Effects of breed type, silage harvest date and pattern of offering concentrates on intake, performance and carcass traits of finishing steers

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The objective of this experiment was to investigate the effects and interactions of breed type, silage harvest date and pattern of offering concentrates on intake, performance and carcass traits of finishing steers. Seventy-two steers (36 Friesian and 36 beef cross) were blocked on weight within breed type and assigned to a pre-experimental slaughter group or to one of 4 dietary treatments in a 2 (breed type) × 2 (early- or late- cut silage) × 2 (flat rate or varied pattern of offering concentrates) factorial arrangement of treatments. The flat-rate feeding pattern was silage *ad libitum* plus 5 kg concentrates per head daily to slaughter. The varied feeding pattern was silage only for 79 days followed by concentrates *ad libitum* to slaughter. All animals were slaughtered together after 164 days when the groups on the two feeding patterns had consumed the same total quantity of concentrates. Friesians had a higher ($P < 0.001$) silage dry matter (DM) intake and a higher ($P < 0.01$) total DM intake than the beef crosses. Live-weight gain was similar for both breed types but the beef-cross animals had a higher ($P < 0.001$) kill-out proportion, higher ($P < 0.01$) carcass gain, and better ($P < 0.001$) carcass conformation than the Friesians. The beef-cross type also had a higher ($P < 0.001$) proportion of muscle and a lower ($P < 0.001$) proportion of bone in the carcass. Silage harvest date had no effect on silage or total DM intakes but the early-cut silage did result in higher ($P < 0.01$) carcass gain. Animals on the varied feeding pattern consumed less ($P < 0.01$) silage DM and less ($P < 0.001$) total DM than those on the flat rate feeding pattern. Live-weight gain and carcass gain were similar for the two feeding patterns. It is concluded that Friesians had a higher intake, but had lower carcass gain

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than the beef-cross type. Animals on the early-cut silage had higher carcass gain than those on the late-cut silage. The varied feeding pattern resulted in lower DM intake but efficiency of feed energy utilisation was similar for both feeding patterns. Interactions were generally not statistically significant.

Keywords: beef cattle; breed type; concentrate feeding pattern; silage quality; winter finishing

Introduction

Concentrates are a major cost component of the winter finishing diet of beef cattle in Ireland, accounting for 49% and 52% of total feed costs for Friesian and beef-cross types, respectively (Teagasc, 2005). Alternative feeding practices could improve efficiency or reduce feed cost. The conventional system of feeding finishing cattle during winter is to offer silage *ad libitum* and offer concentrates separately at a flat rate, or to offer a total mixed ration (TMR) with fixed proportions of silage and concentrates throughout the finishing period. An alternative feeding strategy is to offer silage only for up to 3 months and then offer concentrates *ad libitum* to slaughter. This is designated “varied feeding pattern” and results in approximately the same total concentrate consumption over the same duration of finishing as the flat rate or TMR feeding methods. It has a lower machinery requirement (i.e. no need to distribute two feeds all the time or for a mixer wagon) and saves predominantly concentrates rather than silage plus concentrates if circumstances favour the marketing of animals earlier than expected. Previous work has shown that offering the same total concentrate allowance at a flat rate over the finishing period, or *ad libitum* in the latter half of the finishing period, resulted in similar animal performance (Keane, 2001). However, it has not been established if the outcome is dependent on breed type or silage digestibility.

Dairy breeds have a higher intake than beef breeds because genetic selection for higher milk yield has resulted in dairy animals having a larger gastrointestinal tract (Geay and Robelin, 1979) and a higher feed intake capacity (Langholz, 1990). This has been confirmed by O’Connell *et al*. (2000), Kennedy *et al.* (2003) and Boland (2005), all of whom reported that higher genetic merit dairy cows had significantly higher grass dry matter (DM) intake than lower genetic merit cows. In finishing beef steers on forage-based diets, intake per unit live weight was greater for pure bred Friesians than for beef × Friesians (Keane, More O’Ferrall and Connolly, 1989; Keane and More O’Ferrall, 1992). Similarly, O’Brien (1997) observed that both Holstein and Friesian steers had higher intakes of silage-based diets than Charolais × Friesian steers. While these and other results in the literature demonstrate that Friesians have a higher intake than beef breeds when the diet is forage based, it is less clear if this also holds for diets based on concentrates. If Friesians have a higher *ad libitum* forage intake but do not have a higher *ad libitum* concentrate intake than beef breeds this would result in an interaction between breed type and feeding pattern (flat or varied). With flat rate feeding where forage is available *ad libitum,* Friesians can express their higher intake capacity because forage intake is mainly regulated by physical constraints such as rumen fill (Illius and Gordon, 1991). In contrast, with a varied feeding pattern where concentrates are available *ad libitum* towards the end of the finishing period, Friesians may not express their greater rumen fill capacity because in this situation, intake is more likely to be determined by metabolic constraints related to the animal's ability to utilise absorbed nutrients (Illius and Jessop, 1996).

Silage harvest date, and in particular silage digestibility may interact with the pattern of concentrate feeding in that the substitution rate of concentrates for silage is a function of silage digestibility. In a study by Steen (1984), supplementation of two silages differing in digestibility resulted in a greater substitution rate of silage DM per 1 kg concentrate DM for the higher digestibility silage than the lower digestibility silage. With a varied feeding pattern, the opportunity for silage digestibility to influence substitution rate is limited because the two feeds are not offered together except for the short changeover period. A further consideration is that if animals on a varied feeding pattern are offered lower digestibility silage in the early phase resulting in a lower growth rate, they may exhibit compensatory gain later when moved to *ad libitum* concentrates. Consequently, the effects of a difference in silage digestibility may be less with a varied feeding pattern than with flat rate feeding. Normally with flat rate feeding, an increase in digestibility of silage with a satisfactory fermentation increases animal intake and performance (Steen and McIlmoyle, 1982; Dawson *et al.,* 2002; Steen, Kilpatrick and Porter, 2002). Steen (1988) reported increases in carcass weight gain in finishing cattle, of 33 and 29 g/day per 10 g/kg increase in digestibility for unsupplemented diets and diets containing 20% to 37% concentrates, respectively. Caplis *et al*. (2005) described the response of finishing steers to concentrate supplementation. As concentrate input increased from zero to *ad libitum* availability, live-weight and carcass gains increased by 780 and 570 g/day, respectively.

