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A comparison of finishing strategies to fixed slaughter weights for Holstein Friesian and Belgian Blue × Holstein Friesian steers

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Cattle finishing strategies may involve feeding a high energy diet throughout or following a period of moderate growth. The objective of this study was to compare Holstein Friesian (HF) and Belgian Blue × Holstein Friesian (BB) steers (24 per breed type, initial live weight 434 and 431 kg for HF and BB, respectively) finished to 560 kg or 620 kg target slaughter weight, on either a concentrate diet *ad libitum* from the start of the finishing period (C), or on a concentrate diet *ad libitum* following an 84-day period on grass silage (SC). Slaughter weights were similar for HF and BB, but kill-out proportion, carcass weight and carcass conformation class were superior ($P < 0.001$), and carcass fat score was inferior ($P < 0.001$), for BB. Total concentrate, dry matter and net energy intakes were higher ($P < 0.001$) for HF, and efficiency of utilization of net energy for carcass-weight gain was lower ($P < 0.01$). Mean daily live-weight gain was higher for C than SC ($P < 0.001$) and for slaughter at 560 kg than at 620 kg ($P < 0.05$). Kill-out proportion was higher for C than SC ($P < 0.05$) and for 620 kg compared to 560 kg slaughter weight ($P < 0.001$). Measures of fatness were unaffected by feeding treatment but all were higher ($P < 0.01$) for the 620 kg slaughter weight. Net energy required per unit carcass-weight gain was higher for C than SC ($P < 0.001$) and for 620 kg than for 560 kg slaughter weight ($P < 0.001$). When slaughtered at 620 kg live weight there was no difference between the feeding treatments in net energy required per unit carcass-weight gain. While both breed types had similar live-weight gain BB had 9% greater ($P < 0.01$) carcass-weight gain and were 14% more efficient ($P < 0.01$) in converting feed energy to carcass weight. Neither breed type had commercially acceptable carcasses at 560 kg slaughter weight when finished on SC.

Keywords: beef cattle; breed type; finishing strategies; steers

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Introduction

For orderly marketing of beef it is desirable to have an all year round supply of finished cattle. Indoor finishing on conserved and purchased feeds in winter is more costly than outdoor finishing on pasture in summer (Keane and Allen, 1998) but this cost difference is not necessarily reflected in beef price. Prior to 2005, low winter-finishing margins were offset by payment of the second Special Beef Premium (SBP) in spring (Irish cattle are predominantly spring born). With the SBP now decoupled from animals (Council of the European Union, Luxembourg Agreement, 2003) beef production systems can only be sustainable if they are profitable.

In Ireland, winter finishing diets for beef cattle generally comprise of a mix of grass silage and concentrate (Caplis *et al*., 2005), and the cost of the concentrate component, which can exceed 1 t per animal over a typical 5-month finishing period, is considerable. Thus, strategies to reduce the concentrate input and/or increase its efficiency of utilization merit examination. A number of recent studies have involved the evaluation of silage: concentrate ratios, discrete feeds v. total mixed rations, and patterns of concentrate feeding for fixed-duration finishing periods (Caplis *et al*., 2005; Keane, Drennan and Moloney, 2006). These studies resulted in carcass weights and levels of finish that differed markedly among the different treatments whereas the beef processing industry prefers carcasses of uniform weight and finish. To allow for possible interactions, comparisons of breed types, feeding levels or finishing strategies should have more than one slaughter end point (Keane, 1994).

About half of all Irish beef cattle originate in the dairy herd and vary from pure Holstein to early and late maturing beef crosses (CMMS Report, 2007). While Limousin remains the late maturing beef breed of choice for crossing on dairy cows, in recent years the Belgian Blue has become popular because of its relatively short gestation length and relatively low frequency of serious calving difficulty (McGuirk, Going and Gilmour, 1998; ICBF, 2006). There are a number of reports on the relative productivity of Holstein Friesian and Belgian Blue × Friesian cattle (Keane, 1994, 2003; Steen, 1995; Keane and Drennan, 2008, 2009) but none have examined the production of carcasses of similar weight from these breed types, and in that context, possible interactions of breed type, finishing strategy and slaughter weight.

The objectives of this study were (i) to compare the performance and slaughter traits of Holstein Friesian (HF) and Belgian Blue × Holstein Friesian (BB) steers, (ii) to compare the effects of two finishing treatments on these breed types, (iii) to compare the effects of two slaughter weights, and (iv) to ascertain if there were interactions between breed type, finishing treatment and slaughter weight.

