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Intake and growth of steers offered different allowances of autumn grass and concentrates

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Abstract

The aim of this experiment was to quantify the relationship between autumn grass supply and concentrate supplementation level on grass intake and animal performance. One hundred and ten continental steers (567 kg) were assigned to 10 treatments. The experimental design was a three grass allowances (6, 12 and 18 kg dry matter (DM) per head daily) by three concentrate levels: (0, 2·5 and 5 kg per head daily) factorial with a positive control group offered concentrates ad libitum *and no grass. Grass allowance was offered daily and concentrates were given individually. The experiment began on 22 August and all animals were slaughtered after a mean experimental period of 95 days. Grass intake was calculated using the n-alkane technique and diet digestibility using ytterbium acetate as an indigestible marker. There was an interaction* (P < 0·05) *between grass allowance and concentrate level for grass intake. At the low grass allowance there was no effect of offering animals supplementary concentrates on grass intake, at the medium and high grass allowances, supplementary concentrates reduced grass intake by 0·43 and 0·81 kg DM respectively per kg DM concentrate offered. Increasing grass allowance increased* (P < 0·001) *complete diet organic matter (OM) digestibility at all concentrate levels and supplementary concentrates increased* (P < 0·001) *complete diet OM digestibility only at the low grass allowance. Both offering animals supplementary concentrates* (P < 0·001) *and increasing daily grass allowance* (P < 0·001) *increased their carcass growth rate. Relative to the animals offered the low grass allowance and no concentrate, supplementing with concentrate increased carcass growth by 116 g/kg concentrate DM eaten whereas increasing the grass allowance, increased carcass growth by 38 g/kg DM grass eaten. As a strategy for increasing the performance of cattle grazing autumn grass, offering supplementary concentrates offers more scope than altering grass allowance.*

Keywords: *autumn, concentrates, grass intake, steers.*

Introduction

Food costs are a major proportion of total variable costs in most beef systems and efficiently managed grazed grass can be the cheapest foodstuff in temperate climates. Achieving high annual intakes of grazed grass can therefore be an important tool in reducing beef production costs. Grass growth varies widely throughout the year (Brereton, 1995) and as grass growth declines in the autumn, herd demand for food often exceeds supply of grass. McDonald *et al.* (1995) suggested that autumn grass had a lower net energy or feeding value compared with grass grown earlier in the season. Nutrient supply from autumn grass may thus be insufficient to support the levels of animal live-weight gain achievable earlier in the grazing season. In Ireland, growth by grazing cattle is frequently poor after mid-summer (Devaney *et al.*, 1997). This may be related to the quantity and/ or quality of grass supply relative to the requirements of the grazing animals. Two strategies that could potentially increase performance of cattle grazing autumn grass are (a) an increase in the supply of grass or (b) offering additional foodstuffs such as supplementary concentrates.

Previous research in which supplementary concentrates were offered to cattle grazing grass has shown that where pasture supply was adequate or where animals were at low stocking rates, there was no significant animal production response to concentrates (Dodsworth and Ball, 1962; Conway, 1968; Tayler and Wilkinson, 1972; Vadiveloo and Holmes, 1979; Steen, 1994; Steen and Kilpatrick, 1998). Conway (1968) hypothesized that when offered supplementary concentrates when adequate grass is available, cattle substituted part of their dietary grass intake with concentrates while maintaining performance. However, when pasture supply or quality was limiting (Vadiveloo and Holmes, 1979) there was an animal growth response to feeding concentrates. These published trials evaluated supplementation in either the early part of the grazing season when grass quality is generally good, or throughout the entire grazing season, thereby not evaluating the potential advantage of supplementation in autumn.

An alternative strategy to concentrate supplementation for maintaining animal performance is to increase the allowance of grazed grass. Reed (1978) postulated that offering an increased allowance of grass during the autumn period would enable animals to impose a greater degree of selection on the grass consumed, maximize grass intake and thus minimize the seasonal depression in animal performance. O'Riordan (1996) observed a quadratic response in animal carcass gain to grass allowance in the autumn with a large response by increasing daily grass allowance from 10 to 20 g grass dry matter (DM) per kg live weight but no effect on animal performance from increasing daily grass allowance from 20 to 30 g grass DM per kg live weight.

The objective of this experiment was to quantify the response to grass supply and level of concentrate supplementation on grass intake and steer performance in the autumn.

Material and methods

Experimental design

One hundred and ten Limousin and Charolais crossbred steers (567 (s.d. 32·3) kg mean initial live weight) were blocked on weight and assigned at random from within blocks to one of 10 treatments. Nine treatments were arranged in a three (grass allowances) by three (concentrate level) factorial design. The three daily grass allowances were 6 (low), 12 (medium) and 18 (high) kg DM per head and the daily concentrate allowances were 0, 2·5 and 5 kg fresh weight per head. A 10th treatment group (positive control) was individually offered concentrates *ad libitum* indoors but had free access to an outdoor environment without grass. All animals were grazed together and offered 2 kg concentrate for 2 weeks prior to the start of the experiment which began on 22 August 1996.

