Session: 11 - "Use of crosses and dairy calves for beef production"
Abstract: 1811
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Quality beef production from pure and crossbred dairy calves

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INTRODUCTION

The EU27 has a total cow population of 34 m (MLC, 2007) of which 65% are dairy cows, indicating that around 60% of the total slaughter of prime beef animals originates from the dairy herd. Therefore, beef from the dairy herd constitutes a major proportion of the total output of prime beef from the cattle sector. In addition to evaluating the quality of beef sourced from dairy genotypes, this paper also compares beef production from dairy calves with beef originating from beef suckler calves in terms of:

1. Biological efficiency of the total beef system assessed as nutrient inputs required per kg carcass beef and saleable meat produced
2. Assessments of carcass and meat quality, and sensory characteristics of the meat
3. Potential environmental impact per kg carcass beef produced in relation to both water quality and the production of greenhouse gases (methane)

The comparisons presented in this paper are mainly taken from replicated studies carried out within research centres in both Northern Ireland and the Republic of Ireland.

1. Beef production systems in Ireland

The temperate maritime climate of Ireland is well suited to grassland farming. As a potential low cost renewable feed source of high nutritional value, grassland is a central feature of the ruminant livestock industry. Thus beef production systems are heavily reliant on grass either grazed in summer or conserved as silage for winter feed with moderate inputs of concentrate feeds. While the vast majority of dairy cows are of pure bred Holstein Friesian type, a wide range of beef sires, mainly late maturing European continental breeds, is used on a proportion of dairy cows within herds, giving a wide range of genotypes as finished beef. A limited niche market exists for crossbred steers sired by traditional early maturing beef breeds, e.g. Aberdeen Angus and Hereford sires.

The majority of dairy bred beef calves in Ireland are spring born (mainly January to March). This system of production is a typical grass-based system, with heavy dependence on both grazed grass and grass silage, with minimal inputs of concentrates. The typical age at slaughter is 22 to 26 months for steers and a slightly younger age of 18-22 months for heifers. Keane and Allen (2002) obtained a carcass weight of 324 kg with spring born pure bred Holstein Friesian steers, which had a mean live weight of 624 kg and a lifetime rate of liveweight gain of 0.74 kg/day, when slaughtered at 25.6 months of age. The inputs of concentrates are minimal until the finishing phase, when a higher level of concentrates is used, which increases the energy content of the diet to produce an adequate level of finish on the animals. The diets used by Keane and Allen (2002) and levels of performance in each stage are shown in Table 1. The final carcass weight of 324 kg was obtained with a lifetime concentrate intake of approximately 1 tonne, including the calf rearing stage. With autumn born calves the total quantity of concentrates can be reduced to under 0.5 tonnes per finished animal where the steers are finished off grass. Furthermore, considerable reductions in the total quantities of concentrates with both autumn and spring born animals can be achieved by improving the rate of liveweight gain from grazed grass, e.g. young stock as leaders in leader/follower systems with yearling stock following, and using grass silage of higher feeding value during the winter feeding periods (Steen, 2000).

Table 1 Steer production under grass-based systems (Keane and Allen, 2002)

Age (months)[1]	Live weight (kg)	Liveweight gain (kg/day)	Stage	Diet
Birth	48			
		0.61	Housed	Milk replacer, concentrates and silage
2.5	92			
		0.68	Grazing	Grass plus average 0.37 kg concentrates/day
8.6	219			
		0.59	Housed	Grass silage plus 1.0 kg concentrates/day
13.6	307			
		0.74	Grazing	Grass alone
20.2	458			
		1.03	Housed	Grass silage plus 4.5 kg concentrates/day
25.6	624			

Output – 324 kg carcass; concentrate input – approx. 1 tonne per finished animal
[1] Assumes 30.4 days/month

A primary feature of this system is the high stocking rate achieved in the early part of the grazing season (Table 2), reaching a peak of 3000 kg live weight/ha in early June, with high individual animal gains and sufficient ungrazed area to be conserved as silage for winter feed (O'Riordan, 2000). The use of late maturing continental beef cross steers, e.g. Charolais X Holstein Friesian will increase the rate of liveweight gain in the calf to finishing system by approximately 10% to give final carcass weights of around 360 kg (O'Riordan, 2000).

Table 2 Stocking rates for dairy calf to beef systems (O'Riordan, 2000)

	Month							
	April	May	June	July	August	September	October	November
Area grazed (%)	40	40	40	60	60	100	100	100
Live weight (kg/ha)	1700	2400	3000	2200	2300	1550	1650	1700

For a system mainly comprising pure Holstein Friesian steers but with some continental X Holstein Friesians, O'Riordan (2000) has set targets as follows:

Stocking rate 0.45 ha/animal unit (yearling plus calf)
Herbage production approximately 10 t DM/ha
Concentrate input of 2.2 t/ha, i.e. 1 t/finished steer

Output of 2.2 finished steers/ha, i.e. 750 kg carcass/ha with suggestion that carcass output can be increased by improved management and the exclusive use of continental cross steers.