Materials and Methods

Animals

A total of 48 (24 HF and 24 BB) animals were used. They were purchased as calves from cooperating dairy farms that had used the sire breeds by artificial insemination (AI). The calves were the progeny of 7 Holstein Friesian and 5 Belgian Blue sires, representative of the bulls of these breeds then available through commercial AI. The calves remained on the farms of origin until they were 4 to 6 weeks of age and were then transferred to Grange Beef Research Centre where they were reared to slaughter.

Calf rearing was as described by Fallon and Harte (1987). Calves were penned individually and offered a total of 15 kg milk powder over a 5-week period plus calf concentrate (750 kg coarsely rolled barley, 170 kg soya bean meal, 55 kg molasses, 25 kg mineral/vitamin premix per tonne), with a crude protein (CP) concentration of 165 g/kg, up to a maximum of 2 kg per head daily and hay *ad libitum* until turn-out. The composition of the mineral/vitamin mix (g/kg) was: ground limestone 722, dicalcium phosphate 80, sodium chloride 140, manganese sulphate 20, zinc sulphate 28, ferrous sulphate 5, copper sulphate 2, cobalt sulphate 0.2, and trace quantities of potassium iodine and sodium selenite. It also contained vitamins A, D and E (500, 125 and 1.5 M international units per tonne, respectively). On 12 June, the calves were put to pasture and grazed ahead of yearling steers in a leader/follower rotational grazing system. They were treated with invermectin (Qualimac, Janssen Animal Health, High Wycombe, UK) by injection at 3, 8 and 13 weeks after turn-out for the control of internal parasites.

On 19 September, the calves were castrated and from then until housing on 20 November, they were offered 1 kg per head daily of cattle concentrate (875 kg rolled barley, 65 kg soya bean meal, 45 kg molasses, 15 kg mineral/vitamin premix per tonne) with a CP concentration of 130 g/kg. During the first winter, the animals were accommodated in a slatted shed in groups of 6 and offered grass silage (dry matter (DM) 208 g/kg, CP 146 g/kg DM, *in vitro* DM digestibility (DMD) 701 g/kg, pH 3.9) *ad libitum* plus 2 kg cattle concentrate per head daily until 20 January, when the concentrate was withdrawn. Animals were turned out to pasture for a second grazing season on 25 March and were rotationally grazed until second housing on 29 October when the finishing treatments commenced.

Treatments

Following weighing on 2 consecutive days, the animals were blocked on the mean of these weights, within breed type and assigned from within block to 4 finishing strategies in a 2 (breed type) × 2 (finishing treatment) × 2 (slaughter weight) factorial experiment. The 4 finishing strategies were:

(i) Concentrate *ad libitum* to slaughter at approximately 560 kg mean live weight (C560).
(ii) Concentrate *ad libitum* to slaughter at approximately 620 kg mean live weight (C620).
(iii) Silage only for 84 days followed by concentrate *ad libitum* to slaughter at approximately 560 kg mean live weight (SC560).
(iv) Silage only for 84 days followed by concentrate *ad libitum* to slaughter at approximately 620 kg mean live weight (SC620).

The chemical composition of the silage was DM 189 g/kg, CP 144 g/kg DM, *in vitro* DMD 713 g/kg and pH 3.9. The cattle concentrate described earlier was fed during finishing. Feed analyses were carried out using the methods described by Cummins *et al.* (2007). The animals were adapted to concentrate *ad libitum* over a 25-day period by gradually increasing the daily concentrate allowance while also offering silage *ad libitum*. When the stage was reached where the animals no longer consumed all the concentrate offered the silage allowance was gradually reduced to approximately 1 kg DM per head daily to maintain normal rumen function. Twenty-eight animals (3 or 4 of each breed type per finishing strategy) were accommodated in a slatted floor shed fitted with Calan gates for measurement of individual feed intake and calculation of efficiency of feed net energy utilization. The remaining animals were accommodated in 4 groups (1 group per finishing strategy) in a slatted floor shed. Silage and concentrate were offered to proportionately 0.05 and 0.10, respectively in excess of previous intake. Fresh feeds were offered and refusals were weighed back daily. Refusals were discarded twice weekly. Animals on silage alone received 70 g/day of the mineral/vitamin premix described earlier dusted on the silage. The animals were weighed at 3-week intervals throughout the finishing period.