Grazing management

Animals were rotationally grazed in nine adjacent groups on swards of mixed botanical composition (mainly perennial ryegrass, *Poa trivialis* and *Agrostis* with negligible clover content) which had been harvested for silage in mid July and subsequently received 50 kg nitrogen per ha. The rotation interval varied between 6 and 9 weeks and the mean pre-grazing yield was 2980 kg DM per ha. Daily grass allowances were achieved by varying the size of the grazing area. Animals were offered a fresh allowance daily and did not have access to the remainder of the previous day's allowance. Pre-grazing grass mass was estimated by cutting four strips (each 1·2 m × 5 m; 4 cm stubble height; measured using a rising platemeter) three times weekly from the areas to be grazed by each treatment group. Post-grazing grass yield was estimated three times weekly by cutting four strips (each 0·55 m × 5 m) to a 4 cm stubble height, from the area grazed by the steers on each treatment. All plots were subsequently grazed to a target (4 cm) post-grazing height by non-experimental animals just after each passage of the experimental animals. A fresh sample (500 g) of grass was collected three times weekly and sub-divided into leaf, stem and dead material and dried at 98ºC for 24 h to determine morphological composition.

Concentrate feeding

A pelleted concentrate, which was a mixture of (per kg) ground barley (290 g), unmolassed beet pulp (290 g), maize gluten (290 g), soya-bean meal (50 g), molasses (50 g) and mineral/vitamin mix (30 g), was offered individually to all animals receiving supplementary concentrates. The appropriate animals were restrained individually in a purpose built mobile feeder in the field and offered 2·5 kg concentrates per head at 08:00 h, before being allocated a fresh daily grass allowance. Animals remained restrained until the concentrates were consumed (approx. 20 min). Animals receiving 5 kg concentrates daily were restrained and offered a further 2·5 kg concentrates at 16:00 h. The control group of animals was offered concentrates *ad libitum* individually indoors, following a 12-day adjustment period, and 1 kg straw, through electronically controlled gates.

Animal management

Grass intake and diet digestibility were estimated over two 3-day periods (days 82 to 85 and 86 to 88) for each treatment using the n-alkane technique and ytterbium acetate as a faecal output marker, respectively. The technique used the grass C33 (n-tritriacontane) to C32 (n-dotriacontane) ratio using the technique of Mayes *et al.* (1986) as modified by Dillon and Stakelum (1988). Faecal output was measured concurrently using the technique described by Siddons *et al.* (1985). All animals were restrained and dosed twice daily (07:00 h and 17:00 h) starting on day 76 with gelatine capsules containing 500 mg C32 and 200 mg of ytterbium acetate (41% ytterbium w/w) in solution (ytterbium acetate dissolved in distilled water, 4 g/l). Faecal samples were collected by rectal sampling twice daily for two 3-day periods after allowing for a 6-day adjustment period. Samples of the pre- and post-grazing grass were analysed for C32 and C33 content to estimate the n-alkane content of the grass consumed by the animals on each treatment. This was calculated from the equation: (pre-grazing yield × C32% – post-grazing yield × C32%)/(pre-grazing yield – post-grazing yield). Group mean grass intake was also estimated from the difference between pre- and post- grazing yield.

All animals were weighed unfasted on 2 days consecutively at the start of the trial (day –1 and day 0) and the 2 days before their respective slaughter dates. Live-weight gain was calculated from the difference between the means of initial and final weights. Animals were also weighed every fortnight during the experiment to monitor performance.

On days 28, 56 and 84 blood samples were collected by jugular venipuncture from all animals on each of the nine grazing treatments. Lithium heparin was used as an anticoagulant. Blood samples were immediately centrifuged at 3000 **g** for 10 min. The plasma was separated into 5 ml containers and stored at –20ºC prior to analysis. Animals from the four heaviest blocks were slaughtered after 89 days, from the next four heaviest four blocks after 95 days, and from the remaining three blocks after 101 days.

After slaughter, cold carcass weight (hot carcass weight × 0·98) was recorded. Killing-out proportion was expressed as the cold carcass weight as a proportion of the final live weight. Carcass gains were calculated as the difference between the final carcass weight and proportionately 0·53 of the initial live weight. The carcasses were classified for carcass conformation (1 = poorest and 5 = best conformation) and fat score (1 = leanest and 5 = fattest) using the EU Beef Carcass Classification Scheme (Commission of the European Communities, 1982). The weight of kidney and channel fat (KCF) on each carcass was also recorded.

Chemical analyses

The grasses were subsampled for determination of DM concentration (dried at 98ºC for 16 h in an oven with forced air circulation). Chemical analyses were conducted on samples dried at 40ºC for 48 h and ground through a 1-mm screen using a hammer mill. A sample of the supplementary concentrates offered was taken twice weekly. A 100 g subsample was dried for 16 hours at 98ºC to estimate DM concentration and a further 100 g subsample was dried at 40ºC for 48 h for chemical analysis.

