered in the milking parlour in two equal feeds at both morning and evening milking. The concentrate composition on a fresh weight basis was: ground citrus pulp 0.305, barley 0.237, maize gluten 0.249, soya hulls 0.14, vitamin/minerals 0.043 and fat 0.026. The chemical analysis of the herbage and concentrate offered during PI is shown in Table 8.

Table 8. Selected herbage and concentrate chemical composition during Period I (Feb 20 to May 7)

DHA	**13kg**	**17kg**	**SED**	**Significance**	**Conc.**	**S.D**
Dry Matter (%)	19.6	19.2	-	-	882	4.6
<u>Analysis</u>						
OM Digestibility (g/kg DM)	862[a]	869[b]	2.3	*	-	-
Crude protein (g/kg DM)	256	261	5.5	NS	186	16.7
Crude fibre (g/kg DM)	-	-	-	-	82	17.2
ADF (g/kg DM)	206	210	4.9	NS	-	-
NDF (g/kg DM)	370	351	9.4	NS	248	40.8
Ash (g/kg DM)	74.2	71.9	2.02	NS	100	6.6

[a-f] Means within a row with different superscripts differ (P<0.05). *, P<0.05. NS= Not significant.
DHA = Daily Herbage allowance. Conc.= concentrate.

During the 12 weeks (8 May to 1 August) following PI, all animals were reassigned to a two-treatment grazing study in a randomised block design based on data collected during the final two weeks of PI. Period two (PII) of the experiment was a crossover design, six animals from each treatment were assigned to one of two herbage allowances (n=36). During PII the DHA offered were 17kg (medium - MM) and 21kg

DM/cow/day (high - MH) (> 4cm). No concentrate was offered during this period. The objective of PII was to investigate the carryover effects of the treatments imposed in PI on milk yield and composition, dry matter intake, bodyweight and BCS. The chemical analysis of the herbage offered in PII is shown in Table 9.

During PI half of the paddocks were randomly assigned to the low DHA treatment with the remaining half assigned to the high DHA treatment. The low herbage allowance treatments (L0, L3 and L6) grazed as three separate herds adjacent to one another separated by temporary electric wires, as did the animals offered a high DHA (H0, H3 and H6). Two grazing rotations were completed during PI. Individual herds did not re-graze the exact area within a paddock in the second rotation as was grazed in the first rotation. During PII the two treatments (MM and MH) grazed adjacent to one another, separated by a temporary electric wire. Four grazing rotations were completed during PII. Sward and animal measurements were similar to those collected in Experiment I.

Results

Table 9. Selected herbage and chemical composition during Period II (May 8 to Aug 1)

DHA	17kg	21kg	SED	***DHA***
Dry Matter (%)	18.2	17.7	0.4	NS
Analysis (g kg^{-1} DM)				
OM Digestibility (g kg^{-1} DM)	840	843	2.0	NS
Crude protein (g kg^{-1} DM)	229	220	7.1	NS
ADF (g kg^{-1} DM)	232	235	4.3	NS
NDF (g kg^{-1} DM)	403	395	9.0	NS
Ash (g kg^{-1} DM)	75^a	72^b	1.2	*

$^{a-f}$ Means within a row with different superscripts differ (P<0.05). *, P<0.05. NS= Not significant.

The first grazing rotation began on 20 February and was completed on 4 April (44 days), the second grazing rotation finished 26 days later. The herbage offered to both the low and high DHA herds was similar in quality. Daily herbage allowance significantly (P<0.01) affected pre-grazing herbage mass (>4 cm) which was 1375 kg DM/ha for the low DHA herds and 1439 kg DM/ha for the high DHA herds during PI. This corresponded to a mean sward density of 230 kg DM/ha/cm. Animals offered a high DHA received approximately 20% more area than those on the low DHA treatment (101 m^2/cow/day) throughout PI, this equated to a stocking rate of 2.3 cows/ha for the low DHA herd and 1.8 cows/ha for the high DHA herd. As the treatments were managed as six individual herds post-grazing sward height ranged from 3.5 cm (L0) to 5 cm (H6) (P<0.001, Table 10). Cows grazing the high DHA treatments had consistently higher post-grazing sward heights than those grazing the low DHA treatments. At both DHA's for every 1 kg increase in concentrate DM offered, post-grazing sward height increased by 0.1 cm. Herbage utilisation (>4cm) was highest with the low DHA treatment (1.03), while the high DHA treatment utilised 0.89 of the offered herbage.

Total concentrate inclusion in the diet for the 3 kg herds (L3 and H3) from the 20 February until 7 May was 231 kg DM/cow; animals on the 6 kg allowance (L6 and H6) received a total of 462 kg DM/cow for the duration of the experiment.

During PII there was no difference in pre-grazing sward height (12.7 and 12.5cm), sward density (212 and 214 kg DM/ha/cm) or herbage mass (1813 and 1785 kg DM/ha) between the MM and MH treatments, respectively (Table 11). Animals on the MH treatment received approximately 28% greater area/day (P<0.001) than those on the MM treatment (100 m^2/cow/day). Offering the higher DHA during PII increased (P<0.001; +0.8cm) post-grazing sward height and herbage removed per cow/day (P<0.001; +1.2 kg DM/cow/day) in comparison to the medium DHA (4.8 cm and 15.3kg DM/cow/day, respectively). Sward utilisation was increased (P<0.001) when animals were offered the 17kg DHA (0.90) in comparison to the 21kg DHA (0.79) during PII.

