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Effects of supplementary concentrate level with grass silage, and separate or total mixed ration feeding, on performance and carcass traits of finishing steers

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Concentrates are a major component of feed costs in winter finishing of beef cattle. The objectives of this study were (1) to determine the response to increasing levels of supplementary concentrates with grass silage, and (2) to determine the effects of feeding silage and concentrates separately or as a total mixed ration (TMR). A total of 117 finishing steers (mean initial live weight 538 (s.d. 35.5) kg) were assigned to a pre-experimental slaughter group of 9 animals and to 6 feeding treatments of 18 animals each. The feeding treatments were (1) silage only offered *ad libitum* (SO), (2) SO plus a low level of concentrates offered separately (LS), (3) SO plus a low level of concentrates offered as a TMR (LM), (4) SO plus a medium level of concentrates offered separately (MS), (5) SO plus a medium level of concentrates offered as a TMR (MM), and (6) concentrates *ad libitum* plus a restricted silage allowance (AL). Low and medium concentrate target levels were 3 and 6 kg dry matter (DM) per head daily. When silage (210 g/kg DM, 758 g/kg *in vitro* DM digestibility, pH 3.7) and concentrates were fed separately, the daily concentrate allowance was given in one morning feed. The animals were individually fed for a mean period of 132 days. After slaughter, carcasses were weighed and graded and a rib (6^{th} to 10^{th}) joint was dissected into its component tissues. Silage DM intake decreased ($P < 0.001$) but total DM intake increased ($P < 0.001$) with increasing concentrate level. Average live-weight gains for SO, LS, LM, MS, MM and AL was 0.34, 0.86, 0.86, 1.02, 1.00 and 1.12 (s.e. 0.064) kg/day, respectively. Corresponding carcass weight gains were 0.25, 0.58, 0.58, 0.71, 0.68 and 0.82 (s.e. 0.028)

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kg/day. All measures of fatness increased (P < 0.05), bone proportion of the rib joint decreased (P < 0.001), and muscle proportion was not significantly affected by dietary concentrate level. There were no significant interactions between concentrate level and method of feeding. Compared with offering the feeds separately, feeding as a TMR increased silage DM intake by proportionately 0.06 (P < 0.05) and total DM intake by proportionately 0.04 (P < 0.05). Method of feeding had no significant effect on performance, slaughter or carcass traits. It is concluded that silage intake decreased and total intake increased with increasing concentrate level. Live-weight and carcass-weight gains also increased with increasing concentrate level. Feeding a TMR had no effect on animal performance or carcass traits compared with separate feeding.

Keywords: Beef cattle; carcass traits; concentrate feeding; silage; total mixed rations; winter finishing

Introduction

Winter finishing is the most expensive phase of beef production systems in Ireland and the main feed cost element is purchased concentrates, which can amount to one tonne per animal over a typical 5-month-finishing period. The optimum level of concentrate feeding depends on the animal production response. A number of studies have examined the response to concentrate feeding level with grass silage (Steen and McIlmoyle, 1982; Steen, 1984; Drennan and Keane 1987 a,b), but the findings are now outdated and not applicable to current commercial practice because of changes in breed type and animal genetic merit, changes in management practices (e.g. banning of anabolic agents) and changes in the relative costs of silage and concentrates. In addition, some previous studies measured live-weight effects only, and as concentrate to forage ratio can affect kill-out proportion (Keane and Drennan, 1994), live-weight gain is not necessarily a good indicator of carcass weight gain or value.

In the past, cattle finished on forage plus concentrates were generally offered their concentrate allowance once or twice daily separately from the forage. Recently, many producers have moved to using complete diets or total mixed rations (TMR). This mechanises feeding and saves labour, but it is unclear if there are associated animal performance, efficiency or carcass compositional benefits. There is little published information on comparisons of separate and TMR feeding of beef cattle but there is a considerable body of literature relating to dairy cows.

Many of the TMR comparisons with dairy cows have produced equivocal or conflicting results. Gordon *et al.* (1995) summarised 13 studies in which TMR feeding was compared with separate or twice daily feeding of concentrates. Feed intake was increased by proportionately 0.06 due to TMR and milk yield was increased by proportionately 0.04. There was no consistent effect on milk composition. Patterson and Mayne (1997) reported that up to a level of about 8 kg/day of concentrates (0.5 of dry matter (DM) intake) there was no effect on intake or milk yield but at a higher level of concentrate feeding (13.5 kg/day or 0.62 of total DM intake) milk yield was increased.