Samples of the pre-grazing grass and concentrates were analysed for crude protein (CP), *in vitro* DM digestibility (DMD), *in vitro* organic matter (OM) digestibility (OMD), crude fibre, oil, water-soluble carbohydrates (WSC), acid-detergent fibre (ADF) and neutral-detergent fibre (NDF). CP determination was based on the Association of Official Analytical Chemists (AOAC) method 990-03 using LECO FP-428. Ash and oil A and B concentration determinations were based on European Community (Marketing of Feedstuff) Regulations (1984). DMD was determined by the method of Tilley and Terry (1963). Crude fibre, NDF and ADF concentrations were determined according to Van Soest (1963). WSC concentration were determined according to the method Birch and Mwangelwa (1974). Samples of the post-grazing grass were analysed for ash and DMD.

Plasma urea, glucose, and creatinine were all analysed using a Corning 550 Express analyser and Randox laboratory kits (VR446, CR528, and GL2623 for urea, creatinine, and glucose respectively). The C32 and C33 contents of the grass, faeces and concentrate were measured according to Vulich *et al.* (1995). Complete diet digestibility was calculated from faecal OM output as a proportion of total OM ingested.

Statistical analyses

Live weight and carcass traits for the 10 treatments were first subjected to analysis of variance appropriate for a single factor randomized complete block design (Steel and Torrie, 1960). The statistical model included block and treatment effects. The treatment that offered concentrates *ad libitum* was then compared with all other treatments individually using linear contrasts.

Intake and diet digestibility data were averaged over the two time periods to give a single value for each individual animal. Intake, diet digestibility, live weight and carcass traits for the nine grazing treatments were then subjected to analysis of variance appropriate for a two-factor randomized complete block design (Steel and Torrie, 1960). The

Table 1 *Morphological composition of grass and mean chemical composition (with s.d.) of grass and concentrates offered*

	Grass†	Concentrate‡
Leaf (g/kg dry matter (DM))	762 (48)	
Stem (g/kg DM)	145 (32)	
Dead material (g/kg DM)	93 (18)	
Dry matter (g/kg)	198 (23)	872 (7)
Crude protein (g/kg DM)	225 (25)	143 (4)
Ash (g/kg DM)	125 (1·6)	48 (1·2)
Water-soluble carbohydrates (g/kg DM)	89 (11·2)	49 (1·3)
In vitro DM digestibility (g/kg)	738 (52)	
In vitro organic matter digestibility (g/kg)	758 (52)	844 (11)
Crude fibre (g/kg DM)	287 (64)	101 (1·1)
Oil (g/kg DM)§	29 (4·0)	24 (1·8)
Acid-detergent fibre (g/kg DM)	257 (22)	152 (8)
Neutral-detergent fibre (g/kg DM)	428 (41)	535 (53)

† No. = 29.
‡ No. = 15.
§ Oil A for grass and oil B for concentrate.

statistical model included block, concentrate level, grass allowance and the interaction of grass allowance and concentrate level. The linear, quadratic and cubic coefficients of the effects of grass intake and supplementary concentrate level on carcass gain were tested by orthogonal contrasts.

Plasma urea, glucose and creatinine concentrations were averaged over the three sampling time points to give a single value for each individual animal. Plasma metabolite concentrations for the nine grazing treatments were then subjected to analysis of variance appropriate for a two-factor randomized complete block design.

Regression analysis (Steel and Torrie, 1960) were used to quantify treatment effects on grass intake, carcass gain and live-weight gain

Results

Food composition

The chemical composition of the grass and concentrates used are shown in Table 1. The concentrate had tabulated protein digested in the small intestine when nitrogen is limiting microbial protein synthesis (PDIN) and protein digested in the small intestine when energy is limiting microbial protein synthesis (PDIE) values of 108 and 112 g/kg DM respectively and a tabulated net energy value of 1·08 UFL (unite fouragere de lait) per kg DM (O'Mara, 1996)

Table 2 *The effect of grass allowance and concentrate level on intake, diet digestibility and faecal output*

	Daily grass allowance per head (G)										Significance			
	6 kg			12 kg			18 kg			Control				
Daily concentrate level per head (C)	0 kg	2·5 kg	5 kg	0 kg	2·5 kg	5 kg	0 kg	2·5 kg	5 kg	14·4 kg	G	C	G × C	s.e.†
Grass dry matter (DM) intake (kg/day)‡	5·29	5·40	5·23	9·28	7·98	7·34	12·95	9·42	9·27		***	***	*	0·332
Grass organic matter (OM) intake (kg/day)‡	4·49	4·59	4·45	7·89	6·78	6·00	10·67	7·73	7·78		***	***	*	0·520
Total DM intake (kg/day)	5·29	7·65	9·72	9·28	10·23	11·83	12·95	11·67	13·76	13·33				
Grass DM intake (kg/day)§	5·59	5·16	5·13	9·37	9·16	8·44	12·46	11·87	10·76					
Post-grazing DM digestibility (g/kg)	459	527	533	592	629	627	629	648	669					
Digestibility of grass DM eaten (g/kg)‖	758	772	773	779	772	785	786	784	784					
Faecal OM output (kg/day)	1·36	1·50	1·81	1·34	1·69	1·65	1·44	1·55	1·80			***		0·0934
Diet OM digestibility (g/kg)¶	684	773	788	829	807	831	853	840	851		***	*	***	14·4

† s.e. for G × C interaction.
‡ Estimated individually using n-alkanes.
§ Estimated per treatment group from the pre- and post-grazing herbage mass.
‖ Estimated from the difference between digestibility of pre- and post-grazing mass and the proportion consumed.
¶ Estimated from individual grass intake and faecal output.

