End of Project Report

Studies of autumn calving suckler cows, bulls at pasture and winter grazing

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Most beef and dairy cows are spring calving leading to distinct seasonality of supply. Calving a proportion of the beef herd in the autumn would lead to a more uniform annual supply of cattle for slaughter and potentially increase the proportion of grazed grass in the diet of the suckler progeny. Autumn calving sucklers also facilitate the use of AI, which should enhance the product quality.

This project aimed to address the technical aspects of autumn calving sucklers, which differ from those of spring calvers. The currently available international energy models were evaluated for autumn calving lactating suckler cows using the type of cow typically found in Irish suckler herds (Experiment 1). The winter accommodation of the suckler cow and calf unit and its impact on cow reproductive performance was evaluated (Experiment 2).

The final part of the project evolved into component studies to determine the effect of supplementary feed on the performance of grazing bulls (Experiment 3), and the consequences of weanling cattle grazing pasture in winter as an alternative to housing them in winter (Experiments 4 to 7).

Experiment 1

Cow and calf performance of autumn calving suckler cows offered different energy allowances during the winter

Winter feeding is one of the most significant costs of autumn calving suckler cow beef production. Currently available models for predicting energy requirements of autumn calving suckler cows are based on crossbred British beef breeds (ARFC, 1993) or on pedigree French breeds (INRA, 1989). However, the vast majority of suckler cows in Ireland are continental (Charolais or Limousin) x Holstein Friesian that have different milk requirements and energy efficiency to the animals used for deriving the above models. The objectives of this experiment were (1) to evaluate the effect of energy allowance for continental cross autumn calving suckler cows on cow and calf performance in winter and subsequent performance at grass and (2) to determine which of the currently available models was the most appropriate for predicting the nutrient requirements of autumn calving suckler cows in Ireland.

Materials and methods

Thirty autumn calving cows and calves were assigned to one of three energy allowances during the winter. The energy allowances were designed from AFRC (1993) to provide adequate metabolisable energy (ME) for maintenance and 6, 9, or 12 kg milk daily. The target allowances were 0.52 MJ ME/kg of body weight$^{0.75}$ and 5.5 MJ/kg of milk. The mean duration of the experiment was 139 days until 4 April 2001 from when all cows and calves were grazed together until weaning at 241 days (30 July 2001).

The diets were formulated to have a similar ratio of forage to concentrate DM for all treatments of 0.54 of silage: 0.46 of concentrate. The silage offered had an ME of 10.27 MJ/kg DM and a DOMD of 685 g/kg. The formulation of the pelleted concentrate (g/kg) was barley 680, maize 176, soya bean meal 132 and molasses 12. The cows were housed in groups of five and individually offered their daily allowances. From the beginning of the experiment each group of five calves were offered a concentrate mix that was restricted to the *ad libitum* intake of the treatment with the lowest intake to ensure similar intake by all treatments. Three times during the winter, milk yields of the cows were determined using the weigh-suckle-weigh technique. At the same three times, faecal samples were collected twice daily from each cow for four consecutive days. One week after assignment to treatments and one week before turnout the total urea space of all cows was determined using the urea dilution technique and total body protein was calculated from live weight and urea space. Data were analysed using ANOVA.

Results

Increasing energy allowances increased ($P<0.001$) cow liveweight gain (Table 1). The relationship was linear ($P<0.001$) and best described by the equation: liveweight gain (kg/day) = 0.0118x – 1.245, (R^2 = 0.32), x = energy intake (MJ/day). The first energy increment increased ($P<0.01$) total body protein at turnout and winter body protein gain. However, there was no effect of the second energy increment on body protein gain or total body protein at turnout. The relationship between energy intake (MJ/day) and body protein gain (kg/day) was quadratic and best described by the equation: $y = -0.0055x^2 + 1.36x – 80.9$, ($R^2$ = 0.35). The first energy allowance increment also increase ($P<0.01$) milk yield, but there was no effect of the second increment. The relationship between energy intake (MJ/day) and mild yield (kg/day) was also quadratic and best described by the equation: $y = -0.0014x^2 + 0.3608x – 16.097$, ($R^2$ = 0.33). There was a linear relationship ($P<0.05$) between the energy allowance during the winter and summer grass intake with a 15 g/day reduction in grass intake per MJ of ME offered during the winter. Increasing energy allowance during the winter decreased ($P<0.001$) summer liveweight gain but increased weight ($P<0.01$) of cows at weaning. There was no significant effect of energy allowance to cows on calf liveweight gain during the winter or summer periods or on calf weaning weight.

Conclusion

Increasing energy allowance above a maintenance and 6 kg milk yield level, to autumn calving suckler cows, gave no benefit in calf weaning weight but increased cow liveweight gain. Autumn born calves can compensate for low milk yield of their dams by increasing grass and creep intake, which should be more efficient than increasing energy allowance to the cows.

References

AFRC (1993). Energy and protein requirements of ruminants. An advisory manual prepared by the AFRC technical committee on responses to nutrients.

INRA (1989) Ruminant Nutrition, recommended allowances and feed tables. R. Jarrige (ed.).

Table 1: Effect of energy allowance to autumn calving cows on cow and calf liveweight gain and cow milk yield.

	Energy allowance				
Response variable	**Low**	**Medium**	**High**	**s.e.**	**F test**
Cow winter liveweight gain (kg/day)	-0.17	0.14	0.32	0.075	***
Cow body protein gain (kg)	-0.68	2.85	2.93	0.758	**
Cow summer liveweight gain (kg/day)	0.70	0.43	0.32	0.106	***
Cow weight at weaning (kg)	677	683	695	8.5	**
Milk yield (kg/day)	6.07	7.30	7.43	0.314	**
Calf winter liveweight gain (kg/day)	0.95	1.01	1.00	0.033	NS
Calf summer liveweight gain (kg/day)	1.09	1.06	1.11	0.073	NS
Calf weaning weight (kg)	329	332	338	7.3	NS

Experiment 2

Effect of underfoot surface on expression of oestrus in autumn calving suckler cows

There is increasing interest in autumn calving of beef cow herds. This requires breeding during winter when animals are housed. While housing facilitates the use of AI it reduces the expression of oestrus and, consequently detection is more difficult. It was shown (French and Hickey, 2004) that cattle over-wintered on a so-called out-wintering pad (OWP) had superior liveweight gain and carcass gain compared with animals housed on conventional slatted floors. Prior to this study, there was no information on the suitability of the OWP for beef cows and their calves. New radio-telemetric head detection systems make possible the comprehensive evaluation of oestrous behaviour in beef cows indoors on slatted floors and outdoors on the OWP. The objective of this study was to monitor oestrous activity in beef cows on an OWP and compare this to cows on conventional slatted floors.

Materials and methods

In year 1, 32 dry cows and 26 lactating Charolais x Limousin beef cows were used. Within lactation status, cows were assigned randomly to one of two experimental treatments as follows: (i) indoor pen with a conventional concrete slatted floor at a spacing of 3.75 m^2/cow and calf (Slats) and (ii) OWP with an underfoot surface of wood chips at a spacing of 13.5 m^2/cow and calf. All cows were placed on their respective treatments 1 week before the study began. All cows were given free access to grass silage plus a daily ration of concentrate of 2 kg/cow. Calves were given free access to concentrates (creep feed).

In year 2, 28 lactating Charolais x Limousin cows were randomly assigned to either (i) slats, or (ii) and OWP, as described above.

At about 40 days after calving, a vasectomised teaser bull was placed with one pen of cows on each treatment. Detection of heat was carried out using the HeatWatch radio-telemetric system that involved attaching pressure sensitive transmitters to the tail head region of each cow. Milk and blood samples were taken three times per week, assayed for progesterone, and the resultant profiles were used to estimate the occurrence of ovulation and the incidence of silent heat.

Data were analysed by PROC GLM with the model including terms for treatment and lactation status, presence or absence of teaser bull where appropriate.

Results

In year 1, underfoot surface had a significant effect on the recorded duration of standing heat, number of mounts received, and on the incidence of false heats (Table 2). The duration of standing heat was shorter in lactating cows than in dry cows (5.3 ± 4.67 h v. 8.4 ± 6.34 h; P<0.01) whereas the number of mounts received (lactating: 11.8 (range 3-51) v dry: 13.0 (range 3-139); P>0.05) was similar.

In year 2, the presence of a teaser bull increased the number of mounts received by cows on both surfaces as well as increasing the recorded duration of heat (Table 3).

The associations between number of mounts and time from heat onset to 16 h after heat onset for cows on slats and OWP were described by decreasing exponential models: Slats: $y = 2.9677x^{-1.3394}$ (R^2 = 0.87) and OWP: $y = 7.1151x^{-1.22}8$ (R^2 = 0.77). The average number of mounts received for the first 12 hours of standing heat was greater for cows on the OWP than for cows on slats. For both surfaces there was a significant decline in mounting activity with interval from heat onset (P<0.05).

Table 2: Mean duration of standing heat (± SD), number of mounts received (range), and incidence of false heats.

Response variable	Slats	OWP	Significance
Duration of heat (h)*	5.6 ± 6.04	7.8 ± 5.81	P<0.05
Number of mounts*	7.6 (3-29)	18.2 (3-139)	P<0.05
% silent heats	57	22	P<0.05

*Excludes silent heats.

Table 3: Effect of teaser bull on duration of heat (h) and number of mounts (back transformed) received.

Surface	Bull	Mean ± SD duration of standing heat*	Mean number of mounts* (range)
Slats	Absent	3.7 ± 3.90	5.8 (3-13)
	Present	10.0 ± 3.80	16.1 (6-33)
OWP	Absent	6.9 ± 2.71	11.8 (5-19)
	Present	10.1 ± 4.22	22.0 (4-28)
Significance		P<0.05	P<0.05

*Does not include cows with silent heats.