The rationale for TMR feeding is to achieve a more stable rumen pH and fermentation pattern throughout the day (Kaufmann, 1976). This would facilitate better cellulose digestion resulting in a higher lipogenic to non-lipogenic volatile fatty acid (VFA) ratio which should alleviate the depression in milk fat concentration normally associated with high levels of concentrate feeding (Sutton, 1981). However, these effects have not been consistently demonstrated. Phipps *et al.* (1984) reported that digestibility with TMR was lower in one experiment and similar in another when compared with separate feeding of ingredients, and Gordon *et al*. (1995) reported significantly lower DM, N and gross energy digestibilities for TMR diets compared with the same feeds offered out-of-parlour. It was suggested that the differences may have been due to inaccurate estimates of the quantities of feeds consumed in the TMR. This is a major practical difficulty which is rarely alluded to in comparisons of TMR and separate feeding.

Cooke *et al*. (2004) compared separate and TMR feeding of finishing heifers. The diet comprised grass silage (0.23), maize silage (0.15), concentrates (0.59) and straw (0.03). Compared with separate feeding, TMR increased feed intake, live-weight gain, slaughter weight and carcass weight.

The objectives of this study were (1) to characterise the current response of finishing beef steers to increasing levels of supplementary concentrates with grass silage, (2) to determine the effects of feeding method (silage and concentrates offered separately or as TMR), and (3) to determine if there were interactions between supplementary concentrate level and method of feeding on intake, performance, slaughter and carcass traits.

Materials and Methods

Animals and treatments

A total of 117 steers (52 Charolais × Friesians and 39 Belgian Blue × Friesians which had been reared together since calfhood, and 26 purchased Charolais crosses) were used. The Charolais crosses were purchased directly from farms two months before the experiment commenced and grazed together with the others until housing. Mean age was about 19 months. All animals were weighed at removal from pasture on two consecutive days and were assigned, within type, on the mean of these two live weights, to blocks of 13. From within blocks, one animal was assigned at random to a pre-experimental slaughter group and two were assigned at random to each of the following six experimental treatments (18 steers per treatment):

1. Grass silage only offered *ad libitum* (SO).
2. SO plus a low level of supplementary concentrates offered separately (LS).
3. SO plus a low level of supplementary concentrates offered as TMR (LM).
4. SO plus a medium level of supplementary concentrates offered separately (MS).
5. SO plus a medium level of supplementary concentrates offered as TMR (MM).
6. Concentrates offered *ad libitum* with restricted silage (AL).

The pre-experimental slaughter group remained at pasture with a herbage allowance sufficient for maintenance until slaughter 13 days later. The experimental animals were housed in two slatted floor sheds equipped for individual feeding. One shed had 84 animal feeding spaces fitted with Calan-Broadbent doors arranged in 12 pens of 7 spaces each. The second shed had 24 individual pens. The animals were weighed every 2 weeks. All were dosed with oxfendazole (Synantic, Shering Plough) 2 weeks after housing to control gastro-intestinal parasites, and twice during the experimental period they were treated with deltamethrin pour-on

(Spot-on, Hoechst Roussel Uclaf) to control skin lice.

Feeds and feeding
Low and medium concentrate target levels were 3 and 6 kg DM per head per day, respectively. The concentrate composition (kg/t) was 870 rolled barley, 67.5 soyabean meal, 47.5 molasses and 15 mineral/vitamin premix.

When silage and concentrates were fed separately, the concentrates were offered once daily before the silage and silage was then offered once daily 40 to 60 min later. Animals offered silage only had 70 g per head daily of a mineral/vitamin premix dusted on the silage. For the TMR treatments, the quantities of silage and concentrates to be used in the mix were based on the silage and concentrate intakes of the corresponding separate-fed groups during the previous week. After daily mixing, the TMR was discharged on to a concrete apron and the individual animal allowances were weighed in. Refusals were weighed back daily. Feed was offered to proportionately 0.1 in excess of intake. Refusals were removed and discarded twice weekly.

The silage and mixes were sampled twice weekly. The silage was sampled in duplicate. One sample was dried immediately at 40 °C for 48 h. The other was stored at –20 °C and later analysed for pH, Kjeldahl N expressed as crude protein (CP), NH_3N (Sigma Diagnostics proc. No. 171), acid detergent fibre (ADF) and neutral detergent fibre (NDF) (Van Soest, Robertson and Lewis, 1991), ash (550 °C for 12 h) and *in-vitro* DM digestibility (DMD) (Tilly and Terry, 1963). Concentrates were sampled weekly and analysed for DM, CP, ADF, NDF, oil, ash and DMD. Feed refusals were sampled on the dates of removal and samples were analysed for DM and DMD proportions. Using these values for the SO and AL refusals, the weights of silage and concentrates in the mix refusals were estimated. Intakes of silage and concentrates were then calculated for all groups by subtracting the weights of refusals from the weights offered.

