

End of Project Report

OPTIMISING THE RESPONSE TO SUPPLEMENTARY CONCENTRATES BY BEEF CATTLE IN WINTER

**(Comparison of supplementary concentrate level with grass
silage, separate or total mixed ration feeding, and duration
of finishing in steers).**

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1. SUMMARY

Concentrates are a major component of feed costs in winter finishing of beef cattle. Two separate experiments were carried out to evaluate the response to increasing supplementary concentrate level with grass silage and the effects of feeding the silage and concentrates separately or as a total mixed ration (TMR). In experiment 1, a total of 117 finishing steers (initial live weight 538 kg, s.d. 35.5) 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 (SO) only offered *ad libitum*, 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 target concentrate levels were 3 and 6 kg dry matter (DM) per head daily. When silage 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 the ribs joint was dissected into its component tissues. Silage DM intake decreased but total DM intake increased with increasing concentrate level. Live weight gains for SO, LS, LM, MS, MM and AL were 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) kg/day. All measures of fatness increased, ribs joint bone proportion decreased, 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 a TMR increased silage DM intake by proportionately 0.06 and total DM intake by proportionately 0.04. Otherwise, method of feeding had no significant effect on performance, slaughter or carcass traits. Mean rumen pH decreased while ammonia concentration tended to increase with increasing concentrate level. Total volatile fatty acids and the acetate to propionate ratio were lowest for SO. Method of feeding had no significant effect on rumen fermentation.

In Experiment 2, the effects of supplementary concentrate level and method of feeding were again evaluated together with the effects of duration of the finishing period. A total of 117 finishing steers were assigned to a pre-experimental slaughter group of 9 animals and to 12 finishing groups in a 6 feeding treatments x 2 durations

of finishing (Short, S and Long, L) factorial experiment. The 6 feeding treatments were: 1) silage (SO) only offered *ad libitum*, 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 high level of concentrates offered separately (HS), 5) SO plus a high level of concentrates offered as a TMR (HM), and 6) concentrates *ad libitum* plus restricted silage (AL). Target low and high concentrate levels were proportionately 0.375 and 0.750 of daily DM intake, respectively. S and L finishing periods were 105 and 175 days, respectively. Silage DM intake decreased ($P < 0.001$) and total DM intake increased ($P < 0.001$) with increasing concentrate level. Maximum DM intake occurred at the high concentrate level but maximum net energy intake occurred on *ad libitum* concentrates. Live weight gains for the feeding treatments as listed as were 0.21, 0.90, 0.93, 1.11, 1.09 and 1.21 (s.e. 0.046) kg/day. Corresponding carcass gains were 0.12, 0.51, 0.54, 0.66, 0.63 and 0.75 (s.e. 0.025) g/day. Kill-out proportion, carcass conformation score and all measures of fatness increased significantly with increasing concentrate level. Feeding a TMR increased silage intake at the low concentrate level but otherwise had no effect on animal performance or carcass traits. Extending the finishing period reduced ($P < 0.001$) daily live weight gain, but the associated reduction in carcass weight gain was not statistically significant. It is concluded that the response to supplementary concentrates decreased with increasing level, there was no animal production advantage to a TMR over separate feeding of the dietary constituents, and extending the duration of the finishing period reduced mean daily gain and increased fatness.

2. INTRODUCTION

Winter finishing is the most expensive phase of beef production systems because of the high costs of concentrates which can amount to 1t per animal over a typical 5 month finishing period. The optimum level of supplementary concentrates with silage depends on the relative costs of silage and concentrates, and the animal production response which can vary with breed type, genetic merit and management practices. Production responses are generally measured as live weight gain but 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.

The rationale for TMR feeding is to achieve a more stable rumen pH and fermentation pattern throughout the day. This would facilitate better cellulose digestion resulting in a higher lipogenic to non-lipogenic volatile fatty acid (VFA) ratio. Two separate experiments were carried out at Grange Beef Research Centre to evaluate the response to increasing levels of supplementary concentrates with grass silage and the effects of feeding the silage and concentrates separately or as a TMR.

3. EXPERIMENT 1

The objectives of this experiment were (1) to characterise the responses in 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.

3.1 Materials and Methods

3.1.1 *Animals and treatments*

A total of 117 steers (52 Charolais x Friesians and 39 Belgian Blue x Friesians which had been reared together since calf-hood, and 26 purchased Charolais crosses) were used. 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. Silage plus a low level of supplementary concentrates offered separately (LS).
3. Silage plus a low level of supplementary concentrates offered as TMR (LM).
4. Silage plus a medium level of supplementary concentrates offered separately (MS).
5. Silage 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 two weeks. All were dosed with oxfendazole (Synantic, Shering Plough) two 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.

3.1.2 *Feeds and feeding*

Low and medium target concentrate levels were 3 and 6 kg dry matter (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 minutes 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. The individual animal allowances were weighed in and 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 hours. The other was stored at -20°C and later analysed for pH, crude protein (CP), NH₃N, acid detergent fibre (ADF), neutral detergent fibre (NDF), ash and *in-vitro* DM digestibility (DMD). 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.

3.1.3 Slaughter and carcass assessment

To facilitate the carcass assessments, the cattle were slaughtered unfasted by block over three 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 x Friesians and 18 Belgian Blue x 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, carcass grades for conformation and fatness, and carcass measurements were recorded. Carcasses were chilled at 4°C for 48 hours 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 fifth rib but without the flank) and a fore quarter that included the flank. The ribs 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 ribs joint was weighed and separated into subcutaneous fat, intermuscular fat, LTL, other muscle, bone and *ligamentum nuchae*. The latter was included with bone in the statistical analysis. A sample of LTL was chemically analysed for moisture, protein and lipid concentrations. 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 g/kg, s.d. 12.4) was used to estimate the initial carcass weights of the experimental animals. Carcass gains were estimated as the difference between the initial and final carcass weights.

3.1.4 Ruman fluid composition

Separately from the main experiment a rumen fluid study was undertaken. In a 5 x 5 latin square design, 5 rumen cannulated Friesian steers were offered 5 of the feeding treatments (SO, LS, LM, MS, MM) for 5 periods of 28 days each. Rumen fluid samples were collected on day 28 of each period in the mornings immediately before feeding (0h) and at 1, 2, 4, 8, 14 and 24 h after feeding. The pH, ammonia and VFA concentrations were measured.

3.1.5 Statistical analysis

The production and carcass data were statistically analysed using the general linear model least squares procedures of SAS. The model had terms for block, treatment and error. The 5 d.f. for treatment were partitioned into 5 *a priori* contrasts, one each for the linear, quadratic and cubic effects of concentrate level, one for the effect of feeding method (separate or TMR) and one for the concentrate level x feeding method interaction. The data are presented as the means for the 6 experimental treatments with the appropriate s.e. (n = 18 for intake, performance and slaughter data, and n = 14 for ribs composition data). Because the cubic effect of concentrate level was rarely significant and of limited biological relevance it is not included in the tables. The rumen fluid data were also analysed in SAS. The model had terms for feeding treatment, period and animal with sampling time as a repeated measure.