The objective of the present study was to examine the effects, and in particular the interactions, of breed type, grass silage harvest date and pattern of offering concentrates on intake, performance and carcass traits of finishing steers.

Materials and Methods

Animals and treatments

Seventy-two steers, comprised of 36 Friesians and 36 beef-cross (predominantly Limousin × Friesians) animals, which had been reared and managed together at Grange Beef Research Centre since calfhood, were used. Before commencement of the experiment, the animals were housed in a slatted-floor shed and offered a diet of grass silage *ad libitum* during a two-week period to standardise gut contents. They were weighed on two consecutive days and, based on the mean of these two live weights, were assigned, within breed type, to 4 blocks of 9 animals each. They were then allocated at random, from within blocks, to a pre-experimental slaughter group (1 per block) or to one of 4 dietary treatments (2 per block) in a 2 (breed types) × 2 (early- or late-cut silage) × 2 (flat rate or varied feeding pattern) factorial arrangement of treatments. The pre-experimental slaughter group continued on the silage diet until slaughter one week later. The flat rate feeding pattern was 5 kg concentrates per head daily with silage *ad libitum* to slaughter. The varied feeding pattern was silage only for 79 days after which the animals were adjusted to concentrates *ad libitum* plus 1 kg silage DM per head daily to slaughter. All 64 finishing animals were individually fed for a mean period of 164 days and all were slaughtered together when the mean total quantity of concentrates consumed was similar for both feeding patterns. Fifty-six steers were housed in a slatted shed equipped with Calan-Broadbent doors arranged in 8 pens of 7 spaces each, and 8 steers were tethered in 8 feeding spaces in another shed. All treatments were balanced across the two sheds. Two weeks after the commencement of the experiment, animals were injected with Qualimec (Janssen Animal Health; 1% ivermectin, 1% benzyl alcohol) to control gastro-intestinal parasites. Animals were also treated with Butox pour-on (Intervet Productions S.A.; deltamethrin 0.75% w/v) on two occasions to control skin lice. They were weighed every 21 days (in the morning before daily feeding) to monitor growth rate.

Feeds and feeding

The early-cut silage was made from a perennial ryegrass (*Lolium perenne*) sward harvested on 19 May, 2004 and the late-cut silage was made from a similar sward harvested on the 9 June. The grass was harvested using a rotary disc mower, wilted for 24 h and precision-chopped (Pottinger, Mex VI). The chopping knife and feed roller speeds were chosen, according to the manufacturer's instructions, to give a chop length of 19 mm. The grass was ensiled without an additive in separate roofed, walled concrete silos. During the feeding period, silages were removed from the silos once daily using a shear grab. Animals receiving silage only for the first 79 days had a mineral/vitamin premix dusted on the silage (70 g per head). Animals on the flat rate feeding pattern were adjusted gradually over the first two weeks to 5 kg concentrates per head, offered once daily, 40 min before the silages were offered. Silage was offered at 1.1 times the previous day's consumption, intake was recorded daily and refusals were discarded twice weekly. Animals on the varied feeding pattern were adjusted to concentrates *ad libitum* over a 20-day period from Day 79 to Day 99, concentrate intake was recorded daily until slaughter, and refusals were discarded once weekly. All animals received the same concentrate coarse ration of (kg/t) 870 rolled barley, 67.5 soya bean meal, 47.5 molasses and 15 minerals/vitamins.

Feed analysis

Silages were sampled twice weekly at feeding. Samples were stored at –18 °C and composited using a bowl chopper (Muller, Type MKT 204 Special, Saarbrücken, Germany) every 3 weeks. Duplicate 200 g sub-samples were dried at 85 °C for 16 h for DM determination, weighed and then discarded. This DM value was corrected for volatiles using the equation of Porter and Murray (2001). A further sub-sample was dried at 40 °C for 48 h, ground through a Wiley mill (1 mm mesh sieve) and analysed for *in vitro* DM digestibility (DMD) and *in vitro* organic matter digestibility (OMD), ash, total nitrogen, water soluble carbohydrates (WSC) and neutral detergent fibre (NDF). The DMD and OMD values were determined by the method of Tilley and Terry (1963) with the modification that the final residue was isolated by filtration rather than centrifugation. Ash concentration was determined by complete combustion in a muffle furnace at 550 °C for 5 h. Total nitrogen (g/kg DM) was determined using the LECO FP-428 instrument based on the methods of the Association of Official Analytical Chemists (AOAC) 990-03 (1990). The WSC concentration was quantified by the anthrone method (Thomas, 1977) and the NDF value, exclusive of ash, was determined using the Ankom fibre analyser (Van Soest, Robertson and Lewis, 1991). An aqueous extract was mechanically obtained from undried sub-samples of silage and used for measurement of pH (using an Orion SA720 pH meter and electrode), lactic acid (using the Olympus AU400 and the L-Lactic Acid UV-method test kit (Boehringer Mannheim/R-Biopharm catalogue number 10139084035)), volatile fatty acids (VFA), ethanol (measured by gas chromatography (Ranfft, 1973)) and ammonia nitrogen (NH_3-N) (measured using the Olympus AU400 and the Thermo Electron Infinity

Ammonia Liquid Stable Reagant kinetic method). Concentrate samples were taken once weekly, stored at −18 °C and composited monthly. From each composite, duplicate 100 g sub-samples were dried at 98 °C for 16 h for DM concentration. These samples were then discarded. A second sub-sample was dried at 40 °C for 48 h, ground (1 mm mesh sieve) and used to measure starch ('Megazyme' total starch assay procedure, AOAC Method 996.11 (McCleary, Gibson and Mugford, 1997)), NDF, N, ash, DMD and OMD.