Slaughter and carcass assessment
To facilitate the carcass assessments, the cattle were slaughtered unfasted by block over 3 consecutive weeks giving a mean experimental feeding period of 132 days. The 24 Charolais crosses were slaughtered on the first date and on each of the two subsequent dates 24 Charolais × Friesians and 18 Belgian Blue × Friesians were slaughtered. After slaughter in a commercial meat plant carcasses were weighed hot. Cold carcass weight was estimated as 0.98 of hot carcass weight. Weights of perirenal plus retroperitoneal fat and carcass grades for conformation and fatness (Commission of the European Communities, 1982) were recorded. After carcasses were placed in the chill a number of carcass measurements (De Boer *et al*., 1974) were made. Carcasses were chilled at 4 °C for 48 h after which the right sides, from the 84 animals slaughtered on the second and third slaughter dates, were cut between the 5th and 6th ribs into a pistola hind quarter (i.e. the hind quarter to the 6th rib but without the flank) and a fore quarter that included the flank (Keane and Allen, 1998). A rib joint (ribs 6 to 10) was removed by cutting between the 10th and 11th ribs and taken to the meat laboratory. Subcutaneous fat depth and *m. longissimus thoracis et lumborum* (LTL) area were measured at the 10th rib. The rib joint was weighed and separated into subcutaneous fat, intermuscular fat, LTL muscle, other muscle, bone and *ligamentum nuchae*. The latter was included with bone in the statistical analysis. Muscle (following a 2-h blooming period) and

subcutaneous fat colour values were measured by a Hunterlab D25A colour meter, with scales for brightness (L) (0 = black, 100 = white), redness (a) (+ = red, – = green) and yellowness (b) (+ = yellow, – = blue).

The mean killing-out proportion of the pre-experimental slaughter group (510 (s.d. 12.4) g/kg) was used to estimate the initial carcass weight for the experimental animals. Carcass gains were estimated as the difference between the initial and final carcass weights.

Statistical analysis

The data were statistically analysed using the general linear model procedures of SAS (SAS, 1989/92). The model had terms for block, treatment and error. The sums of squares due to treatment were partitioned, using orthogonal contrasts, into linear, quadratic and cubic effects of concentrate level, the effect of feeding method (separate *v.* TMR) and effect due to the concentrate level × feeding-method interaction. The data are presented as the means for the six experimental treatments with the appropriate s.e. (n = 18 for intake, performance and slaughter data and n = 14 for rib composition data). Because the cubic effect of concentrate level was rarely significant and of limited biological relevance it is not included in the tables.

Results

Feed analysis

The DM concentration of the silage was 210 g/kg and the composition of the DM (g/kg) was CP 137, ash 89, DMD 758, ADF 312 and NDF 544. The silage pH was 3.7, NH_3N was 62 g/kg of total N and the estimated net energy (Unite Fourragere Viande (UFV), Jarrige, 1989) value was 0.83 UFV/kg DM. The DM concentration of the concentrate was 845 g/kg and the concentrations (g/kg) of CP, ash, DMD, ADF, NDF and oil in the DM were 126, 38, 885, 45, 150 and 14, respectively. The estimated net energy value of the concentrates was 1.14 UFV/kg DM.

Feed and energy intake

Concentrate level: Silage intake decreased, and total DM intake increased, with increasing concentrate level, with both the linear and quadratic effects significant (Table 1). For concentrate intake where three of the levels (zero, low and medium) were controlled, only the linear effect was significant. Calculated net energy (UFV) intake paralleled total DM intake with both the linear and quadratic terms significant. As proportions of total DM intake, concentrates comprised 0, 0.31, 0.55 and 0.85 for the zero, low, medium and *ad libitum* concentrate levels, respectively. Relative silage intakes for silage only and the low, medium and *ad libitum* concentrate levels were 1.00, 0.89, 0.64 and 0.21, respectively.

Feeding method: There was no significant concentrate level × feeding-method interaction for any of the variables in Table 1. Compared with feeding separately, mixing increased ($P < 0.05$) silage intake and as a consequence total DM intake was increased ($P < 0.05$). However, the difference in UFV intake did not reach significance. The mean intake increases were:- silage DM, 0.34 kg/day; total DM, 0.41 kg/day; net energy, 0.36 UFV/day.