3.2 Results

3.2.1 Feed analysis

The DM content 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, NH₃N was 62 g/kg of total N and the estimated net energy (Unite Fourragere Viande (UFV)) value was 0.83 UFV/kg DM. The DM content 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.

3.2.2 Feed and energy intakes

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. 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.

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

	Treatment						s.e. ¹	L ²	Q ³	M ⁴
	SO	LS	LM	MS	MM	AL				
<u>Dry matter intake (kg/day)</u>										
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 ⁵	-	0.31	0.31	0.55	0.54	0.85	0.005	***		

¹For n = 18; ²Linear component of concentrate effect; ³Quadratic component of concentrate effect; ⁴Method of feeding effect; ⁵Dry matter basis. There was no significant concentrate level x feeding method interaction.

There was no significant concentrate level x 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 0.34 kg/day silage DM, 0.41 kg/day total DM and 0.36 UFV/day.

3.2.3 Animal performance

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 live weight responses at slaughter to the low, medium and *ad libitum* concentrate levels 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 before and after 70 day periods 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.

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

	Treatment						s.e. ¹	L ²	Q ³
	SO	LS	LM	MS	MM	AL			
<u>Live weights (kg)</u>									
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	***	**
<u>Live weight gains (kg/day)</u>									
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	***	***

¹For n = 18; ²Linear component of concentrate effect; ³Quadratic component of concentrate effect. There was no significant effect of feeding method and no significant concentrate level x feeding method interaction.

There was no significant concentrate level by feeding method interaction and there was no significant effect of feeding method on any of the performance parameters.

3.2.4 Slaughter and carcass traits

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 class and carcass fat class increased with increasing concentrate level and the linear and quadratic effects were significant for both. Perirenal plus retroperitoneal fat weight and its proportion of carcass weight increased with increasing concentrate level and the linear and quadratic effects were significant for both. 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						s.e. ¹	L ²	Q ³
	SO	LS	LM	MS	MM	AL			
Carcass weight (kg)	308	352	351	369	364	382	5.39	***	**
Kill-out (g/kg) ⁴	528	539	538	547	543	557	3.06	***	
Conformation Class ⁵	2.11	2.61	2.67	2.67	2.83	2.83	0.118	***	*
Fat Class ⁶	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	**	***

¹For n = 18; ²Linear component of concentrate effect; ³Quadratic component of concentrate effect; ⁴g cold carcass per kg slaughter weight; ⁵EU Beef Carcass Classification Scheme: scale 1 (poorest = P) to 5 (best = E); ⁶EU Beef Carcass Classification Scheme: scale 1 (leanest) to 5 (fattest). There was no significant effect of feeding method and no significant concentrate level x feeding method interaction.

3.2.5 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.

Table 4. Regressions ($y = a + b_1X + b_2X^2$) of silage and total dry matter intakes (kg) and daily live weight gain (kg) on concentrate level (kg)

<u>X = Concentrate level</u>	Intercept		Regression coefficients				<u>R²</u>
	<u>a</u>	<u>s.e.</u>	<u>b₁</u>	<u>s.e. (b₁)</u>	<u>b₂</u>	<u>s.e. (b₂)</u>	
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

	Treatment						<u>s.e.¹</u>	<u>L²</u>	<u>Q³</u>
	<u>SO</u>	<u>LS</u>	<u>LM</u>	<u>MS</u>	<u>MM</u>	<u>AL</u>			
<u>Carcass measurements (cm)</u>									
Carcass length	136.7	137.3	138.4	139.2	138.0	139.3	1.064	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	0.661		
Leg width	45.0	46.6	45.4	46.2	45.4	45.7	0.545		
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	***	*
<u>Carcass measurements (cm/kg)</u>									
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	0.14.9	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	***	*

¹For n = 18; ²Linear component of concentrate effect; ³Quadratic component of concentrate effect.

There was no significant effect of feeding method and no significant concentrate level x feeding method interaction.

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

	Treatment						s.e. ¹	L ²	Q ³
	SO	LS	LM	MS	MM	AL			
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	**	
Ribs 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 (cm ²)	83.5	87.6	86.7	92.4	90.5	93.0	2.81	**	
LTL (cm ² /kg carcass)	0.277	0.251	0.252	0.254	0.252	0.250	0.0078	*	
<u>Ribs composition (g/kg)</u>									
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	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	***	**
<u>Muscle chemical composition (g/kg)</u>									
Moisture	749	739	737	729	732	733	3.2	***	*
Protein	227	228	228	228	226	226	8.3		
Lipid	21	28	32	36	34	34	3.1	*	
<u>Colour measurements</u>									
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		*

¹For n = 14; ²Linear component of concentrate effect; ³Quadratic component of concentrate effect. There was no significant concentrate level by feeding method interaction and no significant effect of feeding method. LTL= *m. longissimus et thoracis*

3.2.6 Carcass measurements

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.

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.

3.2.7 Carcass traits, ribs joint composition and tissue colour

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. Ribs joint weight 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 ribs joint weight, 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, other muscle, nor total muscle weights relative to ribs joint weight, were significantly affected by concentrate level but relative bone weight decreased (linear and quadratic effects significant) with increasing concentrate level.

Muscle moisture concentration decreased (linear and quadratic components significant) and muscle lipid concentration increased (linear term significant) with increasing concentrate level. Muscle protein level was not significantly affected by 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.

There was no significant concentrate level by feeding method interaction and no significant effect of feeding method for any of the carcass, chemical composition or colour traits.

3.2.8 Rumen fluid analysis

There was no significant feeding treatment by sampling time interaction. Mean rumen pH was significantly lower for the high concentrate level than for silage only (Table 7). Differences between treatments in ammonia concentration were not significant but the silage only treatment had the lowest value. Total VFA was significantly higher for the high concentrates fed separately than for silage only but other differences between treatments were not significant. The acetate to propionate ratio tended to be lower for the silage only than for the concentrate supplemented groups. There was no effect of feeding method but the acetate to propionate ratio tended to be lower for mixed compared with separate feeding.

The effects of sampling time are shown in Table 8. There was a decrease in pH after feeding for 8 h, and then an increase to 24 h. Ammonia and VFA increased for 2-4 h after feeding and then decreased to 24 h. Acetate to propionate ratio decreased up to 8 h and then increased to 24 h.

Table 7. The effect of concentrate level and separate or mixed feeding on rumen fermentation variables

	Treatment					s.e.d.	Sig
	SO	LS	LM	HS	HM		
pH	6.81 ^b	6.64 ^{ab}	6.55 ^a	6.38 ^a	6.48 ^a	0.121	*
Ammonia ¹	12.60	15.10	14.30	15.79	13.19	1.685	
Total VFA ²	85.6 ^a	91.3 ^{ab}	98.8 ^{ab}	104.5 ^b	94.5 ^{ab}	8.53	*
Ac:pr ratio ³	3.58	4.12	3.82	4.14	3.99	0.191	P<0.07

¹mg/l; ²mmol/l; ³acetate:propionate ratio

Values with a common superscript do not differ significantly (P<0.05).