After slaughter in a commercial beef processing plant, perirenal plus retroperitoneal fat was weighed, and cold carcass weight (hot weight × 0.98), carcass conformation class (E,U,R,O,P) and carcass fat score (1 to 5) (Commission of the European Communities, 1982) were recorded. Initial carcass weight was estimated by multiplying initial live weight by 0.475 and 0.515 for HF and BB, respectively (Keane and Moloney, 2009).

Slaughter sequence

The experimental treatments commenced on 29 October (Day 0). The animals offered concentrate *ad libitum* from the start were slaughtered at 560 kg live weight after 91 days (28 January). Those on silage for 84 days followed by concentrate *ad libitum* were slaughtered at 560 kg live weight after 127 days (5 March). The animals on concentrate *ad libitum* from the start to 620 kg live weight were slaughtered after 155 days (2 April), and those on silage for 84 days followed by concentrate *ad libitum* to 620 kg live weight were slaughtered after 180 days (27 April). The mean live weight of the animals in a particular breed by target slaughter weight category was used to determine the actual slaughter date, which was the same for all animals in the category.

Statistical analysis

Data were analysed using the general linear model procedure of the Statistical Analysis Systems Institute (SAS, 2002–2003). Live weights and live-weight gains up to the start of finishing were analysed for breed effects only. Otherwise, data were analysed as a 2 × 2 × 2 factorial with terms for block, breed type, finishing treatment, slaughter weight and two-way interactions. Birth date was included as a covariate for live weight and carcass weight variables. Analyses of feed intake and efficiency were confined to data for the individually fed animals. The data are presented as the breed type main effect means, together with the individual feeding treatment by slaughter weight means. Where there were significant interactions with breed type, the individual means are shown in footnotes.

Results

Live weights and live-weight gains to start of finishing

Live weights and daily live-weight gains for HF and BB from arrival to the start of the finishing treatments are shown in Table 1. Birth and arrival (at Grange) dates were earlier ($P < 0.01$), and arrival weight was greater ($P < 0.001$), for BB than HF. Otherwise, there was no significant live weight difference between the breed types up to the start of finishing. From arrival to 1st turn-out, HF gained faster ($P < 0.001$) than BB but there were no significant differences in live-weight gains between the breeds otherwise.

Finishing live weights and live-weight gains

Live weights and daily live-weight gains during finishing are shown in Table 2. There were no significant differences between HF and BB in live weight or live-weight gain at any time during the finishing period, or for slaughter weight per day of age. Animals on concentrate *ad libitum* were heavier ($P < 0.001$) after

Table 1. Birth and arrival[1] dates, live weights and live-weight gains for Holstein Friesian (HF) and Belgian Blue × Holstein Friesian (BB) steers

Variable	HF	BB	s.e.	Significance
Birth date	4 April	18 March	3.48[a]	***
Arrival date	7 May	28 April	2.31[a]	**
Live weight (kg) at:				
Arrival turn-out	62	73	1.9	***
1st turn-out (Jun. 12)	86	90	2.0	
1st housing (Nov. 20)	186	193	4.2	
2nd turn-out (Mar. 25)	286	276	7.7	
2nd housing (Oct. 29)	434	431	6.0	
Live-weight gain (g/day) for:				
Arrival–1st turn-out	665	424	37.0	***
1st turn-out–1st housing	662	641	22.6	
1st housing–2nd turn-out	798	667	52.7	
2nd turn-out–2nd housing	680	708	22.0	
1st turn-out–2nd housing	691	676	10.7	

[1] At Research Centre.

[a] Days.

84 days than those on silage only. Mean slaughter weights were close to target. Mean live-weight gain over the first 84 days for those offered concentrate *ad libitum* was considerably higher ($P < 0.001$) than for those offered silage only but the opposite was so from Day 84 to slaughter. Averaged over both slaughter weights, animals offered concentrate *ad libitum* throughout had a higher ($P < 0.001$) mean daily gain than those offered concentrate *ad libitum* following 84 days silage feeding. The animals finished on concentrate *ad libitum* throughout had a lower ($P < 0.001$) mean daily gain from start to slaughter for the 620 kg than the 560 kg slaughter weight, whereas the animals finished on silage followed by concentrate *ad libitum* had similar mean daily gains for the two slaughter end points ($P < 0.06$ for the finishing strategy × slaughter weight interaction).

Slaughter and carcass traits

Carcass weight was heavier ($P < 0.001$) for BB than HF (Table 3) because of a higher ($P < 0.001$) kill-out proportion. This was also reflected in a significantly ($P < 0.01$) greater carcass weight per day of age for BB. Carcass conformation score for BB was superior ($P < 0.001$) to that for HF but carcass fat score was lower ($P < 0.001$). Perirenal plus retroperitoneal fat weight ($P < 0.01$) and its proportion of carcass weight ($P < 0.001$) were also lower for BB.