In the dairy calf to beef steer system, with spring born calves and slaughter age of 24 months, the animals have a housed finishing period of 4 to 6 months based on a diet of grass silage typically supplemented with, e.g. 5 to 6 kg/day of concentrates on a flat rate basis from housing to slaughter. Keane (1998) examined the effect of flat rate feeding of 5 to 6 kg of concentrates versus offering the same total quantity of concentrates over the finishing period as a regime of only grass silage for the first half of the finishing period with concentrates offered *ad libitum* for the second half. The pattern of concentrate feeding had no effect on the rate of live weight or carcass gain or carcass quality, which offers flexibility in the choice of pattern of concentrate feeding in the finishing phase.

Very few bull calves are finished as entire males in Ireland and the production of intensive cereal beef is minimal. However, Steen (1994) compared semi intensive systems of bull beef production involving continuous housing or pasture grazing from 5 to 10 months of age in a set stocking system, with examination of the effects of herbage allowance and concentrate supplementation on lifetime performance and carcass quality of dairy calves (mixture of British Friesian and continental beef breed X Friesian calves). From 10 months of age until slaughter all animals were given access to grass silage *ad libitum* supplemented with 3.5 kg concentrates per head daily. The finished animals had a mean age, live weight and carcass weight at slaughter of 17 months, 604 kg and 338 kg respectively. Reducing sward surface height from 11.0 to 9.3 cm did not affect performance during the grazing period, but further reductions to 7.9 and 6.7 cm reduced liveweight gain by 0.13 and 0.32 kg/day respectively. Concentrate supplementation did not enhance the performance of animals grazing swards which were 7.9 cm or taller. Continuous housing did not increase lifetime carcass gain or carcass composition over that obtained with a grazing period from 5 to 10 months of age where the set stocking sward height was at least 9 cm (measured using HFRO sward stick) with no concentrate supplementation during grazing. The results from this study clearly demonstrate the potential of grazed grass, without concentrate supplementation, to produce high rates of gain in young bulls of high growth potential.

2. Biological efficiency comparisons

Biological efficiency and economic efficiency are generally closely correlated and focus on the issue of nutrient cost per unit of beef output. Comparisons can be made at several levels, e.g. dairy versus suckler beef, between pure dairy breeds and between beef breed X dairy breed crosses.

(a) Dairy versus suckler beef

In a dairy system there are two main outputs from the cow, namely milk and calves. As the primary purpose of keeping dairy cows is to produce milk for selling, it can be assumed that although parturition is a prerequisite for the initiation of lactation and the production of replacement heifers, the male calves are a by-product of commercial milk production, therefore all the energetic costs of maintenance of the cow can be attributed to the milk production process. Energetic calculations were carried out using the ME system (AFRC, 1993) to estimate the gestation (products of conception) energy cost, in terms of feed ME input, of producing a 48 kg male Holstein Friesian calf excluding any contribution to the maintenance energy cost of maintaining the cow. To this value was added the energetic cost of taking a Holstein Friesian early spring born steer from birth to slaughter at 25 months of age and 324 kg carcass weight in a predominantly grass-based system as estimated from the production data of Keane and Allen (2002). The estimated ME cost/kg carcass weight produced from the dairy beef system was 146 MJ/kg (Table 3) (Patterson, Dawson and Yan, unpublished data).

A similar calculation was carried out for a spring born continental beef (Limousin) sired suckler steer from a Hereford X Friesian beef cow, with a slaughter age of 24 months and a carcass weight of 394 kg based on the production data provided by Drennan and Fallon (1998). A calving interval of approximately 400 days can be estimated from data collected by Keady *et al.* (2004) based on 3200 cows in commercial suckler herds. The calculation therefore included the full maintenance cost of the suckler cow for 400 days, in addition to the requirement to cover the products of conception and the lifetime energy requirements of the steer animal. The estimated ME cost/kg carcass weight produced from the suckler beef system was 200 MJ/kg (Table 3) which is 54 MJ/kg (37%) higher than for the dairy beef system. The saleable boned-out meat yields from the dairy and suckler beef carcasses were estimated from carcass conformation grade and fat class, using the MLC (1994) saleable meat yield grid. Estimated meat yields were 695 and 701 g/kg carcass for dairy and suckler cow progeny respectively, indicating a proportionately 36% higher ME requirement/kg saleable beef for the suckler beef animals (Table 3).

Table 3 Estimated feed ME requirement[1] per finished steer from dairy or beef cow origin (Patterson, Yan and Dawson, unpublished data)

	Dairy herd steer[2]	Beef herd steer[3]
Steer performance		
Birth weight (kg)	48.0	46.0
Age at slaughter (months)	25.6	24.0
Live weight at slaughter (kg)	624	719
Carcass weight (kg)	324	394
Saleable meat yield (kg)	225	276
ME requirement		
Dam maintenance for 400 days (GJ)	-	20.4
Pregnancy (GJ)	2.6	2.5
Steer lifetime (GJ)	44.6	55.7
Total ME requirement (GJ)	47.2	78.6
ME requirement/carcass weight (MJ/kg)	(100) 146	(137) 200
ME requirement/saleable meat (MJ/kg)[4]	(100) 210	(136) 285

[1] AFRC (1993)
[2] Keane and Allen (2002)
[3] Drennan and Fallon (1998)
[4] Saleable meat yield estimated from carcass fat class and conformation grade using MLC saleable meat grid (MLC, 1994)

Alternatively, it can be considered that the energy costs of the newborn male calf in the dairy cow and beef cow systems were 2.6 and 22.9 GJ respectively, representing an 8.8 fold increase for the suckler calf. While it is recognised that as suckler cows operate at a much lower level of output than dairy cows, they can subsist on marginal and inaccessible land with poorer quality herbage, many suckler cows are kept on good quality lowland grassland, and a holistic model scenario could be envisaged in which the current national milk pool and beef output could be produced by reducing the number of beef cows and using an increased number of dairy cows of dual purpose type with lower milk yields. An appropriate dual purpose type of cow would require lower levels of nutrient inputs, would have improved biological fitness and could potentially reduce the environmental footprint by being less intensive with no increase in the total number of cows required to produce current national levels of milk and beef output from the same area of land.