Table 8. The effect of sampling time on rumen fermentation variables

	Time (h)							s.e.d.	Sig
	0	1	2	4	8	14	24		
pH	6.80 ^a	6.66 ^{ab}	6.44 ^b	6.28 ^{bc}	6.24 ^{bc}	6.45 ^b	7.14 ^d	0.143	***
Ammonia ¹	7.67 ^a	14.34 ^b	20.02 ^c	18.85 ^c	17.85 ^{bc}	13.03 ^b	7.59 ^a	1.994	***
Total VFA ²	75.8 ^a	94.7 ^{ab}	107.7 ^b	108.9 ^b	105.5 ^b	101.8 ^b	70.1 ^f	10.10	***
Ac:pr ratio ³	4.60 ^a	3.92 ^b	3.63 ^{bc}	3.67 ^{bc}	3.37 ^c	3.68 ^{bc}	4.62 ^a	0.226	***

¹mg/l; ²mmol/l; ³acetate:propionate ratio

Values with a common superscript do not differ significantly (P<0.05).

3.3 Discussion

3.3.1 Rationale for study

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 range (0.30 - 0.55) most applicable to commercial practice.

With the fixed duration of finishing and the large differences between treatments in energy intake, there were inevitably large differences in physiological maturity at slaughter. 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.

3.3.2 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 a 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. Substitution rate is influenced by silage digestibility. As silage digestibility increases, substitution rate also increases.

Despite the good quality silage, intake of 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 but here it was 0.73 for silage only.

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.

Mean total ribs joint fat values for silage only, low concentrates, medium concentrates and concentrates *ad libitum* were 148, 205, 200 and 195g/kg, respectively. Thus, carcass fat proportion did not increase beyond the low concentrate level even though the rate of gain and slaughter weight did.

Bone proportion decreased with increasing concentrate level, but above the low concentrate level differences were marginal. Normally, any increase in fat proportion with increasing feeding level and slaughter weight is greater than the decrease in bone proportion so there is also a decrease in muscle proportion. However, in the present study, there was no significant difference in muscle proportion between the feeding treatments. It may be that late maturing cattle, like those used, which have a greater potential for muscle deposition, show less effects of dietary energy level on carcass composition than early maturing types.

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 and several studies have shown that fat yellowness decreases as dietary concentrate level increases. This is due to the lower carotene concentration in concentrates than in green forages. In the present study, the *ad libitum* concentrates group had the lowest yellowness value, with little difference between the other groups.

3.3.3 Feeding method

While a number of reports show an increase in intake due to TMR feeding there are also reports showing no increase or a reduction in intake. Sometimes, the difference in intake can be explained by the rejection of unpalatable feeds in unmixed rations, something that is not possible in a TMR.

There are reports of both no effects and of positive effects 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 this experiment, 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.

4. EXPERIMENT 2

In Experiment 1, there were no differences between a TMR and separate feeding of the same feed ingredients when the duration of the experimental period was the same for all treatments. The outcome may have been different if the animals had all been taken to a constant slaughter weight or carcass weight. Using serial slaughter permits adjustment of the data to a constant end point so in this experiment the treatments were imposed for two finishing periods. In addition, the proportions of concentrates in the mixed treatments were higher than in Experiment 1 where it could be argued that one or perhaps both were below the level at which a response to mixing would be expected.

Accordingly, the objectives of this experiment were (1) to determine the production and carcass responses to supplementary concentrates with a basal diet of grass silage, (2) to determine the effects of feeding method (silage and concentrates offered separately or as TMR), (3) to determine the effects of duration of the finishing period, and (4) to ascertain if there were interactions between supplementary concentrate level, method of feeding and duration of finishing.

4.1 Materials and Methods

4.1.1 Animals and treatments

A total of 117 19-month-old finishing steers [65 Friesians, 466 (s.d. 18.8) kg, and 52 Charolais x Friesians, 486 (s.d. 23.0) kg] were used. All had been reared at Grange Beef Research Centre from shortly after birth and had been at pasture together for the previous grazing season. They were weighed on two consecutive days, and based on the mean of these two live weights, they were assigned from within breed type to 9 (5 Friesians and 4 Charolais x Friesians) blocks of 13 animals each. From within blocks animals were randomly allocated to a pre-experimental slaughter group of 9 animals and to 12 experimental groups of 9 animals each. The animals in the pre-experimental group were slaughtered the following day and the 12 experimental groups were assigned in a 6 x 2 factorial design to 6 feeding treatments x 2 durations (short (S) and long (L)) of finishing.

The 6 feeding treatments were:

1. Grass silage only offered *ad libitum* (SO)
2. Silage plus a low level of supplementary concentrates offered separately (LS)
3. Silage plus a low level of supplementary concentrates offered as a TMR (LM)
4. Silage plus a high level of supplementary concentrates offered separately (HS)
5. Silage plus a high level of supplementary concentrates offered as a TMR (HM)
6. Concentrates offered *ad libitum* with restricted (1 kg DM/day) silage (AL)

The mean durations of the S and L finishing periods were 105 and 175 days, respectively. The animals were individually fed in two slatted floor sheds. One shed accommodated 84 animals in 12 pens fitted with Calan doors for individual feeding. The second shed had 6 pens (one pen per feeding treatment) of 4 (2 S and 2 L) animals each. The mean intake per pen of group-fed animals was included with the individual intake values in the statistical analysis. Two weeks after housing all animals were dosed with oxfendazole (Synantic, Schering Plough) to control gastrointestinal parasites and all were treated with deltamethrin pour-on (Spot-on, Hoechst Roussel Uclaf) to control skin lice.

4.1.2 Feeds and feeding

Target low and high concentrate levels were 0.375 and 0.750 of daily DM intake, respectively. The concentrate composition (kg/t) was rolled barley 870, soya bean meal 67.5, molasses 47.5 and mineral/vitamin premix 15.

Initially, all animals were offered silage *ad libitum* and concentrates were increased gradually until the various groups reached their target concentrate intakes. Concentrate intakes were calculated weekly for the TMR groups and their mean daily concentrate intakes became the allowances for the corresponding separate-fed groups for the following week. The objective was to ensure the same concentrate intakes for the corresponding TMR and separate-fed groups. For the separate-fed groups, the concentrate allowance was offered once daily in the morning and fresh silage was offered about one hour later. The

animals on silage only received 70 g/day of a mineral/vitamin premix top dressed on the silage. All feeds were weighed in daily. Refusals were weighed back daily and discarded twice weekly. The silage (in duplicate), concentrates and mixes were sampled weekly. One silage sample was dried immediately at 40°C for 48 hours. This was used to estimate current DM intakes and adjust the daily concentrate allowance for the separate fed groups as necessary. The other silage samples were frozen and later composited for two-week periods. They were analysed for pH, CP, DMD and ash. Concentrate samples were also composited for two-week periods and analysed for DM, CP, ash, oil and DMD. Feed refusals were sampled at discarding, composited for two-week periods and analysed for DM and DMD. These values were used to estimate the proportions of silage and concentrate DM in the TMR refusals.

