Irish Journal of Agricultural and Food Research **49:** 11–26, 2010

Comparison of pasture and concentrate finishing of Holstein Friesian, Aberdeen Angus × Holstein Friesian and Belgian Blue × Holstein Friesian steers

M.G. Keane[1]† and A.P. Moloney[2]

[1]*Teagasc, Livestock Systems Research Department, Animal & Grassland Research and Innovation Centre, Dunsany, Co. Meath, Ireland*

[2]*Teagasc, Animal & Bioscience Research Department, Animal & Grassland Research and Innovation Centre, Dunsany, Co. Meath, Ireland*

Crossbreeding Holstein Friesian dairy cows with both early and late maturing beef breed bulls is common in Ireland. This study concerned the comparison of spring-born Holstein Friesian (HF), Aberdeen Angus × Holstein Friesian (AA) and Belgian Blue × Holstein Friesian (BB) steers slaughtered directly off pasture in the autumn or following a period of concentrate finishing indoors. Male calves (18 per breed type) were reared together until August of their second year when they were assigned to a 3 (breed type) × 3 (finishing strategy) factorial experiment. The three finishing strategies were (i) pasture only for 94 days to slaughter (PE), (ii) concentrate *ad libitum* indoors for 94 days to slaughter (CE), and (iii) pasture only for 94 days followed by concentrate *ad libitum* indoors for 98 days to slaughter (PC). For HF, AA, and BB, mean carcass weight, carcass conformation score and carcass fat score values were 275, 284 and 301 (s.e. 5.1) kg, 1.75, 2.42 and 2.89 (s.e. 0.11), and 2.48, 2.89 and 2.17 (s.e. 0.11), respectively. Pasture alone supported live-weight and carcass-weight gains of approximately 800 g/day and 400 g/day, respectively. Live-weight and carcass-weight gains on concentrate *ad libitum* were approximately 1400 and 870 g/day, respectively. For PE, CE and PC, mean carcass weight, carcass conformation score and carcass fat score values were 244, 287 and 329 (s.e. 5.1) kg, 1.81, 2.56 and 2.69 (s.e. 0.11), and 1.83, 2.71 and 3.01 (s.e. 0.11), respectively. It is concluded that none of the breed types reached an acceptable carcass weight on PE and only HF had acceptable carcass finish. All breed types were acceptably finished on both concentrate finishing strategies.

Keywords: beef cattle; breed type; concentrate feeding; finishing; pasture

†Corresponding author: gerry.keane@teagasc.ie

Introduction

Ensuring adequate replacement heifers for the dairy herd is a high priority for dairy farmers. This necessitates breeding about 0.5 of the herd to dairy breed bulls. In Ireland, where 97% of dairy cows are Holstein Friesian, any cows not required for the production of replacement heifers are crossed with beef bulls. The most common crossing breed is Aberdeen Angus, but Belgian Blue is also used (AIM Bovine Statistics Report, 2008).

Cattle breeds differ in growth rate, body composition and maturity at a fixed age or weight (Kempster, Cook and Southgate, 1982; Southgate, Cook and Kempster, 1982; Keane *et al*., 1990), and thus in suitability for production systems differing in finishing intensity and duration. Amongst the beef breeds commonly used for crossing on dairy cows in Ireland, Aberdeen Angus and Belgian Blue represent the extremes in body composition and maturity (Kempster *et al*., 1982; Keane, 2002).

Finishing spring-born steers at 2 years of age involves an expensive final winter feeding period and, prior to the Luxembourg Agreement (Council of the European Union, 2003) that decoupled premia payments, profitability was highly dependent on the payment of the special beef premium. In the absence of the special beef premium, less expensive finishing options must be explored.

The objectives of this study were (i) to compare the productivity of spring-born Holstein Friesian (HF), Aberdeen Angus × Holstein Friesian (AA) and Belgian Blue × Holstein Friesian (BB) steers for beef production, (ii) to evaluate different finishing strategies for those breed types, and (iii) to ascertain if there were breed type by finishing strategy interactions.

Materials and Methods

Animals and management

Spring-born calves of HF, AA and BB breed types were purchased on 14 dairy farms following identification from artificial insemination records. They were the progeny of at least five sires per breed. The calves were transferred from their farm of origin to Grange Beef Research Centre at 3 to 4 weeks of age, and reared according to standard methods (Fallon and Harte, 1987). They were penned individually and offered a total of 25 kg milk replacer over a rearing period of 8 weeks. Hay was available *ad libitum* and calf concentrate (750 g coarsely rolled barley, 170 g soya bean meal, 55 g molasses and 25 g mineral/vitamin premix per kilogram) was offered up to a maximum of 2 kg per head daily. On May 17, any calves in excess of 18 per breed type were culled on the basis of extreme birth date, or low live-weight associated with earlier illness. Data from these animals were not used. Thereafter, no animals were lost from the study. The calves were turned out to pasture and grazed ahead of yearling steers in a leader/follower system of rotational grazing. They were injected with ivermectin (Qualimec, Janssen Animal Health) for the control of internal parasites at 3, 8 and 13 weeks after turnout to pasture.

The calves were castrated on 20 September, and from than until housing on 7 October they were offered 1 kg concentrate (875 g rolled barley, 65 g soya bean meal, 45 g molasses and 15 g mineral/vitamin premix per kilogram) per head daily. During the first winter they were accommodated in a slatted floor shed and offered grass silage (dry matter (DM) 206 g/kg, crude protein (CP) 132 g/kg DM, *in vitro* DM digestibility (DMD) 708 g/kg, pH 3.9) *ad libitum* plus 1 kg concentrate per head daily until 19 January, when the concentrate was withdrawn. The animals were turned out to pasture for a second grazing season on 23 March and later followed calves in a leader/follower system of rotational grazing.