Conclusion

Autumn calving cows on an OWP exhibit more mounting, have a longer recorded standing heat, and have fewer silent heats than cows on concrete slats. The presence of a teaser bull ameliorates the negative effect of the concrete slatted floor on heat-related activity. Mounting activity is greatest during early heat and declines with time.

References

French P. and Hickey M.C. (2004) Out-wintering pads (OWPs): effects on beef cattle production. Agricultural Research Forum, 1st and 2nd March, 2004, Tullamore, Co. Offaly, Ireland, p. 15.

Experiment 3

Effects of concentrate supplementation at pasture on carcass weight gain of continental bulls

The profitability of beef production is greatly influenced by the proportion of total carcass weight gain obtained from pasture relative to that obtained from indoor feeding. Systems which finish cattle off pasture using concentrates may be more competitive than those with a long indoor finishing period (French et al., 2001). The potential for male progeny to be produced as bulls that graze on pasture and supplement either with or without concentrate would be important for an autumn calving suckler herd in which the aim is to produce progeny before their second winter.

The objectives of this experiment were (1) to ascertain the performance of yearling bulls at pasture, (2) to determine the response of concentrate supplementation at pasture and (3) to compare performance at pasture with that of animals finished indoors.

Materials and methods

The experiment was conducted at Grange over 2 years (2004 and 2005). A randomised block design was applied using Charolais × Limousin and Limousin bulls starting at 11-14 months of age. The average initial live weight was 405 (s.e. 29) kg in 2004 and 478 (s.e. 52) kg in 2005. Animals were blocked on breed and initial live weight. Six dietary treatments were assigned at random to animals in each block in 2004 while a seventh treatment was applied in 2005. There were 20 animals per treatment.

T1. Pasture only
T2. Pasture plus 25% of the diet as concentrates (3-4 kg/head/day)
T3. Pasture plus 50% of the diet as concentrates (6-8 kg/head/day)
T4. Pasture only in the first half of the grazing season ('spring') and then concentrates *ad libitum* indoors in the second half of the grazing season ('autumn')
T5. Pasture plus 25% of the diet as concentrates (3-4 kg/head/day) in spring and then concentrates *ad libitum* indoors in autumn
T6. Concentrates *ad libitum* indoors
T7. Concentrates *ad libitum* on out-wintering pads (2005 only)

In 2004, 'spring' was 24 Apr. to 31 Aug. (129 days) and 'autumn' was 1 Sep. to 24 Nov. (84 days). In 2005, 'spring' was 4 May to 10 Aug. (98 days) and 'autumn' was 11 Aug. to 16 Nov. (97 days).

Pasture was mainly *Lolium perenne* with average DMD and crude protein levels of 778 g/kg DM and 163 g/kg DM, respectively. Animals were given fresh pasture every day in 2004 and every second day in 2005. The average daily pasture allowance (measured above 4 cm) was about 2.5 kg DM per 100 kg of live weight for all grazing treatments.

Animals given concentrates *ad libitum* were also given grass silage as roughage. The concentrate was 87.0% barley, 6.8% soyabean, 4.8% sugarcane molasses and 1.5% minerals. The DM content was 83.0%.

At the end of spring, animals were re-blocked on most recent live weight and breed within groups and two slaughter dates were assigned at random to animals in each block. Ten animals per treatment were slaughtered and carcass weight was measured at the end of spring and autumn. Carcass weight at the start of spring was estimated as 0.55 of starting live weight. Carcass weight gain was estimated as the difference between start and final carcass weight for spring and autumn.

Data were analysed using analysis of variance and the PROC GLM procedure in the statistical package SAS. Significantly different (α=0.05) treatment means were separated using Tukey's test.

Results

There were year × diet interactions ($P<0.05$) for total annual carcass weight gain in spring but not autumn (Table 4). In each of the four periods, carcass weight gain increased ($P<0.05$) with increasing levels of concentrate supplementation at pasture. However, concentrate conversion ratios (kg concentrate/kg carcass weight gain) were nearly doubled when the level of concentrate offered at pasture was increased from 3-4 to 6-8 kg/head per day.

Total carcass weight gain was greatest for animals on concentrates *ad libitum* indoors in spring and autumn (T6). This was followed closely by animals offered 3-4 kg/head per day of concentrates at pasture in spring and then concentrates *ad libitum* indoors in autumn (T5). Animals that received pasture only in spring and then concentrates *ad libitum* in autumn (T4) had a similar total carcass weight gains to the other *ad libitum* concentrate treatments (T5-T7) in 2005 but not in 2004. After growing at the slowest rate in spring, the animals in T4 had the highest rate of carcass weight gain in autumn. They were also more efficient in terms of kg of concentrates consumed per kg of carcass weight gain compared with the other *ad libitum* concentrate treatments in autumn.

There were no significant differences in total carcass weight gain between animals that received concentrates *ad libitum* on outdoor wood chip pads (T7) and those offered the same diet indoors (T6). Daily intake of concentrates was similar across all *ad libitum* concentrate treatments (T4-T7) at about 10-12 kg/head per day.

Table 4: Estimated carcass weight gain of bulls offered different dietary treatments.

	2004			**2005**		
Treatment	**Spring kg/day**	**Autumn kg/day**	**Total kg**	**Spring kg/day**	**Autumn kg/day**	**Total kg**
T1	0.31_{d}	0.29_{d}	65_{d}	0.32_{d}	0.15_{c}	47_{c}
T2	0.55_{c}	0.40_{d}	104_{c}	0.64_{bcd}	0.57_{b}	118_{b}
T3	0.68_{b}	0.57_{cd}	135_{b}	0.73_{abc}	0.54_{bc}	123_{b}
T4	0.30_{d}	1.16_{a}	136_{b}	0.52_{cd}	1.19_{a}	166_{a}
T5	0.64_{bc}	0.98_{ab}	165_{a}	0.91_{ab}	0.82_{ab}	169_{a}
T6	0.89_{a}	0.76_{bc}	178_{a}	0.94_{ab}	0.89_{ab}	178_{a}
T7	-	-	-	1.06_{a}	0.63_{b}	164_{a}
P	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SED	0.035	0.107	8.3	0.115	0.126	12.1

Means within columns with different subscripts are significantly different α=0.05.

Conclusion

Carcass weight gain increased with concentrate supplementation at pasture in both halves of the grazing season but with diminishing returns per unit of concentrate offered. Feeding bulls at pasture for the first half of the grazing season and then offering concentrates *ad libitum* either indoors or on an out-wintering pad appeared to be an effective method of concentrate supplementation.

References

French P., O'Riordan E.G., Moloney A.P., O'Kiely P. and Caffrey P.J. (2001). Irish Journal of Agricultural and Food Research 40: 33-44.

Experiment 4

Effect of pasture allowance in winter on liveweight gain of weanling bulls in winter and in the following spring and summer

Perennial pastures form the main source of nutrients for beef cattle in Ireland. However, pasture growth rate varies over the year and in winter insufficient pasture is available to meet the total feed demand of a calf-to-beef herd. A common solution is to conserve surplus spring/summer pasture as silage or hay to be fed back to the herd in winter.

Potentially, a means of reducing the requirement for conserved feeds and housing in spring/autumn calving herds is for the spring-born weanling cattle to graze in winter pasture which has accumulated since the previous autumn. A wide body of information exists about the growth and management of pastures for grazing in winter. However, much less information is available on the management of weanlings in winter to meet their feed requirement while minimising damage to the continued growth of the sward.

During their first winter, a modest target liveweight gain in weanlings (e.g. 0.4-0.6 kg/day) is often desired to minimise feed requirements and exploit compensatory liveweight gain in the following spring. The amount and quality of grass silage and concentrates that weanlings require to meet these production targets is generally well known. However, the feed requirements of weanlings grazing pasture in winter is less understood. A good starting point would be to record their performance over a range of herbage allowances and in relation to weanlings feeding on supplements (e.g. grass silage) under similar climatic conditions in winter.

The objective of the experiment was to quantify the effect of pasture allowance and grass silage in winter on the liveweight gain of weanling bulls in winter and in the following spring and summer.

Materials and methods

The experiment was conducted at Grange. Treatments were three pasture allowances (3, 5 and 7 kg DM/head per day) and *ad libitum* grass silage from 30 November 2004 to 6 April 2005 (‘winter’). There were two replicate groups per treatment giving eight groups in total.

The animals were 56 spring-born continental weanling bulls (Charolais × Limousin) sourced from farms through a livestock mart in late October 2004. On arrival to Grange each animal was dosed for the prevention of diseases and parasites and then grazed on pasture as a single group for about a month. On 30 November, the animals were blocked into eight weight classes and from each weight class one animal was assigned randomly to each group.

The pasture grazed in winter was divided into six paddocks. In the previous grazing season the paddocks were rotationally grazed by cattle and the final grazing cycle was from mid September to late October. After the final grazing, each paddock was fenced into six lanes of three widths to facilitate the three pasture allowances. Drinking water was supplied in portable troughs. Each group was given a new area of pasture each day and didn’t have access to pasture grazed on previous days using a portable electric fence erected across the six lanes both in front and behind the grazing groups. The portable electric fences enable the area of pasture given each day to be adjusted to given each day was adjusted each week depending on the pre-grazing pasture mass.

Pre-grazing pasture mass was measured each week by cutting three 0.55 m × 5 m strips per grazing group to approximately 4 cm above ground level using a lawn mower with a rotary blade. The fresh herbage was weighed and a 200 g sub-sample was washed (if necessary), dried at 40°C for 48 h and weighed. The average pre-grazing pasture mass in winter was 1870 kg DM/ha. A sample (about 100 g) of pre-grazing pasture was collected each week in winter to determine the botanical composition. It was separated into leaf plus pseudostem, dead material, weeds and white clover and dried at 98^{o}C for 16 h. The average pre-grazing pasture was 55% green leaf, 38% dead material, 2% weeds and less than 1% white clover.