The DM content of the silage was 198 g/kg and the mean composition (g/kg) of the DM was CP 143, ash 93 and DMD 698. The pH value was 3.9. The estimated net energy (Unite Fourragere Viande (UFV) value was 0.74 UFV/kg DM. The DM content of the concentrates was 836 g/kg and the mean composition (g/kg) of the DM was CP 147, ash 55, oil 13 and DMD 874. The estimated net energy value was 1.13 UFV/kg DM.

4.1.3 Slaughter and carcass assessment

The S and L cattle were slaughtered by block on two consecutive weeks to facilitate carcass evaluation. Cold carcass weight was estimated as 0.98 of hot carcass weight. Carcass grades for conformation and fatness, weights of perinephric plus retroperitoneal fat, and carcass measurements were recorded. After 48 hours in the chill, the right side of each carcass was divided into a pistola hind quarter (i.e. the hind quarter to the 5th rib but without the flank) and the remaining fore quarter. Subcutaneous fat depth was measured at the 10th rib. The ribs joint (ribs 6 to 10) was removed, weighed and separated into subcutaneous fat, intermuscular fat, LTL, other muscle, and bone including *ligamentum nuchae*. A sample of LTL was chemically analysed. Within breed type, the mean kill-out value for the pre-experimental slaughter group was used to estimate the initial carcass weight of the experimental animals.

4.1.4 Statistical analysis

The data were statistically analysed using the general least squares linear model procedures of the SAS. The model had terms for block, feeding treatment, duration of finishing period and feeding treatment x duration of finishing period. The effects of the feeding treatments were evaluated using *a priori* contrasts representing the linear, quadratic and cubic effects of concentrate level, the effect of feeding method (separate or TMR), and the concentrate level (low or high) x feeding method interaction. The data are presented as the means (with appropriate s.e.) for the six feeding treatments and the two finishing periods. Because the cubic effect of concentrate level and the feeding treatment x duration of finishing

interaction were not significant, these are not shown. Silage and total DM intakes, and daily live weight and carcass weight gains, were regressed on concentrate level using the model indicated by the analysis of variance. Some carcass, ribs joint composition and muscle chemical composition traits were regressed on carcass weight, carcass fat class and muscle lipid content using all the data including the pre slaughter group and separately for the two breed types.

4.2 Results

4.2.1 Feed intake

Silage intake decreased and total intake increased with increasing concentrate level and both the linear and quadratic effects were statistically significant for all intake variables (Table 9). Mean intakes after 105 days were similar to those up to 105 days. Mean concentrate intakes over the total experimental period for the low, high and *ad libitum* concentrate levels represented 415, 735 and 907 g/kg of total DM intake, respectively. Net energy intake increased with increasing total DM intake, but whereas total DM intake reached a peak at the high concentrate level, net energy intake peaked with *ad libitum* concentrates. Per kg mean live weight, silage intake decreased and total DM intake increased with increasing concentrate level, with both the linear and quadratic effects statistically significant.

There were statistically significant concentrate level x feeding method interactions for silage intake for the period up to 105 days, the period after 105 days, the total experimental period, and for silage intake per kg mean live weight. These interactions were due to the TMR animals having consistently higher silage intakes at the low but not at the high concentrate level throughout the experimental period. Concentrate intake was higher ($P < 0.05$) for TMR than for separate feeding in the period after 105 days and total intake tended ($P < 0.08$) to be higher also. Duration of finishing did not affect absolute intakes up to 105 days or overall, but intakes per kg mean live weight were significantly ($P < 0.001$) lower after 105 days than before.

Table 9. Effects of concentrate level (C), method of feeding (M) and duration of finishing (D) on silage, concentrate and total dry matter intakes of finishing steers

	Feeding treatment							Duration of finishing			Significance				
	<u>SO</u>	<u>LS</u>	<u>LM</u>	<u>HS</u>	<u>HM</u>	<u>AL</u>	<u>s.e.</u> ¹	<u>S</u> ²	<u>L</u> ³	<u>s.e.</u> ⁴	<u>L</u> ⁵	<u>Q</u> ⁶	<u>M</u> ⁷	<u>D</u> ⁸	<u>M x C</u> ⁹
<u>Start to 105 days (kg/day)</u>															
Silage	7.12	5.46	5.91	3.01	2.80	0.99	0.092	4.21	4.22	0.057	***	**			***
Concentrate	-	4.03	3.93	8.02	8.11	9.50	0.165	5.63	5.56	0.103	***	***			
Total	7.12	9.49	9.84	11.03	10.91	10.48	0.190	9.84	9.78	0.119	***	***			
<u>From 106 to 175 days (kg/day)</u>															
Silage	6.94	5.08	5.58	3.04	2.96	0.99	0.112	-	4.10	0.048	***	*	P<0.07		*
Concentrate	-	3.88	4.02	8.01	8.27	9.48	0.178	-	5.61	0.076	***	***	*		
Total	6.94	8.96	9.60	11.04	11.22	10.47	0.215	-	9.71	0.092	***	***	P<0.08		
<u>Start to slaughter (kg/day)</u>															
Silage	7.05	5.33	5.82	2.99	2.84	0.97	0.091	4.19	4.15	0.057	***	***	P<0.07		***
Concentrate	-	3.98	3.96	8.01	8.16	9.49	0.162	5.62	5.56	0.102	***	***			
Total	7.05	9.31	9.78	11.00	11.01	10.46	0.197	9.81	9.71	0.124	***	***			
Net energy intake (UFV/day)	5.22	8.44	8.78	11.26	11.32	11.44	0.184	9.45	9.35	0.116	***	***			
<u>Per kg live weight (g/day)</u>															
Silage	14.5	10.0	10.8	5.4	5.1	1.8	0.15	8.1	7.7	0.10	***	***		***	**
Concentrate	-	7.5	7.3	14.5	14.8	17.2	0.25	10.5	9.9	0.16	***	***		**	
Total	14.5	17.5	18.1	20.0	19.9	19.0	0.30	18.7	17.6	0.19	***	***		***	

¹For n = 15 for start to 105 days, start to slaughter and per kg live weight, and n = 8 for 106 days to 175 days; ²Short; ³Long

⁴For n = 45; ⁵Linear component of concentrate level effect; ⁶Quadratic component of concentrate level effect; ⁷Method of feeding (separate or TMR) effect; ⁸Duration of finishing effect; ⁹Method of feeding x concentrate level interaction. There was no significant Feeding treatment x Duration of finishing interaction.