Animal Performance

Milk Production.

Table 12 presents the production performance of the 6 treatments during PI. There was no interaction between DHA and concentrate allowance throughout the two experimental periods (PI and PII). No quadratic effect of concentrate was detected. Results from PI indicate that increasing DHA increased (P<0.05) milk yield (+1.85kg/cow/d), solids corrected milk (SCM; +1.8kg/cow/d), protein concentration (+0.8g/kg) and mean BW (+12.3kg). Mean BCS and endpoint BCS were also higher

(P<0.05) for herds offered the high DHA (+0.13 and +0.15, respectively). There was a positive linear response (P<0.001) in milk yield to concentrate supplementation throughout PI. Mean milk yield of unsupplemented animals was 26.8kg/cow/d, offering concentrate increased milk yield by 1.8kg/cow/d (3kg) and 4.3kg/cow/d (6kg) compared to the unsupplemented treatment. Milk lactose concentration increased linearly (P<0.05) with concentrate level, as did SCM. Solids corrected milk increased (P<0.001) by 1.8kg/cow/d (3kg) and 3.7kg/cow/d (6kg), compared to the unsupplemented herds (24.2kg/cow/d). There was an increase (P<0.01) in mean BW as concentrate increased from 0 to 3 kg (506 and 524 kg, respectively), however, there was no further increase in BW when 6 kg concentrate (519 kg) was offered. Concentrate supplementation level had no effect on mean BCS or endpoint BCS during PI.

Table 13 presents the carryover effect of early lactation feeding management on mid-lactation milk performance. During PII the high DHA treatment (MH) had a greater milk yield (+0.82 kg/d, P<0.01), but tended to have increased milk lactose concentration (+0.39 g/kg, P<0.05) in comparison to the MM treatment (21.1 kg/day (milk yield). The MH herd had significantly (P<0.01) greater mean BW (+6.3 kg), endpoint BW (+12.1 kg) and had higher BW gain (+12.1 kg) than the MM herd which had corresponding values of 533.7 kg (mean BW), 540.7 kg (endpoint BW) and 24.2 kg (BW gain).

Previous DHA continued to have a significant carryover effect on milk protein concentration (P<0.05), BW change, mean BCS and endpoint BCS (P<0.001) during PII. Concentrate supplementation during PI continued to have a significant (P<0.01) carryover effect on milk yield, SCM yields, mean BW, endpoint BW, BW change and mean BCS during PII.

Dry matter intake and herbage substitution.

There was no interaction between DHA and concentrate allowance for grass dry matter intake (GDMI) or total dry matter intake (TDMI). Table 14 shows the mean GDMI and TDMI for the two experimental periods. During PI, cows grazing the low DHA had lower (P<0.001, -1.6kg) GDMI (13.3kg/cow/d) and TDMI (16.3kg/cow/d) than the high DHA herds. The response in GDMI to extra herbage offered was 0.4kg

GDMI/kg DM offered. Concentrate supplementation increased (P<0.001) TDMI, the unsupplemented herd had a TDMI of 14.7kg/cow/d, whereas the herds offered 3kg and 6kg had a TDMI of 17.7 and 18.9kg/cow/d, respectively. There was no difference in GDMI between the unsupplemented and 3kg concentrate herds (14.7kg DM/cow/d). Grass dry matter intake of herds offered 6kg concentrate was 1.8kg/cow/d lower (P<0.01) than that of the unsupplemented and 3kg concentrate herds.

During Period II, treatment (MM and MH) had no effect on GDMI. Grass DMI was 0.9kg/cow/d less on the MM treatment (17.5kg) than on the MH treatment (18.4kg). Daily herbage allowance and concentrate had no carryover effect on GDMI. Animals previously allocated to the H6 treatment had the lowest GDMI (17.2kg/cow/d), which was 1.7kg/cow/d lower than that of the H3 treatment. On average, during PII the animals offered a low DHA during PI tended to have intakes of 0.21kg/cow/d greater than those offered a high DHA, however this difference was not significant.

Table 10. Effect of daily herbage allowance and concentrate level on pre and post-grazing sward height, herbage mass, utilisation and area offered during Period I (Feb. 20 to May 7)

DHA	13kg			17kg					
Conc. Level	0	3	6	0	3	6	SED	DHA	Conc.
Pre-grazing (cm)	10.0	10.0	10.0	10.2	10.2	10.2	0.31	*	NS
Post-grazing (cm)	3.5^{a}	3.8^{b}	4.1^{c}	4.4^{d}	4.6^{e}	5.0^{f}	0.19	***	***
Density (kg DM/cm/ha)	228^{a}	228^{a}	228^{a}	232^{b}	232^{b}	232^{b}	1.81	***	NS
Herbage Mass >4cm (kg DM/ha)	1375^{a}	1375^{a}	1375^{a}	1439^{b}	1439^{b}	1439^{b}	31.2	**	NS
Area offered (m^{2} cow^{-1} d^{-})	101^{a}	101^{a}	101^{a}	125^{b}	125^{b}	125^{b}	85.6	***	NS
Herbage removed (kg cow^{-1})	13.8^{a}	13.2^{b}	12.4^{c}	15.7^{d}	14.9^{e}	13.9^{a}	0.55	**	***
Herbage utilisation	1.09^{a}	1.03^{b}	0.97^{c}	0.94^{d}	0.89^{e}	0.84^{f}	0.04	***	***

$^{a-f}$Means within a row with different superscripts differ (P<0.05). ***, P<0.001, **, P<0.01, *, P<0.05. NS= Not significant.