Animal performance

Concentrate level: Live weight at both day 70 and at slaughter increased significantly with increasing concentrate level and the linear and quadratic effects were both significant (Table 2). The mean liveweight responses at slaughter to the low, medium and *ad libitum* concentrate levels

Table 1. Effects of concentrate level and feeding method on feed and energy intakes of finishing steers

	Treatment[1]						s.e.	Significance of contrasts[2]		
	SO	LS	LM	MS	MM	AL		L	Q	M
Dry matter intake (kg/day)										
Silage	7.55	6.50	6.87	4.70	5.01	1.59	0.150	***	***	*
Concentrates	–	2.95	3.04	5.76	5.82	8.72	0.096	***		
Total	7.55	9.45	9.90	10.46	10.83	10.31	0.202	***	***	*
Net energy intake (UFV/day)	6.27	8.76	9.17	10.46	10.78	11.28	0.189	***	***	
Relative silage intake	100	86	91	62	66	21	–	–	–	–
Concentrate proportion[3]	–	0.31	0.31	0.55	0.54	0.85	0.005	***		

[1]SO = silage only; LS = silage plus low level of concentrate supplement fed separately; LM = mixed ration of silage with a low level of concentrate supplement; MS = silage plus medium level of concentrate supplement fed separately; MM = mixed ration of silage with a medium level of concentrate supplement; AL = concentrates *ad libitum* with a restricted allowance of silage.
[2]L,Q = linear, quadratic effects of concentrate allowance; M = effect of feeding method (LS + MS – LM – MM).
[3]Dry matter basis.
There was no significant concentrate-level × feeding-method interaction.

Table 2. Effects of concentrate level and feeding method on live weights and gains of finishing steers

	Treatment[1]						s.e.	Significance of contrasts[2]	
	SO	LS	LM	MS	MM	AL		L	Q
Live weight (kg)									
Start	538	538	539	539	538	538	8.4		
Day 70	565	609	603	618	620	627	9.7	***	*
Slaughter	583	653	653	674	671	687	10.5	***	**
Live-weight gain (kg/day)									
Day 0 to 70	0.38	1.00	0.92	1.14	1.17	1.27	0.065	***	***
Day 70 to slaughter	0.30	0.72	0.81	0.90	0.83	0.96	0.069	***	**
Day 0 to slaughter	0.34	0.86	0.86	1.02	1.00	1.12	0.064	***	***
Carcass gain (kg/day)	0.25	0.58	0.58	0.71	0.68	0.82	0.028	***	***

[1, 2]See footnotes to Table 1.
There was no significant effect of feeding method and no significant concentrate-level × feeding-method interaction.

were 70, 90 and 104 kg, respectively. Live-weight gains reflected live weights and increased with increasing concentrate level. Again both the linear and quadratic effects were significant. Live-weight gain after 70 days was proportionately only 0.77 of that for the first 70 days, with the difference between the period before and after day 70 tending to be greater for the higher feeding levels. Overall, live-weight responses to the low, medium and *ad libitum* concentrate levels were 0.52, 0.67 and 0.78 kg/day, respectively. The corresponding carcass weight responses were 0.33, 0.45 and 0.57 kg/day. As a proportion of live-weight gain, carcass gain was 0.73, 0.67, 0.69 and 0.73 for the zero, low, medium and *ad libitum* concentrate levels, respectively.

Feeding method: There was no significant concentrate-level × feeding-method interaction and there was no significant effect of feeding method on any of the performance parameters.

Slaughter and carcass traits

Concentrate level: Results for slaughter traits are shown in Table 3. Carcass weight increased with increasing concentrate level and both the linear and quadratic effects were significant. Kill-out value also increased with increasing concentrate level but only the linear effect was significant. Carcass conformation score and carcass fat score increased with increasing concentrate level and the linear and quadratic effects were significant for both. Perirenal plus retroperitoneal fat weight and its weight relative to carcass weight increased with increasing concentrate level and the linear and quadratic effects were significant for both.

Feeding method: There was no significant concentrate-level by feeding-method interaction and there was no significant effect of feeding method on slaughter traits.

Table 3. Effects of concentrate level and feeding method on slaughter traits of finishing steers

	Treatment[1]						s.e.	Significance of contrasts[2]	
	SO	LS	LM	MS	MM	AL		L	Q
Carcass weight (kg)	308	352	351	369	364	382	5.4	***	**
Kill-out (g/kg)[3]	528	539	538	547	543	557	3.1	***	
Conformation[4]	2.11	2.61	2.67	2.67	2.83	2.83	0.118	***	*
Fat score[5]	2.17	3.43	3.34	3.60	3.68	3.60	0.137	***	***
Perirenal + retroperitoneal fat (kg)	7.6	11.7	11.5	12.3	13.5	12.1	0.65	***	***
Perirenal + retroperitoneal fat (g/kg carcass)	24.7	33.5	32.6	33.6	37.0	32.1	1.76	**	***

[1,2]See footnotes to Table 1.
[3]g cold carcass per kg slaughter weight.
[4]EU Beef Carcass Classification Scheme: scale 1 (poorest = P) to 5 (best = E).
[5]EU Beef Carcass Classification Scheme: scale 1 (leannest) to 5 (fattest).
There was no significant effect of feeding method and no significant concentrate-level × feeding-method interaction.