(b) Pure dairy breeds

A number of pure dairy breeds and breed strains have been compared with the Holstein Friesian breed for milk production under Irish conditions, and the beef producing potential of the steer progeny has been assessed. Dillon *et al*. (2001) compared the performance of Dutch Holstein Friesian with Irish Holstein Friesian, Montbelliarde and Normande steers. While live weight at slaughter was similar for all the genotypes, mean carcass weight was 319 kg at 799 days but the Normande steers had a 7% higher carcass weight ($P<0.01$) than the other genotypes. However, Keane (2006) obtained higher carcass weights for Montbelliarde bulls than for Holstein Friesian young bulls with carcass weights of 280 and 258 kg respectively. McGee *et al*. (2005) found that Holstein Friesian steers of high genetic merit for milk production grew somewhat faster than Holstein Friesian steers of low genetic merit, but had lower kill-out ratio, therefore carcass weights were similar. A comparison of New Zealand Holstein Friesian with European Holstein Friesian steers by Keane (2003) showed that the New Zealand animals had a lower lifetime rate of carcass gain (9% lower), which indicates the lower body size of the New Zealand Holstein genotype.

The beef producing potential of young bulls of the Norwegian Red and Holstein Friesian breeds was compared by Kirkland *et al*. (2005a). Kill-out ratio was 1.8% higher with the Norwegian Red bulls, and while breed had no effect on the rate of carcass gain, the conversion of food to carcass gain was 9.4% more efficient with the Norwegian animals. In contrast, Keane (2006) tended to find a higher rate of carcass gain ($P=0.10$) in Norwegian bulls.

In an attempt to improve the efficiency of producing young bull beef carcasses from Holstein Friesian calves to meet a demand for young carcasses for processing, Kirkland *et al*. (2006) slaughtered young Holstein Friesian bulls, reared on all concentrate diets with minimal roughage, at a series of live weights ranging from 550 to 300 kg (carcass weights 294 to 155 kg). Feed conversion ratio improved in a linear manner with the reduction in slaughter weight so that each 100 kg decrease in live weight at slaughter reduced the concentrate requirement per unit of carcass gain by 1.2 kg DM/kg.

$$\text{FCR (kg concentrate DM/kg carcass gain)} = 2.81 + 0.0121 \text{ final live weight (kg)}$$

($R^2 = 0.65$, se 1.358, $P<0.001$).

(Kirkland *et al*., 2006)

(c) Beef X dairy breed crosses

Data from the Teagasc Grange Research Centre (Keane, 2002) were used to compile a ranking for some common production traits of straight-bred Holstein Friesian (HF) and crosses of HF with the common beef breeds. The animals were reared as steers to around two years of age and relative growth and slaughter data for HF and beef X HF steers are summarised in Table 4. Feed intake, scaled to mean body weight was lower for all beef crosses than for pure HF steers. All beef crosses had higher kill-out proportions than HF, while amongst the beef crosses LM, PM, BL and BB had the highest kill-out values. Carcass weight per day of age was higher for all beef crosses (except PM which was the same) than for HF. Carcass weight per day of age was similar for HR, LM and RO and higher for BL, SM, BB and CH. In summary, BB and CH produced about 10% more carcass weight for age than HF and PM, 6% more than HR, LM and RO and 2% more than BL and SM. Compared with HF, nearly all beef crosses had greater daily muscle growth and all had greater muscle size as measured by *m. longissimus* area scaled for carcass weight (Table 5), while differences between HF and the early maturing breed types were small. Differences between HF and the late maturing breed types were quite large for both muscle growth and muscle area.

Considering the higher values for both carcass gain and muscle growth, in combination with the lower feed intake values indexed to live weight for all the beef breed crosses in comparison with pure Holstein Friesian (Table 4), indicates superior efficiency of feed conversion to both carcass weight and muscle for all the beef crosses compared to the pure Holstein Friesian.

Keane (2002) presented data on calving traits for Holstein Friesian dairy cows in Ireland, which were mated to a range of beef breeds (Table 6). Mean breed calving difficulty score ranged from 1.9% for Hereford to 6.3% for Blonde d'Aquitaine, but it is accepted that the value for Blonde d'Aquitaine appears to be high in comparison with other surveys. However, within each breed there was wide variation (e.g. 0 to 6.1% for the Hereford and 1.0 to 17.8% for Blonde d'Aquitaine.

There was little relationship between the incidence of calving difficulty and calf mortality, which varied little between the breeds. If a gestation length of 283 days is accepted for the Holstein Friesian cow in a non-crossing situation (Keane, 2002), crossing dairy cows with Angus, Hereford or Belgian Blue bulls would not extend gestation length compared to Holstein Friesian, but crossing with the other late maturing beef breeds would extend mean gestation length by up to 5 days.