The cattle were weighed on 1 and 2 August and the mean of these weights was used to assign animals to blocks of 6 within breed type. From within blocks they were assigned to three finishing strategies in a 3 (breed type) × 3 (finishing strategy) factorial arrangement of treatments. The finishing strategies were (i) pasture only for 94 days to slaughter on 4 November (PE; pasture to early slaughter), (ii) concentrate *ad libitum* indoors for 94 days to slaughter on 4 November (CE; concentrate to early slaughter), and (iii) pasture only for 94 days followed by concentrate *ad libitum* indoors for 98 days to slaughter on 10 February (PC; pasture followed by concentrate to late slaughter). Indoor accommodation was in a slatted floor shed in groups of 2 per breed (blocks) giving 9 replicates (3 per breed type) for feed intake measurement. While on *ad libitum* concentrates the animals were also offered 5 kg (~1 kg DM) grass silage per head daily.

The two treatments (PE and PC) on pasture were managed as a single group in a 7-paddock rotational grazing system. To ensure unrestricted availability of herbage, they were offered an estimated (based on sward height) daily herbage allowance (per head) of 14 kg DM above 4.5 cm sward stubble height. Sward height was measured on entry to, and exit from, paddocks and samples of the pre-grazed herbage were retained for chemical analysis. There were two complete grazing rotations during the experimental period.

The housed animals were initially offered grass silage *ad libitum* and concentrate allowance was increased gradually to *ad libitum* intake over a 3-week period. Fresh concentrate was weighed in daily and refusals were weighed back and discarded twice weekly. The concentrate composition (g/kg) was rolled barely 585, extruded full fat soya bean meal 390, mineral/vitamin premix 25. (The inclusion of a high level of full fat soya bean meal was to produce muscle of high unsaturated fatty acid concentration for a related study.)

Carcass assessment

The animals were slaughtered in a commercial meat plant and cold carcass weight (hot weight × 0.98) was recorded. 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 assigned on a 5 point scale using a video imaging analysis system (VBS 2000, E + V, Germany). Carcass measurements (De Boer *et al*., 1974) were also recorded. After 48 h in the chill (4 °C) the right side of each carcass was cut along the caudal edge of the 5th rib and through the spinal column. The abdominal muscles were separated from those of the pelvic limb and the side was cut along the edge of *m. iliocostalis lumborum* through the ribs to the earlier cut at the 5th rib. This divided the side into a pistola hind quarter (i.e. the hind quarter to the 5th rib but without the area on the abdominal side of *m. iliocostalis lumborum*), and a fore quarter that included this area (Keane and Allen, 1998). The quarters were then weighed. The 5th–10th rib joint was removed from the pistola (by cutting between the 10th and 11th ribs). *M. longissimus* area was measured at the 10th rib and the joint was separated into fat, muscle and bone (including *ligamentum nuchae*). A sample of *m. longissimus* at the 10th rib was retained for fatty acid analysis. The sum of the individual fatty acids is reported here as *m. longissimus* lipid concentration.

Initial carcass weight was estimated by applying carcass weight to live-weight ratios (kill-out) of 0.475, 0.485 and 0.515 for HF, AA and BB, respectively, to the initial live weight (Keane and Drennan, 2008). The kill-out proportions from each breed type in the PE group were used to estimate the carcass weight of the corresponding breed types in the PC group at the start of concentrate feeding.

Statistical analysis

Data were statistically analysed using the general linear model procedures 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. The finishing and slaughter data were analysed as a 3 × 3 factorial with terms for block, breed type, finishing strategy and breed type × finishing strategy interaction. Concentrate intake was analysed as a 3 (breed type) × 2 (indoor finishing period) factorial for the CE and PC treatments. Where the overall F value was significant, pair-wise comparisons amongst the breed types and finishing strategies were tested for significance using the PDIFF statement in SAS (2002–2003). Unless otherwise indicated, all differences mentioned were statistically significant ($P < 0.05$). The data are presented as the main effect means except for the assessment of the different breed by finishing strategy combinations in terms of carcass finish and market suitability.

Results

Performance to start of finishing

Mean birth and arrival dates were early to mid February and early to mid March, respectively, for HF and AA, and late February and late March, respectively, for BB (Table 1). Mean live-weight at arrival was similar for HF and AA but was greater for BB. Thereafter, there was no significant difference in live weight among the

Table 1. Dates, live weights and live-weight gains for HF, AA and BB steers

Variable	Breed type[1]			s.e.	Significance
	HF	AA	BB		
Birth date	10 February[a]	13 February[a]	27 February[b]	2.63	***
Date of arrival at research centre	6 March[a]	10 March[a]	28 March[b]	2.74	***
Live-weight (kg) at:					
Arrival	52[a]	57[a]	70[b]	2.0	***
Calf turn-out (17 May)	98	102	96	2.4	
Calf housing (7 October)	209	213	205	4.3	
Yearling turn-out (23 March)	294	299	295	6.1	
Early summer (12 May)	340	341	343	6.3	
Live-weight gain (g/day) from:					
Arrival to calf turn-out	646	671	516	68.0	
Calf turn-out to housing	777	771	768	27.5	
Housing to yearling turn-out	506	517	534	28.0	
Yearling turn-out to late summer	899	831	838	47.5	
Calf turn-out to yearling turn-out	631	635	644	29.8	
Calf turn-out to late summer	754	732	743	21.2	

[1] HF = Holstein Friesian, AA = Aberdeen Angus × Holstein Friesian, BB = Belgian Blue × Holstein Friesian.

[a,b] Values without a superscript in common differ significantly ($P < 0.05$).

breed types up to the start of the finishing period. Live-weight gain from calf arrival to turn-out, during the first winter, and during the second grazing season, did not differ among the breed types.

Performance during finishing

Estimated initial carcass weight together with live weights, live-weight gains and estimated carcass-weight gain are shown in Table 2. There was no significant effect of breed type on live-weight at any time although by the PC slaughter date, AA and BB were 11 and 26 kg, respectively, heavier than HF. Live weights were similar for PE and PC while both were at pasture. Although starting live weights were similar, estimated initial carcass weight was greater for BB than for both HF and AA which did not differ. At the time of slaughter of PE and CE, estimated mean carcass weight of PC was heavier for BB than for HF or AA, which did not differ. Estimated initial carcass weight was similar for the three finishing strategies, as intended.