Aerobic stability and deterioration of the silages were assessed for 8 days at 20 °C as described by Walsh *et al.* (2008). Indices of aerobic stability were time (h) to temperature rise by >2 °C and >5 °C, the maximum temperature rise (°C) and the time (h) to the maximum temperature rise. Indices of aerobic deterioration were the accumulated temperature rise to 120 and 192 h (°C).

Slaughter and carcass assessment

To allow carcass assessments to be conducted, the animals were slaughtered by block in a commercial meat plant over two consecutive weeks. The animals were weighed on two consecutive days prior to slaughter and the mean of these two weights was taken as the slaughter weight. Hot carcass weight was recorded immediately post slaughter. Cold carcass weight was estimated at 0.98 of hot carcass weight. The perinephric plus retroperitoneal fat was removed from both sides of the carcass and weighed. Carcass conformation and fat classes (Commission of the European Communities, 1982) were determined using a Video Imaging Analysis (VIA) carcass classification system (VBS2000, E+V, Germany). Linear measurements were taken from the right side of the carcass using a measuring tape and callipers (De Boer *et al.*, 1974). Carcasses were chilled at 4 °C for 72 h after which time the right side of each carcass was cut through the spinal column, and extending between the 5th and 6th ribs. The abdominal muscles were then freed where they join the pelvic limb and the side was cut along the edge of *m. iliocostalis lumborum* through the ribs to the earlier cut between the 5th and 6th ribs (Williams and Bergstrom, 1980). This divided the side into a pistola hind-quarter (i.e. the hind-quarter to the 6th thoracic vertebra without the area on the abdominal side of *m. iliocostalis lumborum*) and a fore-quarter, which included the afore-mentioned area. These quarters were then weighed, boned out and all visible fat was removed. The remaining hind quarter tissue was separated into the following meat joints: leg, heel, silverside, *m. semitendinosis*, topside, knuckle, rump, fillet, striploin and rib joint. The fore quarter was separated into: front shin, brisket, chuck, neck, forerib (ribs 1 to 5), plate (ribs 6 to 13), *m. triceps brachii*, bladesteak, braising muscle and clod. Bones, fat and lean trim were weighed separately for each quarter. *M. longissimus* area at the 10th rib was measured and a sample was frozen for chemical analysis. Protein concentration was determined by the LECO method (Sweeney and Rexroad, 1987), and intramuscular fat and moisture concentrations were determined using a CEM microwave moisture/solids analyser system and a CEM automatic fat extraction system (Bostian *et al.*, 1985).

Statistical analysis

All data were analysed according to the 2 × 2 × 2 factorial randomised complete block design using Proc GLM (SAS, 2002–2003). The results are presented as the main effect means with the significance of the factors and interactions indicated. Where interactions occurred, the individual treatment means are shown in table footnotes. One Friesian steer assigned to the early-cut silage by varied feeding pattern was removed from the experiment due to illness that could not be attributed to the experimental treatment and missing values were calculated.

Results

Feed analysis

The mean (s.d.) chemical composition of the silages and concentrates are given in Table 1. As indicated by their pH values and relatively low concentrations of ammonia-N and butyrate, both silages were well preserved. A difference of 69 g/kg in the *in vitro* DMD between the early- and late-cut silages resulted in the early-cut silage having a higher *in vitro* OMD and higher estimated net energy value than the late-cut silage. Later harvesting reduced the total N concentration and increased the NDF concentration of the silage. The early-cut silage had lower ammonia-N and butyric acid concentrations than the late-cut silage.

The main indices of aerobic stability and deterioration are also shown in Table 1. While both silages were very stable, the early-cut silage was more sensitive to aerobic spoilage than the late-cut silage. While deterioration was observed under the conditions of the test, no deterioration was observed in the feeds on offer to the animals as refusals were discarded twice weekly.

Feed and energy intake

Friesians had higher silage DM intake ($P < 0.05$) than the beef-cross animals and,

Table 1. Mean (s.d.) chemical composition and aerobic stability indices of the feeds

	Silage		Concentrate
	Early-cut	Late-cut	
Dry matter (DM) (g/kg)	209 (13.1)	232 (10.2)	809 (6.1)
pH	4.0 (0.11)	3.9 (0.11)	
Dry matter digestibility[1] (g/kg)	739 (24.1)	670 (20.5)	864 (7.0)
Organic matter digestibility[1] (g/kg)	729 (23.7)	656 (21.6)	862 (7.5)
Composition of DM (g/kg)			
Starch			518 (22.2)
Ash	96 (11.3)	90 (8.2)	42 (6.5)
Total nitrogen	26 (1.5)	22 (0.9)	20 (1.1)
Neutral detergent fibre	507 (19.1)	559 (15.5)	164 (12.8)
Water soluble carbohydrates	13 (4.9)	18 (7.5)	
Estimated net energy[2] (UFV/kg)	0.80	0.70	1.14
Fermentation indices (g/kg DM, unless otherwise stated)			
Lactic acid	65 (6.1)	96 (18.6)	
Acetic acid	23 (6.8)	17 (8.1)	
Butyric acid	1 (0.9)	3 (2.6)	
Propionic acid	1.4 (1.19)	0.8 (1.07)	
Ammonia N (g/kg total N)	75 (7.1)	112 (16.6)	
Aerobic stability indices			
Time to temp rise >2 °C (h)	115 (60.5)	171 (42)	
Time to temp rise >5 °C (h)	132 (60.7)	179 (27)	
Maximum temperature rise (°C)	16 (10.3)	3 (5.2)	
Time to maximum temperature rise (h)	158 (43.0)	192 (0.1)	
Accumulated temperature rise[2] at 120 h (°C)	15 (24.8)	1 (1.6)	
Accumulated temperature rise[2] at 192 h (°C)	50 (50.5)	7 (11.9)	

[1] Determined *in vitro.*

[2] Unit Fourragere Viande (Jarrige, 1989).

as a consequence, had higher total DM and net energy intakes (P < 0.05) over the entire finishing period (Table 2). On a per kg mean live weight basis, the higher silage intake of the Friesians tended towards significance (P = 0.09) but the difference in total DM intake was not significant.