The two groups assigned to grass silage were accommodated in two pens (7.3 x 17.1 m each) on an out-wintering pad exposed to the prevailing weather. Each pen was bedded with wood chips and supplied with drinking water. Liquid effluent drained into a storage tank and soiled wood chips were replaced about every 2 months. Grass silage was offered daily into a feed trough in each pen.

Each group was supplemented with meal at 2 kg/head per day. The meal was 87% barley, 6.75% soya, 4.75% sugar (cane) molasses and 1.5% calcium carbonate and sodium chloride (John Flynn, Mullingar, Ireland).

Pasture, silage and concentrate samples were taken in winter for chemical analysis. The average DMD and crude protein content of the feeds offered in winter was 719 and 244 g/kg DM for the pasture, 705 and 21 g/kg DM for the grass silage and 814 and 123 g/kg DM for the concentrate, respectively. The average DM content of the concentrate was 80.1 g/kg of fresh material. In spring and summer, the average DMD and crude protein content of the pasture was 752 and 201 g/kg DM, respectively.

At the end of winter each group was moved to another area of grassland where they rotationally grazed on pasture in their original groups. Each group was moved to a new paddock every 3 to 5 days and grazed to the same target sward height of about 6-7 cm. Each group was supplemented with meal (described above) at 3 kg/head per day in summer for 76 days before slaughter on 22 August 2005 at a commercial meat processing factory. The average pre- and post-grazing pasture masses were 2160 and 620 kg DM/ha, respectively.

Each animal was weighed at the start and end of winter and prior to slaughter to determine liveweight gain. Carcass weight and conformation (1 = poor to 5 = very good) were measured at the factory. Post-grazing pasture mass in winter was estimated once a week by cutting three 0.55 m × 10 m strips per group using a rotary lawn mower to 4 cm. Apparent pasture intake was the difference between pre- and post-grazing pasture mass per group. Apparent silage intake was estimated by disappearance over a single 8 day period.

Impacts of treading to areas grazed on at least two grazing dates for every week grazed during three periods in December, January-February, and early March, were assessed on 28 and 29 April 2005. One 1 m^2 quadrat, sub-divided into 100 squares, was placed in the centre of each grazed area, and any square with less than 50% of pasture cover was deemed as bare ground to estimate percentage of the pasture area as bare ground. The effect of pasture allowance in winter on spring pasture yield was estimated on 31 May 2005 from areas that had been grazed on 8, 10 and 12 February. Pasture yield was estimated by taking 1.5 m x 5 m cuts harvested to 5 cm above ground level using a Haldrup forage harvester.

Weather data were recorded daily at Grange (Table 5). The difference between daily rainfall and potential evapo-transpiration (PET) was expressed as the hydrological balance (Table 6). The average rainfall and hydrological balance were higher in January-February than December and March, with the lowest hydrological balance in March when rainfall was lower than in the other months and PET was higher.

Table 5: Weather data for each month from 1 December 2004 to 31 August 2005 and long-term data (presented in brackets) at Grange.

Month	Rainfall (mm)	Max. air temp. (°C)	Min. air temp. (°C)	Mean air temp. (°C)	Mean soil temp. (°C)	Sunshine (h)
Dec.	57 (84)	9.4 (8.3)	3.2 (2.8)	6.0 (5.0)	5.2 (4.2)	32 (38)
Jan.	105 (83)	9.1 (7.8)	3.5 (2.0)	6.1 (4.2)	5.0 (3.4)	43 (49)
Feb.	42 (62)	7.6 (7.6)	1.6 (1.7)	3.9 (4.3)	3.7 (3.5)	71 (65)
Mar.	50 (65)	11.1 (9.6)	4.5 (2.5)	7.3 (6.2)	6.4 (5.0)	86 (97)
Apr.	68 (61)	12.0 (11.8)	4.4 (3.2)	8.9 (8.3)	8.5 (7.7)	132 (140)
May	89 (61)	14.7 (14.7)	5.9 (5.9)	11.5 (11.3)	11.6 (11.5)	188 (173)
June	25 (66)	19.5 (17.3)	10.8 (8.8)	15.3 (13.6)	16.5 (14.5)	129 (144)
July	91 (56)	19.2 (19.1)	11.7 (10.6)	15.8 (15.2)	17.3 (15.9)	91 (133)
Aug.	34 (71)	19.4 (18.8)	11.0 (10.4)	15.7 (14.9)	15.7 (14.9)	141 (139)

Table 6: Mean rainfall, potential evapo-transpiration (PET) and hydrological balance (HB) in winter (Dec. 2004 – Mar. 2005) at Grange.

	Dec.	Jan./Feb.	Mar.
Rainfall (mm/day)	1.8	2.5	2.05
PET (mm/day)	0.3	0.5	1.7
HB (mm/day)	1.5	2.0	0.35

Data were analysed in SAS using a mixed effects model: $Y_{ij} = \mu + T_i + b_j + \varepsilon_{ij}$, where Y_{ij} is the response variable of an experimental unit with the ith treatment in the jth block, μ is the overall mean, T_i is the fixed effect of treatment, b_j is the random effect of block, and ε_{ij} is the error terms. The ε_{ij} terms are assumed to be independent Normal deviates with mean zero and constant variance σ2. The bj effects are assumed to be independent normally distributed with mean zero and variance σb2. The terms, εij and bj are assumed to be independent of each other. Means significantly different (α=0.05) from each other were separated using the Tukey-Kramer multiple range test in SAS (pdiff adjust = tukey). Outliers defined as being two or more standard deviations away from overall mean, were removed before analysis.

Results

There was an effect (P<0.01) of pasture allowance and grass silage on liveweight gain in winter (Table 7). The liveweight gain for pasture at 7 kg DM/head per day was higher than for pasture at 3 and 5 kg DM/head per day and grass silage, which were similar. Live weight at the end of winter (6 April) for the highest pasture allowance was 35 kg greater than for the other three treatments.

Liveweight gain in the following grazing season was affected (P<0.01) by pasture allowance and grass silage in winter (Table 7). Liveweight gain for pasture at 3 kg DM/head per day and grass silage was about 0.25 kg/day higher than for pasture at 5 and 7 kg DM/head per day. There was no effect of winter treatment on final live weight, carcass weight and carcass conformation (Table 8).

Table 7: Effect of pasture allowance and grass silage in winter on liveweight gain of continental bulls in winter and in the following spring and summer.

Treatment	**LW 1 Dec. (kg)**	**LW 6 Apr. (kg)**	**LW 22 Aug. (kg)**	**LWG winter (kg/day)**	**LWG spring (before meal) (kg/day)**	**LWG summer (with meal) (kg/day)**
3 kg/d	344	6 Apr.	594	0.63^{b}	1.70	1.00^{ab}
5 kg/d	337	425	574	0.74^{ab}	1.45	0.82^{b}
7 kg/d	343	431	605	0.89^{a}	1.41	0.82^{b}
Silage	345	460	616	0.85^{ab}	1.61	1.06^{a}
P value	NS	443	NS	<0.05	NS	<0.01
SED	16.7	NS	27.3	0.087	0.141	0.080

NS = not significant. Within columns, means with same or no superscript are not significantly different (α=0.05).

Table 8: Effect of pasture allowance and grass silage in winter on carcass weight and conformation of bulls.

Treatment	Carcass weight (kg)	Conformation
3 kg/d	303	2.9
5 kg/d	302	2.8
7 kg/d	319	3.1
Silage	317	2.9
P value	NS	NS
SED	17.6	0.19

Pasture allowance in winter affected apparent pasture intake and post-grazing pasture mass (Table 9). The pasture intake for pasture at 7 kg DM/head per day was greater than for pasture at 3 and 5 kg DM/head per day (P<0.01). The average apparent intake of grass silage (6.3 kg DM/head per day) was greater (P<0.05) than the apparent pasture intake for any of the grazing treatments. The average post-grazing pasture mass was 370-400 kg DM/ha for pasture at 5 and 7 kg DM/head per day compared with 260 kg DM/ha (P<0.01) for pasture at 3 kg DM/head per day.

Table 9: Effect of pasture allowance in winter on post-grazing pasture mass and apparent pasture intake by weanling bulls.

Pasture allowance	Post-grazing pasture mass (kg DM/ha)	Pasture intake (kg DM/head per day)
3 kg/d	260^{b}	3.3^{b}
5 kg/d	370^{a}	3.8^{b}
7 kg/d	400^{a}	4.7^{a}
P value	<0.01	<0.05
SED	6.6	0.87

NS = not significant. Within columns, means with the same or no superscript are not significantly different (α=0.05).

There was no significant difference between the three pasture allowances in ‘treading damage’, with average bare ground results of 24.1, 18.5 and 17.3% of post-grazing area for 3, 5 and 7 kg DM/head per day, respectively. However, the average bare ground percentages differed (P<0.01) between grazing periods in winter with the greatest bare ground observed after swards were grazed in January-February (34%), followed by December (22.6%) and the lowest in March (3.3%).

Pasture yield in spring was not significantly affected by pasture allowance in winter. Average yields were 5.8, 6.2 and 5.5 t DM/ha for pasture allowances of 3, 5 and 7 kg DM/head per day, respectively.

Conclusions

- Increasing pasture allowance from 3 to 7 kg DM/head per day in winter resulted in an increase in liveweight gain in weanling bulls.
- Pasture allowance affected liveweight gain by affecting pasture intake.
- Increased pasture allowance decreased pasture utilisation, which could have a negative impact on pasture yield and quality in spring.
- Pasture allowances at 5 and 7 kg DM/head per day resulted in similar or better liveweight gains compared to grass silage.
- Any effects of diet in winter were largely eliminated in the following pasture growth season as all treatments ended with similar overall animal performance.
- Impacts of treading by weanlings on pastures grazed in winter were more closely associated to soil moisture (hydrological balance) than herbage allowance.