There was no significant effect of breed type on live-weight gain during finishing or on slaughter weight per day of age but the values were numerically higher for the two beef crosses than for HF. There was also no difference among the breed types in carcass-weight gain from start to early slaughter, or overall from start to slaugh-

Table 2. Effect of breed type and finishing strategy on live weights and gains, initial carcass weight and carcass-weight gain

Variable	Breed type[1] (B)			Finishing strategy[2] (F)			s.e.[3]	Significance[4]	
	HF	AA	BB	PE	CE	PC		B	F
Live weight (kg) at:									
Start of finishing	418	418	419	419	415	420	7.6		
Early slaughter	514	520	514	496	555	497	8.4		***
Late slaughter	615	626	641	–	–	627	17.8†		–
Arrival to slaughter (days)	635[a]	631[a]	613[b]	593	593	691	3.2	*	–
Carcass weight (kg) at:									
Start of finishing	198[a]	202[a]	216[b]	206	204	206	3.4	**	
Early slaughter	236[a]	239[a]	257[b]	–	–	244	4.6†	*	–
Live-weight gain (g/day) from:									
Start to early slaughter	1022	1086	1014	818[a]	1489[b]	814[a]	36.9		***
Early to late slaughter	1208	1361	1415	–	–	1328	146.7†		–
Start to slaughter	1086	1190	1108	819[a]	1489[b]	1076[c]	40.8		***
Slaughter weight per day of age	833	852	864	797[a]	886[b]	866[b]	13.5		***
Carcass-weight gain (g/day) from:									
Start to early slaughter	539	577	575	403[a]	887[b]	400[a]	21.9		***
Early to late slaughter	784[a]	868[b]	943[b]	–	–	865	43.8†	*	–
Start to slaughter	604	660	663	403[a]	887[b]	637[c]	23.5		***
Carcass weight per day of age	412[a]	429[a]	464[b]	392[a]	459[b]	454[b]	7.4	***	***

[1] See footnotes Table 1.
[2] PE = finished on pasture, CE = finished on *ad libitum* concentrate indoors, PC = finished on pasture followed by *ad libitum* concentrate indoors.
[3] For Breed type and Finishing strategy (n = 18) except where indicated otherwise.
[4] There was no significant B × F interaction.
† For Breed type (n = 6).
[a,b,c] See footnotes Table 1.

ter, but carcass-weight gain from early to late slaughter, and carcass weight per day of age, were greater for BB than for HF.

Live-weight gain at pasture was approximately 0.8 kg/day while that on *ad libitum* concentrate indoors was > 1.4 kg/day. Live-weight gain during the indoor concentrate feeding period was similar CE and PC. For the finishing period as a whole, live-weight gain differed among the three finishing strategies, being lowest for PE and highest for CE. Slaughter weight per day of age was lower for PE than for the two concentrate-finished groups, which did not differ. Estimated carcass-weight gains reflected live-weight gains with no difference between PE and PC up to the time of early slaughter. For the finishing period as a whole, estimated carcass-weight gain differed for the three finishing strategies being lowest for PE and highest for CE. Carcass weight per day of age did not differ between CE and PC, but was lower for PE.

Pasture measurement and concentrate intake

Mean pre-grazing sward height for the first and second grazing rotations was 12.5 and 11.6 (s.e. 0.36) cm, respectively. Corresponding post grazing values were 6.0 and 5.1 (s.e. 0.19) cm. Estimated pre-grazing herbage DM yields were 1495 and 1355 (s.e. 58.3) kg/ha, with corresponding post grazing DM yields of 497 and 349 (s.e. 31.4) kg/ha for the first and second grazing rotations, respectively. Mean pre-grazing herbage DM, CP and DMD concentrations were 184 (s.d. 34.8), 141 (s.d. 21.6) and 690 (s.d. 28.8) g/kg, respectively.

Concentrate DM intake, during finishing, for CE and PC is shown in Table 3. There was no effect of breed type on concentrate intake. Mean daily and total intakes were higher for PC but as the difference in mean live weight was proportionately greater than the difference in intake, intake per kilogram live weight was actually lower for PC.

Slaughter and carcass traits

Slaughter weight was not affected by breed type (Table 4) but kill-out proportion was higher for BB and lower for HF than for AA. This resulted in carcass weight being heavier for BB than for HF and AA, which did not differ. Carcass conformation score was better for BB than for AA, and for AA than HF. Carcass fat score was higher for AA than for the other two breed types, which did not differ. Weight of perinephric plus retroperitoneal fat did not differ among the breed types, but when scaled for carcass weight, it was significantly higher for HF than for BB, with AA intermediate and not significantly different from the other two.

Slaughter weight and carcass weight were greater for CE than for PE, and for PC than for CE. Kill-out proportion and carcass conformation did not differ between the two concentrate finishing

Table 3. Effect of breed type and finishing strategy on intake of concentrate dry matter

Intake variable	Breed type[1] (B)			Finishing strategy[2] (F)		s.e.	Significance[3]
	HF	AA	BB	CE	PC		F
Intake (kg/day)	9.36	9.56	9.29	9.22	9.60	0.078	**
Intake (g/kg live weight)	18.02	18.20	17.69	19.00	17.08	0.198	***
Total intake (kg)	899	918	892	867	941	9.7	**

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

[3] There was no significant effect of Breed type and no B × F interaction.