Table 4 Ranking (HF = 100) of Holstein Friesian (HF) and beef X HF steers for production traits

Sire breed	HF[1]	HR	LM	PM	RO	BL	SM	BB	CH
Slaughter weight/day (g)	803	101	98	95	101	102	106	104	107
Kill-out (g/kg)	527	102	105	105	104	105	104	105	104
Carcass weight/day (g)	425	103	103	100	104	107	109	109	111
Carcass conformation[2]	2.19	133	136	139	139	132	136	138	143
Carcass fat class[3]	3.52	125	103	86	97	91	103	95	90
Feed intake (g/kg LW)	18.2	98	96	94	92	96	98	97	97

[1] Approximate actual values are given for HF and values for the other breed types are expressed relative to the HF value = 100
[2] Scale: 1 = P to 5 = E, [3] Scale: 1 (leanest) to 5 (fattest)
HR = Hereford; LM = Limousin; PM = Piemontese; RO = Romagnola; BL = Blonde d'Aquitaine; SM = Simmental; BB = Belgian Blue; CH = Charolais; LW = Live weight
Source: Keane (2002)

Table 5 Ranking of breeds (HF = 100) for muscle growth and *m. longissimus* area

Sire breed	HF[1]	HR	LM	PM	RO	BL	SM	BB	CH
Muscle growth (g/day)	256	102	109	113	115	116	116	119	117
M. longissimus area[2]	22.3	103	117	118	117	110	108	112	114
Muscle:bone ratio	3.22	105	117	115	114	115	109	117	116
High value muscle (g/kg muscle)	446	100	102	103	103	101	102	102	102

[1] Approximate actual for HF, values for other breeds expressed relative to HF = 100
[2] cm^2/100 kg carcass
Source: Keane (2002)

Table 6 Calving traits for beef bulls mated to Holstein Friesian cows (Keane, 2002)

		Bull breed						
		AA	BL	BB	CH	HF	LM	SM
Calving difficulty (%)	Mean	2.7	6.3	3.7	4.7	1.9	4.2	3.6
	Range	0.3-8.5	1.0-17.8	1.3-5.2	1.2-19.6	0.0-6.1	0.2-18.8	1.0-9.8
Calf mortality (%)	Mean	1.5	1.5	2.6	2.0	1.5	2.3	1.9
	Range	0.0-4.2	0.4-2.9	0.8-4.1	0.3-4.2	0.2-3.3	0.6-8.6	0.1-3.9
Gestation length (days)	Mean	281	288	283	286	283	286	285
	Range	280-282	286-289	281-284	283-287	282-284	284-290	283-288
No.		19	5	10	32	94	29	40

Breed codes as in Tables 4 and 5

3. Assessment of carcass quality

Holstein Friesian breed

Comparisons of carcass characteristics within the Holstein Friesian breed showed that finished beef animals with higher genetic merit for milk production had poorer carcass conformation (McGee *et al*., 2005; Dillon *et al*., 2001) and lower carcass fatness in the study reported by McGee *et al*. (2005). McGee *et al.* (2005) also found that the total fat proportion was lower and the proportion of muscle was higher in the pistola of higher merit animals. In a comparison of New Zealand Holstein Friesian and European Holstein Friesian animals, finished as both bulls and steers under Irish conditions, Keane (2003) found equal fat score, conformation score and eye muscle area, but the New Zealand genotype had a higher weight of perinephric plus retroperitoneal fat. Despite equality of conformation score between the two strains of Holstein cattle, significantly higher carcass compactness measurements (carcass weight per unit of carcass length and depth) were obtained with the New Zealand Holstein Friesian animals. As the New Zealand animals had 18 kg lower carcass weight, despite being 22 days older at slaughter, it was estimated that the European genotype produced approximately 10% more muscle than the New Zealand genotype. However, the proportion of bone in the carcass was significantly higher with the European animals resulting in a lower soft tissue to bone ratio in the carcass, therefore the New Zealand animals had a higher ratio of boned-out beef in the carcass.

When Kirkland *et al*. (2006) examined the effects of reducing the live weight at slaughter of young intensively fed Holstein Friesian bulls by 50 kg increments from 550 to 300 kg, carcass conformation grade and fat classification were reduced by 0.6 and 1.0 units respectively. While reduction in slaughter weight reduced the killing-out proportion from 526 to 509 g/kg the proportion of boned out red meat in the carcass (Kirkland *et al*., 2005b) was unaffected by slaughter weight (mean yield of boned out red meat, 707 g/kg carcass) (Table 7). Interestingly, lower slaughter weight increased both the proportion of hind quarter in the carcass and the proportion of high priced boned out joints. While lower slaughter weight reduced the proportion of manufacturing grade beef in the carcass, increasing slaughter live weight from 500 to 550 kg produced a major increase in the proportion of joints (increase of 28%) attaining supermarket grade specification, which considerably increases the financial value of the carcass.

Comparisons of pure dairy breeds

A number of pure bred alternatives to the Holstein Friesian breed have been assessed for milk production and beef output under Irish conditions. Dillon *et al*. (2001) reported carcass data for pure bred Montbelliarde and Normande steers versus Dutch Holstein genotype steers. Both Montbelliarde and Normande steers had higher conformation grade (0.8 and 0.7 units higher respectively), similar carcass fatness grade, but lower weight of perirenal plus retroperitoneal fat than Holstein Friesian steers. Similarly, Keane (2006) found similar carcass fatness grade and a tendency to improved conformation in Montbelliarde versus Holstein Friesian bulls.