Carcass weight was not significantly affected by feeding treatment. Kill-out proportion was higher ($P < 0.05$) for concentrate *ad libitum* throughout than for silage followed by concentrate *ad libitum*, and was also higher ($P < 0.001$) for the 620 kg than for the 560 kg slaughter weight. There was a feeding treatment by slaughter weight interaction for kill-out proportion, with the difference between the slaughter weights being greater for silage followed by concentrate than for concentrate *ad libitum* throughout. Carcass conformation class was better ($P < 0.001$) for concentrate *ad libitum* throughout than for silage followed by concentrate

Table 2. Effect of breed type, finishing strategy and slaughter weight on live weights and live-weight gains of steers during the finishing period

Variable	Breed type[1] (B)		s.e.	Finishing strategy (F) × Slaughter weight[2] (S)				s.e.	Significance[3]	
	HF	BB		C560	C620	SC560	SC620		F	S
Live weight (kg) at:										
Start (Day 0)	434	431	6.0	433	432	429	434	8.5		
Day 84	508	510	6.4	551	554	471	460	9.0	***	
Slaughter	592	593	7.2	560	619	563	626	10.2		***
Duration of finishing (days)	138	138	0.03	91	155	127	180	0.04	***	***
Live-weight gain (g/day) for:										
Start to Day 84	887	948	48.4	1411	1458	502	305	68.4	***	
Day 84 to slaughter	1477	1545	91.9	1214	917	2186	1726	130.1	***	**
Start to slaughter	1172	1191	35.2	1397	1211	1058	1063	49.7	***	

[1] HF = Holstein Friesian; BB = Belgian Blue × Holstein Friesian.

[2] C = concentrate *ad libitum*; SC = silage only for 84 days followed by concentrate *ad libitum*; 560 = slaughtered at 560 kg live weight; 620 = slaughtered at 620 kg live weight.

[3] There was no significant effect of Breed type and no significant interactions.

Table 3. Effect of breed type, finishing strategy and slaughter weight on slaughter and carcass traits of steers

Variable	Breed type[1] (B)		s.e.	Finishing strategy (F) × Slaughter weight[2] (S)				s.e.	Significance			
	HF	BB		C560	C620	SC560	SC620		B	F	S	I[3]
Carcass weight (kg)	300	326	4.2	296	331	289	335	5.9	***		***	
Kill-out (g/kg)	507	549	3.2	528	535	513	536	3.71	***	*	***	F×S*
Carcass conformation score[4]	2.09	3.00	0.079	2.83	2.58	2.18	2.58	0.112	***	**		F×S**
Carcass fat score[4]	3.44	2.96	0.050	3.09	3.35	3.06	3.29	0.071	***		**	B×S*[5]
Perirenal + retroperitoneal fat (kg)	8.20	6.79	0.316	6.53	9.23	6.85	9.36	0.447	**		***	
Perirenal + retroperitoneal fat[6] (g/kg)	27.2	20.9	1.13	22.1	27.9	23.7	27.9	1.60	***		***	

[1,2] See footnotes Table 2.

[3] Interaction.

[4] EU Beef Carcass Classification Scheme: conformation scale 1 (poorest = P) to 5 (best = E); fat scale 1 (leanest) to 5 (fattest).

[5] Values of 3.23, 3.64, 2.92 and 3.00 for HF560, HF620, BB560 and BB620, respectively.

[6] Relative to carcass weight.

but there was no significant effect of slaughter weight. There was a finishing strategy × slaughter weight interaction for carcass conformation class with a higher value for concentrate *ad libitum* throughout at the 560 kg slaughter weight and a higher value for silage followed by concentrate at the 620 kg slaughter weight. There was no effect of finishing treatment on carcass fat score which was higher ($P < 0.01$) for the 620 kg slaughter weight but there was a breed type × slaughter weight interaction. This was due to a greater difference in fat score between the 560 kg and 620 kg slaughter weights for HF than BB. Neither perirenal plus retroperitoneal fat weight, nor its proportion of carcass weight, were affected by feeding treatment but both were higher ($P < 0.001$) for the 620 kg slaughter weight.