Table 4. Effect of breed type and finishing strategy on weight at slaughter, carcass weight and classification, and on carcass measurements

Variable	Breed type[1] (B)			Finishing strategy[2] (F)			s.e.[3]	Significance[4]	
	HF	AA	BB	PE	CE	PC		B	F
Weight at slaughter (kg)	554	564	561	496[a]	551[b]	627[c]	9.3		***
Kill-out proportion (g/kg)	494[a]	502[b]	536[c]	491[a]	518[b]	524[b]	3.7	***	***
Carcass weight (kg)	275[a]	284[a]	301[b]	244[a]	287[b]	329[c]	5.1	**	***
Carcass conformation score[5]	1.75[a]	2.42[b]	2.89[c]	1.81[a]	2.56[b]	2.69[b]	0.109	***	***
Carcass fat score[5]	2.48[a]	2.89[b]	2.17[a]	1.83[a]	2.71[b]	3.01[c]	0.112	***	***
Perinephric + retroperitoneal fat (kg)	7.0	6.5	6.3	3.2[a]	6.7[b]	9.3[c]	0.32		***
Perinephric + retroperitoneal fat[6] (g/kg)	24.7[a]	22.2[ab]	20.5[b]	13.4[a]	23.5[b]	30.4[c]	1.11	*	***
Carcass measurements[6] (cm/kg)									
Carcass length	0.508[a]	0.483[b]	0.445[c]	0.547[a]	0.463[b]	0.426[c]	0.0074	***	***
Carcass depth	0.181[a]	0.167[b]	0.157[c]	0.194[a]	0.160[b]	0.151[c]	0.0028	***	***
Leg length	0.292[a]	0.251[b]	0.234[b]	0.287[a]	0.260[b]	0.230[c]	0.0107	**	**
Leg width	0.163[a]	0.151[b]	0.147[b]	0.176[a]	0.153[b]	0.132[c]	0.0026	***	***
Leg thickness	0.096	0.096	0.093	0.109[a]	0.096[b]	0.080[c]	0.0014		***

[1,2,3] See footnotes Tables 1 and 2.
[4] There was no significant B × F interaction.
[5] EU Beef Carcass Classification Scheme: conformation scale 1 = P (poorest) to 5 = E (best), fat scale 1 (leanest) to 5 (fattest).
[6] Relative to carcass weight.
[a,b,c] See footnotes Table 1.

strategies but both were lower for pasture finishing. All indicators of fatness were higher for PC than for CE, and for CE than PE.

With an exception of leg thickness, which did not differ among the breed types, all carcass measurements scaled for carcass weight were lower for AA than for HF, and relative carcass length and depth were lower for BB than for AA. All carcass measurements scaled for carcass weight were lower for CE than for PE, and for PC than CE.

Relative to carcass side weight, pistola proportion did not differ between HF and BB but was lower for AA (Table 5). The weight of the rib joint was greater for BB than for HF, with AA intermediate. *M. longissimus* area, both absolutely and scaled for carcass weight, did not differ between HF and AA but was greater for BB. As proportions of the rib joint, neither *m. longissimus* nor total muscle differed between HF and AA, but BB had higher proportions of both. AA had less other muscle than HF and BB which did not differ in this respect. AA also had more total fat and less bone than HF, while BB had a similar fat proportion to HF and a similar bone proportion to AA. *M. longissimus* lipid concentration was higher for AA and lower for BB than for HF.

Pistola weight as a proportion of carcass side weight was greater for PE than for CE, and for CE than PC. *M. longissimus* area was greater for CE than PE, but when scaled for carcass weight, the difference was not significant. There was no difference between CE and PC in absolute *m. longissimus* area, but when scaled for carcass weight, it was greater for CE. *M. longissimus* as a proportion of the rib joint did not differ amongst the finishing strategies but other muscle proportion was lower for PC than for PE and CE which did not differ. Total muscle proportion was lower for CE than for PE, and for PC than CE. Fat proportion was higher for CE than for PE, and for PC than CE. Bone proportion was similar for the two concentrate finishing strategies but was higher for PE. *M. longissimus* lipid concentration did not differ for CE and PC and both were higher than PE.

Discussion

Selection of breed types

Data on the breed composition of the national calf crop (AIM Bovine Statistics Report, 2008) show that proportionately 0.49 of calves born to Irish dairy cows in 2008 were by Holstein Friesian sires, 0.17 were by Aberdeen Angus sires and 0.03 were by Belgian Blue sires. Thus, the breed types used in the present study represent proportionately 0.69 of Irish dairy-bred calves. The relatively high usage of Aberdeen Angus bulls in dairy herds reflects a preference for their use on heifers because of their shorter gestation length and lower incidence of calving difficulty (Keane, 2002; ICBF, 2006). The Belgian Blue breed is becoming increasingly popular for crossing on dairy cows because it has a shorter gestation length and a lower incidence of calving difficulty than other late maturing breeds (McGuirk, Going and Gilmour, 1998). The Aberdeen Angus and Belgian Blue breeds were specifically chosen because they represent extremes in fatness (at a fixed age/weight), carcass conformation and muscling (Kempster *et al*., 1982; Keane, 2002). Differences in these traits imply differences in the suitability of the breed types to different finishing systems, with Aberdeen Angus crosses more suited to earlier, less intensive finishing, and Belgian Blue crosses more suited to later, more intensive finishing.

Table 5. Effect of breed type and finishing strategy on carcass components and composition of the rib joint

Variable	Breed type[1] (B)			Finishing strategy[2] (F)			s.e.[3]	Significance[4]	
	HF	AA	BB	PE	CE	PC		B	F
Pistola weight[5] (g/kg)	468^{a}	459^{b}	472^{a}	483^{a}	464^{b}	453^{c}	2.4	**	***
M. longissimus area (cm^2)	62.2^{a}	67.4^{a}	78.8^{b}	62.3^{a}	70.8^{b}	75.3^{b}	1.91	***	***
Relative m. longissimus area[6] (cm^2/kg)	0.228^{a}	0.239^{a}	0.264^{b}	0.255^{a}	0.247^{a}	0.229^{b}	0.0063	***	**
Weight of rib joint (kg)	6.91^{a}	7.31^{ab}	7.52^{b}	5.98^{a}	7.32^{b}	8.45^{c}	0.174	*	***
Composition of rib joint (g/kg)									
M. longissimus	188^{a}	194^{a}	224^{b}	203	201	203	4.2	***	
Other muscle	440^{a}	418^{b}	440^{a}	453^{a}	437^{a}	407^{b}	6.2	*	***
Total muscle	627^{a}	613^{a}	663^{b}	655^{a}	639^{b}	610^{c}	5.8	***	***
Total fat	144^{a}	183^{b}	133^{a}	103^{a}	162^{b}	195^{c}	6.5	***	***
Total bone	229^{a}	204^{b}	204^{b}	242^{a}	199^{b}	195^{b}	3.9	***	***
M. longissimus lipid (g/kg)	33.3^{a}	42.3^{b}	25.0^{c}	24.8^{a}	36.3^{b}	39.5^{b}	1.56	***	***

[1,2,3] See footnotes Tables 1, 2.
[4] There was no significant B × F interaction.
[5] Relative to side weight.
[6] Relative to carcass weight.