DHA = Daily Herbage allowance (kg DM/cow/day). Conc.= concentrate level (kg DM/cow/day).

Table 11. Effect of daily herbage allowance on pre and post-grazing sward height, herbage mass, utilisation and area offered during Period II (May 8 to Aug 1)

DHA	17kg	21kg	SED	Treatment
Pre-grazing (cm)	12.7	12.5	0.22	NS
Post-grazing (cm)	4.8[a]	5.6[b]	0.08	***
Density (kg DM/cm/ha)	212	214	1.6	NS
Herbage Mass >4cm (kg DM/ha)	1813	1785	43.2	NS
Area offered (m^2 cow^{-1} d^{-1})	101[a]	130[b]	157.1	***
Herbage removed (kg cow^{-1})	15.3[a]	16.5[b]	0.20	***
Herbage utilisation	0.90[a]	0.79[b]	0.009	***

[A-b] Means within a row with different superscripts differ (P<0.05). ***, P<0.001, **, P<0.01, *, P<0.05. NS= Not significant.

DHA = Daily Herbage allowance (kg DM/cow/day).

Table 12. Effect of daily herbage allowance and concentrate level on milk production performance of spring calving cows in early lactation (Period I: Feb 20 to May 7).

DHA	13kg			17kg					
Concentrate level	0	3	6	0	3	6	SED	DHA	Conc.
Milk yield (kg/day)	25.7^{a}	27.4^{a}	30.5^{b}	27.8^{a}	29.8^{b}	31.6^{b}	1.15	**	***
Milk fat content (g/kg)	36.6	38.0	36.6	38.0	36.8	36.6	1.76	NS	NS
Milk protein content (g/kg)	32.1^{a}	32.6^{a}	33.1^{a}	33.1^{a}	33.6^{b}	33.7^{b}	0.69	*	NS
Milk lactose content (g/kg)	46.2^{a}	46.5^{a}	46.8^{ab}	45.8^{ac}	47.0^{ab}	46.7^{a}	0.49	NS	*
SCM yield (kg/day)	23.1^{a}	25.0^{ac}	27.3^{bc}	25.3^{ac}	26.9^{ac}	28.6^{b}	1.31	*	**
Average Bodyweight (kg)	500^{a}	518^{bc}	513^{ab}	512^{ab}	531^{c}	525^{bc}	8.5	**	**
End Bodyweight (kg)	490^{a}	515^{b}	515^{b}	514^{b}	534^{b}	532^{b}	10.1	**	**
Bodyweight change (kg)	-37.6^{a}	-8.5^{b}	-7.1^{b}	-5.4^{b}	-2.2^{b}	+0.3^{b}	10.00	*	*
Average BCS	2.68^{a}	2.78^{ab}	2.63^{a}	2.81^{ac}	2.89^{bc}	2.77^{ac}	0.089	*	NS
End BCS	2.56^{a}	2.73	2.60	2.75	2.83	2.77	0.106	*	NS
BCS change	-0.43^{a}	-0.18^{ac}	-0.16^{bcd}	-0.25^{ade}	-0.12^{bce}	-0.19^{ad}	0.125	NS	NS

$^{A-e}$ Means within a row with different superscripts differ (P<0.05). ***, P<0.001, **, P<0.01, *, P<0.05. NS= Not significant.

DHA = Daily Herbage allowance (kg DM/cow/day). Conc.= concentrate level (kg DM/cow/day).

SCM=Solids corrected milk yield. BCS = body condition score.

Table 13. Carryover effect of daily herbage allowance and concentrate level offered in early lactation on milk production performance of spring calving cows in mid lactation (Period II: May 8 to Aug 1).

DHA	13kg			17kg					
Concentrate	0	3	6	0	3	6	SED	DHA	Conc.
Milk yield (kg/day)	20.7[ad]	22.2[bc]	21.3[ace]	19.8[d]	22.8[b]	22.1[be]	0.54	NS	***
Milk fat content (g/kg)	34.4[a]	36.1[ab]	37.4[b]	37.2[b]	36.8[b]	37.2[b]	1.19	NS	NS
Milk protein content (g/kg)	31.6[a]	32.3[ab]	32.7[b]	32.9[b]	32.7[b]	32.4[b]	0.34	*	NS
Milk lactose content (g/kg)	45.8	45.5	45.3	44.9	46.0	45.5	0.27	NS	*
SCM yield (kg/day)	17.6[a]	19.5[b]	19.1[b]	17.8[a]	20.3[b]	19.7[b]	0.63	NS	***
Avg. Bodyweight (kg)	524[a]	547[b]	535[c]	527[a]	546[b]	542[bc]	3.6	NS	***
End Bodyweight (kg)	537[a]	558[b]	544[ac]	537[a]	554[b]	551[bc]	4.8	NS	***
Bodyweight change (kg)	48.8[a]	43.2[a]	31.8[b]	22.0[bc]	22.8[b]	12.8[c]	4.79	***	***
Average BCS	2.65[a]	2.55[a]	2.53[a]	2.73[b]	2.86[b]	2.71[c]	0.040	***	**
End BCS	2.50[a]	2.57[ac]	2.48[a]	2.73[b]	2.77[b]	2.65[bc]	0.074	***	NS
BCS change	-0.07	-0.08	-0.13	-0.03	-0.06	-0.17	0.090	NS	NS