Grass intake and diet digestibility

There was an interaction ($P < 0{\cdot}05$) between grass allowance and concentrate level on grass DM and grass OM intake ($P < 0{\cdot}05$) and complete diet OMD ($P < 0{\cdot}001$) (Table 2). At the low grass allowance, there was no effect of supplementary concentrates on the grass DM or grass OM intakes, however at the medium and high grass allowances, supplementary concentrates reduced grass intake. Increases in grass allowance increased complete diet OMD significantly at all concentrate levels and supplementary concentrates increased ($P < 0{\cdot}05$) complete diet OMD at the low grass allowances. The *ad libitum* concentrate group consumed 12·53 kg concentrate DM and 0·8 kg straw DM daily.

Animal performance

An increased grass allowance increased final live weight ($P < 0{\cdot}001$) and live-weight gain ($P < 0{\cdot}001$) (Table 3). Offering supplementary concentrates also increased their final live weight ($P < 0{\cdot}001$) and live-weight gain ($P < 0{\cdot}001$). There was no significant interaction between the effects of grass allowance and concentrate level on final live weight or live-weight gain. Animals offered supplementary concentrates had higher ($P < 0{\cdot}001$) killing-out proportions by approximately 20 g/kg live weight. Grass allowance did not affect killing-out proportion nor was the positive control group of animals significantly different from any other group. Offering animals supplementary concentrates and increasing their grass allowance increased both their carcass gain and final carcass weight ($P < 0{\cdot}001$). There was no significant interaction between the effects of grass allowance and level of concentrates offered on carcass gain. The relationship between carcass gain (Y) (kg/day) and supplementary concentrates (X) (kg/day) was quadratic ($P < 0{\cdot}001$) and was best described by the equation: $Y = -0{\cdot}0099X^2 + 0{\cdot}1364X + 0{\cdot}2459$ ($R^2 = 0{\cdot}60$, no. = 99). The relationship between carcass gain (Y) (kg/day) and grass intake (X) was also quadratic ($P < 0{\cdot}01$) and was best described by the equation: $Y = -43X^2 + 275X + 133$ ($R^2 = 0{\cdot}48$, no. = 99). The *ad libitum* concentrate group of animals had higher ($P < 0{\cdot}05$) carcass gain than all other treatments except the treatment which offered the high grass allowance and 5 kg concentrate.

Carcass traits

Supplementary concentrates increased ($P < 0{\cdot}001$) carcass conformation scores, however the numerical increase in carcass conformation due to increased grass allowance did not reach statistical significance. The animals offered concentrates *ad libitium* had a higher ($P < 0{\cdot}05$) conformation score than all the unsupplemented animals but did not significantly

Table 3 *The effect of grass allowance and concentrate level on intake, diet digestibility, feed efficiency, animal growth, and carcass traits*

	Daily grass allowance per head (G)										Significance			
	6 kg			12 kg			18 kg			Control				
Daily concentrate level per head (C)	0 kg	2·5 kg	5 kg	0 kg	2·5 kg	5 kg	0 kg	2·5 kg	5 kg	14·4 kg	G	C	G × C	s.e.†
Final live weight (kg)	583	620	654	619	643	669	641	668	676	703	***	***		11·38
Live-weight gain (g/day)	140	540	940	530	780	1060	750	1050	1140	1430	***	***		64·2
Carcass weight (kg)	304	332	352	323	348	361	330	355	363[a]	371	***	***		5·49
Carcass gain (g/day)	88	393	617	290	551	695	360	631	727[a]	809	***	***		24·0
Killing-out proportion (g/kg)	522[a]	537[a]	538[a]	521[a]	541[a]	540[a]	551[a]	532[a]	538[a]	528		***		4·0
Carcass conformation‡	2·27	2·73	3·18[a]	2·64	3·09[a]	2·91[a]	2·73	3·09[a]	3·09[a]	3·09	0·069	***	0·069	0·141
Fat score§	3·73	3·79	3·79	3·85	4·15	3·91	4·03	3·97	4·14	4·64	*			0·108
KCF (kg)‖	5·05	7·35	8·82[a]	6·79	7·57	8·93[a]	7·93	9·19[a]	10·25[a]	10·69	**	***		0·301
KCF/carcass weight (g/kg)	17	22	25	21	22	25	24	26	28[a]	29	*	**		2·1

[a] Values with superscript were not significantly different ($P < 0{\cdot}05$) from *ad libitum* concentrate (control) group.
† s.e. for G × C interaction.
‡ 1 = poorest, 5 = best.
§ 1 = leanest 5 = fattest.
‖ Kidney plus channel fat.