Breed type effects

While cross breeding of Holstein Friesian dairy cows with both Aberdeen Angus and Belgian Blue bulls is common in Ireland, there are few reports in the literature of direct comparisons of these beef crosses. However, there have been studies where either was compared with Holstein Friesian. Harte and Conniffe (1967) and Southgate *et al*. (1982) reported that growth rate was lower for AA than HF. In the present study, there was no significant difference between these breed types in live growth rate but carcass growth rate was significantly higher for AA because of a higher kill-out proportion.

Comparisons of Holstein Friesian with Belgian Blue crosses reported in the literature show that Belgian Blue × Friesian had a higher kill-out proportion and a greater carcass weight than Friesian (Keane, 1994; Steen, 1995). The Belgian Blue crosses also had less perinephric plus retroperitoneal fat, lower carcass fat and bone proportions, and a higher muscle proportion (Keane, 1994). The present study (using rib joint composition as an indicator of carcass composition) confirms these findings. Compared with Holstein Friesian, Belgian Blue × Holstein Friesian steers consumed 8% less feed, and as their lean tissue gain per day was 18% higher, their efficiency of energy utilisation for lean gain was 27% higher (Steen, 1995). The magnitude of differences between Belgian Blue × Holstein Friesian and straight bred Holstein Friesian may depend on the strain of the latter in the comparison as Keane (2003) showed that a Holstein Friesian strain of European/American descent had greater slaughter and carcass weights than a New Zealand strain.

Comparisons of progeny of Aberdeen Angus and Belgian Blue sires tend to be from beef-breed rather than from dairy-breed dams. One such comparison is that of Ferrell and Jenkins (1998). Sire breed did not significantly affect feed consumption, live-weight gain or carcass weight, but in agreement with present results, carcass weight tended to be greater and fatness was lower for Belgian Blue progeny. As Aberdeen Angus was one of the dam breeds there was some confounding of heterosis effects.

Differences amongst breed types in carcass composition are particularly relevant in the context of different finishing systems. Truscott, Lang and Tulloh (1976) compared the carcass composition and tissue distribution of Friesian and Aberdeen Angus (presumably pure bred) steers over the same slaughter weight range. The Aberdeen Angus animals had a greater carcass weight, reflecting their higher dressing proportion (as also observed in the present study) but there was little difference between the breeds in muscle production although the Aberdeen Angus animals had more fat and less bone (as observed for the rib joint in the present study). Their greater proportion of fat at the same carcass weight indicates that Aberdeen Angus would have the same proportion of carcass fat as Friesian at a lower carcass weight. This agrees with the report of Kempster *et al*. (1982) who noted that Friesian and Aberdeen Angus × Friesian had the same carcass fat proportion when the Aberdeen Angus crosses were proportionately 0.83 of the Friesian carcass weight.

Following evaluation of a range of fatness indicators, Kempster, Chadwick and Charles (1986) found that visual assessment of carcass subcutaneous fat to the nearest percentage unit was the single most precise predictor of carcass lean proportion but there were substantial biases for individual breeds. Carcass fat score (scale 1–7) was the next most precise predictor, while perinephric plus retroperitoneal fat proportion was also a useful predictor. The authors remarked that while some useful predictors do exist there will always be problems in applying general relationships to mixed-breed cattle populations because of differences between breeds in fat partitioning.

Finishing strategy

Live-weight gain at pasture exceeded 0.8 kg/day, which is at the upper end of the range reported in the literature (French *et al*., 1997, 2001a,b) for steers grazing autumn herbage. The potential gain of these steers, as represented by the performance on *ad libitum* concentrate indoors, was > 1.4 kg/day. The potential of pasture relative to concentrate for carcass-weight gain was even lower than for live-weight gain due to the lower kill-out proportion of the pasture finished animals. It is somewhat surprising that there was no difference in performance between the two concentrate-finished groups during the concentrate-feeding period. It might be expected that the PC group would have grown faster (expressed some compensatory growth) than the CE group because of their previously low rate of gain at pasture (Coleman and Evans, 1986). However, as the two concentrate finishing periods were not contemporaneous, direct comparison may not be appropriate. In the study of Coleman and Evans (1986), compensating animals had a lower feed intake than their previously full-fed comrades but when scaled for metabolic body size intakes were similar. In the present study, the late concentrate finished animals were heavier and did have higher intake, but the greater intake was not commensurate with their greater live-weight. Consequently, their intake per kilogram live weight was lower, suggesting a lower proportion of feed energy above maintenance available for growth.

Since two of the three finishing strategies involved concentrate *ad libitum* rather than concentrate as a supplement to pasture, responses to concentrate supplementation cannot be calculated for comparison with previous results (Keane and Drennan, 2008), but overall efficiency of concentrate utilisation can be calculated. The early concentrate finished animals gained 140 kg live weight and 83 kg carcass weight for a concentrate input of 867 kg DM, giving conversion ratios of 6.2 and 10.5 for live-weight and carcass-weight gain, respectively. While these gains were being achieved indoors, the animals at pasture gained 77 kg live weight and 36 kg carcass weight. Thus, the marginal response to concentrate was 63 kg live weight and 47 kg carcass weight, giving marginal conversion ratios of concentrate DM to live-weight and carcass-weight gains of 13.8 and 18.4 kg, respectively. Based on current concentrate costs and beef carcass prices, the break-even value for conversion of concentrate DM to carcass is about 15:1. Thus, the early concentrate finishing strategy in the present study would not be financially sustainable.