[A-e] Means within a row with different superscripts differ (P<0.05). ***, P<0.001, **, P<0.01, *, P<0.05.
NS= Not significant. DHA = Daily Herbage allowance (kg DM/cow/day). Conc.= concentrate level (kg DM/cow/day).
SCM=Solids corrected milk yield. BCS = body condition score.

Table 14. Mean herbage and total dry matter intake values measured during Period I (20 Feb to 7 May) and Period II (8 May to 1 Aug).

DHA (kg/ cow/ day)	13kg			17kg					
Concentrate (kg/ cow/ day)	0	3	6	0	3	6	SED	DHA	Conc.
DM intakes (PI)									
Herbage intake (kg DM d^{-1})	13.6[a]	13.9[a]	12.5[a]	15.8[b]	15.5[b]	13.4[a]	0.76	***	**
Concentrate intake (kg DM d^{-1})	-	3	6	-	3	6			
†TDMI (kg DM d^{-1})	13.6[a]	16.9[b]	18.5[bd]	15.8[b]	18.5[bd]	19.4[cd]	0.76	***	***
DM intakes (PII)									
[1]Herbage intake (kg DM d^{-1})	17.8	18.2	18.3	17.5	18.9	17.2	0.86	NS	NS

[A-d] Means within a row with different superscripts differ (P<0.05). ***, P<0.001, **,P<0.01, *,P<0.05.
NS= Not significant. DHA = Daily Herbage allowance (kg DM/cow/day). Conc.= concentrate level (kg DM/cow/day).
† TDMI = Total dry matter intake. TDMI is calculated by assuming animals consumed all concentrate offered and adding the offered concentrate allowance to actual herbage intake which is calculated using the n-alkane technique.
[1]No concentrate was offered during P2.

CONCLUSIONS

Approximately 0.8 to 1.0t herbage per cow is required to offer the herd a diet of 80% grazed grass from February to mid April, with the remainder as concentrate. This represents an achievable target for grassland dairy farmers. In spring, it is possible to achieve high grass utilisation in line with the level of herbage offered. Experiment I found lower post-grazing sward heights with decreasing DHA, while offering concentrate supplementation resulted in higher post-grazing sward heights. The grazing residual results of the current study represent high grass utilisation. Bargo et al. (2003) stated that if the aim is to maximise pasture DMI of high producing dairy cows, management must ensure unrestricted pasture quality and quantity, which is only found in short periods during the spring. Unrestricted pasture conditions (i.e. high DHA) implies low grass utilisation (kg pasture DMI/kg DHA (>4cm) <62%; Christie et al., 2000). The current study shows that it is possible to achieve high utilisation levels without compromising dairy cow performance. During PI animals on the low DHA continually achieved higher sward utilisation rates than those offered a high DHA. Supplementing animals reduced grass utilisation, but to lower levels than that suggested by Stakelum (1986), when herbage allowance was measured from ground level. The extent of the reduction in pasture utilisation will depend on both DHA and supplementation level. For each 1 kg increase in concentrate offered, post-grazing sward height increased by 0.1 cm (range 0.08 - 0.12 cm). Kennedy et al. (2007a) found similar increases (mean 0.12 cm/kg concentrate) in post-grazing sward height. The post-grazing sward heights achieved in the current study are well within practical guidelines set out by Kennedy et al. (2007b). However grazing leniently in spring due to the allocation of high DHA in order to increase cow performance will result in sward quality deterioration in mid and late season and a sharp reduction in animal performance (Mayne et al., 1987; Hoogendoorn et al., 1992; Kennedy et al., 2007c). The possibilities of increasing DMI by increasing DHA are limited; Kennedy et al. (2007a) found very small increases in grass DMI when increasing DHA from 13 to 19kg DM/cow/day. Finding the correct balance between DHA and concentrate level is likely to be beneficial in terms of both an animal production response and grass utilisation perspective.

The current study supports the concept that spring calving dairy cows should get access to grass as early as possible in spring and that available grass should be budgeted until grass growth is sufficient to meet requirements for milk production. Milk production performance was increased when a high level of DHA (17kg grass DM) was offered. Supplementing with up to 6kg concentrate resulted in a linear increase in milk production. From an early spring feed budgeting scenario, when grass supply is in deficit, offering concentrate with an adequate level of DHA has the additive effects of maintaining the grazing rotation at the target length as well as ensuring that the herd is adequately fed. The current study shows that in spring both these objectives can be attained by offering 17kg DM DHA with 3kg DM/cow concentrate in the early lactation period however, in scenarios where grass supply is limited this study concludes that offering a low DHA (13kg DM/cow/d) and 6kg DM/cow concentrate will also support a high level of milk production.