Regressions on concentrate level

The linear and quadratic regression coefficients for silage and total DM intake and daily live-weight gain on daily concentrate intake (all concentrate levels included) are shown in Table 4. The intercept value for silage intake in the absence of concentrates was 7.60 kg DM/day. The linear coefficients for silage and total DM intakes on concentrate level were –0.180 and 0.821, respectively, and the quadratic coefficient was –0.054 for both. The live-weight gain (kg/day) intercept was 0.379 and the linear and quadratic coefficients were 0.168 and –0.029, respectively.

Carcass measurements

Concentrate level: Carcass length tended to increase linearly ($P < 0.07$) but not quadratically with increasing concentrate level while carcass depth was not affected (Table 5). Neither leg length nor leg width were significantly affected by concentrate level but both leg thickness and circumference of round increased with increasing concentrate level with the linear and quadratic effects significant for both. When scaled for carcass weight, all carcass measurements decreased with increasing concentrate level and both the linear and quadratic effects were significant for all variables except for leg thickness where only the linear effect was significant.

Feeding method: There was no significant concentrate-level by feeding-method interaction and there was no significant effect of feeding method on any carcass measurements either absolutely or scaled for carcass weight.

Carcass traits, composition of the rib joint and tissue colour

Concentrate level: In line with the changes in carcass weight, both fore quarter and pistola weights increased with increasing concentrate level, and the linear and quadratic effects were significant (Table 6). Relative to the side weight, the pistola weight decreased linearly but not quadratically with increasing concentrate level. Weight of rib joint also increased linearly but not quadratically with increasing concentrate level and LTL area did likewise. Although fat depth was considerably lower for the zero than for the other concentrate levels, neither the linear nor quadratic effects of concentrate level were significant. Scaled for carcass weight, LTL area decreased linearly but not quadratically with increasing concentrate level.

Relative to the weight of the rib joint, both subcutaneous and intermuscular fat weights increased with increasing concentrate level and both the linear ($P < 0.06$ for intermuscular fat) and quadratic effects were significant. As a consequence, relative total fat weight increased significantly (linear and quadratic effects) with increasing concentrate level. Neither LTL muscle, other muscle, nor total muscle weights relative to weight of the rib joint

Table 4. Regressions ($y = a + b_1 x + b_2 x^2$) of silage and total dry matter intakes (kg) and daily live-weight gain (kg) on concentrate level (x; kg)

Dependent variable (y)	Intercept±s.e.	Regression coefficient±s.e.		R^2
	a	b_1	b_2	
Silage intake (kg/day)	7.60±0.916	–0.180±0.0270	–0.054±0.0043	0.84
Total intake (kg/day)	7.60±0.968	0.821±0.0317	–0.054±0.0051	0.62
Live-weight gain (kg/day)	0.379±0.048	0.168±0.0431	–0.029±0.0071	0.64

Table 5. Effects of concentrate level and feeding method on carcass measurements and on carcass measurements scaled for carcass weight

Carcass measurements	Treatment[1]						s.e.	Significance of contrasts[2]	
	SO	LS	LM	MS	MM	AL		L	Q
Actual (cm)									
Carcass length	136.7	137.3	138.4	139.2	138.0	139.3	1.06	$P < 0.07$	
Carcass depth	50.3	50.2	49.6	49.8	49.6	51.5	0.65		$P < 0.06$
Leg length	73.1	74.6	73.7	73.9	74.1	74.5	0.66		
Leg width	45.0	46.6	45.4	46.2	45.4	45.7	0.55		
Leg thickness	27.9	29.2	29.0	29.2	29.3	28.2	0.34	***	*
Circumference of round	117.3	122.9	121.8	123.0	122.9	124.1	0.91	***	*
Relative to carcass weight (cm/kg)									
Carcass length	0.454	0.396	0.402	0.381	0.384	0.376	0.0070	***	***
Leg length	0.242	0.215	0.214	0.202	0.206	0.201	0.0038	***	***
Carcass depth	0.167	0.145	0.144	0.136	0.138	0.139	0.0027	***	***
Leg width	0.149	0.134	0.132	0.127	0.126	0.123	0.0022	***	***
Leg thickness	0.092	0.084	0.084	0.080	0.082	0.076	0.0015	***	
Circumference of round	0.389	0.354	0.354	0.337	0.342	0.335	0.0056	***	*

[1,2] See footnotes to Table 1.
There was no significant effect of feeding method and no significant concentrate-level × feeding-method interaction.