Live-weight and carcass-weight gains during the concentrate finishing period for PC were 130 and 85 kg for a concentrate input of 941 kg DM, giving conversion ratios of concentrate to live-weight and carcass-weight gains of 7.2 and 11.1, respectively. Based on these values the late concentrate finishing strategy would be financially sustainable at current concentrate costs and beef carcass prices. While this finishing strategy may be attractive financially it cannot be considered an early finishing strategy. Early finishing involves slaughtering the animals off pasture before housing becomes necessary whereas the PC strategy required a 3-month housing period after the end of the grazing season.

Conversion rate of concentrate to live-weight or carcass-weight gain depends on factors such as live weight and genetic potential of the animals, the duration of the finishing period and expression of compensatory growth. Sinclair *et al.* (1998) showed that feed conversion ratio disimproved by 0.07 kg DM per 1 kg live-weight gain per week of finishing in young bulls, and the rate of change was greater for Angus than for Charolais crosses. Similarly, Hankey and Kay (1988) showed that feed conversion efficiency declined with increasing length of feeding period, and was poorer for Angus than for Charolais heifers. Because many factors influence feed conversion ratio, comparisons across experiments are of limited value. However, the values reported here for *ad libitum* concentrate finishing appear to be at the lower end of the scale. For a similar finishing period, French *et al.* (1997) reported conversion rates for late maturing steers of 8.8 for live-weight gain and 15.7 for carcass-weight gain. Other relevant values from the literature include 8.1 and 12.6 (Caplis *et al.*, 2005) and 9.4 and 15.2 (Keane, Drennan and Moloney, 2006) for live-weight and carcass-weight gains, respectively.

The higher kill-out proportion of the concentrate finished groups would be expected as the proportion of carcass in live-weight gain increases with increasing dietary energy concentration and live-weight gain (Caplis *et al.*, 2005). The absence of a significant difference in kill-out between the two groups finished on concentrate was somewhat surprising as kill-out generally increases with increasing weight (Patterson, Moore and Steen, 1994), but there was a numerical difference in favour of the heavier, later finished group.

The observed improvement in carcass conformation score due to concentrate finishing is in line with many reports in the literature (Sinclair *et al.*, 1998; Caplis *et al.*, 2005; Keane *et al.*, 2006), but it is somewhat surprising that there was no additional improvement for the PC group compared with the CE group (Patterson *et al.*, 1994). However, bearing in mind that one third of the animals were Holstein Friesian, a breed in which conformation score rarely exceeds a value of 2 (Class O), and the beef crosses were half Holstein Friesian, perhaps there was limited potential for conformation to exceed the values observed. Even though conformation did not differ between CE and PC carcass compactness did, suggesting that the unit of measurement of conformation may be too large to reflect relatively small differences in carcass compactness. The increases observed in the indicators and measures of fatness with increasing weight and feeding level have been widely reported in the literature (Hironaka *et al.*, 1994; Patterson *et al.*, 1994; Mandell *et al.*, 1997).

The decrease in the pistola as a proportion of the carcass side with increasing weight reflects its allometric growth coefficient of < 1.0 (Keane and Allen, 2002). The general effects of increases in feeding level and slaughter weight are increases in fat and decreases in muscle and bone proportions (Berg, Andersen and Liboriussen, 1978; Steen, 1995), but there have been instances with relatively immature cattle where only the fat and bone proportions were affected (Patterson *et al.*, 1994; Caplis *et al.*, 2005). In the present study, when animals were slaughtered at the same time, the effect of concentrate feeding was mainly to increase fat proportion and reduce bone proportion.

Commercial acceptability of carcasses

While there were no statistically important interactions between breed type and finishing strategy, relatively small differences in carcass weight, conformation and fatness can affect carcass value, particularly since the recent introduction of a quality payment system for carcasses (Anonymous, 2010). Under this system, carcasses of R= and R– conformation (scale values of 3.0 and 2.75, respectively) receive the base price, carcasses of poorer conformation are progressively discounted and carcasses of better conformation receive a premium. Likewise, carcasses of fat class 2+ to 4– (scale values 2.25 to 3.75) receive the base price and carcasses outside of this range are discounted. Although not specified in the quality payment system, in practice there is a carcass weight threshold of about 270 kg below which discounting is also applied. To permit assessment of the experimental treatments in the context of these criteria, breed type × finishing strategy group means for selected traits are shown in Table 6. None of the groups finished at pasture had an acceptable mean carcass weight whereas all those finished on concentrate did. Likewise, none of the pasture finished groups and no HF group met the minimum carcass conformation class (R–), but all the beef cross groups finished on concentrate did. Other than HF and BB finished on pasture, all groups reached the minimum carcass fat class (2+). However, AA finished on pasture only, and BB on the CE finishing strategy barely exceeded the minimum value. No group was close to the upper fat class limit.

Regression analysis showed that HF, AA and BB would have a mean carcass fat score of 3 and a mean fat proportion of 150 g/kg in the rib joint, at approximate carcass weights of 300, 280 and 350 kg, respectively. Assuming a starting weight of 420 kg for all breed types, these carcass weights would be achieved on *ad libitum* concentrate after 121, 83 and 151 days for HF, AA and BB, respectively (based on carcass-weight gains to early slaughter of 833, 942 and 886 g/day for HF, AA and BB, respectively). Corresponding periods for late concentrate finishing would be 82, 47 and 99 days (based on carcass-weight gains during late concentrate finishing of 784, 868 and 943 g/day for HF, AA and BB, respectively).

While there is no commercially specified minimum value for the lipid concentration in muscle, a value of 25 g/kg is assumed (Meurice *et al*., 2008). Of the groups finished at pasture, only AA reached a lipid concentration of 25 g/kg in the *m. longissimus*, but HF were close (24 g/kg). With the exception of BB steers finished on the PE regime, all groups exceeded a lipid concentration of 25 g/kg in the *m. longissimus,* with the AA animals finished on PC exceeding 50 g/kg.