Experiment 5

Effect of grazing residence time in winter on liveweight gain and pasture intake by weanling bulls

The effects of pasture allowance were observed in Experiment 4 where weanlings were moved to a new 'break' of pasture every day. This system aimed to ration the limited supply of pasture throughout the winter, increase the duration of pasture regrowth after grazing and reduce impacts of treading to a small area. In Ireland, however, part-time beef farming is increasing and less labour is likely to be spent on feeding animals during the winter. Potentially, a means of reducing labour inputs in a winter grazing system would be to move animals to new pasture less frequently but at a fixed mean daily pasture allowance. However, increasing the length of time animals remain in a given area of pasture (grazing residence time) may also have an impact on sward regrowth due to prolonged treading, reduced regrowth interval and could influence daily herbage intake and so affect animal performance.

Therefore, the objective of this experiment was to examine the effects of grazing residence time on liveweight gain and pasture intake of weanling bulls rotationally stocked on pasture without supplementation during winter. A second objective was to examine the association between values of daily herbage intake estimated using a disappearance method and an n-alkane marker method.

Materials and methods

A field experiment was conducted from 30 November 2005 to 17 January 2006 (48 days) at Grange. A randomised block design was laid out in three blocks. Blocks were adjacent paddocks of permanent pasture and different area (4.36, 3.68 and 5.48 ha), pasture mass (1500-2000 kg DM/ha) and botanical composition. The main plant species present in the swards were perennial ryegrass, meadow grasses and a small proportion (<0.05) of white clover. Each block was divided into four plots of equal area (1.09, 0.92 and 1.37 ha for blocks 1, 2 and 3, respectively) using permanent electric fences to give a total of 12 plots. Four grazing residence times of 1, 2, 4 and 8 days were assigned at random to the four plots within each block. The grazing residence times were imposed in each of 48, 24, 12, or six subplots or 'breaks' per plot, respectively. The area of each break was the same within plots but differed between plots (Table 10).

Table 10: Mean (standard deviation) plot area, number and area of breaks (subplots) per plot, and number of animals per group for 1, 2, 4 and 8 days per break.

Grazing residence time (days) per break	Plot area (ha)	Number of breaks	Break area (m^2)	Number of weanlings per group
1	1.13 (0.227)	48	235 (47.3)	4.3 (0.58)
2	1.13 (0.227)	24	469 (94.7)	4.3 (0.58)
4	1.13 (0.227)	12	939 (189.4)	4.3 (0.58)
8	1.13 (0.227)	6	1878 (378.7)	4.3 (0.58)

Sixty spring-born, weaning Charolais crossbred bulls were sourced from farms through a livestock mart in early November 2005; mean (SD) age was 8 (0.9) months and live weight was 292 (28.0) kg. Animals were stratified into five weight blocks (light to heavy) with 12 animals per block; the 12 plots were assigned at random to animals within each weight block giving five animals in each group and each group had a similar mean live weight. The experiment used five animals per plot in blocks 1 and 2, and four animals per plot in block 3 to achieve a similar target pasture allowance of 9 kg DM/head per day (measured to mean 1.5 cm above ground level) across the 12 plots.

Each plot was divided evenly into six 8-day grazing periods. In each grazing period, eight, four, two, or one break(s) was grazed for 1, 2, 4 or 8 days, respectively (Figure 1). Animals were allowed to adapt to the grazing regimes during the first two grazing periods (day 1 to 16 of the study) before detailed measurements of daily pasture intake were carried out during the third grazing period (day 17 to 24).

The breaks were individually fenced prior to grazing using portable single-wire electric fences connected to the permanent electric fences around each plot. Each break within each plot was grazed in sequence by a single group. After a break was grazed for the assigned residence time the group was moved to the next adjacent break. The sequence by which each break was grazed was alternated across the 12 plots with the aim of reducing any interactions between the groups of weanlings. All animals had free access to water supplied using portable water troughs.

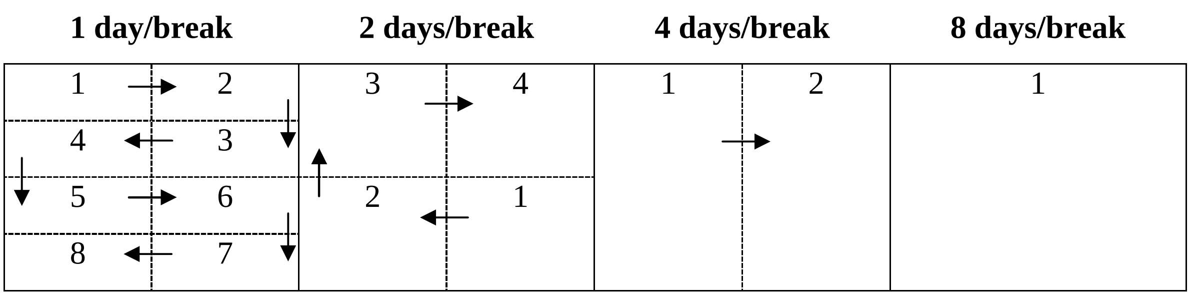

Figure 1: A diagrammatic example of the sequence which 8, 4, 2, or 1 break(s) was grazed for residence times of 1, 2, 4 and 8 days, respectively, over one of the six 8-day grazing periods during the study (48 days) at Grange.

Each animal was weighed at the start and end of the experiment to determine liveweight gain. Apparent pasture intake was estimated as the disappearance of pasture mass over the six grazing periods. Immediately before grazing each break, pasture mass was estimated using a rising plate meter (Filip's Folding Plate Pasture Meter, Jenquip, Fielding, New Zealand). On each occasion, 30, 60, 120 or 240 meter readings were taken within each break with grazing residence times of 1, 2, 4 and 8 days, respectively. Pasture mass was calculated from the average plate meter reading for each break using a plate meter calibration equation. After the allocated grazing residence time, the above steps were repeated to determine post-grazing pasture mass. The rising plate meter was calibrated against pasture mass at the start of the experiment (winter) and in March (early spring).

Daily patterns of pasture mass, pasture allowance and apparent pasture intake were estimated for each grazing residence time throughout the third 8-day grazing period from 16 – 24 December (days 17 to 24 of the experiment). As for all grazing periods, the third grazing period involved the grazing of 8, 4, 2, or 1 breaks for their complete residence times of 1, 2, 4 and 8 days, respectively. The same procedures as above were followed to estimate apparent pasture intake with the exception that the steps were repeated at 24 h intervals.

Pasture intake was also estimated using an n-alkane marker method (Dove and Mayes, 1991) at the same time as apparent pasture intake was estimated throughout the third 8 day grazing period from 16 – 24 December. Intra-ruminal controlled-release capsules (type MCM, Captec Ltd, Auckland, New Zealand) designed for cattle of 300-650 kg live weight were used. The capsules release the alkanes n-doctriacontane (C_{32}) and n-hexaptriacontane (C_{36}) within the rumen at a constant rate for a period of approximately 20 days. The capsules are routinely tested by the manufacturer who checks the disappearance of the matrix length over time in rumen fistulated cattle grazing perennial ryegrass / white clover pasture. The expected mean release rates of alkanes documented by the manufacturer for the batch of capsules used in this study were 328.9 and 323.9 mg/day for C_{32} and C_{36}, respectively. Three animals in each group were dosed with a capsule at 08:00-10:00 h on 9 December (day 10) using an applicator specifically designed for MCM capsules. After dosing, 8 days were allowed for the alkanes to establish equilibrium in the intestinal tract before faecal sampling.

Faeces samples from the dosed animals were collected daily at 08:00-10:00 h from 17 – 25 December (days 18 to 25). The faeces samples were collected from the ground using the following procedure. The dosed animals were made to graze separately from the other animals in each break using additional single-wire temporary electric fences. The fences were positioned carefully so that stocking density (number of animals per unit area) remained the same across each break. On days when animals were allowed to continue to graze the same break, all of the dung pats deposited by the dosed animals were sprayed with a coloured marker after sampling. This procedure ensured the sampling of fresh faeces each day from the dosed animals only.

Pasture samples were collected daily at 08:00-10:00 h from 16 – 24 December (days 17 to 24). The lead time of 24 h relative to faecal sampling was assumed sufficient to allow for passage through the gastro-intestinal tract. For each sampling day, strips (about 0.10 m x 0.30 m) of pasture were cut using hand shears at random within the area of each subplot that would be grazed by the dosed animals. The strips of pasture were cut from the top third of the sward so that they would be representative of pasture eaten. The fresh samples from each subplot were thoroughly mixed and three representative sub-samples were taken for analyses of 1) n-alkane concentration, 2) botanical composition and 3) nutritive value.

Dry matter and ash concentrations of each faeces and herbage sample were determined in parallel to the analysis of alkane concentrations. Duplicate samples of about 1 g of dried, ground material were dried at 105°C for 4 h for DM determination, and incinerated in a muffle furnace at 550°C for 5 h for ash determination.

The analysis of alkanes from faeces and herbage samples was undertaken by direct saponification following the methods described by Mayes et al. (1986), Dove (1992) and Elwert et al. (2004) with minor modifications as described in detail below.

Saponification: Duplicate dried, ground samples (~0.5 g of faeces and ~1.5 g of herbage) were weighed into borosilicate glass culture tubes (120 mm × 20 mm for faeces and 150 mm × 20 mm for herbage) fitted with PTFE-lined screw caps. A solution of n-tetratriacontane (C_{34}) dissolved in n-undecane (C_{11}) (0.8 mg/g) was added by weight (0.2499 g) to each tube as an internal standard, followed by 7 ml (faeces) or 10 ml (herbage) ethanolic KOH (1 M). The tubes were capped and incubated for 16 h at 90°C in a dry-block heater (Techne DB-3, Techne Ltd., Duxford, Cambridge, UK). During the incubation the samples were repeatedly shaken vigorously to ensure complete saponification.