Table 6. Effects of concentrate level and feeding method on carcass traits, rib joint weight, rib joint composition and on muscle and fat colour

Trait	Treatment[1]						s.e.	Significance of contrasts[2]	
	SO	LS	LM	MS	MM	AL		L	Q
Fore quarter weight (kg)	78.9	92.5	91.8	97.8	96.3	101.0	2.06	***	*
Hind quarter (pistola) weight (kg)	71.9	82.5	80.7	85.2	82.9	85.4	1.60	***	**
Pistola (g/kg side)	477	477	471	469	464	461	4.4	**	
Rib joint weight (g)	7949	9003	9272	9680	9419	9375	373.2	**	
Fat depth (mm)	7.8	11.2	12.1	10.4	10.1	11.5	1.09		
LTL[3] (cm^2)	83.5	87.6	86.7	92.4	90.5	93.0	2.81	**	
LTL[3] (cm^2/kg carcass)	0.277	0.251	0.252	0.254	0.252	0.250	0.0078	*	
Rib joint composition (g/kg)									
Subcutaneous fat	33	57	58	55	53	53	4.3	**	***
Intermuscular fat	115	142	154	151	140	142	9.3	$P < 0.06$	*
Total fat	148	199	211	206	194	195	12.2	*	**
LTL[3]	225	215	208	217	219	224	6.9		
Other muscle	416	399	397	403	408	403	9.0		
Total muscle	640	614	604	620	627	627	11.7		
Total bone	211	187	188	175	180	178	4.4	***	**
Colour measurements									
Muscle "L" (brightness)	34.2	36.0	35.6	36.5	35.7	36.2	0.50	**	
Muscle "a" (redness)	11.1	13.6	13.1	14.1	13.6	13.5	0.48	***	**
Muscle "b" (yellowness)	6.7	8.2	8.0	8.7	8.2	8.3	0.29	***	**
Fat "L" (brightness)	66.9	64.3	65.3	65.8	64.5	66.0	1.04		
Fat "a" (redness)	8.1	11.1	9.3	9.9	10.6	9.2	0.67		**
Fat "b" (yellowness)	18.2	18.7	18.7	18.5	18.8	17.5	0.42		*

[1,2]See footnotes to Table 1.
[3]LTL = *m. longissimus thoracis et lumborum.*
There was no significant concentrate-level by feeding-method interaction and no significant effect of feeding method.

were significantly affected by concentrate level but relative bone weight decreased (linear and quadratic effects significant) with increasing concentrate level.

Muscle brightness (L value) increased linearly but not quadratically with increasing concentrate level while muscle redness (a value) and yellowness (b value) both increased linearly and quadratically. Fat brightness was not affected by concentrate level but fat redness and yellowness were both quadratically (but not linearly) related to concentrate level. Fat redness was lowest for silage only and yellowness was lowest for *ad libitum* concentrates.

Feeding method: There was no significant concentrate level by feeding method interaction and no significant effect of feeding method for any of the carcass traits.

Discussion

The purpose of the study was to describe the responses to concentrate supplementation with grass silage applicable to current commercial practice, and to ascertain if there were animal performance or carcass effects from using a TMR compared with separate feeding of silage and concentrates. The treatments were deliberately chosen to measure the responses to the full range of concentrate feeding options from zero to *ad libitum*. The silage and concentrate mixes were chosen to cover the concentrate to silage ratio range (0.30–0.55) most applicable to commercial practice.

The silage used in this study was above average quality for Ireland. Keating and O'Kiely (1993) reported that the mean DMD of first cut grass silage (11043 samples) was 675 g/kg. The silage was also aerobically stable. When mixed with the low or medium levels of concentrates it remained stable (i.e. no rise in temperature) for 6 and 4 days, respectively. Thus, there should have been no decline in its nutritive value during the period it was on offer to the animals, and neither should intake have been impaired by aerobic deterioration.

With the fixed duration of the finishing period and the large differences between treatments in energy intake, there were inevitably large differences in physiological maturity which were reflected in differences in slaughter weight and carcass weight. Many of the differences in carcass traits can be attributed to these differences in physiological maturity rather than directly to dietary effects. It can be argued that by taking all the treatment groups to a constant slaughter weight, a better measure of the direct dietary effects would be obtained. However, the silage only treatment was not considered a realistic finishing diet but was included simply as a baseline for the measurement of the concentrate responses. Even if the animals continued to grow at the same rate, which is unlikely, it would have taken an additional 7 months for the silage only group to reach the same slaughter weight as the next lightest group, and then there would have been a confounding effect of age. Excluding the silage only group, the range in mean slaughter weight between the other five treatment groups was only 34 kg. The carcass weights and grades of these five groups were all within the acceptable commercial range so the results are applicable to commercial practice.

Concentrate level

The relationships between concentrate level and silage and total DM intakes were curvilinear. Total DM intake increased up to the medium concentrate level, but beyond this, a further increase in concentrates did not result in any further increase in total DM intake. Mean substitution rates of concentrate DM for silage

DM for the first, second and final concentrate increments were 0.29, 0.65 and 1.1 kg/kg, respectively. Some substitution rates reported in the literature for low levels of supplementary concentrates with silage are 0.60 (Drennan and Lawlor, 1976), 0.67 (Steen and McIlmoyle, 1982), 0.53 (Steen, 1984) and 0.24 (Drennan and Keane, 1987a). Substitution rate is influenced by silage digestibility. As silage digestibility increases, substitution rate also increases (Drennan and Keane, 1987a).