Silage harvest date had no significant effect on silage or total DM intakes. However, because of its higher energy value, the daily net energy intake was 0.32 UFV/head higher (P < 0.05) for animals on the early-cut silage. When expressed relative to mean live weight, animals on the late-cut silage had higher (P < 0.01) total DM intakes than those on the early-cut silage.

Steers on the flat rate feeding pattern had higher silage (P < 0.01) and total DM (P < 0.001) intakes than those on the varied feeding pattern. Consequently, as both groups received the same total quantity of concentrates, the steers on the flat rate feeding pattern had a higher net energy intake (P < 0.01) for the finishing period as a whole. On a per kg live weight basis, animals on the flat feeding pattern had higher (P < 0.01) silage and total DM intakes than those on the varied feeding pattern. Concentrate DM intake per unit live weight was similar for both feeding patterns.

There were silage-harvest-date × feeding pattern interactions for silage and total DM intakes over the first 79 days – animals on the flat rate feeding pattern had higher intake of the early-cut than the late-cut silage whereas the difference was reversed for those on the varied feeding pattern. The interaction for total net energy intake was due to the difference between the feeding patterns being greater for the early-cut silage. The interaction for total DM intake per unit live weight was due to the absence of a difference between the feeding patterns for the early-cut silage whereas for the late-cut silage, intake was higher for the varied feeding pattern.

Animal performance

Friesians were heavier (P < 0.001) at the start and on Day 79 (P < 0.01) than the beef-cross animals (Table 3), and at slaughter the difference was close to significance (P = 0.057). Beef-cross animals had numerically higher live-weight gain throughout the experimental period but the difference never reached statistical significance. However, they had higher (P < 0.01) carcass gain. Beef-cross animals had a greater efficiency of energy utilisation for live-weight gain (P < 0.01) and carcass gain (P < 0.001) than the Friesians.

Live-weight gain was higher (P < 0.01) for steers on the early-cut silage over the first 79 days and the effect for the total experimental period approached significance (P = 0.059). Steers on the early-cut silage also gained 0.05 kg/day more (P < 0.01) carcass than those on the late-cut silage. This higher carcass gain resulted in a greater (P < 0.05) efficiency of energy utilisation for carcass production by animals on the early-cut silage than those on the late-cut silage.

Steers on the flat rate feeding pattern had a higher (P < 0.001) live-weight gain during the first 79 days and consequently they had a greater (P < 0.001) live weight on Day 79. This situation was reversed over the following 85 days when the steers on the varied pattern of feeding gained 0.48 kg/day more than steers on the flat rate pattern of feeding with the result that, for the experimental period overall, feeding pattern had no significant effect on live-weight gain, live weight or carcass weight gain. Feeding pattern had no significant effect on efficiencies of energy utilisation for either live-weight gain or carcass gain.

Table 2. Effects of breed type (B), silage harvest date (S) and feeding pattern (F) on feed and energy intakes

	Breed[1] (B)		Silage harvest date (S)		Feeding pattern (F)		s.e.[2]	Significance			
	FR	BC	Early-cut	Late-cut	Flat	Varied		B	S	F	Interaction
Silage DM intake (kg/day)											
Day 1 to 79	6.64	6.22	6.35	6.51	5.60	7.26	0.118	*		***	*[5]
Day 80 to 164[3]	4.13	3.75	3.88	4.00	5.10	2.78	0.083	*		***	
Day 1 to 164	5.24	4.83	4.98	5.09	5.22	4.86	0.082	***		**	
Concentrate DM intake (kg/day)											
Day 1 to 79	2.05	2.05	2.05	2.05	4.09	0.00	0.000			***	
Day 80 to 164[3]	5.86	5.77	5.72	5.91	3.99	7.64	0.092			***	
Day 1 to 164	3.98	3.94	3.92	4.01	4.02	3.90	0.046				
Total DM intake (kg/day)											
Day 1 to 79	8.69	8.27	8.40	8.56	9.69	7.26	0.118	*		***	*[6]
Day 80 to 164[3]	9.99	9.52	9.60	9.91	9.09	10.42	0.133	*		***	
Day 1 to 164	9.22	8.77	8.90	9.10	9.24	8.76	0.099	**		***	
Net energy intake[4] (UFV/day)											
Day 1 to 79	7.31	6.99	7.41	6.89	8.87	5.43	0.091	*	***	***	
Day 80 to 164[3]	9.77	9.39	9.63	9.53	8.37	10.79	0.130	*		***	
Day 1 to 164	8.47	8.11	8.45	8.13	8.50	8.09	0.086	**	*	**	*[7]
DM intake per unit live weight ($g^{-1} kg^{-1} day^{-1}$)											
Silage	9.79	9.45	9.48	9.76	9.92	9.32	0.137	P = 0.09		**	
Concentrate	7.45	7.72	7.48	7.69	7.67	7.50	0.089	*			
Total	17.24	17.17	16.96	17.45	17.59	16.82	0.163		*	**	*[8]

[1] FR = Friesian; BC = Beef cross.
[2] For n = 32.
[3] Includes a 3 week change over period from silage *ad libitum* to concentrates *ad libitum* for animals on the varied feeding pattern.
[4] Calculated from DM intake and estimated net energy value (UFV) of the feeds (Jarrige, 1989).
[5] S × F means were 5.73 v 5.47 and 6.97 v 7.55 for early- v late-cut for flat and varied, respectively.
[6] S × F means were 9.82 v 9.56 and 6.97 v 7.55 for early- v late-cut for flat and varied, respectively.
[7] S × F means were 8.79 v 8.21 and 8.12 v 8.05 for early- v late-cut for flat and varied, respectively.
[8] S × F means were 17.58 v 17.62 and 17.32 v 16.31 for early- v late-cut for flat and varied, respectively.