Extraction: After partial cooling (to 50-60°C), a hot extraction was performed where 7 ml (faeces) or 10 ml (herbage) heptane was added and the tube was capped and shaken gently. Water (2 ml for faeces, 3 ml for herbage) was added and the tube was recapped and shaken vigorously. After separation of the aqueous and solvent layers, the solvent (top) layer was transferred to a scintillation vial using a Pasteur pipette. Another 7 ml (faeces) or 10 ml (herbage) heptane was added to the original tube and the extraction repeated, adding the solvent layer to the respective scintillation vial from the first extraction step.

Purification: In order to separate the alkanes from pigments, sterols and alcohols, the scintillation vials were placed on a dry-block heater fitted with a sample concentrator blowing air into the vials and evaporated to dryness at about 80°C. The extracts were re-dissolved in 1.5 ml heptane, with warming, and pipetted onto small columns containing silica-gel (Keiselgel 60, mesh size 70-230 μm) with a bed volume of 5 ml. The hydrocarbons were eluted into scintillation vials by the addition of 12 ml heptane to the column. After the elution of hydrocarbons from the columns had stopped, the hydrocarbons were evaporated to dryness, re-dissolved in 0.4 ml heptane and, after warming, transferred into auto-sampler vials for gas chromatography.

Gas chromatographic analysis: Alkane analysis was performed using a gas chromatograph (Philips PU4500) equipped with an auto-sampler unit (Philips PU4700), a temperature-programmable injector with a Supelco capillary injection adaptor for packed columns and a flame ioniser detector. Alkane extracts were injected on a 30-m bore glass capillary column, bonded phase type SPB-1 with 0.75 mm outer diameter and 1 μm film thickness (Supelco, Poole, Dorset, UK). Helium was used as a carrier gas at a constant flow of 15 ml/min. The injection volume was 0.8 μl. A temperature programme was used for the column (2 min at 210°C; 6°C/min to 285°C; 3 min at 285°C). The injector and detector were maintained at 340°C and N was used as the make-up gas at 40 ml/min. Two injections per sample replicate were run.

The calculation of chromatogram peak area values was performed by a data collection system which used a Spectra-Physics Chromjet integrator (dual-channel) linked to a 486 PC via a LABNET system and Spectra-Physics WINNER software.

The gas chromatographic method was calibrated with a standard solution that contained a mixture of synthetic alkanes (from C_{24} to C_{36}) with concentrations similar to those found in extracts. The standard solution was injected after every 15-20 sample vials in order to monitor the gas chromatograph response.

For each sample, chromatogram peak identities and peak areas were exported to an Excel (Microsoft Excel 2003) spreadsheet which held all samples from an extraction run.

During the extraction process a temperature-based discrimination of longer-chain alkanes might occur (Oliván and Osoro, 1999). Thus, during the sample analysis, the peak area of C_{34} in the standard solution was compared with peak areas of other synthetic alkanes in the mixture and the peak areas of alkanes in all faeces and herbage samples were corrected for any observed discrimination. This correction assumed a linear discrimination depending upon the chain length of the alkanes. The corrected peak areas of alkanes in the samples were calculated from the ratio of average peak areas of C_{34} to the other alkanes in the standard solution and the peak areas of alkanes in the sample. The concentration of alkanes was then calculated from the ratio of corrected peak areas of alkane to C_{34} in the sample and the known amount of C_{34} in the internal standard added to the sample.

In order to test the accuracy of the manufacturer's stated release rates of n-alkanes from the controlled-release capsules, four Holstein-Friesian steers (~500 kg live weight) with permanent rumen fistulae fitted with cannulae were used. The steers were allowed to graze perennial ryegrass / meadow grass pasture for the duration of the test.

The length of tablet in each of four capsules was measured at four equidistant points around the circumference of the capsules (Dove et al., 2002). Then, one capsule was inserted into the rumen of each steer via the fistula and was suspended from the cannula plug by a nylon cord of sufficient length to permit movement of the device around the rumen.

On day 3 after capsule insertion, at approximately the same time of day when the capsules were inserted, the capsules were removed from the rumen and the length of the tablet was measured again. The capsules were then returned carefully to the rumen. This procedure was repeated every second – third day up to and including day 21 after insertion.

The daily release rates (mm/day) of tablet from the capsules were estimated as the slope of linear regressions of length of tablet against elapsed time. Tablet release rates were converted to mg of C_{32} and C_{36} per day from the analyses of alkane linear density in mg/mm tablet, as indicated by the manufacturer (145.0 mg of C_{32}/mm and 142.8 mg of C_{36}/mm).

The period of constant release rate was estimated as the number of days after insertion to when the length of tablet, derived from linear regression models, equalled 0 mm.

The concentrations of naturally occurring, odd-chained (C_{33}) and dosed, even-chained (C_{32}) n-alkanes in both herbage and faeces samples were used to calculate daily herbage intake according to the equation given by Dove and Mayes (1991):

Equation 1: Pasture intake (kg DM/head/day), $I = \left(\frac{F_i}{F_j} \times D_j \right) \Big/ \left(H_i - \frac{F_i}{F_j} \times H_j \right)$

where H_i and F_i are the respective concentrations (mg/kg DM) of C_{33} in the herbage and faeces, H_j and F_j are the respective concentrations of C_{32} in the herbage and faeces, and D_j is the release rate (mg/day) of C_{32} from the controlled release capsule. In this equation, it is assumed that the C_{32} and C_{33} alkanes, with a similar chain length, have a similar faecal recovery.

The botanical composition of the pre-grazing pasture was estimated during four of the six 8-day grazing periods from 16 December to 17 January. Sub-samples of herbage collected each day during the third 8-day grazing period were also analysed for botanical composition. Each sub-sample was separated into green grass leaf, dead material, white clover and weeds.

Pasture regrowth in early spring was estimated using the rising plate meter. On 21 March 2006, pasture yield was assessed for pasture that was previously grazed during each of the six 8-day grazing periods. The duration of pasture regrowth, between when pastures were last grazed during winter and 21 March, ranged from 113 days for pasture previously grazed in the first grazing period (completed on 8 December) to 65 days for pasture previously grazed in the last grazing period, which was completed on 17 January.

Data were analysed in SAS using a mixed effects model: $Y_{ijk} = \mu + P_i + RT_j + P_i{*}RT_j + b_k + \varepsilon_{ijk}$, where Y_{ijk} is the response variable of an experimental unit with the ith grazing period or day and jth residence time in the kth block, μ is the overall mean, P_i is the fixed effect of period or day, RT_j is the fixed effect of residence time, $P_i{*}RT_j$ is the interaction, b_k is the random effect of block, and ε_{ijk} is the error terms. The ε_{ijk} terms are assumed to be independent Normal deviates with mean zero and constant variance σ^2. The b_k effects are assumed to be independent Normally distributed with mean zero and variance σ_b^2. The terms, ε_{ijk} and b_k are assumed to be independent of each other. Means significantly different (α = 0.05) from each other were separated using the Tukey-Kramer multiple range test in SAS (pdiff adjust = tukey). Outliers defined as being two or more standard deviations away from overall mean, were removed before analysis.

For linear regression analysis of release rates of the controlled-release capsules the procedures ANOVA and REG were used for simple linear regression with replication and unequal sample sizes as the length of tablet approached zero. A simple linear regression model was fitted to individual data points and a lack-of-fit test was conducted. Mean values of herbage intake estimated using the disappearance and alkane methods were compared using a t-test.

Results

Rainfall was lower than average in December to February and April but higher than average in March and May (Table 11). Mean temperature and sunshine were higher than long-term means in December, January, April and May, but lower in February and March.

Table 11: Total rainfall, mean daily maximum, minimum and mean air temperatures, mean daily soil temperature (5 cm) and total sunshine hours for each month from 1 Dec. 2005 to 31 May 2006 and long-term (1971 to 2000) data (presented in brackets) at Grange.

Month	**Rainfall (mm)**	**Max. air temp. (°C)**	**Min. air temp. (°C)**	**Mean air temp. (°C)**	**Mean soil temp. (°C)**	**Sunshine (h)**
Dec.	68 (84)	8.4 (8.3)	3.0 (2.8)	5.6 (5.0)	4.5 (4.2)	45 (38)
Jan.	24 (83)	8.2 (7.8)	2.2 (2.0)	5.0 (4.2)	3.6 (3.4)	60 (49)
Feb.	41 (62)	8.0 (7.6)	1.5 (1.7)	4.0 (4.3)	3.2 (3.5)	67 (65)
Mar.	90 (65)	8.7 (9.6)	2.3 (2.5)	5.3 (6.2)	4.5 (5.0)	83 (97)
Apr.	38 (61)	12.3 (11.8)	3.6 (3.2)	8.6 (8.3)	7.6 (7.7)	177 (140)
May	160 (61)	15.1 (14.7)	6.1 (5.9)	11.2 (11.3)	11.8 (11.5)	155 (173)

Plate meter calibration: During winter and early spring, there were moderate ($0.51<R^2<0.79$) and highly significant ($P<0.001$) positive linear associations between plate meter reading and pasture mass. There were no significant differences ($P>0.31$) between *a* and zero and therefore *a* was set at zero. With $a = 0$, the associations were strong ($0.93<R^2<0.97$) and highly significant ($P<0.001$), and there were significant differences ($P<0.05$) between *b* across pasture types (block 1 vs. blocks 2 and 3). Therefore, different calibration models with *a* set at zero were used to estimate pasture mass during winter in block 1 (HM = 146.1*MR) and blocks 2 and 3 (HM = 107.5*MR) and during early spring in block 1 (HM = 159.9*MR) and blocks 2 and 3 (HM = 143.7*MR).