Despite the good quality silage, intake by the animals offered silage only was low (13.5 g/kg live weight) and live-weight gain was also low (0.34 kg/day). This low live-weight gain may be an under-estimate as carcass gain was 0.25 kg/day. At low growth rates, carcass gain is normally 0.55 to 0.60 of live-weight gain (Keane, 2003) but here it was 0.73 for silage only.

A quadratic relationship between supplementary concentrate level and live-weight gain was reported previously (Drennan and Keane, 1987a). In that study, the responses (g live weight per kg concentrates) to the first, second and final concentrate increments were 203, 96 and 57 g, respectively, with moderate quality silage, and 130, 49 and 24 g, respectively, with higher quality silage. In the present study, the values for similar concentrate increments were 174, 54 and 38 g/kg DM, respectively. Because increasing concentrate level was accompanied by an increasing substitution rate, the improvement in efficiency of energy utilisation with increasing concentrate level (above the low concentrate level) was marginal.

While most relationships with concentrate level were curvilinear, that for kill-out proportion was linear. Similar results were reported previously (Drennan and Keane, 1987a,b; Keane and Drennan, 1994).

Any increases in carcass physical measurements with increasing concentrate level were small and proportionately much less than the increases in carcass weight. This indicates that carcasses became more compact (more weight per cm) as concentrate level and slaughter weight increased, which reflects the parallel improvement in conformation. Increased carcass compactness with increased feeding level and slaughter weight has been reported previously (Keane, 1994; Keane and Allen, 2002). The composition of the rib joint is a good predictor (r = 0.96 for rib joint and carcass fat proportions, and r = 0.92 for rib joint and carcass muscle proportions) of carcass composition (Moloney and Keane, 2001). Mean total fat values for silage only, low concentrates, medium concentrates and concentrates *ad libitum* were 148, 205, 200 and 195 g/kg, respectively. Thus, carcass fat proportion did not increase beyond the low concentrate level even though the rate of gain and slaughter weight did. This is in agreement with earlier findings showing that replacing grass silage by concentrates in the diet did not increase fatness even though growth rate and slaughter weight increased (Keane, 1998, 2001).

Bone proportion decreased with increasing concentrate level, but above the low concentrate level differences were marginal. Decreases in bone proportion with increasing feeding level and slaughter weight have been demonstrated in numerous studies (Berg, Andersen and Liboriussen, 1978; Shahin and Berg, 1985; Keane and Allen, 1998, 1999). Normally, the increase in fat proportion with increasing feeding level and slaughter weight is greater than the decrease in bone proportion so there is a decrease in muscle proportion (Berg and Butterfield, 1976). However, in the present study, there was no significant difference in muscle proportion between the feeding treatments. There are other reports in the literature which show little or no change in muscle proportion with increased feeding level (Smith *et al*., 1977; Patterson, Price and Berg, 1985). It may be that late maturing cattle, like those used in the present study, which have a greater potential for muscle deposition, show less effects of dietary energy level on carcass composition than early maturing types. This was the conclusion of Prior *et al.* (1977) who reported that increased energy density of the diet (leading to increased carcass weight) resulted in greater fatness and a marked reduction in the proportion of retail product in early-maturing but not in late-maturing type steers.

In some European markets, particularly in Mediterranean countries, consumers discriminate against beef with yellow fat, while in more Northern countries yellowness is regarded as an indicator of more extensive production systems based on grazed and conserved grass. In the present study, the silage-only group had muscle which was less bright and less red than the other groups. It is well established that muscle colour is darker in forage-fed than in concentrate-fed animals (Regan *et al.*, 1977; Davis *et al.*, 1981; French *et al.*, 2000). Several studies have shown that fat yellowness decreases as dietary concentrate level increases (Davis *et al*., 1981; Moloney *et al.,* 2000; French *et al.,* 2000). This is due to the lower carotene concentration in concentrates than in green forages (Knight and Death, 1999). In the present study, the group on *ad libitum* concentrates had the lowest yellowness value, with little difference between the other groups.