Table 4 *The effect of grass allowance and concentrate level on plasma concentrations of creatinine, glucose and urea*

	Daily grass allowance per head (G)											
	6 kg			12 kg			18 kg			Significance		
Daily concentrate level per head (C)	0 kg	2·5 kg	5 kg	0 kg	2·5 kg	5 kg	0 kg	2·5 kg	5 kg	G	C	s.e.†
Creatinine (mol/l)	131·5	125·1	123·3	132·2	126·9	118·0	122·1	120·6	121·3		**	2·93
Glucose (mmol/l)	4·09	3·99	4·07	4·32	4·15	4·18	4·20	4·15	4·15			0·055
Urea (mmol/l)	5·38	5·19	5·02	5·59	5·06	5·09	5·09	5·77	5·47	*		0·123

† s.e. for G × C interaction. G × C interaction was not significant ($P > 0{\cdot}05$).

differ from the supplemented animals except at the lowest grass allowance and level of supplement.

Increasing the grass allowance increased ($P < 0{\cdot}05$) carcass fat scores. However, offering animals supplementary concentrates did not significantly alter their carcass fat scores. Both KCF weight and KCF as a proportion of carcass weight were increased by offering animals supplementary concentrates ($P < 0{\cdot}01$) and by increasing the grass allowance ($P < 0{\cdot}05$).

Plasma metabolite concentrations

Offering supplementary concentrates reduced ($P < 0{\cdot}01$) plasma creatinine concentration, however there was no effect of grass allowance. There was no effect of dietary treatment on plasma glucose concentration. Increasing the grass allowance offered to the steers increased ($P < 0{\cdot}05$) their plasma urea concentration (Table 4). However, offering supplementary concentrates did not affect their plasma urea concentration and there was no interaction between grass allowance and concentrate level for this metabolite.

Discussion

Grass composition

The composition of the grass was typical of grass grown during the autumn period (Munro and Walters, 1986), characterized by a low DMD and high CP concentration. Throughout the spring and summer, grass CP concentration is low while grass is growing rapidly. The grass plant is apparently unable to synthesize protein at a rate to match grass DM production. However, in the autumn period as grass growth declines, CP concentration increases (Thomas and Morris, 1973). The mean DMD was 738 g/kg, but ranged from 625 to 832 g/kg. This variation occurred over time as a uniform sward of similar composition was offered to each treatment daily. The relatively low mean DMD may reflect the high pre-grazing herbage mass (approx. 3000 kg DM per ha) and the prolonged regrowth interval (6 to 9 weeks). However, due to the large herbage mass present, animals had the opportunity to select grass of a higher digestibility than the average of that offered, particularly at the high grass allowance where lowest utilization (520 to 710 g/kg) was observed.

Grass intake

Increasing the daily grass allowance increased grass intake and at the unsupplemented high grass allowance (18 kg DM per head per day), equivalent to 30 g DM per kg live weight animals achieved 0·97 of the DM intake of the positive control offered concentrates *ad libitium.* Increasing concentrate intake by 4·4 kg DM per day at this grass allowance increased total DM intake by only 0·81 kg DM per day. French (1998) offered similar type animals 40 g DM autumn grass per kg live weight per day and observed similar DM intakes as in this study. It is apparent that the animals offered the unsupplemented high grass allowance achieved close to their potential intake of this forage. Assuming that the potential forage intake was achieved by the group offered the unsupplemented high allowance, then the unsupplemented low and medium allowances facilitated 0·41 and 0·72 respectively of the potential forage intake.

Substitution rate

At the low grass allowance, daily grass intakes were approximately 5·5 kg DM and there was no effect of offering animals supplementary concentrates on their grass intake. At the medium and high grass allowances, supplementary concentrates reduced grass intake by 0·43 and 0·81 kg DM respectively per kg DM concentrate offered. Kibon and Holmes (1987) observed that herbage intake was depressed by a cereal-based concentrate when animals were grazing long pasture (6·5 cm) but not when they grazed a shorter pasture (5 cm). It is generally accepted that substitution rates increase when herbage allowances increase (Leaver, 1986; Mayne, 1991). The substitution rate by the groups offered the medium grass allowance is similar to that reported by Sarker and Holmes (1974), Umoh and Holmes (1974) and Hodgson and Tayler (1972) for animals grazing throughout the grass growing season. They reported substitution rates of approximately 0·5 kg grass DM per kg concentrate when supplementing beef cattle during the grazing season.

Diet digestibility

Offering animals supplementary concentrates at the medium and high grass allowance did not significantly change their diet OMD even though they may have had the opportunity to select grass of a higher digestibility than their unsupplemented comrades due to the substitution of concentrates for grass by the animals offered these allowances. It is therefore difficult to separate the effects of grass allowance *per se* and concentrate level on diet OMD at the medium and high grass allowances. At the low grass allowance there was no effect of concentrate supplementation on grass intake so therefore an evaluation of the effect of concentrate supplementation on grass digestibility can be made. When these animals were offered 2·5 kg concentrate, their complete diet OMD was higher than the additive values of the grass (estimated from the unsupplemented animals) and concentrates (estimated *in vitro*) even though total DM intake was significantly increased. This would imply that the supplementary concentrates increased the grass OMD. In contrast, many previous authors would have reported that concentrates depress the digestibility of forage (Drennan and Keane, 1987) and that diet digestibility decreases as total DM intake increases (Zinn *et al.*, 1995). There was no difference in complete diet OMD between the 2·5 and 5 kg concentrate treatments.