UFV = Unite Fourragere Viande.

4.2.2 Animal performance

From 41 days after commencement of the experiment to slaughter, live weights increased ($P<0.001$) with increasing concentrate level and both the linear and quadratic effects were significant (Table 10). Daily live weight gains for all periods of the experiment and carcass weight gains increased ($P<0.001$) with increasing concentrate level also and the linear and quadratic effects were significant for all. The mean live weight gain responses to the low, high and *ad libitum* concentrate levels were 703, 888 and 995 g/day, respectively. Corresponding carcass weight gain responses were 404, 529 and 627 g/day. Carcass weight gains as proportions of live weight gains for the zero, low, high and *ad libitum* concentrate levels were 0.56, 0.57, 0.59 and 0.62, respectively.

There was a significant ($P<0.01$) concentrate level x feeding method interaction for live weight gain over the first 41 days because of a positive effect of mixing at the low but not at the high concentrate level. Otherwise, mixing had no significant effect on live weights, live weight gains or carcass weight gains.

As intended, there was a significant increase in slaughter weight ($P<0.001$) with increasing length of finishing period. Average daily live weight gain to slaughter was lower ($P<0.01$) for L than S but the difference in carcass weight gain was not statistically significant. As proportions of live weight gains up to 105 days, live weight gains from 106 to 175 days were 0.91, 0.90, 0.88 and 0.81 for the zero, low, high and *ad libitum* concentrate levels, respectively. The corresponding proportions for carcass weight gains were 1.40, 1.04, 0.92 and 0.88. Thus, unlike live weight gain which declined after 105 days at all concentrate levels, there was no decline in carcass weight gain at the zero and low concentrate levels, and at the high and *ad libitum* concentrate levels the decline was proportionately less than for live weight gain.

4.2.3 Slaughter and carcass traits

Carcass weight, carcass fat class and perinephric plus retroperitoneal fat weight increased with increasing concentrate level and both the linear and quadratic effects were significant (Table 11). Kill-out proportion and carcass conformation class increased linearly ($P<0.001$) with increasing concentrate level.

There were no significant concentrate level x feeding method interactions and there was no significant effect of feeding method for any variables.

Duration of finishing significantly affected all variables except carcass conformation. Carcass weight was greater ($P<0.001$) for L than S and there were associated increases in kill-out proportion ($P<0.001$), carcass fat class ($P<0.05$), and weight ($P<0.001$) and proportion ($P<0.001$) of perinephric plus retroperitoneal fat.

Table 10. Effects of concentrate level (C), method of feeding (M) and duration of finishing (D) on live weights, live weight gains and carcass weight gains of finishing steers

	Feeding treatment							Duration of finishing			Significance				
	<u>SO</u>	<u>LS</u>	<u>LM</u>	<u>HS</u>	<u>HM</u>	<u>AL</u>	<u>s.e.</u> ¹	<u>S</u> ²	<u>L</u> ³	<u>s.e.</u> ⁴	<u>L</u> ⁵	<u>Q</u> ⁶	<u>M</u> ⁷	<u>D</u> ⁸	<u>M x C</u> ⁹
<u>Live weights (kg)</u>															
Start (Day 0)	476	476	476	476	476	476	4.94	474	478	2.94					
Day 41	490	519	534	539	538	551	6.43	526	531	3.79	***	***			
Day 97 ¹⁰	497	570	580	601	592	607	6.77	573	576	3.99	***	***			
Slaughter	506	601	609	630	626	641	7.96	577	627	4.69	***	***	***		
<u>Live weight gains (g/day)</u>															
Day 0 to 41	322	1040	1408	1522	1476	1816	79.1	1253	1276	46.6	***	***	*		**
Day 0 to 97	210	967	1046	1290	1190	1352	49.2	1008	1010	29.0	***	***			
Day 0 to slaughter	212	900	929	1111	1089	1207	46.2	970	846	27.2	***	***	**		
Carcass gain (g/day)	119	506	540	662	633	746	25.4	545	524	15.0	***	***			
<u>Start to slaughter (g/day)</u>															
Live weight gain (S)	222	949	973	1170	1169	1338	64.9								
Live weight gain (L)	201	851	885	1051	1009	1077									
Carcass gain (S)	99	481	546	693	656	793	35.7								
Carcass gain (L)	139	530	535	630	611	700									

¹For n = 18; ²Short; ³Long; ⁴For n = 54; ⁵Linear component of concentrate level effect; ⁶Quadratic component of concentrate level effect; ⁷Method of feeding (separate or TMR) effect; ⁸Duration of finishing effect; ⁹Method of feeding x concentrate level interaction; ¹⁰Last weight before any animals were slaughtered. There was no significant Feeding treatment x Duration of finishing interaction.

Table 11. Effects of concentrate level (C), method of feeding (M) and duration of finishing (D) on slaughter traits of finishing steers

	Feeding treatment							Duration of finishing			Significance		
	<u>SO</u>	<u>LS</u>	<u>LM</u>	<u>HS</u>	<u>HM</u>	<u>AL</u>	<u>s.e.¹</u>	<u>S²</u>	<u>L³</u>	<u>s.e.⁴</u>	<u>L⁵</u>	<u>Q⁶</u>	<u>D⁷</u>
Carcass weight (kg)	258.5	312.5	316.5	332.5	328.8	343.7	4.49	297.6	331.1	2.64	***	***	***
Kill-out (g/kg)	509	520	523	529	526	536	4.22	516	532	2.5	***		***
Conformation class ⁸	2.02	2.25	2.34	2.47	2.43	2.78	0.089	2.41	2.35	0.052	***		
Fat class ⁹	2.78	3.51	3.54	3.62	3.59	3.70	0.108	3.36	3.55	0.064	***	***	*
Perinephric + retroperitoneal fat (kg)	6.4	12.1	12.3	12.0	12.4	12.5	0.80	9.5	13.1	0.47	***	***	***
Perinephric + retroperitoneal fat (g/kg) ¹⁰	25.0	39.3	38.9	35.7	37.6	36.4	2.65	31.9	39.0	1.56	*	**	**

¹For n = 18; ²Short; ³Long; ⁴For n = 54; ⁵Linear component of concentrate level effect; ⁶Quadratic component of concentrate level effect; ⁷Duration of finishing effect; ⁸EU Beef Carcass Classification Scheme: Scale 1 = P (poorest) to 5 = E (best); ⁹EU Beef Carcass Classification Scheme: Scale 1 (leanest) to 5 (fattest); ¹⁰Of carcass. There was no significant method of feeding (separate or TMR) effect, no significant method of feeding x concentrate level interaction and no significant Feeding treatment x Duration of finishing interaction.