Feeding method

There are a number of reports showing an increase in intake due to TMR feeding (e.g. Gill and Castle, 1983) but there are also reports of no increase in intake or of a reduction in intake (Gaynor *et al.,* 1989). Sometimes, the difference in intake can be explained by the rejection of unpalatable feeds in unmixed rations, something which is not possible in a TMR (Phipps *et al*., 1984). Gordon *et al.* (1995) summarised 13 studies with dairy cows and reported a mean intake increase due to TMR of proportionately 0.06 while Patterson and Mayne (1997), who also compiled results from a series of experiments, concluded that TMR had no effect on intake. The explanation for the contrasting conclusions was that the latter studies involved out-of-parlour feeding in which the concentrates were offered up to four times daily, whereas in the former, concentrates were fed twice daily. There are few reports in the literature on TMR feeding of beef cattle with which the present results can be compared. Before the advent of mixer wagons, Petchey and Broadbent (1980) compared discrete or mixed (in the trough) feeding of silage and concentrates at silage:concentrate ratios ranging from 0 to 1.0. Mixing increased DM intake by proportionately 0.09 with no evidence of an interaction between feeding method and silage:concentrate ratio.

There are reports of both no effects (Phipps *et al*., 1984; Gaynor *et al*., 1989; Agnew, Mayne and Doherty, 1996) and of positive effects (Istasse *et al*., 1986; Gordon *et al.,* 1995; Yan, Patterson and Gordon, 1998) of TMR feeding on milk production of dairy cows. Differences in production generally follow differences in intake and/or digestibility of the diet. Thus, when the experimental protocol results (sometimes inadvertently) in differences in intake or digestibility (e.g. differences between separate and TMR feeding in forage:concentrate ratios), differences in production cannot be attributed directly or entirely to method of feeding. In the review of Gordon *et al*. (1995), there was a mean proportionate increase in milk yield of 0.04 for a mean proportionate increase in intake of 0.06. Gibson (1984) reported a mean milk yield increase of proportionately 0.03 from an analysis of 35 experiments. However, in only four of these was milk yield significantly increased. Patterson and Mayne (1997) reported that up to a concentrate level of about 8 kg/day (0.50 of total DM intake) method of feeding had no effect on milk production, but at a higher level of concentrates (0.62 of total DM intake), milk production was increased by proportionately 0.07 without any increase in DM intake.

With finishing beef steers, Petchey and Broadbent (1980) found no significant effect of diet mixing on live-weight gain for silage:concentrate ratios varying from 0.2 to 0.8 (DM basis) even though the animals fed the mixed diet had proportionately 0.09 higher intake. Renton and Forbes (1974) found no effect of once, twice or three times a day feeding of concentrates with hay on diet digestibility or efficiency of feed utilisation by beef cattle. The proportion of concentrates in the diet was 0.48. Cooke *et al*. (2004) offered finishing heifers a ration of grass silage, maize silage, straw and concentrates both separately and mixed. Mixing increased DM intake by proportionately 0.04 but increased live-weight gain by proportionately 0.15. The live-weight gain on the mixed ration did not differ significantly from that on an all concentrate ration offered *ad libitum.* A possible explanation for the difference between the present findings and those of Cooke *et al*. (2004) may be that the forage used by Cooke *et al*. (2004) included maize silage, straw and grass silage whereas in the present study only grass silage was used. Yan *et al*. (1998) have stated that when a benefit was obtained to TMR feeding, forages other than grass silage were offered.

In the present study, the generally similar DM and DMD values of the refusals for the silage only and separately-fed silage and concentrates treatments indicated that the entire concentrates allowance was consumed and the refusals were all silage. These values were then used to estimate the proportion of silage (the remainder being concentrates) in the refusals from the mixed diets on the assumption that all silage refusals were of similar composition. This may or may not be the case. For example, animals offered the mixed diets may have had a greater opportunity for selection resulting in differences in the composition of the silage residue. More precise measurements of the composition of feed refusals are required before the detailed effects of mixing on intake can be evaluated with complete confidence.

Conclusions

There were no interactions between concentrate level and method of feeding. The relationships between supplementary concentrate level and silage intake, total DM intake, daily live-weight gain and daily carcass gain were curvilinear. Maximum DM intake occurred at the medium concentrate level but maximum energy intake occurred on *ad libitum* concentrates. Efficiency of energy utilisation was poorest on silage only and best on *ad libitum* concentrates but there was little difference in efficiency between the low and medium concentrate levels. Carcass conformation improved with increasing concentrate level and slaughter weight. Measures of fatness increased to a plateau with the first increment of concentrate feeding. Bone proportion decreased with increasing concentrate level and slaughter weight. Muscle growth paralleled carcass growth and muscle remained a constant proportion of the rib joint across concentrate levels. Muscle from animals fed silage only was less bright and less red than that from animals fed concentrates. Fat colour was little affected by concentrate level but animals offered *ad libitum* concentrates had the least yellow fat.

Feeding a TMR increased silage and total DM intake but this may reflect difficulties in accurately measuring the intake of the separate ingredients in the TMR. Otherwise, feeding a TMR had no effect on growth, efficiency, slaughter, carcass or colour traits.

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