Experiment III. Early lactation dairy cows: Development of equations to predict intake and milk performance at grazing

Introduction

Grazing pasture places a constraint on the cow and restricts her ability to achieve high intake levels which would ultimately limit the animals' capacity to achieve its potential milk yield (MY_{Pot}). The extent of this restriction is undefined in grazing dairy systems. Accurate estimation of these factors is essential to ensure adequate energy intake at grazing in early lactation and to identify losses in milk yield with grazing cows.

Estimating animal intake at grazing is more difficult than in confinement systems. Several models predicting and evaluating dry matter intake (DMI) in confined systems have been described. The availability of models predicting intake at grazing is less comprehensive with no data available for the early lactation period. The ability to accurately predict the intake capacity and milk yield of a grazing dairy cow is essential as production costs continue to increase.

Two early lactation grazing studies, (experiments I and II) had overlapping grazing treatments, examined over a similar time frame (<100DIM). The generation of such data allowed the opportunity to amalgamate the studies into a common dataset (n=335) and examine the relationship between feeding management at pasture and the early lactation performance of spring calving grazing dairy cows. The objective of this study was to examine the effect of parity and days in milk (DIM) on DMI and milk yield of grazing dairy cows in early lactation and to develop equations to predict DMI and milk yield for grass based systems of milk production (<100 DIM).

Materials and Methods

A database was assembled from the two grazing studies described above which were carried out during the spring of 2005 (YI; Experiment I) and 2006 (YII; Experiment II).

Y I. The experiment was a randomised block design with a 3 × 2 factorial arrangement of treatments. Sixty-six Holstein Friesian dairy cows were randomised across 6 treatments (n=11) consisting of 3 DHA (13, 16 and 19 kg DM/cow) and 2 concentrate levels (0 and 4 kg DM/cow).

Y II. The experiment was a randomised block design with a 2 × 3 factorial arrangement of treatments. Seventy-two Holstein-Friesian dairy cows were randomised across 6 treatments (n=12) consisting of 2 DHA (13 and 17 kg DM/cow) and 3 concentrate levels (0, 3 and 6kg DM/cow).

Dry matter intake was measured during two weeks in YI, at approximately 40 and 80 DIM and three weeks in YII, at approximately 35, 55 and 85 DIM. Individual milk yields (kg) were recorded daily. Milk composition was calculated once during each measurement period. Bodyweight (Winweigh software package; Tru-test Limited, Auckland, New Zealand) and BCS (Lowman et al., 1976) were recorded once during each measurement period. The variation in intake and milk yield across parity and DIM for grazing dairy cows in early lactation provides a database of high yielding cows to develop prediction equations for DMI and milk yield (Table 15).

Table 15. Description of the mean and range of cow and treatment variables in the developmental data used to evaluate prediction equations for DMI and milk yield.

Variable	Mean (n=335)	Max	Min	2005YI (n=130)	YII *(n=205)*
Herbage mass (>4cm; kg DM/ha)	1733	2826	1107	2190	1443
Area (m^2/cow per d)	98.2	158	50.6	79.9	108.8
Allowance (>4cm; kg DM/cow)	15.3	20.0	12.5	16.0	14.9
Days in milk	56	99	15	57	56
Milk yield actual (kg)	28.2	44.3	14.1	27.3	28.9
Fat %	3.69	5.73	2.07	3.70	3.68
Protein %	3.29	3.96	2.79	3.32	3.27
Lactose %	4.74	5.21	4.20	4.86	4.68
Bodyweight (kg)	509	696	374	509	509
Calving BCS	3.10	4.25	2.25	3.13	3.08
BCS	2.80	3.75	2.00	2.90	2.74
Grass DMI (kg/cow per d)	14.2	23.5	5.3	14.3	14.2
Total DMI (kg/cow per d)	16.8	26.5	8.5	16.3	17.1
UFL intake (cow/d)	17.7	28.7	8.8	17.3	17.9
UFL required (cow/d)	18.0	27.1	12.1	17.7	18.2
EB (UFL; cow/d)	-0.3	6.6	-7.5	-0.4	-0.3

BCS= body condition score; DMI= dry matter intake; UFL= Unité Fourragère Lait (Feed unit for milk)

Developmental Database

Parity. In YI thirty animals were in their first lactation (primiparous) and thirty-six animals were in their second or greater lactation (multiparous). In YII, twenty-four animals were primiparous and forty-eight animals were multiparous. A dataset containing 335 observations from 134 Holstein Friesian dairy cows was available for analyses. Observations were available on primiparous (n=130) and multiparous cows (n=205).

Days in milk. In YI animal data were collected at approximately 40 and 80 DIM. In YII animal data were collected at approximately 35, 55 and 85 DIM. Animal data was divided into two classes of DIM, those measurement periods which occurred less than 50 DIM (<50DIM; (n=148 records; mean 34.7 DIM; s.d. 9.35 days)) and those which occurred greater than 50 DIM (>50DIM; (n=187 records; mean 73.0 DIM; s.d. 13.03 days)).