Feed intake and efficiency

Silage intake did not differ significantly between the breed types but concentrate and total DM intakes were significantly lower ($P < 0.001$) for BB (Table 4). Feeding treatment significantly affected all measures of intake. Silage intake was lower ($P < 0.001$), and concentrate and total DM intakes were higher ($P < 0.001$), for concentrate *ad libitum* throughout than for silage followed by concentrate. There were breed type by feeding treatment interactions for daily silage, concentrate and total DM intakes, total silage and total concentrate intakes, and daily concentrate intake per unit mean live weight. These were due to greater differences between HF and BB in silage, concentrate and total DM intakes for SC than C. Daily silage intake, expressed both absolutely and per kg mean live weight, was higher ($P < 0.001$) for the 560 kg slaughter weight, but total silage intake was higher ($P < 0.001$) for the 620 kg slaughter weight. Concentrate intake per day, per kg mean live weight, and total concentrate and DM intakes were higher ($P < 0.001$) for the 620 kg than for the 560 kg slaughter weight. There were finishing treatment by slaughter weight interactions for daily silage intake both in absolute terms and when expressed per kg live weight, and for all measures of concentrate and total DM intakes. These were invariably due to the differences between the slaughter weights being greater for the silage followed by concentrate treatment than for the treatment involving concentrate *ad libitum* throughout. There was a breed type by slaughter weight interaction for total DM intake due to a greater intake difference between the breeds at the 620 kg than at the 560 kg slaughter weight.

Total live-weight and carcass-weight gains, total net energy intake (expressed as Unite Fourragere Viande (UFV), Jarrige, 1989) and the net energy conversion ratio for live-weight and carcass-weight gains are summarized in Table 5. Total live-weight gain did not differ between the breed types but carcass-weight gain was greater ($P < 0.01$) for BB. Although BB had a significantly lower net energy intake than HF, there was no significant difference between the breed types in efficiency of net energy utilization for live-weight gain, but efficiency for carcass-weight gain was superior ($P < 0.01$) for BB. There were breed type by slaughter weight interactions for carcass-weight gain, net energy intake, and net energy conversion ratio for live-weight and carcass-weight gains. These were due to greater differences between the breed types at the 620 kg than at the 560 kg slaughter weight. Total net energy intake was higher ($P < 0.01$) for concentrate *ad libitum* throughout than for silage followed by concentrate, and for the 620 kg than the 560 kg slaughter weight. Efficiency of net energy utilisation for both live-weight and carcass-weight gains was superior for

Table 4. Effect of breed type, finishing strategy and slaughter weight on dry matter intake of steers during the finishing period

Variable	Breed type[1] (B)		s.e.	Finishing strategy (F) × Slaughter weight[2] (S)				s.e.	Significance			
	HF	BB		C560	C620	SC560	SC620		B	F	S	I[3]
Silage:												
Daily (kg)	3.62	3.44	0.064	1.97	1.76	5.92	4.46	0.090		***	***	B×F*[5], F×S***
Daily[4] (g/kg LW)	6.81	6.58	0.155	3.83	3.31	11.37	8.28	0.219		***	***	F×S***
Total (kg)	515	485	10.3	179	273	746	803	14.5		***	***	B×F*[6]
Concentrate:												
Daily (kg)	6.64	6.08	0.068	8.25	9.37	1.75	6.06	0.096	***	***	***	B×F***[7], F×S***
Daily[4] (g/kg LW)	12.5	11.6	0.22	16.1	17.6	3.4	11.3	0.31	**	***	***	B×F*[8] F×S***
Total (kg)	914	843	7.8	751	1452	221	1091	10.9	***	***	***	B×F***[9] F×S***
Total:												
Daily (kg)	10.25	9.52	0.094	10.21	11.13	7.67	10.52	0.133	***	***	***	B×F*[10] F×S***
Daily[4] (g/kg LW)	19.4	18.2	0.30	19.9	20.9	14.7	19.5	0.42	**	***	***	F×S***
Total (kg)	1429	1328	13.2	930	1725	967	1894	18.6	***	***	***	B×S*[11] F×S**

[1,2,3] See footnotes Tables 2 and 3.

[4] LW = mean live weight.

[5] Values of 1.87, 5.37, 1.87 and 5.01 for HFC, HFSC, BBC and BBSC, respectively.

[6] Values of 226, 805, 226 and 745 for HFC, HFSC, BBC and BBSC, respectively.

[7] Values of 9.31, 3.97, 8.31 and 3.85 for HFC, HFSC, BBC and BBSC, respectively.

[8] Values of 17.7, 7.4, 16.0 and 7.2 for HFC, HFSC, BBC and BBSC, respectively.