A number of comparisons have been made of the carcass characteristics of pure Norwegian Red bulls and Holstein Friesian bulls. Both Kirkland *et al*. (2005a) and Keane (2006) found similar carcass fat class with the Norwegian Red animals. While Kirkland *et al*. (2005a) obtained a higher carcass conformation score (0.6 unit increase) with the Norwegian Red bulls, Keane (2006) observed no significant difference in conformation grade despite a significant increase in carcass compactness of the Norwegian Red carcasses (carcass compactness assessed as length and depth scaled for carcass weight). This assessment of carcass compactness by Keane (2006) demonstrates the poor carcass compactness of Holstein Friesian beef carcasses compared with other breeds and crosses and the poor agreement between carcass conformation score and compactness.

Beef X dairy crosses
The Grange comparison (Keane, 2002) of beef characteristics of beef breed X Holstein Friesian steers (Table 4) showed that all beef crosses were very superior to Holstein Friesian in carcass conformation (approximately one class) with relatively small differences between the various beef crosses. Large differences were obtained between the breeds in fat score ranking. Fat scores were broadly similar for HF, LM, RO and SM; HR had a much higher value and BL, BB, CH and particularly PM, had lower values. The fat scores indicate that, at approximately the same age, HR were considerably fatter, and BL, BB, CH and PM were considerably leaner than the others.

Compared with HF, all beef crosses had greater muscle size as indicated by *m. longissimus* area scaled for carcass weight (Table 5). The difference between HF and HR, which is an early maturing breed, was small, while differences between HF and the late maturing breeds were quite large. Muscle to bone ratio, which is correlated with conformation score, is positively related to the ratio of boned-out saleable beef in the carcass, and was greater for all beef crosses, being lower for the HR cross than for the other crosses. While differences in the proportion of high value muscle/total muscle were small, the late maturing beef crosses had a higher proportion of high value muscle.

4. Assessment of meat quality

Holstein Friesian breed
Kirkland (2005c) examined the effect of live weight at slaughter (300 to 550 kg) of young intensively fed Holstein Friesian bulls, on instrumental measurements of meat quality of samples of *longissimus dorsi* muscle (Table 8). The results indicate that redness of meat increased and cooking loss decreased with increasing slaughter weight, while all bulls, regardless of weight, produced sirloins which were acceptably tender. Furthermore, Holstein Friesian bulls produced beef with similar meat quality to steers slaughtered at the same live weight. Moss *et al*. (2005) carried out sensory evaluations of sirloin meat from the treatment groups of young Holstein Friesian bulls described by Kirkland *et al*. (2006). The sensory evaluation (Table 9) indicated that the eating quality of sirloin was similar across the range of slaughter weights and that bulls produced beef of similar meat quality to that of steers slaughtered at the same live weight. It is of note that the juiciness of the meat from these bulls did not increase linearly with increase in slaughter weight despite the presence of a highly significant linear increase ($P<0.001$) in marbling score with increase in live weight in these animals (Kirkland *et al*., 2006).

Table 7 The effect of weight at slaughter and sexual status on boning out characteristics of Holstein bulls and steers

Slaughter wt (kg)	Bulls 300	350	400	450	500	550	Steers 450	SED	Significance Linear	Asymp	Bulls v Steers[1]
Carcass weight (kg)	150.4	175.0	205.2	231.8	260.1	292.0	228.8	2.91	***	NS	NS
Red meat (kg)	105.2	122.1	146.0	163.8	185.1	207.4	160.5	2.53	***	NS	NS
High price joints (g/kg carcass)	280.3	281.2	282.0	273.1	262.8	268.8	264.8	6.03	***	NS	NS
Percentage carcass as:											
Hind quarter	52.3	52.3	51.8	50.9	50.5	50.9	51.0	0.57	***	NS	NS
Fore quarter	47.7	47.7	48.2	49.1	49.5	49.1	49.0	0.57	***	NS	NS
Red meat	70.0	69.8	71.2	70.7	71.2	71.0	70.2	0.81	NS	NS	NS
Red meat grade (%)											
Supermarket	0.0	0.0	0.0	0.0	5.7	34.0	2.8	3.29		***	NS
Commercial	46.9	46.9	48.5	47.1	39.2	11.7	42.4	3.49		***	NS
Manufacturing	52.5	52.3	52.6	53.9	55.1	54.3	54.8	0.94	**	NS	NS

[1] Both slaughtered at 450 kg live weight
Source: Kirkland *et al* (2005b)

Table 8 The effect of weight at slaughter and sexual status on meat quality of *longissimus dorsi* of Holstein Friesian bulls and steers (Kirkland *et al.,* 2005c)