Energy balance. The net energy value required for maintenance, growth and milk production (expressed as Unité Fourragère Lait (UFL)) was calculated for each animal at each measurement period according to equations described by Faverdin et al. (2007). A UFL requirement for growth is included for animals less than 40 months old, otherwise the UFL requirement for growth is 0. The fill unit value (FU) and the UFL of the feed were calculated using the OMD values of the offered herbage and concentrate (Baumont et al., 2007). Energy balance (EB) of each cow was calculated as the difference between estimated UFL requirement and estimated UFL intake.

INRA Equation comparison

The equations as described by Faverdin et al. (2007) were used to calculate MY_{Pot} and the intake capacity ($TDMI_{Theo}$) of each cow. The equations of Faverdin et al. (2007) have not previously been evaluated under grazing conditions in early lactation. The equations were tested and the precision of the predictions to examine the variability in DMI and MY_{Pot} between cows were statistically analysed.

Results

There was no interaction between parity and DIM on DMI (Table 16). Average GDMI and TDMI were lower for primiparous cows compared to multiparous cows. Average GDMI and TDMI was greater for animals >50 DIM (+1.8 kg) than animals <50 DIM (12.6 and 15.8 kg, respectively). There was no interaction between parity and DIM for MY_{Act}, milk concentration, BW and BCS. Parity ($P<0.001$) and DIM ($P<0.05$) had a significant effect on MY_{Act}. Primiparous cows had a similar level of milk yield regardless of DIM (<50 or >50 DIM). MY_{Act} of multiparous cows >50 DIM was 31.4 kg compared to 33.0 kg for multiparous cows <50 DIM. As feeding level increased in early lactation the difference between MY_{Act} and MY_{Pot} decreased, the effect of DHA on this relationship is shown clearly in Figure A.

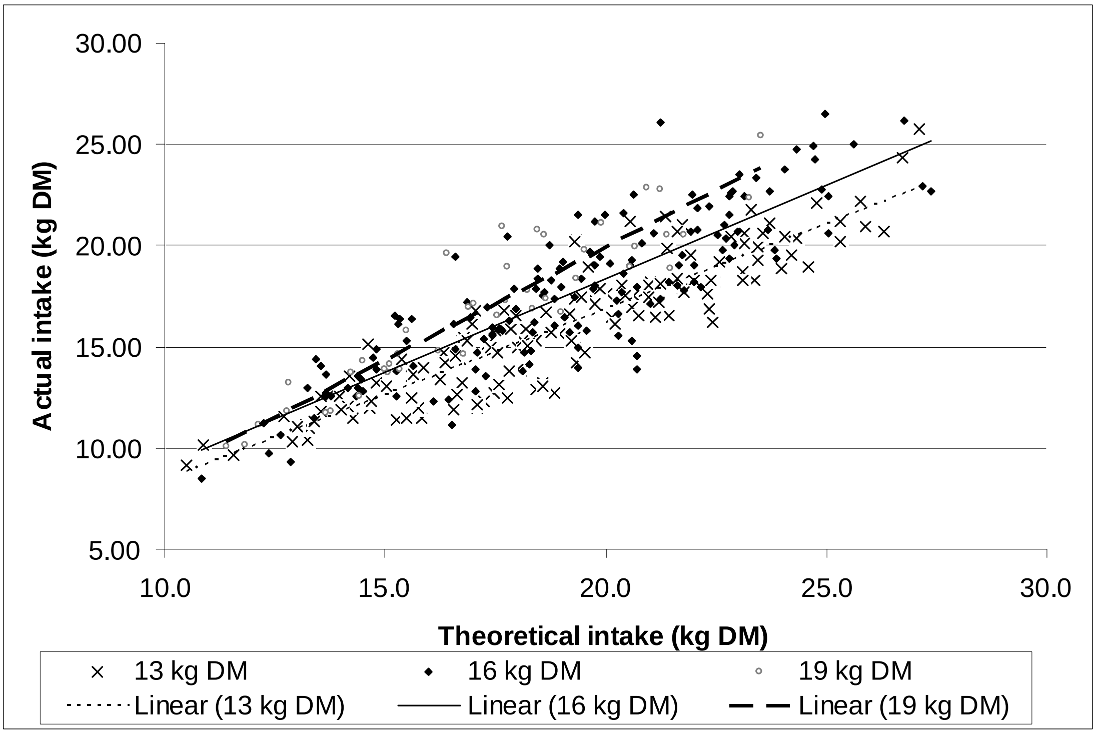

Figure A. Effect of daily herbage allowance on the actual total dry matter intake (TDMI) of grazing dairy cows compared to the Theoretical intake (Faverdin et al., 2007) of the cows.