Table 3. Effects of breed type (B), silage harvest date (S) and feeding pattern (F) on live weights, live-weight gains and carcass gains

	Breed[1] (B)		Silage harvest date (S)		Feeding pattern (F)		s.e.[2]	Significance		
	FR[1]	BC[2]	Early	Late	Flat	Varied		B	S	F
Live weight (kg) at:										
Start	474	444	457	461	458	460	4.3	***		
Day 79	522	496	514	504	532	486	5.4	**		***
Slaughter	594	576	590	580	590	580	6.4	P = 0.057		
Live-weight gain (kg/day) for:										
Day 0 to 79	0.61	0.67	0.73	0.55	0.95	0.33	0.041		**	***
Day 80 to slaughter	0.93	1.04	0.98	0.99	0.75	1.23	0.049			***
Day 0 to slaughter	0.77	0.85	0.85	0.76	0.84	0.77	0.032		P = 0.059	
Carcass gain (kg/day)	0.45	0.50	0.50	0.45	0.49	0.46	0.014	**	**	
Live-weight gain/net energy intake[3]	90	104	100	94	99	95	3.1	**		
Carcass gain/net energy intake[3]	54	65	61	57	60	59	1.6	***	*	

[1, 2] See footnotes to Table 2.
[3] g/UFV.
There were no significant breed × silage, breed × feeding pattern, silage × feeding pattern or breed × silage × feeding pattern interactions.

Carcass traits

Carcass traits are shown in Table 4. Beef-cross animals had a higher carcass weight ($P < 0.05$), kill-out rate ($P < 0.001$) and conformation score ($P < 0.001$) than Friesians. There was no significant difference in fat score between the Friesians and the beef-cross type but eye muscle area was greater ($P < 0.001$) for the latter. Beef-cross animals had a lower weight ($P < 0.05$) and proportion ($P < 0.01$) of perinephric plus retroperitoneal fat than Friesians.

With the exception of perinephric plus retroperitoneal fat weight and proportion, which were greater for animals on the early-cut silage, silage harvest date had no significant effect on any of the measured carcass traits.

Pattern of feeding had no significant effect on carcass weight, kill-out rate, conformation score, fat score or eye muscle area but the animals on the varied feeding pattern had a lower weight ($P < 0.05$) and proportion ($P < 0.01$) of perinephric plus retroperitoneal fat. There was a breed type × harvest date interaction for carcass fat score due to the breed type effect being greater for the early- than the late-cut silage. There were 3-way interactions for perinephric plus retroperitoneal fat weight and proportion because of increased values for Friesians on the flat-rate feeding pattern and offered the early-cut silage and lower values for beef-cross animals on the varied feeding pattern and offered the late-cut silage.

Carcass measurements

Friesians had a greater ($P < 0.001$) carcass length, carcass depth, leg length and leg width than the beef-cross animals but there was no significant difference in leg thickness between the two breed types (Table 5). This was so both for the absolute values and for the values scaled for carcass weight.

Silage harvest date had no significant effect on carcass measurements either absolutely or when scaled for carcass weight. Pattern of feeding had no significant effect on actual carcass measurements or on carcass measurements scaled for carcass weight.

There was a breed type × feeding pattern interaction for carcass depth per unit carcass weight due to a greater difference between the breed types for the varied than for the flat rate feeding pattern.

Carcass composition

Notwithstanding the significant difference in carcass weight, the 4.1 kg difference in side weight between the two breed types was not significant (Table 6). The beef-cross type had 8.4 kg more muscle ($P < 0.001$), 2.9 kg less bone ($P < 0.001$) and 1.4 kg less fat than the Friesian. In line with these weight differences there were differences in tissue proportions (muscle, bone and fat weights as proportions of side weight) with the beef-cross animals having 38 g/kg more muscle ($P < 0.001$), 26 g/kg less bone ($P < 0.001$) and 12 g/kg less fat ($P < 0.05$).

Neither silage harvest date or feeding pattern had any significant effect on side weight or on any of its component weights or proportions.

Weight and tissue proportions and m. longissimus *composition*

Beef-cross animals had a greater ($P < 0.05$) proportion of hind quarter in the side weight than Friesians (Table 7). However, there were no significant differences between the breed types in the distribution of the main tissues of the side.

Animals on the late-cut silage had a greater ($P < 0.05$) proportion of hind quarter in the side weight and a greater ($P < 0.05$) proportion of side muscle in the hind quarter

Table 4. Effects of breed type (B), silage harvest date (S) and feeding pattern (F) on carcass traits

	Breed[1] (B)		Silage harvest date (S)		Feeding pattern (F)		s.e.[2]	Significance			
	FR	BC	Early-cut	Late-cut	Flat	Varied		B	S	F	Interaction
Carcass weight (kg)	295	307	303	299	302	300	3.4	*			
Kill-out (g/kg)	495	526	513	508	510	511	2.4	***			
Conformation score[3]	1.45	2.53	2.01	1.97	1.97	2.01	0.092	***			
Fat score[3]	2.98	3.06	3.04	3.00	3.03	3.01	0.094				* [5]
M. longissimus[4] (cm^2/kg)	0.21	0.25	0.23	0.23	0.23	0.24	0.006	***			
Perinephric + retroperitoneal fat (kg)	9.8	8.7	9.9	8.6	9.9	8.6	0.35	*	**	*	* [6]
Perinephric + retroperitoneal fat[4] (g/kg)	32.9	28.5	32.6	28.8	32.7	28.7	1.00	**	**	**	* [7]

[1, 2] See footnotes to Table 2.

[3] EU Beef Carcass Classification Scheme: scale 1 (poorest = P) to 5 (best = E) for conformation and 1 (least) to 5 (fattest) for fat.

[4] Relative to carcass weight.

[5] B × S means were 6.95 v 6.61 and 6.50 v 6.13 for Friesian v Beef cross on early- and late-cut silages, respectively.