Slaughter wt (kg)	Bulls 300	350	400	450	500	550	Steers 450	SED	Significance Linear	Asymp	Bulls v Steers[1]
Colour											
L* (lightness)	37.9	39.3	38.8	38.5	36.8	38.0	39.2	1.84	NS	NS	NS
a* (redness)	16.2	16.4	15.9	17.4	17.9	18.0	19.6	1.13	**	NS	NS
b* (yellowness)	11.9	12.1	11.6	12.0	13.0	11.9	13.6	0.80	NS	NS	NS
Ultimate pH	5.62	5.57	5.65	5.67	5.69	5.57	5.56	0.054	NS	NS	NS
Cooking loss (%)	27.9	26.4	27.4	25.7	25.0	25.7	24.3	1.31	**	NS	NS
7-day WBSF (kg/cm[2])	2.45	2.48	2.71	2.56	2.47	2.31	2.32	0.182	NS	NS	NS

[1] Both slaughtered at 450 kg live weight
[2] Warner Bratzler Shear Force

Table 9 The effect of slaughter weight and sexual status on sensory characteristics of sirloin from Holstein Friesian bulls and steers (Moss *et al.,* 2005)

	Bulls						Steers	SED	Significance		Bulls v
Slaughter wt (kg)	300	350	400	450	500	550	450		Linear	Asymp	Steers[1]
Acceptability[2]											
Aroma	71.5	69.9	68.7	68.5	70.9	70.5	71.5	0.98	NS	*	*
Flavour	68.7	65.5	65.4	64.5	69.7	64.4	69.8	1.17	NS	NS	*
Texture	69.1	66.4	66.2	65.3	69.3	61.3	67.4	1.81	NS	***	NS
Overall	69.5	67.4	66.4	65.5	71.2	64.1	69.9	1.29	NS	NS	*
Intensity[3]											
Aroma	52.1	53.0	50.4	51.3	54.8	54.1	51.8	1.68	NS	NS	NS
Flavour	51.8	53.2	50.6	50.2	53.4	50.4	54.1	1.52	NS	NS	NS
Tenderness	61.9	60.7	60.7	62.9	67.7	51.2	61.7	2.64	NS	*	NS
Juiciness	51.8	54.7	54.6	56.5	62.5	50.4	58.2	2.45	NS	NS	NS
Satisfaction[4]	2.5	2.4	2.4	2.4	2.6	2.2	2.6	0.06	NS	NS	NS

[1] Both slaughtered at 450 kg live weight
[2] 0 = unacceptable; 100 = extremely acceptable
[3] 0 = low intensity; 100 = extremely intense
[4] 4 point category scale where 1 = unsatisfactory, 2 = everyday quality, 3 = better than everyday quality and 4 = premium quality

Keane *et al*. (2001) compared the eating quality of cooked steaks from finished Holstein Friesian animals of high and lower genetic merit for milk production. There was no significant difference between the two dairy strains for lipid content of muscle or any taste panel trait (Table 10), thus indicating no effect of strain of Holstein Friesian on eating quality of the meat. It is of interest to note that in comparison with the lower merit strain of Holstein Friesian, the higher merit strain had similar level of lipid in muscle despite having significantly lower EU carcass fat score.

Table 10 Effect of breed on carcass fatness measurements and taste panel traits of steaks (Keane *et al*., 2001)

	Breed				
	Holstein Friesian high merit	Holstein Friesian lower merit	Charolais x Holstein Friesian	s.e.d.	Significance
Carcass wt (kg)	327[a]	321[a]	353[b]	6.1	***
Fat score[1]	3.4[a]	4.3[b]	4.1[b]	0.12	***
Lipid in muscle (g/kg)[2]	51[a]	56[a]	37[b]	5.4	**
Tenderness	4.6	4.7	3.7	0.39	
Moistness	4.9	4.5	4.2	0.34	
Flavour	3.9	3.7	3.5	0.22	
Texture	3.5[a]	3.7[a]	3.2[b]	0.14	*
Chewiness	3.4[a]	3.7[a]	3.1[b]	0.17	**
Overall acceptability	3.4	3.4	3.0	0.23	

[1] EU Beef Carcass Classification Scheme: Scale 1 (leanest) to 5 (fattest)
[2] Mean of 7 muscles

A comparison of the muscle and adipose colour of male progeny of Irish and New Zealand strains of Holstein Friesian (Dunne *et al*., 2004) showed that adipose tissue from the New Zealand genotype was more yellow, but there was no difference in colour of muscle.

Lively *et al*. (2005a) compared the eating quality of sirloin muscle from Holstein Friesian steers with muscle from ¾ bred Charolais suckler steers (Table 11). Both genotypes were finished on similar diets. It was concluded that the Charolais genotype of suckler origin produced leaner, heavier and better conformed carcasses relative to the Holstein regardless of slaughter weight (Lively *et al*., 2005b), but beef from the Holstein Friesian steers was more tender and had a lower cooking loss percentage than the Charolais suckler beef. It was considered that high marbling score was a major contributor to the lower mean shear force value observed for the Holstein Friesian meat, with marbling score values (scale 1 to 8) of 3.16 and 1.22 for the Holstein Friesian and Charolais steers respectively. Holstein Friesian animals typically have higher marbling score than finished animals of suckler herd origin, in situations where the terminal sire is of late maturing continental type, e.g. Lively *et al*. (2006) obtained marbling scores of 3.04 and 2.03 ($P<0.001$) for these respective genotypes across a total of 524 animals.