Table 12. Effects of concentrate level (C), method of feeding (M) and duration of finishing (D) on carcass measurements and carcass measurements per cm carcass weight of finishing steers

<u>Carcass measurements (cm)</u>	Feeding treatment							Duration of finishing			Significance		
	<u>SO</u>	<u>LS</u>	<u>LM</u>	<u>HS</u>	<u>HM</u>	<u>AL</u>	<u>s.e.¹</u>	<u>S²</u>	<u>L³</u>	<u>s.e.⁴</u>	<u>L⁵</u>	<u>Q⁶</u>	<u>D⁷</u>
Carcass length	134.1	136.9	137.8	137.7	134.9	135.8	1.02	134.2	138.2	0.60		*	***
Carcass depth	51.2	51.3	52.2	51.0	51.7	51.0	0.64	50.8	52.0	0.38			*
Leg length	72.4	74.3	73.2	74.8	73.8	73.2	0.55	73.0	74.2	0.32	*	*	**
Leg width	44.5	45.0	45.8	45.5	45.7	45.7	0.45	45.0	45.7	0.27			
Leg thickness	26.6	27.8	28.3	27.8	28.0	28.4	0.28	27.5	28.2	0.16	**	P<0.06	**
Circumference of round	112.5	117.2	116.6	119.2	117.0	118.7	0.91	114.0	119.7	0.54	***	*	***

<u>Carcass measurements (cm/kg)</u>	Feeding treatment							Duration of finishing			Significance		
	<u>SO</u>	<u>LS</u>	<u>LM</u>	<u>HS</u>	<u>HM</u>	<u>AL</u>	<u>s.e.¹</u>	<u>S²</u>	<u>L³</u>	<u>s.e.⁴</u>	<u>L⁵</u>	<u>Q⁶</u>	<u>D⁷</u>
Carcass length	0.525	0.442	0.439	0.416	0.412	0.398	0.0059	0.457	0.421	0.0035	***	***	***
Carcass depth	0.201	0.166	0.166	0.155	0.158	0.150	0.0031	0.173	0.158	0.0018	***	***	***
Leg length	0.284	0.241	0.235	0.228	0.228	0.216	0.0029	0.249	0.228	0.0016	***	***	***
Leg width	0.174	0.145	0.146	0.138	0.140	0.134	0.0023	0.153	0.139	0.0014	***	***	***
Leg thickness	0.104	0.090	0.090	0.084	0.085	0.083	0.0014	0.093	0.086	0.0008	***	***	***
Circumference of round	0.440	0.377	0.370	0.360	0.357	0.348	0.0049	0.387	0.363	0.0029	***	***	***

¹For n = 18; ²Short; ³Long; ⁴For n = 54; ⁵Linear component of concentrate level effect; ⁶Quadratic component of concentrate level effect; ⁷Duration of finishing effect. There was no significant method of feeding (separate or TMR) effect, no significant method of feeding x concentrate level interaction and no significant Feeding treatment x Duration of finishing interaction.

4.2.4 Carcass measurements

Generally, the absolute values for carcass measurements were little affected by concentrate level although leg length and circumference of round increased (significant linear and quadratic effects) with increasing concentrate level (Table 12). Per kg carcass weight, all measurements decreased ($P < 0.001$) with increasing concentrate level with both the linear and quadratic effects significant for all.

There was no significant concentrate level x feeding method interaction and there was no significant effect of feeding method for any of the carcass measurements either absolutely or per kg carcass weight.

Other than leg width which was unaffected, all the carcass measurements were significantly greater for the longer finishing period. When expressed per kg carcass weight however, all measurements were less ($P < 0.001$) for the longer finishing period.

4.2.5 Carcass traits and ribs joint composition

Weights of fore quarter, hind quarter and ribs joint increased with increasing concentrate level with both the linear and quadratic effects significant (Table 13). As a proportion of carcass side weight, hind quarter weight decreased linearly ($P < 0.001$) and fat depth increased ($P < 0.001$) linearly and quadratically with increasing concentrate level. The proportions of subcutaneous fat, intermuscular fat and total fat in the ribs joint increased, and the proportions of total muscle and bone decreased, with increasing concentrate level. Both the linear ($P < 0.001$) and quadratic ($P < 0.01$) effects were significant for total fat and bone while for total muscle, the linear effect was significant ($P < 0.05$) and the quadratic effect was close to significance ($P < 0.07$).

There was a statistically significant concentrate level x feeding method interaction for ribs joint weight in that it was greater for TMR at the low but not at the high concentrate level. Otherwise, there was no concentrate level by feeding method interaction and no significant effect of feeding method.

Fore and hind quarter weights and fat depth increased ($P < 0.001$), and the proportion of hind quarter in the side decreased ($P < 0.001$) with increasing length of finishing period. The proportions of subcutaneous fat and bone were not significantly affected by finishing period but intermuscular fat and total fat proportions increased ($P < 0.001$), and LTL ($P < 0.005$), other muscle ($P < 0.001$) and total muscle ($P < 0.001$) proportions decreased.

4.2.6 Regressions on concentrate level, carcass weight and fatness

The regressions of intakes and daily gains on concentrate level are shown in Table 14. Silage intake decreased at an increasing rate and total intake increased at a decreasing rate with increasing concentrates. The models accounted for proportionately 0.84 and 0.74 of the variation for silage and total intakes, respectively. Daily live weight and

carcass weight gains increased at a decreasing rate with increasing concentrate level and the models accounted for proportionately 0.74 and 0.75 of the variation for overall live weight and carcass weight gains, respectively.

Regressions on carcass weight, carcass fat score and LTL lipid concentration both for the breed types separately and overall are shown in Table 15. While relationships were generally highly significant, the R^2 values were moderate to low. For the overall data set, carcass weight was moderately predictive of kill-out proportion, carcass conformation class, carcass fat class and perinephric plus retroperitoneal fat weight. Fatness traits were more closely related to carcass weight for Friesians than for Charolais crosses but the opposite was so for kill-out proportion. Carcass weight was generally a better predictor of ribs joint composition for Friesians than for Charolais crosses, and LTL composition, particularly moisture and lipid concentrations, were more closely related to carcass weight for Friesians than for Charolais crosses.

Carcass fat score was a better predictor of perinephric plus retroperitoneal fat weight and ribs joint composition for Friesians than for Charolais crosses, and was also a better predictor of LTL moisture concentration for Friesians. However, it was a better predictor of LTL lipid concentration for Charolais crosses. The LTL moisture concentration was closely and negatively related to lipid concentration, with no differences between breed types, but LTL protein concentration was poorly related to lipid concentration.

4.3. Discussion

4.3.1 *Production context*

While the main objectives were similar for the two experiments the present experiment differed from Experiment 1 in that the TMR concentrate proportions were higher, the composition of the TMRs was fixed for the duration of the study and there were two slaughter end points.

When the duration of the finishing period is fixed and there are large differences between feeding treatments, there are inevitably large differences in slaughter weight and carcass weight. Under such circumstances, it is impossible to ascertain whether differences in carcass traits are due to the differences in carcass weight or to the effects of the dietary treatments. Using serial slaughter overcomes this difficulty as it permits estimation of the length of finishing period required on each feeding treatment to reach a fixed slaughter weight or carcass weight.