[6] B × S × F means were 11.69 v 9.55, 9.14 v 9.13, 9.08 v 9.37 and 9.21 v 6.85 for Friesian v Beef cross on early-cut flat, early-cut varied, late-cut flat and late-cut varied, respectively.

[7] B × S × F means were 38.23 v 31.06, 31.01 v 30.39, 30.74 v 30.38 and 31.35 v 22.24 for Friesian v Beef cross on early-cut flat, early-cut varied, late-cut flat and late-cut varied, respectively.

Table 5. Effects of breed type (B), silage harvest date (S) and feeding pattern (F) on carcass measurements and carcass measurements scaled for carcass weight

	Breed[1] (B)		Silage harvest date (S)		Feeding pattern (F)		s.e.[2]	Significance[3]	
	FR	BC	Early-cut	Late-cut	Flat	Varied		B	Interactions
Absolute values (cm)									
Carcass length	141.2	134.6	138.0	137.8	138.7	137.1	0.68	***	
Carcass depth	51.0	47.6	48.9	49.7	49.6	49.0	0.41	***	
Leg length	75.7	71.9	73.7	73.9	73.9	73.7	0.37	***	
Leg width	46.0	43.8	44.8	45.0	44.6	45.2	0.35	***	
Leg thickness	27.0	27.4	27.0	27.3	27.4	27.0	0.35		
Relative to carcass weight (cm/kg)									
Carcass length	0.480	0.441	0.457	0.463	0.462	0.459	0.0047	***	
Carcass depth	0.173	0.160	0.162	0.167	0.165	0.164	0.0020	***	* [4]
Leg length	0.257	0.235	0.244	0.248	0.246	0.247	0.0023	***	
Leg width	0.157	0.144	0.149	0.152	0.149	0.152	0.0018	***	
Leg thickness	0.092	0.090	0.090	0.092	0.091	0.090	0.0014		

[1, 2] See footnotes to Table 2.

[3] There were no significant silage harvest date or feeding pattern effect.

[4] B × F means were 0.171 v 0.159 and 0.176 v 0.153 for Friesians v Beef crosses on flat and varied, respectively.

Table 6. Effects of breed type (B), silage harvest date (S) and feeding pattern (F) on weights and proportions of the dissected carcass components

	Breed[1] (B)		Silage harvest date (S)		Feeding pattern (F)		s.e.[2]	Significance[3]
	FR	BC	Early-cut	Late-cut	Flat	Varied		B
Weight (kg) of								
Side	145.7	149.8	149.4	146.2	148.7	146.8	1.58	
Muscle	93.8	102.2	98.8	97.2	98.3	97.7	1.07	***
Bone	33.3	30.4	32.0	31.7	32.0	31.7	0.42	***
Fat	18.6	17.2	18.5	17.3	18.4	17.4	0.64	
Tissue proportion (g/kg side)								
Muscle	644	682	661	665	661	665	4.0	***
Bone	229	203	215	217	215	217	2.1	***
Fat	127	115	124	118	124	118	3.6	*

[1, 2] See footnotes to Table 2.
[3] There was no significant silage harvest date or feeding pattern effects and there were no significant interactions.

Table 7. Effects of breed type (B), silage harvest date (S) and feeding pattern (F) on distribution of bone, muscle and fat and on chemical composition of *m. longissimus*

	Breed type[1] (B)		Silage harvest date (S)		Feeding pattern (F)		s.e.[2]	Significance[3]		
	FR	BC	Early-cut	Late-cut	Flat	Varied		B	S	F
Proportion (g/kg)										
Hind weight of side weight	459	465	459	466	461	464	1.9	*	*	
Hind muscle of side muscle	477	479	474	481	478	478	2.4		*	
Hind bone of side bone	466	469	463	471	469	466	3.1			
Hind fat of side fat	365	371	369	367	357	380	6.6			*
M. longissimus *composition (g/kg)*										
Moisture	721	727	723	725	723	725	2.3			
Protein	232	233	234	232	230	236	1.8			*
Lipid	39	31	35	36	39	31	2.6	*		*

[1, 2] See footnotes to Table 2.
[3] There was no significant breed × silage, breed × feeding pattern, silage × feeding pattern or breed × silage × feeding pattern interactions.

than those on the early-cut silage. There was no difference in the proportions of side bone and fat in the hind quarter.

Animals on the varied feeding pattern had a greater ($P < 0.05$) proportion of side fat in the hind quarter than those on the flat rate feeding pattern. Otherwise, there were no effects of feeding pattern on the proportions of the side or side tissues in the hind quarter.

The chemical composition of *m. longissimus* is shown in Table 7. Friesians had a higher ($P < 0.05$) lipid concentration than the beef type, but the differences in moisture and protein concentrations were not significant. Silage harvest date had no significant effect on chemical composition while animals on the varied feeding pattern had a higher ($P < 0.05$) protein concentration and a lower ($P < 0.05$) lipid concentration than animals on the flat rate feeding pattern.

Muscle distribution

The beef type animals had higher ($P < 0.05$) proportions of leg, silverside, *m. semitendinosis* and brisket and lower ($P < 0.05$) proportions of knuckle, *m. triceps brachii*, bladesteak and clod than the Friesians (Table 8). The difference in the proportion of higher value joints between the breed types was not significant.

Animals on the late-cut silage had a greater ($P < 0.05$) proportion of heel and brisket and a lower ($P < 0.05$) proportion of *m. triceps brachii* than animals on the early-cut silage.

Animals on the varied feeding pattern had a lower ($P < 0.05$) proportion of silverside and a greater ($P < 0.05$) proportion of lean trim than those on the flat rate feeding pattern.

There was a breed-type × feeding-pattern interaction for heel proportion which was lower for beef type than Friesian on the flat rate feeding pattern but greater on the varied feeding pattern, and there were breed type × silage harvest date interactions for front shin and lean trim proportions. The interaction for front shin was due to a higher value for Friesians than beef-cross animals on the late-cut but not on the early-cut silage while the lean trim interaction was due to a higher value for beef-cross animals than Friesians on the late-cut and a lower value on the early-cut silage.