Table 11 Effect of genotype on meat quality of Charolais and Holstein steers (Lively *et al*., 2005a)

	Breed[1]			
	CH	HOL	sem	Significance
Marbling score[2]	1.6	2.9	0.11	***
L* (lightness)	36.3	34.9	1.34	NS
a* (redness)	15.6	18.3	0.53	NS
b* (yellowness)	12.3	14.7	0.50	NS
Ultimate pH	5.61	5.59	0.013	NS
Cooking loss (%)	32.8	27.9	0.32	***
WBSF (kg/cm^2)	3.7	2.6	0.11	***
Sarcomere length (μm)	2.4	2.5	0.08	NS

[1] CH = Charolais; HOL = Holstein
[2] 8 point scale; 1 = low marbling, 8 = high marbling
NS = not statistically significant (P>0.05); *** = P<0.001
WBSF = Warner Bratzler Shear Force

Comparisons of pure dairy breeds

Kirkland *et al*. (2007) compared the meat quality characteristics of Holstein Friesian bulls versus pure bred Norwegian Red bulls (Table 12). Breed affected lightness (L*) but had no effect on redness (a*) or yellowness (b*) of the *longissimus dorsi* muscle. *Longissimus dorsi* muscle from the Holstein Friesian bulls tended to have higher marbling score and significantly lower (P<0.001) shear force (WBSF) measurements in cooked muscle than Norwegian Red bulls, indicating superior tenderness and juiciness for Holstein Friesian cooked steaks. In contrast, Lively *et al*. (2004) found no difference in shear force measurements of cooked meat from pure bred Holstein Friesian and Norwegian Red steers.

Table 12 The effect of breed on carcass characteristics and meat quality (Kirkland *et al*., 2007)

	Breed[1]			
	HF	NOR	s.e.d.	Significance
Carcass parameters				
Subcutaneous fat (mm)	3.7	3.1	0.32	NS
Marbling score[2]	2.6	2.2	0.18	P=0.06
Eye muscle area (cm^2)	58.9	58.3	2.24	NS
Meat quality				
Meat colour				
L* (lightness)	34.5	37.3	1.15	*
a* (redness)	18.5	19.2	0.91	NS
b* (yellowness)	12.4	13.3	0.84	NS
Ultimate pH	6.04	5.80	0.108	*
Cooking loss (%)	21.0	22.9	1.46	NS
7-day WBSF (kg/cm^2)	2.40	3.03	0.175	***

[1] HF = Holstein Friesian, NOR = Norwegian dairy breed
[2] 8 point scale: 1 = low marbling, 8 = high marbling

Crossbred genotypes
Keane *et al*. (2001) compared the meat quality of Charolais X Holstein and two strains of Holstein Friesian steers and bulls (Table 10). The crossbred steers tended to have poorer values for tenderness, moistness, flavour and overall acceptability, with significantly lower values for texture and chewiness which indicates that the crossbred meat was generally less desirable than the pure bred Holstein Friesian meat.

However, Monsón *et al*. (2004) found meat from pure bred Limousin bulls had lower shear force values than meat from pure bred Holstein Friesians, while meat from Brown Swiss and Blonde d'Aquitaine bulls had intermediate values, despite significantly higher tissue fat content in the rib joint of the Holstein Friesian animals.

Reciprocal crossbreeding of Holstein Friesian with Norwegian Red (Lively *et al.*, 2004) produced meat with similar shear force values, with values tending to be lower than those obtained with either pure bred genotype at 21-day ageing, but not at 7-day ageing.

The eating quality of beef from a range of sire breeds on Holstein cows was assessed by Homer *et al*. (1997). The sire breeds comprised Aberdeen Angus and Hereford (early maturing British breeds) and Charolais, Limousin, Belgian Blue and Piedmontese (late maturing continental breeds). Pure bred Holstein Friesians were not included. Despite major differences in carcass fatness, there were few differences in quality traits (Table 13). Muscle colour was lighter for Belgian Blue than Aberdeen Angus, and Belgian Blue had more tender joint meat, while the difference in tenderness for steaks tended towards significance. However, in a direct comparison of Belgian Blue X Holstein Friesian versus Holstein Friesian, Dunne *et al*. (2004) found lighter muscle colour with the Belgian Blue X Friesian genotype.

Table 13 Meat quality effects of beef breed cross on Holstein Friesian[1] cows (Homer *et al*., 1997)

	Sire breed[2]						
	HR	AA	PM	LM	BB	CH	s.e.
pH (24 hours post slaughter)	5.78	5.84	5.78	5.77	5.72	5.75	0.04
Colour (EEL value)[3]	23.1[ab]	21.6[b]	23.3[ab]	23.8[ab]	24.6[a]	23.5[ab]	0.72
Fat depth (mm)	7.91[ab]	9.04[a]	5.15[c]	5.56[c]	4.88[c]	6.35[bc]	0.46
Drip loss (g/kg)	12.7	11.8	14.4	14.4	14.6	14.3	1.4
Juiciness[4]	4.4	4.5	4.5	4.3	4.2	4.4	0.12
Tenderness[4]	3.9[a]	3.8[a]	3.8[a]	3.8[a]	4.5[b]	4.0[a]	0.08
Flavour[3]	4.6	4.8	4.7	4.6	4.7	4.7	0.08

[1] Means for steers and heifers
[2] HR, Hereford; AA, Aberdeen Angus; PM, Piedmontese; LM, Limousin; BB, Belgian Blue; CH, Charolais
[3] Higher values indicate lighter colour
[4] Scale: 1 = low to 8 = high
Values with different superscripts differ significantly