There was a strong ($R^2=0.97$) and highly significant ($P<0.001$) negative linear association between the number of days after insertion of the capsule into the rumen and length of tablet (mm) in the capsule (Figure 2). The linear regression was described by $y = 52.17 – 2.61x$, from which the average (± 95% CI) tablet release rate was –2.61 ± 0.16 mm/day and the average (± 95% CI) period of constant release was 20.04 ± 2.38 days. The average tablet release rate, multiplied by the linear density of alkanes in the tablet (mg/mm), indicated by the manufacturer, resulted in average (± 95% CI) alkane release rates of 378.45 ± 23.14 mg C_{32}/day and 372.71 ± 22.79 mg C_{36}/day. There were significant differences between these alkane release rates and the corresponding release rates supplied by the manufacturer of 328.9 mg C_{32}/day ($t_{0.05(2), 34} = 4.356$, $P < 0.001$) and 323.9 mg C_{36}/day ($t_{0.05(2), 34} = 3.910$, $P < 0.001$) respectively. Therefore, alkane release rates calculated in this study were used in the calculations of daily intake.

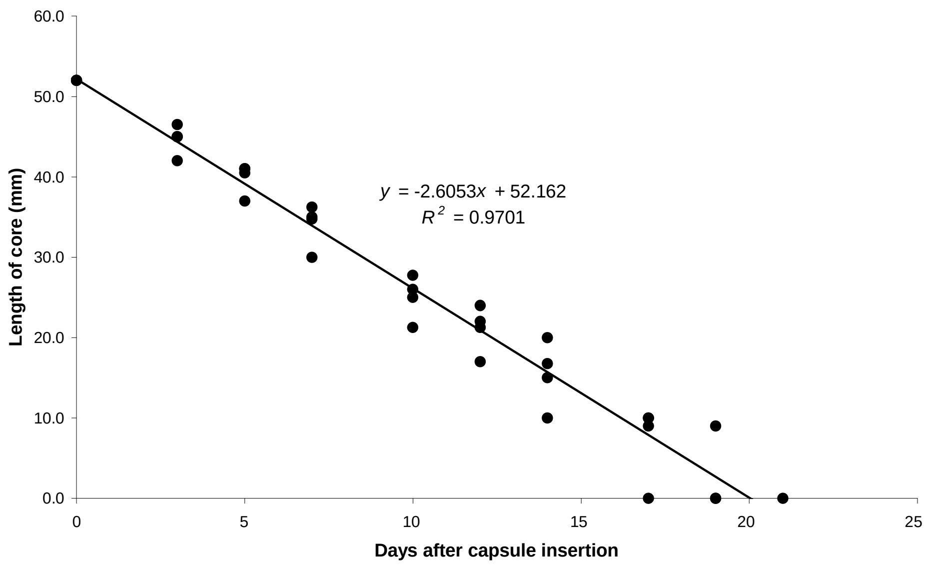

Figure 2: Association between the number of days after insertion of intra-ruminal controlled-release capsules (type MCM) into the rumen of fistulated Holstein-Friesian steers and length of tablet (mm) in the capsules.

There were no differences between grazing residence times in liveweight gain (P > 0.05) (Table 12). Pasture mass, allowance, apparent intake and LW-adjusted apparent intake were not different (P > 0.05) across residence times but differed (P < 0.01) across grazing periods (Table 13).

Table 12: Effect of grazing residence time in winter on liveweight gain of weanling bulls.

Grazing residence time (d)	**Live weight (kg)**			**Liveweight gain**
	24 Nov.	**18 Jan.**	**Mean**	**(kg/day)**
1	280	298	289	0.38
2	281	305	293	0.49
4	283	299	291	0.34
8	281	302	291	0.44
P value	0.812	0.429	0.191	0.757
SED	3.2	5.2	1.7	0.137

Table 13: Mean pre- and post-grazing pasture mass (1.5 cm above ground), pasture allowance and apparent pasture intake for weanling bulls grazing pasture at different grazing residence times (RT).

Treatment	**Pre-grazing HM (kg DM/ha)**	**Post-grazing HM (kg DM/ha)**	**Herbage allowance (kg DM/hd/d)**	**Apparent intake (kg DM/hd/d)**	**Apparent intake (kg DM/100 kg LW/d)**
RT (d)					
1	1830	810	9.1	5.0	1.7
2	1876	872	9.3	4.8	1.7
4	1840	851	9.3	4.9	1.7
8	1746	820	8.7	4.5	1.5
P value	0.105	0.066	0.148	0.242	0.111
SED	52.9	25.2	0.29	0.26	0.09
Period					
1	1842^{a}	933^{a}	9.2^{ab}	4.4^{b}	1.5^{b}
2	1800^{ab}	867^{ab}	9.0^{ab}	4.5^{b}	1.6^{b}
3	1811^{ab}	890^{a}	9.0^{ab}	4.4^{b}	1.5^{b}
4	1904^{a}	786^{b}	9.6^{a}	5.4^{a}	1.9^{a}
5	1933^{a}	873^{ab}	9.7^{a}	5.2^{ab}	1.8^{ab}
6	1649^{b}	681^{c}	8.2^{b}	4.7^{ab}	1.6^{ab}
P value	0.001	<0.001	0.002	0.004	0.003
SED	64.8	30.9	0.35	0.31	0.11
RT*Period					
P value	0.282	0.276	0.248	0.076	0.078

Within columns, means with the same or no superscript are not significantly different ($\alpha = 0.05$).

There was an interaction (P<0.001) between residence time and day in their effects on apparent pasture intake, which showed no differences in mean apparent intake (P=0.83) but the effect of day (P<0.001) depended on grazing residence time (Figure 3a). For the 1 day breaks, apparent intake increased from 3.4 kg DM/head per day in the first break to 5.5 kg DM/head per day in the final break. For the 2 day breaks, apparent intake averaged 6.8 kg DM/head per day on the first day of grazing and 2.0 kg DM/head per day on the second day. For the 4 day breaks, there was more variation in apparent intake across days, but it averaged 8.1 kg DM/head per day on the first day of grazing and decreased to an average of 3.3 kg DM/head per day on the second, third and final days in each break. For the 8 day break, mean apparent intake on the first day was 7.1 kg DM/head per day and on the following days was 4.2 kg DM/head per day.

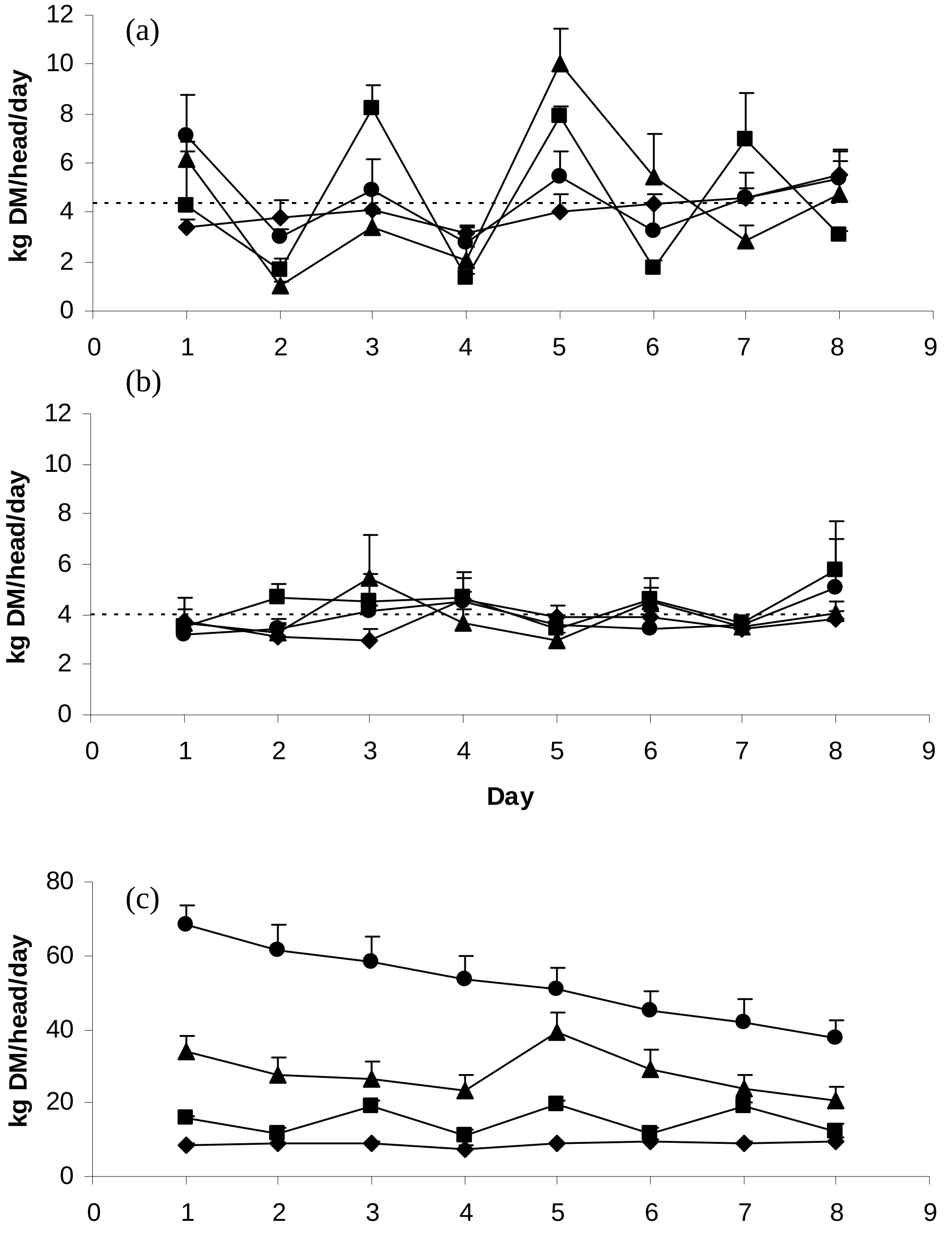

Figure 3: Daily pattern of (a) apparent pasture intake estimated as disappearance of pasture mass, (b) pasture intake estimated using an n-alkane method and (c) pasture allowance for weanlings grazing pasture at residence times of 1 (♦), 2 (■), 4 (▲) and 8 (●) days. Dashed horizontal lines represent mean herbage intake.