[9] Values of 1162, 662, 1041 and 645 for HFC, HFSC, BBC and BBSC, respectively.

[10] Values of 11.17, 9.33, 10.17 and 8.86 for HFC, HFSC, BBC and BBSC, respectively.

[11] Values of 978, 1881, 919 and 1738 for HF560, HF620, BB560 and BB620, respectively.

Table 5. Effect of breed type, finishing strategy and slaughter weight on live-weight and carcass-weight gains, energy intake and energy utilization of steers during the finishing period

Variable	Breed type[1] (B)		s.e.	Finishing Strategy (F) × Slaughter weight[2] (S)				s.e.	Significance			
	HF	BB		C560	C620	SC560	SC620		B	F	S	I[3]
Live-weight gain												
Total weight (kg)	157.7	162.0	4.4	127.1	187.7	133.3	191.3	6.27			***	
Carcass-weight gain												
Total (kg)	91.8	101.7	2.2	79.4	115.6	74.1	118.0	3.13	**		***	B×S*[5]
Per day (g)	684	748	15.9	873	746	588	655	22.6	**	***		F×S***
UFV[4] intake	1419	1317	12.0	982	1846	809	1835	17.0	***	**	***	B×S*[6] F×S***
Conversion ratio (UFV/kg)												
Live weight	9.1	8.3	0.36	8.3	10.4	6.2	9.9	0.51		*	***	B×S*[7]
Carcass weight	14.7	12.8	0.40	12.4	16.3	10.7	15.6	0.56	**	*	***	B×S*[8]

[1,2,3] See footnotes Tables 2 and 3.

[4] Unite Fourragere Viande (Jarrige, 1989) using values of 0.75 and 1.13 for UFV/kg dry matter for silage and concentrate, respectively (O'Mara, 1996).

[5] Values of 75.3, 108.4, 78.3 and 125.2 for HF560, HF620, BB560 and BB620, respectively.

[6] Values of 927, 1911, 864 and 1769 for HF560, HF620, BB560 and BB620, respectively.

[7] Values of 7.1, 11.1, 7.5 and 9.2 for HF560, HF620, BB560 and BB620, respectively.

[8] Values of 11.8, 17.6, 11.4 and 14.3 for HF560, HF620, BB560 and BB620, respectively.

silage followed by concentrate than for concentrate *ad libitum* throughout ($P < 0.05$), and for the 560 kg than the 620 kg slaughter weight ($P < 0.001$). There were finishing treatment by slaughter weight interactions for carcass-weight gain per day and net energy intake. The carcass-weight gain interaction was due to the difference between concentrate *ad libitum* throughout and silage followed by concentrate being greater at 560 kg than at 620 kg slaughter weight, while the interaction for net energy intake was due to a difference between concentrate *ad libitum* throughout and silage followed by concentrate at 560 kg but not at 620 kg slaughter weight.

Discussion

Breed comparison

The two breed types included in this study account for over half of all dairy calves used for beef production in Ireland (CMMS Report, 2007). Holstein Friesian is the most numerous breed type of dairy herd calves, while Belgian Blue is the second most numerous (after Limousin) late maturing beef × dairy breed type. The greater live weight of the BB calves at arrival can be attributed to their greater birth weight (Mee and Dings, 1989) and earlier birth date. Otherwise, the absence of any live-weight gain or live-weight differences between the breed types throughout life agrees with the findings of Keane and Drennan (2008, 2009) who reported that Holstein Friesian and Belgian Blue × Holstein Friesian did not differ significantly in live weight other than at calf arrival. Steen (1995) also reported similar live-weight gain for Friesian and Belgian Blue × Friesian cattle.

The greater carcass weight for BB was due to their higher kill-out proportion. This concurs with the consensus of literature reports showing that Belgian Blue crosses have a higher kill-out proportion and heavier carcasses than Holstein Friesian (Keane, 1994; Steen, 1995; Keane, 2003; Keane and Drennan, 2008, 2009). The superior carcass conformation and lower carcass fat score of BB is also in agreement with literature reports as is their lower weight and relative (to carcass weight) weight of perirenal plus retroperitoneal fat (Keane, 1994, 2003; Keane and Drennan, 2008, 2009).