Parity had no effect on milk fat content. Primiparous and multiparous cows <50 DIM had a similar milk fat content, this decreased (P<0.001) as DIM advanced. Milk fat content of multiparous cows >50 DIM was greater (+0.6 g/kg) than that of primiparous cows >50 DIM (34.7 g/kg). There was a positive effect of DIM and parity on milk protein content. Multiparous cows >50 DIM had the greatest milk protein content (33.6 g/kg) and primiparous cows <50 DIM the lowest (32.0 g/kg). Parity had a significant (P<0.001) effect on BW. There was a negative effect (P<0.01) of DIM and parity on BCS. Primiparous animals <50 DIM had the greatest BCS (2.96). All other groups had a similar BCS of 2.78. There was a significant effect of DHA (P<0.05) and concentrate level (P<0.001) on mean BW.

Table 16. Effect of parity and days in milk (DIM) on animal production and energy balance for dairy cows less than 100 DIM.

Parity	Primiparous		Multiparous				
Class of DIM[1]	<50	>50	<50	>50	SED	Parity	DIM
Milk yield actual (kg)	24.6[a]	24.1[a]	33.0[b]	31.4[c]	0.28	***	*
Fat g/kg	38.2[a]	34.7[b]	38.4[a]	35.3[b]	0.408	NS	***
Protein g/kg	32.0[a]	32.7[b]	33.0[b]	33.6[c]	0.147	***	**
Lactose g/kg	48.5[a]	48.1[a]	47.4[b]	47.1[b]	0.110	***	*
Bodyweight (kg)	444[a]	453[a]	552[b]	554[b]	3.3	***	NS
BCS	2.96[a]	2.80[b]	2.80[b]	2.74[b]	0.026	**	**
GDMI (kg)	10.1[a]	11.9[b]	15.0[c]	16.9[d]	0.26	***	***
TDMI (kg)	13.4[a]	15.2[b]	18.3[c]	20.1[d]	0.15	***	***
UFL intake	14.4[a]	15.9[b]	19.8[c]	20.8[d]	0.16	***	***
UFL required	16.8[a]	16.1[b]	20.2[c]	19.0[d]	0.14	***	***
EB	-2.4[a]	-0.2[b]	-0.4[b]	+1.8[c]	0.16	***	***

[a-d]Means within a row with different superscripts differ (P<0.05); *P<0.05; **P<0.01; ***P<0.001; NS = non significant; SED= SE of the difference. Class of DIM[1] = Cows were grouped depending on days in milk (DIM); less than 50 days in milk (<50) or greater than 50 days in milk (>50). BCS = Body condition score; UFL= Fill units.

Primiparous cows were in greater (P<0.001) negative EB during early lactation than multiparous cows. Cows <50 DIM had a negative EB (P<0.001) in comparison to cows >50 DIM which had a positive EB (Table 16). UFL intake of cows offered 13 kg DHA was lower than cows offered 16 kg or 19 kg DHA. UFL intake of unsupplemented cows was lower (14.9 UFL) in comparison to 18.2 UFL (3 kg) and 20.0 UFL (6 kg concentrate level).

Equations

Dry matter intake. The OMD content of the herbage and concentrate was 844 g/kg DM (s.d. 1.52) and 820 g/kg DM (s.d. 2.43), respectively. The UFL content per kg of herbage was 1.04 UFL (s.d. 0.050) and the concentrate was 1.08 UFL and 1.15 UFL in YI and YII, respectively. The equations which accounted for the greatest proportion of variation in GDMI (79 %) and TDMI (83 %) are described in Table 17.

Table 17. Linear regression model used to calculate DMI, milk yield and energy balance of dairy cows in early lactation (<100DIM)

	GDMI	**TDMI**	**Milk yield**	**EB**
N	335	335	335	335
R^2	0.792	0.828	0.862	0.507
RMSE	1.53	1.53	1.90	1.69
Intercept	-3.40	-3.40	-13.01	0.51
<u>Animal</u>				
Primiparous /Multiparous	-1.00 / +1.00	-1.00 / +1.00	-0.67 / +0.67	-1.17 / +1.17
Bodyweight	+0.02	+0.02	+0.01	+0.01
Body condition score	-1.15	-1.15	/	-1.68
Milk potential	+0.15	+0.15	+0.79	-0.16
Days in milk	+0.05	+0.05	-0.02	+0.06
<u>DHA & concentrate</u>				
DHA (kg DM; >4cm)	+0.31	+0.31	+0.45	+0.11
Concentrate (kg DM)	-0.36	+0.64	+0.92	+0.36

GDMI= grass dry matter intake; TDMI=total dry matter intake; EB= energy balance (calculated as UFL requirement minus UFL intake); DHA= daily herbage allowance. S.E.D= standard error of difference.

Primiparous cows had lower DMI compared to multiparous cows. Dry matter intake increased (P<0.001) by 2.0 kg per 100 kg BW. For each 1 unit increase in BCS, intake decreased (-1.15 kg). As DIM advanced, DMI increased (+ 0.05 kg DMI/ d). Each additional kg of herbage offered increased DMI (+ 0.31 kg/kg DHA offered). Concentrate supplementation decreased GDMI (-0.36 kg/kg concentrate offered) and increased TDMI (+0.64kg/kg concentrate offered).