4.3.2. Concentrate level

For the first, second and third concentrate increments, silage DM intake declined by 0.36, 0.68 and 1.33 kg per kg supplementary concentrate DM, respectively. Correspondingly, total DM intake increased by 0.64, 0.32 and – 0.34 kg/kg concentrate DM. Daily live weight gain responses to slaughter for the first, second and third concentrate increments were 177, 45 and 75 g/kg DM, respectively. Corresponding carcass weight gain responses were 102, 31 and 68 g/kg DM. These are in close agreement with the values found in Experiment 1 of 174, 54 and 38 g/kg live weight, and 110, 41 and 42 g/kg carcass weight. The linear (but not quadratic) effect of concentrate level on kill-out proportion and carcass conformation class also agrees with the findings in Experiment 1. Perinephric plus retroperitoneal fat showed a large weight response to the first concentrate increment but did not increase further with increasing concentrate level. Thus, as a proportion of carcass weight it decreased as concentrates increased above the first increment. The increase in fat depth and in the subcutaneous, intermuscular and total fat proportions of the ribs joint with increasing concentrate level and slaughter weight have been widely reported previously. It is likely that slaughter weight rather than level of concentrates *per se* was the main factor affecting ribs joint composition because dietary energy level has a relatively small effect on carcass composition at constant carcass weight.

The effects of concentrate level on absolute values for carcass measurements were small and if the silage only treatment is excluded there were few differences between the different concentrate levels. Consequently, when scaled for carcass weight, all measurements decreased with increasing concentrate level indicating increasing carcass compactness with increasing concentrate level and weight.

The models relating intakes and gains to dietary concentrate level accounted for high proportions of the variation and the R² values are in good agreement with those reported in Experiment 1.

Table 13. Effects of concentrate level (C), method of feeding (M) and duration of finishing (D) on carcass traits and ribs joint composition of finishing steers

	Feeding treatment (F)							Duration of finishing (D)			Significance			
	SO	LS	LM	HS	HM	AL	s.e. ¹	S ²	L ³	s.e. ⁴	L ⁵	Q ⁶	D ⁷	M x C ⁸
Weight of (kg)														
Fore quarter	67.1	82.9	83.9	89.3	88.1	93.4	1.23	78.1	90.2	0.73	***	***	***	
Hind quarter (pistola)	62.0	72.9	73.8	76.6	75.5	78.4	1.17	70.1	76.3	0.69	***	***	***	
Ribs joint	6.40	7.76	8.24	8.72	8.50	8.78	0.170	8.10	8.03	0.100	***	***		*
Pistola (g/kg side)	481	468	471	464	454	459	2.9	474	461	1.7	***		***	
Fat depth (mm)	4.9	9.1	9.7	10.4	10.6	11.3	0.62	8.3	10.4	0.37	***	***	***	
Ribs joint composition (g/kg)														
Subcutaneous fat	33	56	55	61	64	63	3.7	54	57	2.2	***	***		
Intermuscular fat	129	153	160	176	179	182	7.7	146	181	4.5	**	*	***	
<i>M. longissimus et thoracis</i>	208	192	198	196	197	202	4.8	203	194	2.9		*	*	
Other muscle	401	393	386	376	372	369	6.9	395	371	4.1	*		***	
Total fat	163	209	215	237	242	245	9.3	200	238	5.5	***	**	***	
Total muscle	609	584	584	573	569	571	8.2	598	565	4.8	*	P<0.07	***	
Total bone	227	207	201	190	189	184	4.1	202	197	2.4	***	**		
Muscle composition (g/kg)														
Moisture	752	731	727	724	720	721	738	721	3.2	***	***	***	***	
Protein	220	228	227	227	229	229	226	227	1.6	**	*	*		
Lipid	19	33	39	41	43	42	28	44	3.9	**	**	**	***	

¹For n = 18; ²Short; ³Long; ⁴For n = 54; ⁵Linear component of concentrate level effect; ⁶Quadratic component of concentrate level effect; ⁷Duration of finishing effect; ⁸Method of feeding and concentrate level interaction. There was no significant method of feeding (separate or TMR) effect and no significant Feeding Treatment x Duration of finishing interaction.

Table 14. Regressions ($Y = a + b_1X + b_2X^2$) of silage dry matter (DM) intake, total DM intake and daily gains on concentrate level (kg/day)

X = Concentrate level ¹	Intercept		Regression coefficients				R ²
	a	s.e.	b ₁	s.e (b ₁)	b ₂	s.e (b ₂)	
Silage intake (kg/DM/day)	7.23	0.206	-0.438	0.0866	-0.0136	0.0081	0.84
Total intake (kg/DM/day)	7.23	0.206	0.562	0.0866	-0.0136	0.0081	0.74
Daily gain to 97 days (g)	221	79.2	280	37.8	-18	3.7	0.71
Overall daily gain (g)	222	58.7	221	28.0	-14	2.8	0.74
Carcass gain (g/day)	148	34.0	123	16.2	-7	1.6	0.75

¹Using values of 4.0, 8.0 and 9.5 kg DM/day for low concentrates, high concentrates and *ad libitum* concentrates, respectively

Table 15. Regressions ($y = a + bX$) of carcass traits, ribs joint tissue proportions and *m. longissimus* (LTL) chemical constituents on carcass weight, carcass fat class and *m. longissimus* (LTL) lipid proportion