A possible explanation for the increased OMD of the grass and concentrate in a complete diet could be the result of a better synchronization of available nutrients. In a subsequent study (French *et al.*, 2001) the present authors observed that rates of DM degradation of a concentrate and nitrogen degradation of an autumn grass were similar but rates of DM degradation of the autumn grass were much lower. If that synchronization occurred in this study, it could have led to higher levels of rumen microbial growth in the supplemented animals, which in turn would utilize a larger proportion of the grass fibre. However, there was no apparent effect of synchronization on diet digestibility's at the medium and high grass allowance.

Plasma metabolite concentration

Increasing the grass allowance offered to the steers increased their plasma urea concentration. Plasma urea arises from ruminal ammonia and from amino acid catabolism (Chillard *et al.*, 1995). High plasma urea concentrations result from large intakes of protein or dietary nitrogen which the animal cannot utilize (Rowlands, 1980). Sinclair *et al.* (1994) reported a positive correlation between plasma urea concentrations and the protein content of the diet. In this study, supplementary concentrates increased total dietary nitrogen intake and numerically (but not significantly) reduced plasma urea concentration at the medium and low grass allowances. These findings suggest that the concentrate supplement enabled greater utilization by rumen micro-organisms of the degradable nitrogen supplied by the grass at the medium and low grass allowance.

Animals offered supplementary concentrates had lower blood creatinine concentrations. Creatinine is sometimes used as an indicator of muscle mass, however the concentration of creatinine in the plasma is also dependent on the rate of plasma flow through the kidney (mg creatinine excreted per h per mg creatinine per ml in the plasma = ml of plasma flow through the kidney) (Hawk, 1965). This would imply that the animals on higher feeding levels had higher throughput of plasma through the kidneys thereby removing the creatinine faster. Enright *et al.* (1992) also found a highly significant negative correlation between plasma creatinine concentration and energy intake of heifers of similar initial live weight

A number of studies (Enright *et al.*, 1992; Sinclair *et al.*, 1994) have shown that a decreased energy balance results in lower plasma glucose concentrations. However, in this study there was no significant effect of dietary treatment on plasma glucose concentration despite a large range in energy intake.

Animal performance

Because of the interaction between grass allowance and concentrate level on grass intake, one cannot separate the effects of grass allowance and concentrate level on animal performance using all treatments. To compare the effect of these two strategies on animal performance, the three treatments offered unsupplemented grass were used to determine the effect of grass intake. The three treatments offered the low grass allowance and either 0, 2·5 or 5 kg concentrate were used to determine the effects of concentrate intake as there was no effect of concentrate supplementation on grass intake in these three treatment groups.

The estimated live-weight gain responses were thus 80 g/kg grass DM eaten and 159 g/kg concentrate DM eaten. The live-weight gain response to concentrates at the medium grass allowance is similar to those reported previously for cattle supplemented with concentrates at a medium (20 g/kg live weight) grass allowance (French, 1998), high stocking rates (Conway, 1968 and Drennan *et al.*, 1997) and low pasture supply (Steen, 1994).

The same treatments were selected to determine the animal carcass growth responses to concentrate and grass intake as for the live-weight gain responses. Relative to the animals offered the low grass allowance and no concentrate, supplementing with concentrate increased carcass growth by 116 g/kg concentrate DM eaten whereas increasing the grass allowance, increased carcass growth by 38 g/kg DM grass eaten. The relatively larger difference in carcass gain than live-weight gain between the supplemented and the unsupplemented animals was due to the higher killing-out of the former animals by approximately 20 g carcass per kg live weight. The carcass weight response to concentrates of these groups of grazing animals was twice that of the treatment offered concentrates *ad-libitum* which gained 57 g carcass per kg concentrate DM eaten. This lends further support to our previous assumption that there was more than an additive effect of supplementing autumn grass with concentrates on diet OMD. The carcass growth of the *ad libitum* group of 809 g/day is similar to that reported by Drennan and Keane (1987) for cattle offered barley *ad libitum*.

Carcass traits

The improvement in carcass conformation due to increased grass intake or supplementary concentrates reflected carcass growth rate. Supplementary concentrates increased carcass weight by 40 kg across all treatments and carcass conformation by approximately 0·5 of a conformation score. Increasing grass intake increased carcass weight by 20 kg and carcass conformation score by 0·25 of a conformation score. Drennan *et al.* (1997) and French (1998) both reported improved carcass conformation when supplementing autumn grass with concentrates. However, in the case of Drennan *et al.* (1997) the increased carcass conformation only occurred in one of 2 years, and this concurred with a significant carcass weight response to the concentrate.