Milk yield. The equation which accounted for the highest proportion of variation (86 %) in milk yield is presented in Table 17. Bodyweight, MY_{Pot}, DHA and concentrate level increased predicted milk yield. As DIM advanced the milk yield decreased (-0.02 kg/day). Parity had a significant effect on milk yield, this effect was negative for primiparous cows (-0.67 kg) and positive for multiparous cows (+0.67 kg).

Energy balance. The equation which accounted for the highest proportion of variation (51 %) in EB is presented in Table 17. This reduced to 45 % if parity was excluded from the model. The predicted EB of primiparous cows is lower (-1.17 UFL) than the EB of multiparous cows (+1.17 UFL). Advancing DIM increased EB (+0.06 UFL/d). As MY_{Pot} and BCS increased, EB decreased (-0.16 UFL/kg MY_{Pot} and -1.68 UFL/unit increase in BCS, respectively). Concentrate feeding and increasing DHA increased the EB of the cows.

Equation validation

The accuracy of prediction for intake, milk yield and EB increased when parity was included in the model. A strong linear relationship (Figure B) exists between $TDMI_{Act}$ and the theoretical TDMI ($TDMI_{Theo}$; Faverdin et al., 2007).

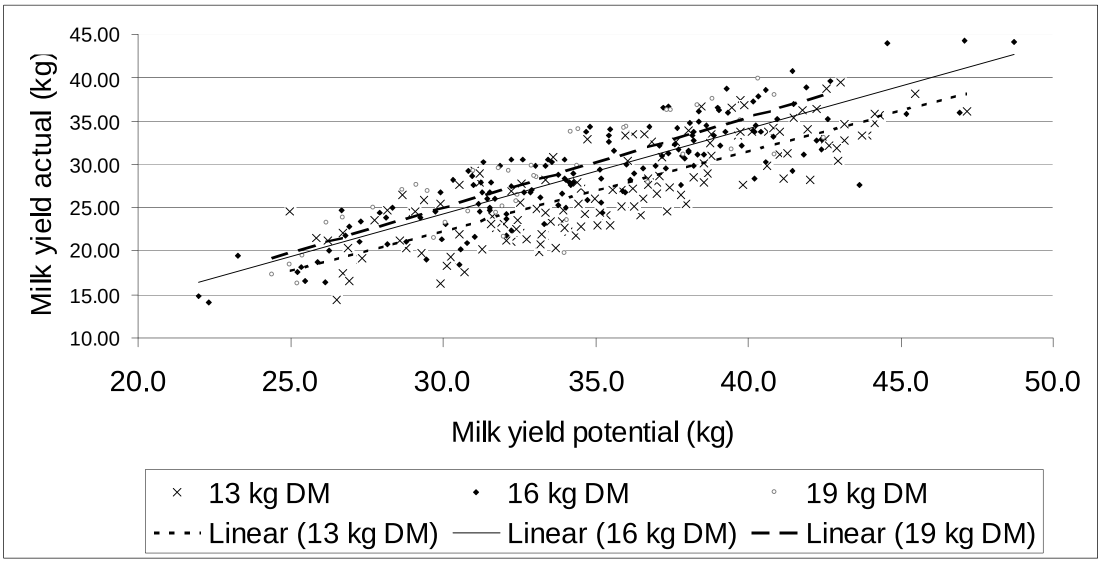

Figure B. Effect of daily herbage allowance on the actual milk yield of grazing dairy cows compared to the potential milk yield (Faverdin et al., 2007) of the cows.

Restrictions due to grazing management conditions resulted in $TDMI_{Act}$ being lower than $TDMI_{Theo}$. As level of DHA increased the difference between $TDMI_{Theo}$ and $TDMI_{Act}$ was reduced. The mean bias between $TDMI_{Act}$ and $TDMI_{Theo}$ was 52% (Table 18). The line bias was 2% and the random error bias was 46%.

Table 18. Statistical comparison of actual (n=335) and potential total dry matter intake and milk yield predictions (Faverdin et al., 2007)

	Kg/cow per day			R^2	MSPE	MPE	***Proportion of MSPE***		
	Actual	Predicted	Bias				Bias	Line	Random
Total DMI	16.81	18.83	-2.02	0.74	7.76	2.79	52.4	2.0	45.6
Milk yield	28.25	34.93	-6.68	0.67	55.98	7.48	79.7	0.2	20.0

DMI= dry matter intake. MSPE=Mean square prediction error; MPE=Mean prediction error

Conclusions

Parity and DIM had a significant effect on DMI and milk production of pasture-based spring calving dairy cows in the early lactation period. Results from this study indicate that as well as parity and DIM, the significant predictors of DM intake and milk production in the early lactation period for spring calving grazing dairy cows include MY_{Pot}, BW, BCS, DHA and concentrate level. When these factors are known, a large proportion of the variation in GDMI, TDMI and milk production can be accounted for in grazing dairy cows under conditions similar to those experienced in this study. This study allows a better understanding of the predictor variables influencing milk production of grazing dairy cows in early lactation, which will ultimately lead to further advances in milk production from pasture.

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4. Acknowledgements

The authors wish to thank Mr. M. Feeney, F. Flynn, J. Nash and Ms. C. Fleming and N. Galvin for their technical assistance and also all the Moorepark farm staff for their care of the experimental animals and assistance with measurements taken during the study.

5. Publications

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