The lower concentrate intake of BB in the absence of a significant difference in silage intake might suggest a difference between the breed types in the regulation of feed intake in that BB were unable to achieve the same intake as HF when offered concentrate but able to do so when offered silage. Such a difference in feed intake regulation is unlikely as the proportional difference between the breeds was similar (6% v. 8%), but because of greater variation, it failed to reach statistical significance for silage intake. Lower intake for Belgian Blue crosses than for Holstein Friesian has been reported previously. At a fixed concentrate intake, Keane (1994, 2003) reported a lower silage intake for Belgian Blue crosses than for two strains of Holstein Friesian. Likewise, Keane and Drennan (2009) reported lower silage and total DM intakes for Belgian Blue crosses than for Holstein Friesian, while Steen (1995) observed that intake of a total mixed ration was lower for Belgian Blue crosses than for Holstein Friesian. The 9% and 14% greater net energy required per unit live-weight and carcass-weight gain, respectively, for HF is in agreement with other reports showing poorer efficiency of feed energy utilization for this breed type (Steen, 1995; Keane, 2003).

Breed type interactions and commercial acceptability of carcasses

While there were few interactions involving breed type for slaughter or carcass traits, it is meaningful to examine the individual means (Table 6) in the context of minimum carcass weight and finish criteria that are commercially acceptable. Generally, the minimum acceptable carcass weight is 270 kg while the minimum acceptable carcass finish is conformation class O (scale value 2) and fat score 3. The treatment means are evaluated relative to these criteria assuming that in practice animals are slaughtered shortly after reaching them. Three of the four HF groups achieved the criteria for conformation and fat score, but the group finished on silage followed by concentrate and slaughtered at 560 kg fell below the conformation class target. As this group was also marginal for fat score (3.12), it could be concluded that they required a somewhat longer feeding period to achieve a mean carcass weight of about 290 kg. All of the BB groups were marginal for fat score, with the group on concentrate *ad libitum* throughout and slaughtered at 560 kg live weight falling below the carcass fat score target of 3. Thus, all of the BB groups would need to be taken to heavier slaughter weights to ensure that the majority of carcasses had an acceptable level of finish.

Because carcass fat score is not a very precise discriminator of carcass fatness (nationally 87% of all steers carcasses fall into fat classes 3 and 4 (Beef Carcass Classification Figures, 2008)), perirenal plus retroperitoneal fat weight scaled for carcass weight has been suggested as an alternative measure of fatness or finish (Keane and Drennan, 2008). As Holstein Friesian animals have a higher proportion of perirenal plus retroperitoneal fat than beef crosses at the same carcass fatness (Kempster, 1981), a higher perirenal plus retroperitoneal fat proportion is required in Holstein Friesian to indicate similar carcass fatness to beef crosses (e.g., 20 g/kg for beef crosses and 25 g/kg for HF). Such

Table 6. Mean slaughter and carcass traits for Holstein Friesian (HF) and Belgian Blue × Holstein Friesian (BB) steers for each combination of feeding strategy and slaughter weight[1]

Variable	HF				BB				s.e.
	C560	C620	SC560	SC620	C560	C620	SC560	SC620	
Slaughter weight (kg)	563	614	565	624	557	625	561	627	14.4
Kill-out (g/kg)	511	509	491	517	546	561	536	553	5.3
Carcass weight (kg)	288	313	277	323	304	350	301	347	8.3
Conformation score[2]	2.33	2.17	1.85	2.00	3.33	3.00	2.50	3.17	0.158
Fat score[2]	3.35	3.70	3.12	3.58	2.83	3.00	3.00	3.00	0.099
Perirenal + retroperitoneal fat (kg)	6.7	10.8	7.4	7.9	6.4	7.7	6.3	6.9	0.63
Perirenal + retroperitoneal fat[3] (g/kg)	23.4	34.8	26.5	24.3	21.0	21.9	20.9	19.8	1.96
Carcass-weight gain (g/day)	871	672	566	626	875	819	611	685	31.9
Conversion ratio[4] (UFV/kg carcass-weight gain)	13.0	18.5	11.6	16.7	11.8	13.9	10.2	14.5	0.79

[1] See footnotes Table 2 for explanation of finishing strategy by slaughter weight.
[2,3] See footnotes Table 3.
[4] See footnotes Table 5.

an assessment of finish is not particularly helpful in the present study, as with one exception (HF finished on *ad libitum* concentrate to 620 kg live weight), the values for the different finishing strategies differed little within breed type.

Growth and carcass traits

As in the current study, a high growth rate on *ad libitum* concentrate over the first 3 months of a finishing period has been observed previously (Keane and Moloney, 2009), and the performance on silage only was in line with that from previous experiments (Caplis *et al*., 2005; Keane *et al*., 2006; Cummins *et al*., 2007). After an initial period of rapid growth on *ad libitum* concentrate, growth rate declines (Keane *et al*., 2006; Keane and Diskin, 2007). This was evident in the lower overall mean daily gain for the animals retained to 620 kg slaughter weight compared with those slaughtered at 560 kg.