Conclusions and implications

It is concluded that there were few differences among the breed types in lifetime live-weight gain. Kill-out proportion was higher for AA than for HF but the difference was not sufficient to yield a significant difference in carcass weight. However, the superior kill-out proportion of BB over the other two breed types did result in a significantly greater carcass weight. Carcass conformation was best for BB and poorest for HF while indicators of fatness were highest for AA and lowest for BB. Muscle proportion in the rib joint and *m. longissimus* area were similar for HF and AA and were higher for BB. The fat proportion in the rib joint was similar for HF and BB, and higher for AA, while bone proportion was similar for AA and BB, and higher for HF. Pasture alone supported live- and carcass-weight gains of approximately 800 g/day and 400 g/day, respectively. Corresponding mean values for concentrate offered *ad libitum* were 1409 and 876 g/day, with no difference

Table 6. Mean breed type × finishing strategy values for selected slaughter and carcass traits

Variable	Finishing strategy by breed type[1]									s.e.[2]
	PE			CE			PC			
	HF	AA	BB	HF	AA	BB	HF	AA	BB	
Live weight at slaughter (kg)	496	496	497	551	571	544	615	626	641	16.1
Carcass weight (kg)	235	240	257	276	289	298	313	324	350	8.9
Kill-out proportion[3] (g/kg)	474	483	517	501	506	547	509	519	546	6.3
Carcass conformation score[4]	1.17	1.92	2.33	2.00	2.67	3.00	2.08	2.67	3.33	0.188
Carcass fat score[4]	1.67	2.50	1.33	2.95	2.83	2.33	2.83	3.35	2.83	0.195
Perinephric + retropertioneal fat (g/kg carcass)	13.4	14.5	12.2	27.1	20.9	22.6	35.5	31.1	26.6	1.93
M. longissimus area (cm^2)	56.0	59.8	71.1	64.2	69.3	79.0	66.4	73.0	86.4	3.31
Relative *m. longissimus* area[5] (cm^2/kg)	0.238	0.249	0.279	0.233	0.241	0.266	0.212	0.227	0.247	0.0109
Fat in rib joint (g/kg)	96	123	88	163	184	140	173	241	171	11.3
Lipid in *m. longissimus* (g/kg)	24.4	28.3	21.7	38.5	46.9	23.6	37.0	51.9	29.8	2.69

[1] See footnotes Tables 1 and 2.
[2] For subclass mean (n = 6).
[3] Carcass weight relative to live weight at slaughter.
[4] See footnotes Table 4.
[5] See footnotes Table 5.

between the early and late concentrate finishing strategies. While concentrate intake was higher for late finishing in absolute terms, it was lower per kilogram mean live weight.

Compared with pasture finishing, concentrate finishing increased kill-out proportion and all measures of fatness. Compared with concentrate finishing to early slaughter, concentrate finishing to late slaughter increased rib joint fat proportion, decreased muscle proportion in the rib joint and had little effect on bone proportion. Conversion ratios of concentrate DM to live- and carcass-weight gains were 6.2 and 10.5, and 7.2 and 11.0 for the early and late concentrate finishing strategies, respectively. None of the breed types finished on pasture produced carcasses of acceptable mean weight whereas all those finished on either concentrate strategy did. Likewise, all groups finished on both concentrate strategies produced carcasses of acceptable finish but only AA finished on pasture did so.

Acknowledgements

The author acknowledges Mr. Joe Farrell for skilled technical assistance, Mr. Brian Duffy for care and management of the animals and the staff at Grange laboratories for feed analysis.

References

AIM (Animal Identification and Movement) Bovine Statistics Report. 2008. Breed composition of 2008 born calves. Published by Department of Agriculture, Fisheries and Food, Ireland, page 11. Available online: www.agriculture.gov.ie [Accessed June 2010].

Anonymous. 2010. Quality Payment System. *Teagasc Beef Advisory Newsletter*, January 2010, Teagasc, Ireland, 4 pages.

Berg, R.T., Andersen, B.B. and Liboriussen, T. 1978. Growth of bovine tissues. 1. Genetic influences on growth patterns of muscle, fat and bone in young bulls. *Animal Production* **26:** 245–258.

Caplis, J., Keane, M.G., Moloney, A.P. and O'Mara, F.P. 2005. Effects of supplementary concentrate level with grass silage, and separate or total mixed ration feeding, on performance and carcass traits of finishing steers. *Irish Journal of Agricultural and Food Research* **44:** 27–43.

Coleman, S.W. and Evans, B.C. 1986. Effect of nutrition, age and size on compensatory growth in two breeds of steers. *Journal of Animal Science* **63:** 1968–1982.

Commission on the European Communities. 1982. Commission of the European Communities (Beef Carcass Classification) Regulations. Council Regulations 1358/80, 1208/81, 1202/82. Commissions Regulations 2390/81, 563/82, 1557/82. Commission of the European Communities, Brussels, Belgium.

Council of the European Union. 2003. CAP Reform – Presidency Compromise (in agreement with the Commission), Brussels, Belgium.

De Boer, H., Dumont, B.L., Pomeroy, R.W. and Weniger, J.H. 1974. Manual on EAAP reference methods for the assessment of carcass characteristics in cattle. *Livestock Production Science* **1:** 151–164.

Fallon, R.J. and Harte, F.J. 1987. Calf Feeding and Management. Beef Series No. 1. *An Foras Taluntais* (now Teagasc), Dublin, Ireland, 26 pages. ISBN 0-948321-19-9.

Ferrell, C.L. and Jenkins, T.G. 1998. Body composition and energy utilization by steers of diverse genotypes fed a high concentrate diet during the finishing period. 1. Angus, Belgian Blue, Hereford and Piedmontese sires. *Journal of Animal Science* **76:** 637–646.