There was no difference (P=0.156) in mean pasture intake between the disappearance (4.4 kg DM/head per day) and n-alkane (4.0 kg DM/head per day) methods of measurement (SED=0.29) (Figure 3b). There were no effects (P>0.17) of grazing residence time on pasture intake estimated using the n-alkane method.

There was an interaction (P<0.001) between residence time and day in their effects on pasture allowance, which showed differences (P<0.001) in mean herbage allowance and an effect of day (P<0.001) which depended on residence time (Figure 3c). For the 1 day breaks, pasture allowance was similar across days and averaged 9 kg DM/head per day. For the 2 day breaks, pasture allowance averaged 19 kg DM/head per day on the first day of grazing and 12 kg DM/head per day on the second day. For the 4 day breaks, herbage allowance averaged 37 kg DM/head per day on the first day and decreased to 22 kg DM/head per day on the final day in each break. For the 8 day breaks, herbage allowance on the first day of grazing was 68 kg DM/head/day and decreased at a constant rate to 37 kg DM/head per day on the eighth day of grazing.

There was an interaction (P<0.001) between grazing residence time and day in their effects on pasture mass during the third grazing period, which showed no differences in mean pasture mass (P=0.08) between residence times but the effect of day (P<0.001) depended on residence time (Figure 4). Across all grazing residence times, there were similar (P>0.20) levels of pre-grazing pasture mass (1820 kg DM/ha, SEM=60.0) and post-grazing pasture mass (920 kg DM/ha, SEM=24.9).

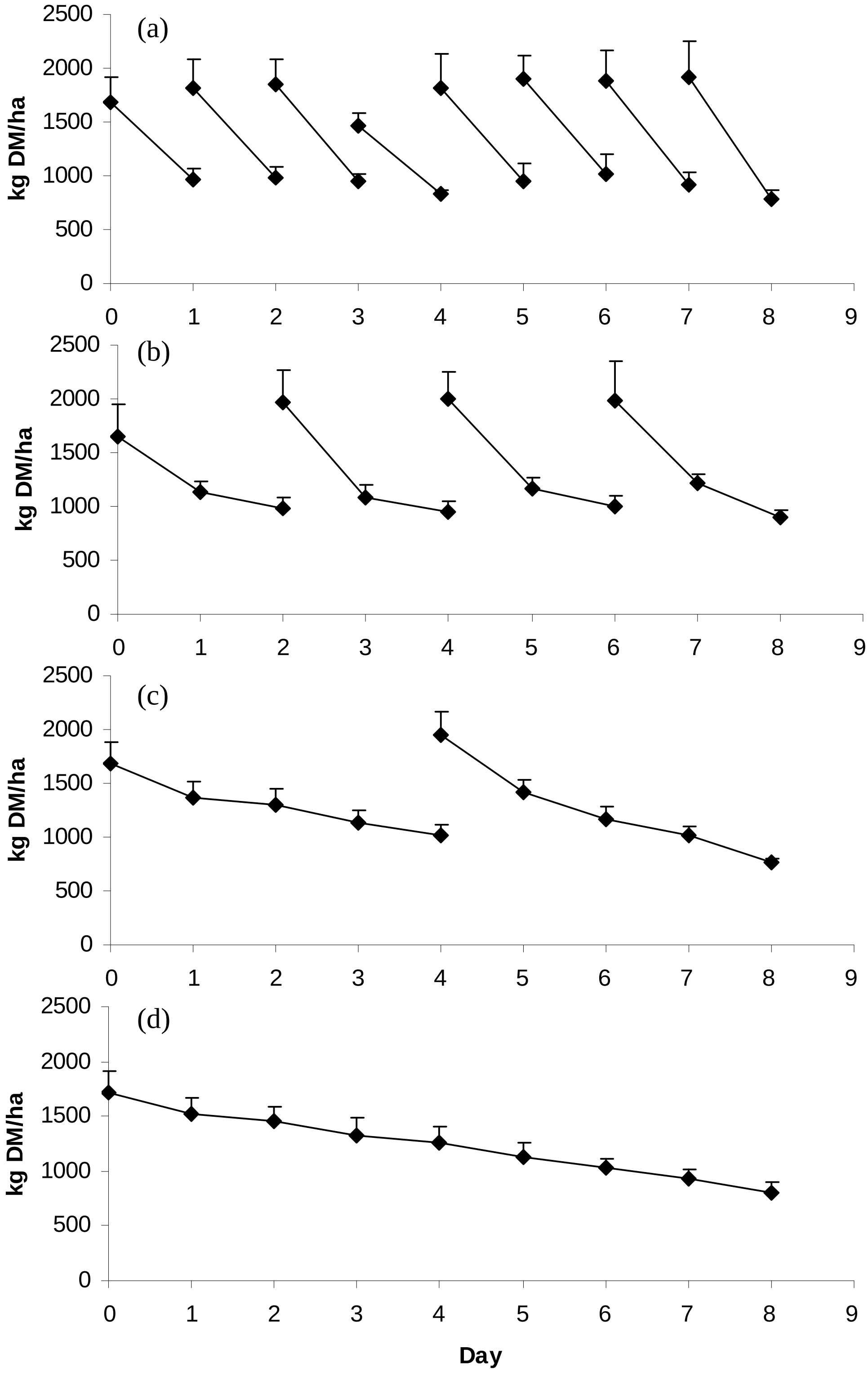

Figure 4: Daily pattern of pasture mass of pasture grazed by bulls at residence times of (a) 1, (b) 2, (c) 4 and (d) 8 days during a single 8-day grazing period.

There was an effect (P<0.01) of grazing residence time and grazing period in winter on pasture mass and regrowth up to 21 March in early spring (Table 14). Pasture mass was about

1350 kg DM/ha for the 1, 2 and 4-day residence times but decreased to about 1150 kg DM/ha as residence time increased to 8 days. Pasture mass decreased ($P<0.05$) from 1356 kg DM/ha for the first grazing period to 1148 kg DM/ha for the final grazing period but regrowth increased from 4.1 to 7.4 kg DM/ha per day with the delay in the last grazing from 8 December to 17 January.

Table 14: Pasture regrowth between the last grazing date in winter and 21 March 2006 (early spring) of pastures grazed by weanlings at different grazing residence times (RT).

Factor	Level	Date of last grazing	Pasture mass on 21 March (kg DM/ha)	Pasture regrowth (kg DM/ha per day)
RT (d)	1	28 Dec. 2005	1353^{a}	6.7^{a}
	2	28 Dec. 2005	1341^{a}	6.0^{ab}
	4	28 Dec. 2005	1248^{ab}	4.9^{bc}
	8	28 Dec. 2005	1152^{b}	4.2^{c}
	P value		<0.001	<0.001
	SED		51.4	0.57
Period	1	8 Dec. 2005	1356^{a}	4.1^{a}
	2	16 Dec. 2005	1346^{a}	5.0^{a}
	3	24 Dec. 2005	1342^{a}	5.2^{a}
	4	1 Jan. 2006	1244^{ab}	5.8^{ab}
	5	9 Jan. 2006	1236^{ab}	5.1^{ab}
	6	17 Jan. 2006	1148^{b}	7.4^{b}
	P value		0.01	0.001
	SED		63.0	0.70
RT*Period	*P* value		0.990	0.620

NS = not significant. Within columns, means with the same or no superscript are not significantly different (α=0.05).

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Conclusions

- Similar liveweight gains in weanling bulls (0.34 – 0.49 kg/day) were achieved by rotational grazing at grazing residence times of 1, 2, 4 and 8 days per break during the middle of winter.
- Liveweight gain was associated with similar average levels of pasture mass, pasture allowance and apparent pasture intake of the autumn-saved pasture with a similar botanical composition and nutritive value.

- There was strong agreement between pasture intake estimated using the disappearance method and the n-alkane method when averaged over 8 days of grazing.

Experiment 6

Phosphorus loss from dung pats during winter

While phosphorus (P) in slurry is known to have an impact on P loading in surface waters, causing eutrophication of lakes and rivers, the contribution of P in dung of grazing animals to this loading is less well documented. It would be expected that loss of P from the animal-soil-plant complex would be greatest when dung remains moist and the grass is least able to take up P i.e. during winter. Further, modelling studies have shown that movement of P in soil from dung voided in winter should be greatest when soil is wet (McGechan, 2003). However, a limiting step to the rate of passage of P through the soil is the rate at which it is lost from the voided dung pat. The objective of this study was to examine the loss of P from dung voided by weanling cattle grazing pasture in winter.

Materials and methods

On 10-11 April 2006, 38 samples of dung voided by a group of 8 weanling bulls grazing pasture between 30 November 2005 and 4 April 2006 were collected. Each day the group was moved to a new area of pasture using a ‘break grazing’ system. Actual dates of voidance were determined from records of the day each area of pasture was grazed. The samples were weighed, freeze dried for 48 h, and then weighed again to determine DM content. The dried samples were milled through a 1 mm screen and stored at room temperature until analysed.