Although there was a much larger (about treble) carcass growth response to supplementary concentrates than to additional grass DM eaten, increasing grass intake significantly increased carcass fat scores whereas offering supplementary concentrates did not. Fat scores are a subjective assessment of carcass subcutaneous fat. This would imply that relative to concentrates, increasing the allowance of autumn grass led to a change in partitioning of energy, from muscle, towards subcutaneous fat. In contrast Lavery and Steen (1998) reported lower levels of carcass fat in beef cattle offered spring and summer grass relative to steers given an all concentrate diet. However, French *et al.* (2001) in a separate study observed lower levels of KCF and intra-muscular fat in steers grown to similar carcass weights on an all concentrate diet relative to those offered an autumn grass diet. Autumn grass is characterized by having a high crude protein content relative to spring or summer grass and in this present study the autumn grass supplied 82 g CP more per kg DM than the supplementary concentrate. Steen and Robson (1995) similarly observed an increase in carcass fatness as dietary CP concentration increased in fattening cattle.

Conclusion

Assuming that the growth potential of the cattle was realized by the *ad libitum* concentrate group, grass grazed, at an allowance of 30 g DM per kg live weight, only supported 0·45 of the potential carcass growth. Per kg of DM eaten, grass supported only one-third the carcass growth of supplementary concentrates. As a strategy for increasing the performance of cattle grazing the type of autumn grass used in this study, offering supplementary concentrates offers more scope than altering grass allowance.

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References

Birch, G. G. and Mwangelwa, O. M. 1974. Calorimetric determination of sugars in sweetened condensed milk products. *Journal of the Science of Food and Agriculture* **25:** 1355-1362.

Brereton, A. J. 1995. Regional and year to year variation in production. In *Irish grasslands their biology and management* (ed. D. W. Jeffrey, B. M. Jones and J. H. McAdam), pp. 12-22. Royal Irish Academy, Dublin.

Chillard, Y., Doreau, M., Bocquier, F. and Lobley, G. E. 1995. Digestive and metabolic adaptations of ruminants to variations in food supply. In *Recent developments in the nutrition of herbivores* (ed. M. Journet, E. Grenet, M. H. Farce, M. Theriez and C. Dermaquilly). *Proceedings of the fourth international symposium on the nutrition of herbivores*, pp. 329-360.

Commission of the European Communities. 1982. *European Communities beef carcass classification regulations*. Council regulations 1358/80, 1208/81, 1202/82. Commission regulations 2930/81, 563/82, 1557/82. Brussels.

Conway, A. 1968. Grazing management in relation to beef production. V. Effect of feeding supplements to beef cattle on pasture at two intensities of stocking. *Irish Journal of Agricultural Research* **7:** 105-120.

Devaney, S., O'Riordan, E. G. and Caffrey, P. J. 1997. On farm monitoring of grassland management and animal performance on drystock farms. *Irish Journal of Agricultural and Food Research* **36:** 92-93.

Dillon, P. and Stakelum, G. 1988. The use of n-alkanes and chromic oxide as markers for determining feed intake, faecal output and digestibility in dairy cows. *Proceedings of the 12th general meeting of the European Grassland Federation, Dublin*, pp. 154-158.

Dodsworth, T. L. and Ball, C. 1962. Studies on the feeding of supplements to beef cattle on grass. *Animal Production* **4:** 221-226.

Drennan, M. J. and Keane, M. G. 1987. Responses to supplementary concentrates for finishing steers fed silage. *Irish Journal of Agricultural Research* **26:** 115-127.

Drennan, M. J., Moloney, A. P., O'Riordan, E. G. and McGee, M. 1997. Effects of supplementary concentrates on performance of finishing heifers at pasture in autumn. *Proceedings of the 23rd annual research meeting of the Irish Grassland and Animal Production Association*, pp. 261-262.

Enright, W. J., McArthur, A., Prendiville, D. J., Spicer, L. J., Campbell, R. and Murphy, M. G. 1992. Beef heifers gaining or losing bodyweight: plasma metabolite and hormone concentrations. *Irish Journal of Agricultural and Food Research* **31:** 96-97 (abstr.).

European Communities (Marketing of Feedstuff) Regulations. 1984. *Statutory instruments S. I. no. 200 of 1984*.

French, P. 1998. The effects of concentrate level and systems of herbage allowance on beef production in the autumn. *M.Agr.Sc. thesis, University College, Dublin*.

French, P., Moloney, A. P., O'Kiely, P., O'Riordan, E. G. and Caffrey, P. J. 2001. Growth and rumen digestion characteristics of steers grazing autumn grass supplemented with concentrates based on different carbohydrate sources. *Animal Science* **72:** 139-148.

Hawk, P. B. 1965. *Hawk's physiological chemistry, 14th edition* (ed. B. Oser). McGraw-Hill Book Company, NY.

Hodgson, J. and Tayler, J. C. 1972. The effect of supplementary barley upon growth and efficiency of food conversion in calves kept at high grazing intensity. *Journal of the British Grassland Society* **27:** 7-14.

Kibon, A. and Holmes, W. 1987. The effect of height of pasture and concentrate composition on dairy cows grazed on continuously stocked pastures. *Journal of Agricultural Science, Cambridge* **109:** 293-301.