5. Potential environmental impact of dairy beef production

Manure N outputs from animal production systems and methane outputs from ruminant digestive processes have environmental implications for water quality and the production of greenhouse gases respectively. Manure N outputs and methane outputs were predicted using a manure N output predictive model for beef cattle (Yan *et al*., 2007) and a methane predictive model for beef cattle (McCourt *et al*., 2005) respectively, for a finished dairy steer and a finished beef steer of suckler herd origin. The predicted values presented in Table 12 are derived from dairy and suckler beef steer data published by Keane and Allen (2002) and Drennan and Fallon (1998) respectively. Additional assumptions included the quality and nitrogen content of the diet required to meet the twelve-month maintenance energy and N requirement of the suckler cow, and N and ME contents of some of the diets were assumed based on typical analytical values for grazed grass and grass silage in Ireland. The manure N and methane output data presented in Table 14 clearly illustrate the potential of dairy beef to reduce the environmental impact of beef production with reductions in manure N output and methane output per kg of carcass weight of 39 and 41% respectively, and the slightly higher predicted proportional yield of saleable meat from the carcasses of the suckler bred steers (MLC, 1994) only marginally reduced the differentials to 38 and 40% respectively.

Table 14 Estimated manure N outputs and outputs of methane per finished steer from a dairy beef system versus a suckler beef system[1] (Yan, Dawson and Patterson, unpublished data)

	Dairy herd steer[2]		Beef herd steer[3]	
Carcass weight of finished steer (kg)	324		394	
Estimated saleable meat (kg)[4]	225		276	
Manure N output (kg)[5]	76		128	
Manure N output/carcass weight (g/kg)		(100) 235		(139) 326
Manure N output/saleable meat (g/kg)		(100) 338		(138) 465
Methane output (,000 l)	158		271	
Methane output/carcass weight (l/kg)		(100) 488		(141) 687
Methane output/saleable meat (l/kg)		(100) 702		(140) 980

[1] Covers birth to slaughter, and the demands of the products of conception for both the dairy and suckler steers, plus 12-month maintenance cost for the suckler dam, but assumed no dam maintenance cost for the dairy steer
[2] Keane and Allen (2002)
[3] Drennan and Fallon (1998)
[4] Predicted from MLC (1994)
[5] Total of faecal N plus urine N

6. Summary of merits of producing beef from the dairy herd

A summary of the factors which contribute to the case for or against producing beef from animals of dairy herd origin, versus suckler herd origin is presented in Table 15. While the main negative factors have been well established, i.e. killing out proportion, carcass conformation, meat yield/carcass, they only comprise part of the total range of relevant factors. The positive factors; good eating quality, high biological efficiency of carcass production and reduced environmental footprint serve to drive a very strong case for producing a major proportion of EU beef supply from the dairy herd. Furthermore, crossing Holstein Friesian dairy cows with late maturing European continental beef sires further enhances the rate of lean tissue gain, whilst improving feed efficiency and increasing muscle depth on the carcass, thus giving higher meat yield per unit of carcass weight.

Table 15 Merits of dairy beef versus suckler beef

Factor	Merit
Visual appeal of live animal/carcass shape	- ve
Killing out proportion	- ve
Carcass conformation	- ve
Meat yield/carcass proportion	- ve
Smaller muscle size	± ve
Higher marbling in muscle	+ ve
Eating quality	+ ve
Biological efficiency	+ ve
Lower intensity dairying/improved biological fitness of dairy cows	+ ve
Reduced environmental footprint	
Water quality	+ ve
Methane emissions	+ ve

7. Future for dairy beef production

Current economic margins for beef production in the United Kingdom and Ireland are very low and are generally financially unsustainable. Whilst post decoupling suckler cow numbers appear to be largely maintained to date, modelling studies suggest a reduction in future suckler cow numbers across the EU as a result of low biological efficiency and poor economic returns. With dairy cows, while milk quotas remain in place, it is considered that cow numbers will decline by 2 to 3% per year due to increases in milk yield per cow, until the demise of the quota regime, probably 2012/2013. After the removal of the milk quota constraint, regions with potential for increased milk production, e.g. Republic of Ireland, are predicted to increase milk production and dairy cow numbers, if milk price remains stable or increases. It appears therefore that until abolition of the EU milk quota regime, the proportional availability of dairy beef versus suckler beef animals will remain similar to the present balance, with a likelihood of some increase in the proportional availability of dairy beef animals post quota. In a scenario where margins from beef production are likely to remain low, the potentially lower environmental footprint and higher biological efficiency of producing beef from the dairy herd, will favour the production of dairy beef.

Furthermore, with decoupling and the removal of age qualification for steers to obtain the second beef premium at 22 months of age, there may be a reduction in slaughter age for steers. It must also be noted that the future potential availability of low cost good quality sexed dairy and beef semen could have a major positive impact on the quantity and quality of prime beef produced per dairy cow, as it would promote the more widespread use of late maturing continental beef sires.

It is concluded that while dairy beef has poorer carcass conformation than beef produced from the suckler herd, the eating quality of Holstein Friesian dairy beef is not inferior, and indeed may be superior, to beef originating from the suckler herd, nor is it affected by the genetic merit of the Holstein Friesian cow for milk production, while scoring strongly in terms of good biological efficiency and reduced environmental footprint.

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