Discussion

Breed type

The higher silage and total DM intakes of the Friesians is consistent with the findings of Istasse *et al*. (1989) for comparisons of Holstein with Belgian Blue bulls and Keane and Allen (2002) for comparisons of Friesian-Holstein with Piedmontese × Friesian-Holstein and Romagnola × Friesian-Holstein steers. When the animals on the varied feeding pattern moved to *ad libitum* concentrates, dry matter intake continued to be numerically higher for the Friesians (7.72 v. 7.56 (s.e. 0.183) kg) but the difference was much less than for silage dry matter intake (6.64 v. 6.22 (s.e. 0.167) kg). For the entire 164-day finishing period, silage intake was proportionately 0.085 higher for Friesians than for beef-cross animals on the varied feeding pattern whereas total concentrate intake was only proportionately 0.010 higher. Thus, the difference between the breeds in intake capacity was greater on silage than on concentrates. A possible explanation is that on a high forage diet, intake is regulated by physical factors such as ruminal fill and Friesians have a higher fill capacity than beef breeds (Jarrige, 1989) whereas on high concentrate diets, intake is controlled by metabolic factors rather than ruminal fill signals (Illius and Jessop, 1996). Absorbed nutrients such as propionate or acetate, both directly or indirectly through hormones, exercise chemostatic control on feed intake (National Research Council,

Table 8. Effects of breed type (B), silage harvest date (S) and feeding pattern (F) on carcass side muscle distribution (g/kg total side lean)

Joint	Breed[1] (B)		Silage harvest date (S)		Feeding pattern (F)		s.e.[2]	Significance			
	FR[1]	BC[2]	Early	Late	Flat	Varied		B	S	F	Interactions
Leg	20.6	21.4	20.8	21.3	21.2	20.9	0.26	*			
Heel	21.3	20.9	20.4	21.8	21.1	21.2	0.44		*		*[4]
Silverside	47.7	50.5	48.5	49.7	50.3	47.8	0.79	*		*	
Topside	87.1	88.1	86.7	88.6	88.6	86.7	0.85				
Knuckle	59.2	56.1	57.2	58.0	57.3	57.9	0.66	**			
Rump	45.9	45.6	45.5	45.9	45.9	45.5	0.63				
Fillet	25.4	25.8	25.6	25.6	26.0	25.2	0.38				
Striploin	48.0	49.9	48.6	49.4	49.1	48.9	0.75				
Rib	43.9	44.5	43.9	44.5	44.1	44.3	0.63				
M. semitendinosis	21.4	24.7	23.4	22.7	22.9	23.2	0.46	***			
Front shin	23.3	22.6	23.0	22.8	22.8	23.1	0.35				*[5]
Brisket	38.5	44.3	40.0	42.7	41.9	40.9	0.94	***	*		
Chuck	79.4	81.1	81.2	79.3	81.1	79.4	1.26				
Neck	53.7	49.8	54.0	49.6	51.0	52.5	2.00				
Fore rib (ribs 1 to 5)	39.9	39.2	40.4	38.7	40.4	38.7	1.17				
Plate (ribs 6 to 13)	123.9	123.9	123.8	124.0	124.4	123.4	1.72				
M. triceps brachii	31.1	29.9	31.3	29.7	30.3	30.7	0.43	*	*		
Bladesteak	26.0	24.7	25.5	25.2	25.6	25.1	0.38	*			
Braising muscle	24.1	23.5	24.5	23.1	23.4	24.2	0.53				
Clod	35.4	31.0	34.0	32.4	34.0	32.4	1.28	*			
Lean trim	104.2	102.4	101.2	105.1	98.6	108.0	2.80			*	*[6]
Higher-value joints[3]	311.4	314.9	310.6	315.7	315.4	310.9	2.05				

[1,2] See footnotes to Table 2.
[3] Silverside + topside + knuckle + rump + fillet + striploin + rib joint.
[4] $B \times F$ means were 22.0 v 20.2 and 20.6 v 21.8 for Friesian v Beef cross on flat and varied, respectively.
[5] $B \times S$ means were 22.8 v 23.2 and 23.7 v 21.9 for Friesian v Beef cross on early- and late-cut silages, respectively.
[6] $B \times S$ means were 107.1 v 96.1 and 101.4 v 108.8 for Friesian v Beef cross on early- and late-cut silages, respectively.

1987) and thus may explain the similar concentrate intakes of the two breed types on *ad libitum* concentrates

The similar live-weight gain for the two breed types is consistent with the findings of Keane *et al.* (1989) who reported similar gains for Friesians and Limousin × Friesians.

The higher kill-out proportion of the beef-cross animals resulting in higher carcass gain, and their superior carcass conformation agree with previous findings (O'Brien, 1997; McGee *et al.,* 2005). Even though carcass fat score did not differ between the breed types, perinephric plus retroperitoneal fat both in absolute terms and expressed relative to carcass weight, was higher for Friesians. This was not surprising as Kempster (1981) has shown that dairy breeds deposit more fat in the internal depots than do beef breeds. Similarly, McGee *et al*. (2005) showed that Holstein-Friesian steers had a greater weight of perinephric plus retroperitoneal fat relative to carcass weight than Charolais × Friesian steers. The greater *m. longissimus* area relative to carcass weight of the beef crosses agrees with the data of Keane and Allen (2002) for Piedmontese × Friesian and Romangola × Friesian steers compared with Holstein-Friesians, while the lower carcass measurements of the beef crosses compared with Friesians, both in absolute terms and when scaled for carcass weight, has also been observed by others (Keane *et al*., 1989; Keane and Allen, 2002; McGee *et al*., 2005).

Differences between breed types in carcass composition and muscle distribution similar to those observed in the present study have been widely reported (Kempster, Cook and Southgate, 1988; Keane *et al*., 1989). The higher proportion of hind quarter in the side for beef crosses is also well documented (Keane and More O'Ferrall, 1992; Keane and Allen, 2002; Keane, 2003).