French, P., O'Riordan, E.G., Moloney, A.P., O'Kiely, P. and Caffrey, P.J. 1997. Autumn grass – are concentrate supplements worthwhile? *Irish Grassland and Animal Production Association Journal* **31:** 85–91.

French, P., O'Riordan, E.G., Moloney, A.P. and Caffrey, P.J. 2001a. Effects of concentrate level and grazing system on the performance of beef cattle grazing autumn herbage. *Irish Journal of Agricultural and Food Research* **40:** 33–44.

French, P., O'Riordan, E.G., O'Kiely, P., Caffrey, P.J. and Moloney, A.P. 2001b. Intake and growth of steers offered different allowances of autumn grass and concentrates. *Animal Science* **72:** 129–138.

Hankey, C. and Kay, M. 1988. A note on the food conversion and meat quality of crossbred Aberdeen Angus and Charolais heifers. *Animal Production* **47:** 497–500.

Harte, F.J. and Conniffe, D. 1967. Studies on cattle of varying growth potential for beef production. 1. Growth rate, feed conversion efficiency, carcass yield and offals. *Irish Journal of Agricultural Research* **6:** 137–152.

Hironaka, R., Freeze, B., Kozub, G.C. and Beauchemin, K.A. 1994. Influence of barley silage:concentrate ratio on rate and efficiency of live weight gain, diet digestibility and carcass characteristics of beef steers. *Canadian Journal of Animal Science* **74:** 495–501.

ICBF (Irish Cattle Breeding Federation). 2006. "Official calving performance proofs for beef AI sires". ICBF, Bandon, Co Cork, Ireland, 28 pages.

Keane, M.G. 1994. Productivity and carcass composition of Friesian, Meuse-Rhine-Issel (MRI) × Friesian and Belgian Blue × Friesian steers. *Animal Production* **59:** 197–208.

Keane, M.G. 2002. Crossbreeding dairy cows with beef breed bulls. *Proceedings 53rd European Association for Animal Production Meeting*, Cairo, Egypt, Paper C3.2, 8 pages.

Keane, M.G. 2003. Beef production from Holstein-Friesian bulls and steers of New Zealand and European/American descent, and Belgian Blue × Holstein-Friesians, slaughtered at two weights. *Livestock Production Science* **84:** 207–218.

Keane, M.G. and Allen, P. 1998. Effects of production system intensity on performance, carcass composition and meat quality of beef cattle. *Livestock Production Science* **56:** 203–214.

Keane, M.G. and Allen, P. 2002. A comparison of Friesian-Holstein, Piemontese × Friesian-Holstein and Romagnola × Friesian-Holstein steers for beef production and carcass traits. *Livestock Production Science* **78:** 143–158.

Keane, M.G. and Drennan, M.J. 2008. A comparison of Friesian, Aberdeen Angus × Friesian and Belgian Blue × Friesian steers finished at pasture or indoors. *Livestock Science* **115:** 268–278.

Keane, M.G., Drennan, M.J. and Moloney, A.P. 2006. Comparison of supplementary concentrate levels with grass silage, separate or total mixed ration feeding, and duration of finishing in beef steers. *Livestock Science* **103:** 169–180.

Keane, M.G., More O'Farrell, G.J., Connolly, J. and Allen, P. 1990. Carcass composition of serially slaughtered Friesian, Hereford × Friesian and Charolais × Friesian steers finished on two dietary energy levels. *Animal Production* **50:** 231–243.

Kempster, A.J., Chadwick, J.P. and Charles, D.D. 1986. Estimation of the carcass composition of different cattle breeds and crosses from fatness measurements and visual assessments. *Journal of Agricultural Science*, Cambridge **106:** 223–237.

Kempster, A.J., Cooke, G.L. and Southgate, J.R. 1982. A comparison of the progeny of British Friesian dams and different sire breeds in 16- and 24-month beef production systems. 2. Carcass characteristics, and rate and efficiency of meat gain. *Animal Production* **34:** 167–178.

Mandell, I.B., Gullett, E.A., Buchanan-Smith, J.G. and Campbell, C.P. 1997. Effects of diet and slaughter end point on carcass composition and beef quality of Charolais cross steers. *Canadian Journal of Animal Science* **77:** 403–414.

McGuirk, B.J., Going, I. and Gilmour, A.R. 1998. The genetic evaluation of beef sires for crossing with dairy cows in the U.K. 1. Sire breed and non-genetic effects on calving survey traits. *Animal Science* **66:** 35–45.

Meurice, P., Brun, J.P., Jurie, C., Picard, B., Nute, G.R. and Hocquette, J.F. 2008. Meta-analysis of beef sensory quality. *Proceedings 59th European Association for Animal Production Meeting*, Vilnius, Lithuania, Session 21, Paper 10.

Patterson, D.C., Moore, C.A. and Steen, R.W.J. 1994. The effects of plane of nutrition and slaughter weight on the performance and carcass composition of continental beef bulls given high forage diets. *Animal Production* **58:** 41–47.

Sinclair, K.D., Cuthbertson, A., Rutter, A. and Franklin, M.F. 1998. The effects of age at slaughter, genotype and finishing system on the organoleptic properties and texture of bull beef from suckled calves. *Animal Science* **66:** 329–340.

Southgate, J.R., Cooke, G.L. and Kempster, A.J. 1982. A comparison of the progeny of British Friesian dams and different sire breeds in 16- and 24-month beef production systems. 1. Live weight gain and efficiency of food utilization. *Animal Production* **34:** 155–166.

SAS. 2002–2003. *Version 9.1.* SAS Institute Inc., Cary, NC., USA.

Steen, R.W.J. 1995. The effect of plane of nutrition and slaughter weight on growth and food efficiency in bulls, steers and heifers of three breed crosses. *Livestock Production Science* **42:** 1–11.

Truscott, T.G., Lang, C.P. and Tulloh, N.M. 1976. A comparison of body composition and tissue distribution of Friesian and Angus steers. *Journal of Agricultural Science*, Cambridge **87:** 1–14.

Received 12 January 2010