The total P in the dung was determined by digesting a representative sub-sample in concentrated nitric acid using microwave heating and then analyzing the sample by Inductively Coupled Plasma Emission Spectroscopy (ICP-ES). Total P concentration was calculated relative to dung DM (g/kg DM). In addition, silica was considered as an inert marker and used as a further standard against which to gauge P content. Silica content (g/kg DM) was determined as acid insoluble ash (AIA) by cooking each dung sample in a muffle furnace at 550°C for 5 h and then treating the ash with 2N HCl solution.

Associations between total P concentration in DM, total P:AIA (g/g) and age of the dung pats were analysed by regression analyses.

Results

There was a negative association ($P<0.001$) between total P concentration in DM and age of voided dung which was most accurately described by a polynomial model (Figure 5). P concentration was about 7.5 g/kg DM in the most recently voided dung and decreased to about 3 g/kg DM in the older dung. There was no significant ($P=0.063$) association between AIA content and age of the dung suggesting that many of the DM constituents were relatively inert over winter. However silica content varied widely, contamination of the dung by soil during sampling possibly contributing to this variability. So it cannot be concluded with confidence that silica content in DM remained constant with age of dung pat. Nevertheless there was a significant association between P:silica ratio ($R^2=0.222$) with the ratio following a negative trend ($P<0.001$) with age of dung (Figure 6). The rate of P loss from dung pats was much faster than the rate of loss of dry matter from the dung and as a consequence the older dung pats had a approximately 50% lower P concentrations than most recently voided dung (Figure 5).

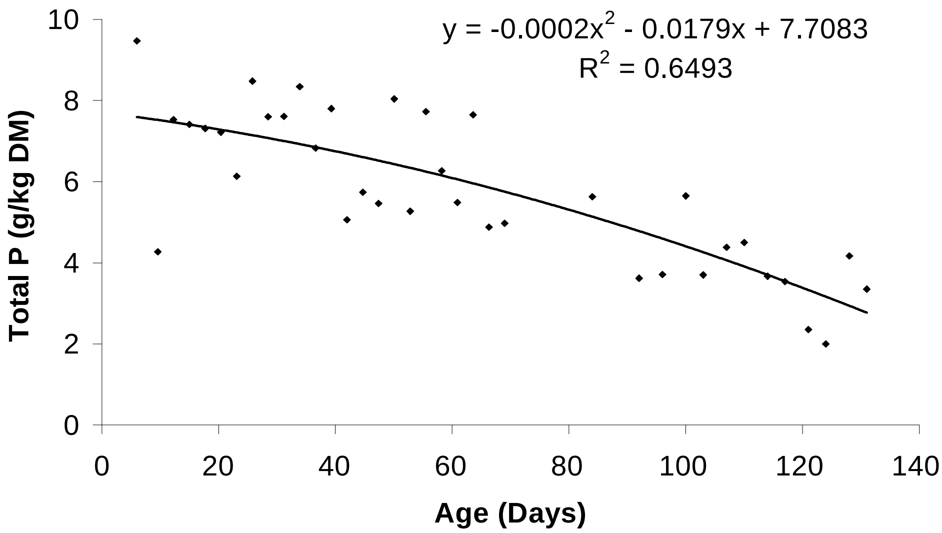

Figure 5: Relationship between total P concentration in the dung and age of dung pat voided by weanling cattle grazing pasture from 30 Nov. 2005 to 4 Apr. 2006 at Grange.

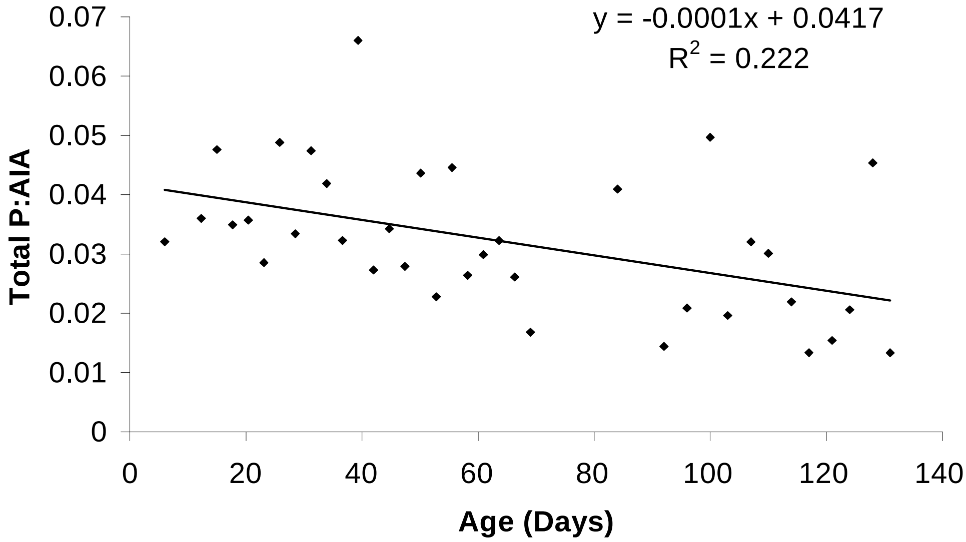

Figure 6: Relationship between total P:acid insoluble ash (AIA) or silica ratio in the dung and age of dung pat voided by weanling cattle grazing pasture from 30 Nov. 2005 to 4 Apr. 2006 at Grange.

Conclusion

These data have implications for extended grazing systems as they suggest that P may enter the soil faster than the degradation of dung pats over winter. As it is not being utilised by the plant due to low root temperatures, the content of P in soil water in winter in extended grazing systems could be higher than expected. The data from this study could be incorporated into models to predict P loss to waterways from winter grazing and warrants further investigation.

References

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Experiment 7

Performance of weanling beef heifers grazing pasture or consuming grass silage during winter

The objective of this study was to compare the growth and feed intake of weanling heifers grazing pasture with that of heifers offered grass silage indoors in winter.

Materials and methods

Fifty weaned, spring-born Charolais × Limousin heifers were sourced in October/November 2006 and transported to Grange. The initial mean (SD) live weight was 275 (27.0) kg and the mean age was 252 (28.0) days. Heifers were blocked on initial live weight and two dietary treatments of grazed pasture and grass silage were assigned at random to heifers within each block. The duration of the study was from 28 November 2006 to 18 April 2007 (141 days).

For the pasture treatment, heifers were rotationally stocked in three replicate groups (two groups of eight and one group of nine) on pasture. Using portable electric fences, the heifers were offered fresh pasture daily and did not have access to the previous day's pasture. A DM allowance of about 3.5 kg DM/100 kg live weight per day and a post-grazing pasture mass of 800-900 kg DM/ha were achieved by varying the size of the area grazed each day. For the grass silage treatment, heifers were housed in five pens (five heifers/pen) in a slatted-floor shed. Animals were given free access to grass silage.

All heifers were weighed at 19-35-day intervals. Liveweight gain was calculated for each interval and for the overall period. For each replicate group, daily feed DM intake was estimated as the difference between mass (kg DM) of available and residual feed (after 24 h) divided by the number of heifers per group. Pasture mass was estimated to ground level using a rising plate meter (Jenquip Ltd., Fielding, New Zealand) calibrated on five dates during the study. Feed conversion efficiency (FCE) was calculated from mean liveweight gain and DM intake for each group.

Data were analysed using a mixed effects model: $Y_{ij} = \mu + T_i + b_j + \varepsilon_{ij}$, where Y_{ij} is the response variable of an individual heifer (for LW, LWG) or group (for allowance, intake, FCE) with the i^{th} treatment in the j^{th} weight block/group, μ is the overall mean, T_i is the fixed effect of treatment, b_j is the random effect of block/ group, and ε_{ij} is the error terms.

Results

The mean liveweight gain of the grazed heifers was higher (P<0.01) and consequently their LW at the end of the winter was 25 kg greater (P<0.001) than those offered grass silage (Table 15). However, the DM intake of the grazed heifers was also higher (P<0.001) at the mean pasture allowance of 11 kg DM/heifer per day compared with 5.8 kg DM/heifer per day (P<0.001) for those offered grass silage *ad libitum*. These differences in liveweight gain and intake resulted in a similar (P=0.202) mean FCE. Differences in liveweight gain and intake were particularly evident during late winter/early spring, which may be associated with increasing pasture quality during this period. These results suggest that weanling heifers grazing pasture in winter can achieve acceptable weight gains using controlled grazing management and feed budgeting.

Table 15: Animal performance, DM allowance, DM intake and FCE of weanling heifers grazing pasture or consuming grass silage indoors in winter.

Response variable	**Treatment**	**28 Nov. - 2 Jan.**	**3 Jan.- 22 Jan.**	**23 Jan.- 19 Feb.**	**20 Feb.- 22 Mar.**	**23 Mar. - 18 Apr.**	**Mean**
Final LW (kg)	Pasture	292	294	308	339	358	311
	Silage	281	291	306	326	333	302
	P value	0.003	0.362	0.601	0.027	<0.001	<0.001
LWG (kg/d)	Pasture	0.47	0.12	0.51	1.00	0.69	0.59
	Silage	0.14	0.51	0.52	0.65	0.27	0.45
	P value	<0.001	0.001	0.858	<0.001	<0.001	0.004
DM allowance (kg/d)	Pasture	8.3	9.9	11.0	11.3	12.6	10.9
	Silage	4.9	5.2	5.8	5.8	6.7	5.8
	P value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
DM intake (kg/d)	Pasture	5.2	6.4	6.9	6.3	6.7	6.3
	Silage	4.3	4.6	5.3	5.3	5.8	5.2
	P value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
FCE (g LW/kg DM)	Pasture	90	16	75	161	102	95
	Silage	34	108	99	122	46	86
	P value	0.070	0.023	0.287	0.120	0.003	0.202

Conclusion

Weanling heifers grazing pasture at a mean daily DM allowance of 11 kg DM/heifer per day gained more live weight than heifers offered grass silage *ad libitum* indoors in winter. This result was associated with a higher DM intake and similar FCE for the grazed heifers.

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