Because slaughter weights were fixed, carcass weight (at the same slaughter weight) could only differ if there was a difference in kill-out proportion. Such a difference did occur in that kill-out proportion at 560 kg slaughter weight was greater for animals finished on concentrate *ad libitum* throughout than for those finished on silage followed by concentrate. More O'Ferrall and Keane (1990) also observed a difference in kill-out proportion at similar slaughter weights for animals finished on diets differing in energy density. This was attributed to differences in gastrointestinal contents as a result of a higher DM intake on the lower energy density diet. The interaction between finishing treatment and slaughter weight for carcass conformation mirrored that for kill-out proportion in that there was a difference between the feeding treatments at 560 kg but not at 620 kg slaughter weight. The greater kill-out proportion, carcass fat score and weight and proportion of perirenal plus retroperitoneal fat at 620 kg than at 560 kg slaughter weight would be expected from the published literature (Steen and Kilpatrick, 1995; Keane *et al*., 2006; Hessle, Nadeau and Johnsson, 2007). An improvement in carcass conformation with increasing slaughter weight would also be expected (Steen and Kilpatrick, 1995; Keane *et al*., 2006; Hessle *et al*., 2007) but this was not observed.

Feed intake

By definition, feeding silage for an 84-day period at the start increased all measures of silage intake and reduced all measures of concentrate intake. Because daily silage intake was lower than daily concentrate intake, feeding silage reduced daily total DM intake, both absolutely and per kg live weight. This was so to a greater extent at the lower slaughter weight because of the shorter time on *ad libitum* concentrate. The higher daily DM intake, both absolutely and per kg live weight, of the animals taken to 620 kg slaughter weight might appear at variance with reports in the literature which indicate that intake per kg mean live-weight decreases with increasing live weight (Hessle *et al*., 2007; Keane and Moloney, 2009). The explanation for this apparent anomaly is the different intervals animals were on *ad libitum* concentrate. For example, after 84 days on silage only there was an adaptation period as the animals moved to *ad libitum* concentrate. As the intake of silage is lower than that of concentrate, when both are available *ad libitum* (Caplis *et al*., 2005; Keane *et al*., 2006), mean DM intake during the adaptation period was lower than later. Thus, because the period on *ad libitum* concentrate was shorter for the animals slaughtered at 560 kg than at 620 kg live weight, the effect of the fixed adaptation period on mean intake was greater.

While differences in total DM intake between the finishing treatments to the same slaughter weight were small there were large differences in the composition (proportion of silage and concentrate) of that intake. For animals slaughtered at 560 kg live weight, those finished on concentrate *ad libitum* throughout had a diet of proportionately 0.19 silage and 0.81 concentrate (DM basis), whereas those finished on silage followed by concentrate had a diet of proportionately 0.77 silage and 0.23 concentrate. Similarly, for animals slaughtered at 620 kg live weight, those finished on concentrate *ad libitum* throughout had a diet of proportionately 0.16 silage and 0.84 concentrate compared with 0.42 silage and 0.59 concentrate for those finished on silage followed by concentrate.

Although total DM intake was higher for animals given the 84-day period of silage feeding, UFV intake was lower because of the lower UFV value of silage than concentrate. The poorer conversion efficiency of UFV to live-weight and carcass-weight gains for the animals taken to 620 kg compared with 560 kg slaughter weight is in line with published results (Keane *et al.*, 2006; Hessle *et al.*, 2007), but the superior efficiency of conversion of UFV to live-weight and carcass-weight gains for silage followed by concentrate, compared with concentrate *ad libitum* throughout, was unexpected. Animals finished on concentrate *ad libitum* to 560 kg slaughter weight required 34% more UFV per unit live-weight gain and 16% more UFV per unit carcass-weight gain (the difference between these values was due to the difference in kill-out proportion discussed earlier) than those finished to the same slaughter weight on silage followed by concentrate. Likewise, the animals finished to 620 kg slaughter weight, required 5% more UFV per unit live-weight gain and 4% more UFV per unit carcass-weight gain when offered concentrate *ad libitum* throughout than when offered silage followed by concentrate. Overall, animals taken to 620 kg slaughter weight required 38% more UFV per unit carcass-weight gain than those slaughtered at 560 kg.

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