The lower *m. longissimus* lipid concentration for the beef crosses compared with the Friesians agrees with data from Keane and More O'Ferrall (1992). When muscle lipid concentration differs between experimental treatments, moisture concentration usually differs in the opposite direction (Robelin and Tulloh, 1992). However, in the present study, while the magnitude of the difference in moisture concentration between the breed types was similar to that for lipid (6 v. 8 g/kg) it failed to reach significance, whereas the lipid difference was significant. No particular pattern was evident in the small differences between the breed types in muscle distribution and, contrary to results from other studies (Keane *et al.,* 1989; Keane and More O'Ferrall, 1992), the beef type animals did not have significantly more of their muscle in the high value joints.

Silage harvest date

Silage digestibility declines as harvest date is delayed (Dawson *et al*., 2002). In the present study, *in vitro* DMD declined by 69 g/kg for a cutting date delay of 21 days. In addition to digestibility, differences also occurred in DM concentration (reflecting prevailing weather conditions during wilting), ash, N and NDF concentrations (reflecting herbage growth stage at harvesting), fermentation characteristics (reflecting weather conditions before and during harvesting, and herbage growth stage) and aerobic stability. Numerous studies (Drennan and Keane, 1987; Rook and Gill, 1990; Steen *et al*., 1998; Dawson *et al.,* 2002) have shown that silage intake increases with earliness of harvest and increasing digestibility but this was not so in the present study. The similar intakes achieved on the two silages may have been in part due to the higher DM concentration of the late-cut silage, a similar effect having been reported by Steen *et al.* (1998) who found an increase in silage DM intake as DM concentration increased. Notwithstanding the absence of a difference in intake, the higher net energy intake of the early-cut silage was reflected in a tendency towards higher live-weight gain and significantly higher carcass gain. Similar findings have been reported by Steen *et al.* (2002) when an increase of 11 g/kg in organic matter digestibility resulted in increases in live-weight and carcass gains of 41 g/day and 29 g/day, respectively.

When the animals on the varied pattern of feeding moved to *ad libitum* concentrates, those previously on the late-cut (lower digestibility) silage had a higher daily intake of concentrates (7.82 v. 7.46 (s.e. 0.130) kg DM) and achieved a similar but not higher rate of gain (1.20 v. 1.25 (s.e. 0.078) kg/day). Thus, there was no evidence of compensatory gain on *ad libitum* concentrates by the animals that previously had lower live-weight gain on the late-cut lower-digestibility silage.

The higher weight and proportion of perinephric plus retroperitoneal fat on the early-cut silage was most likely due to the higher energy intake, as Steen (1995) observed higher fat gains in finishing animals given a higher plane of nutrition. While neither carcass fat score nor side fat proportion were significantly higher for the early-cut (higher digestibility) silage, the trend was in that direction for both indices of fatness, suggesting that the animals on the early-cut (higher digestibility) silage were generally fatter. The lower proportion of hind quarter in the side, and a lower proportion of hind quarter muscle in the side muscle of the animals on the early-cut silage is further evidence that these animals were fatter. Caplis *et al.* (2005) have shown that as energy intake increases and animals become fatter, the proportion of hind quarter in the side decreases.

Concentrate feeding pattern

Previously, Keane (1998, 2001), in agreement with the present results, found that animals on a flat-rate feeding pattern consumed more silage than those on a varied feeding pattern. However, the animals on the varied feeding pattern consumed more concentrates making interpretation of the total intake data difficult. That is why in the present study the animals were slaughtered when both feeding pattern groups had consumed the same total concentrate allowance. When the animals on the varied feeding pattern were moved to *ad libitum* concentrates they expressed compensatory growth and gained 0.48 kg/day more live weight than the animals that continued on the flat rate feeding pattern. However, this was not sufficient to ensure identical live-weight gain for the two feeding patterns over the total period. As a result, the higher silage, total DM and net energy intakes on the flat rate feeding pattern were paralleled by slightly (not significant) higher live-weight and carcass gains resulting in similar efficiencies of energy utilisation for both live-weight gain and carcass production from the two feeding patterns.

The lower proportion of perinephric plus retroperitoneal fat for animals on the varied pattern of feeding is in accord with the findings of Keane (1998) but in the latter study, both fat score and perinephric plus retroperitoneal fat were reduced whereas in the present study fat score was not significantly affected.

Concentrate feeding pattern had no effect on actual carcass measurements or on carcass measurements scaled for carcass weight, and none would be expected because age and carcass weight were similar. Where scaled carcass measurements differ independent of breed, it is because carcasses are heavier or fatter at the same age (Caplis *et al.*, 2005; Keane, Drennan and Moloney, 2006). Contrary to other studies (Keane and More O'Ferrall, 1992; French *et al.*, 2000) that reported no significant effect of concentrate level on *m. longissimus* composition, in this study the varied feeding pattern resulted in a greater protein concentration and a lower lipid concentration than the flat rate feeding pattern. The lower lipid concentration parallels the lower perinephric and retroperitoneal weight and proportion for animals on the varied feeding pattern.

It is concluded that on the flat rate feeding pattern or while on silage only on the varied feeding pattern, Friesian steers had higher silage and total DM intakes than beef-cross steers. However, they did not have a higher intake when on concentrates *ad libitum* on the varied feeding pattern. They also had a lower kill-out proportion, lower carcass gain and poorer carcass conformation than the beef crosses. Animals on the early-cut silage had similar silage and total DM intakes to those on the late-cut lower digestibility silage but had higher carcass gain and a higher weight and proportion of perinephric and retroperitoneal fat. When moved to *ad libitum* concentrates, animals previously on the late-cut silage had similar growth rates to those previously on the early-cut silage (i.e. no compensatory gain). Animals on the varied pattern of feeding had lower silage and total DM intakes but as they also had slightly lower live-weight and carcass gain, efficiency of energy utilisation for carcass production was similar for both feeding patterns.

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