	All data						Friesians						Charolais x Friesians					
	a	s.e. (a)	b	s.e. (b)	Adj R ²	Sig.	a	s.e. (a)	b	s.e. (b)	Adj R ²	Sig.	a	s.e. (a)	b	s.e. (b)	Adj R ²	Sig.
X = Carcass weight (kg)																		
Kill-out (g/kg)	407	14.0	0.37	0.045	0.36	***	434	14.60	0.23	0.049	0.26	***	433	16.4	0.33	0.051	0.45	***
Conformation	0.32	0.325	0.0064	0.0010	0.24	***	0.95	0.225	0.0034	0.0007	0.23	***	0.93	0.474	0.006	0.0015	0.21	***
Fat class	0.47	0.355	0.0093	0.0011	0.36	***	-1.11	0.467	0.015	0.0016	0.58	***	1.92	0.501	0.005	0.0016	0.14	***
Perinephric + retroperitoneal fat (kg)	-6.7	2.71	0.057	0.0087	0.27	***	-15.4	3.73	0.092	0.0124	0.46	***	-5.7	2.95	0.048	0.0091	0.34	***
Total fat (g/kg)	18.7	29.30	0.64	0.094	0.28	***	-76.7	35.97	1.02	0.119	0.53	***	39.8	40.35	0.51	0.125	0.24	***
Total muscle (g/kg)	660	28.2	-0.26	0.091	0.06	**	721	31.9	-0.53	0.106	0.27	***	685	38.8	-0.26	0.120	0.07	*
Total bone (g/kg)	322	11.3	-0.39	0.036	0.49	***	356	16.1	-0.49	0.054	0.56	***	275	14.8	-0.25	0.046	0.37	***
Moisture (g/kg)	812	10.9	-0.26	0.035	0.32	***	844	13.9	-0.39	0.046	0.53	***	811	13.6	-0.23	0.042	0.37	***
Protein (g/kg)	213	4.6	0.04	0.015	0.06	**	216	7.4	0.03	0.025	0.008	NS	210	5.9	0.05	0.018	0.13	**
Lipid (g/kg)	-33	11.9	0.22	0.038	0.22	***	-67	16.2	0.36	0.054	0.40	***	-29	14.6	0.18	0.045	0.23	***
X = Fat class																		
Perinephric + retroperitoneal fat (kg)	-0.06	1.997	3.30	0.589	0.21	***	-1.20	2.505	4.09	0.724	0.33	***	0.55	3.041	2.60	0.875	0.13	**
Total fat (g/kg)	60	19.7	46.8	5.81	0.36	***	62	21.9	50.6	6.60	0.48	***	36	34.5	48.8	9.93	0.31	***
Total muscle (g/kg)	667	19.0	-25.7	5.62	0.15	***	654	18.4	-27.9	5.53	0.28	***	723	32.1	-35.2	9.25	0.21	***
Total bone (g/kg)	273	9.1	-21.1	2.68	0.34	***	284	10.5	-22.7	3.17	0.44	***	241	15.6	-13.6	4.48	0.14	**
Moisture (g/kg)	780	8.2	-14.7	2.43	0.24	***	783	9.3	-17.4	2.80	0.37	***	781	14.2	-13.0	4.10	0.15	**
Protein (g/kg)	220	3.32	1.9	0.978	0.02	*	217	4.7	2.5	1.26	0.04	*	226	5.7	0.30	1.649	0.12	
Lipid (g/kg)	-6	8.76	12.4	2.58	0.16	***	-8	10.6	14.6	3.18	0.24	***	-18	8.2	0.23	0.039	0.40	***
X = Lipid																		
Moisture	763	1.33	-0.92	0.033	0.87	***	763	1.92	-0.91	0.042	0.88	***	765	1.93	-0.95	0.057	0.85	***
Protein	229	1.29	-0.08	0.032	0.04	*	230	1.92	-0.104	0.043	0.07	**	227	1.81	-0.03	0.053	0.02	

4.3.3 Feeding method

Throughout the experiment, silage intake was consistently higher for TMR than for separate feeding at the low but not at the high concentrate level. The magnitude of the intake effect up to 41 days when there was also a live weight gain benefit was similar to that afterwards when there was no live weight gain benefit. A small positive effect of mixing on silage intake was also noted in Experiment 1.

Where animals are fed *ad libitum* it can be difficult to accurately measure the intake of the TMR constituent feeds. Intake is calculated as the difference between the quantities of feeds offered and refused. When feeds are offered separately intake measurement is simple but when feeds are offered as a TMR the refusals must be partitioned into the feed ingredients in the original mix to obtain the intakes of the different feeds. This is practically and logistically difficult in large scale production experiments where the animals are individually fed.

There was an effect of mixing on live weight gain in the first 41 days at the low concentrate level only where the potential benefits of mixing should be less than at the higher level. However, there was no effect of mixing on overall live weight gain.

4.3.4 Duration of finishing

As absolute feed intake was similar before and after 105 days while mean live weight was greater for the latter period, feed intake per kg mean live weight was lower for the longer finishing period. Whether this is a length of finishing, live weight or degree of maturity effect is unclear as all three are confounded. It has been suggested that metabolic body weight rather than absolute body weight is the appropriate scaling factor for intake. Scaling to metabolic body weight did not result in constant intake values in the present study but it did reduce the differences between the periods before and after 105 days. Perusal of the weekly intake data showed that absolute intake reached at peak after about 5 weeks and remained relatively constant thereafter. The slaughter weight difference between S and L was 50 kg, and as there was no increase in feed intake after the S slaughter date, the net energy available for live weight gain above maintenance was lower for L. Mean live weight gain was 124 g/day lower for L than S, but as kill out proportion was higher, carcass weight gain was only 21 g/day lower (not statistically significant). This emphasises the importance of measuring carcass weight gain as well as live weight gain in production experiments and confirms the general finding that as slaughter weight increases kill-out proportion also increases.

The 50 kg greater slaughter weight for the L group translated into 33.5 kg greater carcass weight. This was not associated with improved carcass conformation. Despite the absence of an effect on carcass conformation, all carcass measurements scaled for carcass weight were lower for L indicating greater carcass compactness. The contrasting effects of dietary concentrate level and duration of finishing on carcass conformation imply an

improvement in conformation from carcass weight increases due to a higher feeding level but not from increases due to a longer finishing period.

The decrease in the hind quarter weight as a proportion of the side weight with increasing carcass weight is a consequence of its growth coefficient being <1.0 . The increased fat proportion and decreased muscle proportion would be expected from their growth coefficients of >1.0 and <1.0 , respectively. Generally, bone proportion decreases with increasing carcass weight and length of finishing period but the effect was not significant in this experiment.

5. CONCLUSIONS

It is concluded that the relationships between concentrate level and intake were curvilinear. Silage intake decreased at an increasing rate, and total intake increased at a decreasing rate, with increasing concentrate level. Maximum DM intake occurred at the medium or high concentrate level but maximum net energy intake occurred on *ad libitum* concentrates. Live weight gain, carcass weight gain, slaughter weight, carcass weight and all measurements of fatness increased at a decreasing rate with increasing concentrate level and regressions on concentrate level explained a high proportion of the variation in live and carcass weight gains. Kill-out proportion and carcass conformation class increased linearly with increasing concentrate level. Carcass measurements scaled for carcass weight decreased with increasing concentrate level indicating increasing carcass compactness. Measures for fatness increased with the first increment of concentrates but increased little thereafter. Beyond the first increment, muscle proportion was essentially constant across concentrate levels.

Muscle moisture content decreased and lipid content increased with increasing concentrate level. Fat colour was little affected by concentrate level but those on *ad libitum* concentrates had the least yellow fat. There were no interactions between concentrate level and method of feeding. Feeding a TMR increased silage intake initially particularly at the low concentrate level. Other than an increase in live weight gain during the first 41 days in Experiment 2 at the low concentrate level, TMR feeding had no effect on overall live weight gain, slaughter weight, carcass weight, slaughter traits or ribs joint composition. Rumen pH decreased and total VFA increased with increasing concentrate level but method of feeding had no effect in rumen fermentation variables. There was no effect of duration of finishing on absolute intake so intake per kg live weight decreased with increasing length of finishing period. Kill-out proportion and all measures of fatness were higher for the longer finishing period. The hind quarter as a proportion of the side and ribs joint muscle proportion decreased with increasing length of finishing period.

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