Lavery, N. P. and Steen, R. W. J. 1998. The effects of grazed grass or concentrate diets on performance and carcass composition of beef cattle. *Proceedings of the 24th annual research meeting of the Irish Grassland and Animal Production Association*, pp. 141-142

Leaver, J. D. 1986. Effects of supplements on herbage intake and performance. In *Grazing* (ed. J. Frame). *Occasional symposium. no. 19, British Grassland Society*, pp. 79-88.

McDonald, P., Edwards, R. A., Greenhalgh, J. F. D. and Morgan, C. A. 1995. Grass and forage crops. In *Animal nutrition, fifth edition*, pp. 434-450. Longman Publications, London.

Mayes, R. W., Lamb, C. S. and Colgrove, P. A. 1986. The use of dosed herbage n-alkanes as markers for the determination of herbage intake. *Journal of Agricultural Science, Cambridge* **107:** 161-170.

Mayne, C. S. 1991. Effects of supplementation on the performance of both growing and lactating cattle at pasture. In Management issues for the grassland farmer in the 1990s. (ed. C. S. Mayne). *Occasional symposium no. 25, British Grassland Society*, pp. 55-71.

Munro, J. M. and Walters, R. J. K. 1986. The feeding value of grass. In *Grazing* (ed. J. Frame). *Occasional symposium no. 19, British Grassland Society*, pp. 65-77.

O'Mara, F. 1996. *A net energy system for cattle and sheep*. Report submitted to the Department of Animal Science and Production, University College Dublin.

O'Riordan, E. G. 1996. Effects of herbage allowance on beef production from autumn-grazed pastures *Irish Journal of Agricultural and Food Research* **35:** 70-71 (abstr.).

Reed, K. F. M. 1978. The effect of season of growth on the feeding value of pasture. *Journal of the British Grassland Society* **33:** 227-234.

Rowlands, G. J. 1980. A review of the variations in the concentrations of metabolites in the blood of beef and dairy cattle associated with physiology, nutrition and disease, with particular reference to the interpretation of metabolic profiles. *World Review of Nutrition and Diet* **33:** 172-235.

Sarker, A. B. and Holmes, W. 1974. The influence of supplementary feeding on the herbage intake and grazing behaviour of dry cows. *Journal of the British Grassland Society* **29:** 141-143.

Siddons, R. C., Paradine, D. E., Beever, D. E. and Cornell, P. R. 1985. Ytterbium acetate as a particulate-phase digesta-flow marker. *British Journal of Nutrition* **54:** 509-519.

Sinclair, K. D., Broadbent, P. J. and Hutchinson, J. S. M. 1994. The effect of pre- and post-partum energy and protein supply on the blood metabolites and reproductive performance of single- and twin-suckling beef cows. *Animal Production* **59:** 391-400.

Steel, R. G. D. and Torrie, J. H. 1960. *Principles and procedures of statistics*. McGraw-Hill, New York.

Steen, R. W. J. 1994. A comparison of pasture grazing and storage feeding, and the effects of sward surface height and concentrate supplementation from 5 to 10 months of age on the lifetime performance and carcass composition of bulls. *Animal Production* **58:** 209-219.

Steen, R. W. J. and Kilpatrick, D. J. 1998. Effects of pasture grazing or storage feeding and concentrate input between

5·5 and 11 months of age on the performance and carcass composition of bulls and on subsequent growth and carcass composition at 620 kg live weight. *Animal Science* **66:** 129-141.

Steen, R. W. J. and Robson, A. E. 1995. Effects of forage to concentrate ratio in the diet and protein intake on the performance and carcass composition of beef heifers *Journal of Agricultural Science, Cambridge* **125:** 125-135.

Tayler, J. C. and. Wilkinson J. M. 1972. The effect of level of concentrate feeding on the voluntary intake of grass and on live-weight gain by cattle. *Animal Production* **14:** 85-96.

Thomas, J. G. and Morris, R. M. 1973. Seasonal paterns of digestible organic matter and protein production from grasses in the North Pennines. *Journal of the British Grassland Society* **29:** 275-284.

Tilley, J. M. A. and Terry, R. A. 1963. A two stage technique for the *in vitro* digestion of forage crops. *Journal of the British Grassland Society* **17:** 104-111.

Umoh, J. E. and Holmes, W. 1974. The influence of type and level of supplementary feed on intake and performance of beef cattle on pasture. *Journal of the British Grassland Society* **29:** 301-304.

Vadiveloo, J. and Holmes, W. 1979. The effects of forage digestibility and concentrate supplementation on the nutritive value of the diet and performance of finishing cattle. *Animal Production* **29:** 121-129.

Van Soest, P. J. 1963. Use of detergents in the analysis of fibrous feeds. III. A rapid method for the determination of fibre and lignin. *Journal of the Association of Official Analytical Chemists* **46:** 829-835.

Vulich, S. A., Hanrahan, J. P. and Crowley, B. A. 1995. Modification of the analytical procedure for the determination of herbage and faecal n-alkanes used in the estimation of herbage intake. *Journal of Agricultural Science, Cambridge* **124:** 71-77.

Zinn, R. A., Adam, C. F. and Tamayo, M. S. 1995. Interaction of feed intake level on comparative ruminal and total tract digestion of dry-rolled and steam-flaked corn. *Journal of Animal Science* **73:** 1239-1245.

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