Research Article • DOI: 10.1515/ijafr-2017-0010 IJAFR • 56 • 2017 • 93-103

Irish Journal of Agricultural and Food Research

Animal performance and economic implications of alternative production systems for dairy bulls slaughtered at 15 months of age

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Abstract

The objectives of this experiment were to investigate (i) the influence of varying levels of concentrate supplementation during the grazing season, (ii) alternative finishing strategies for dairy bulls slaughtered at 15 mo of age and (iii) economic implications of these management strategies. Bulls were assigned to a 2 (level of concentrate supplementation during the grazing season: 1 kg [LA] and 2 kg [HA] dry matter [DM]/head daily) × 2 (finishing strategies: concentrates* ad libitum *group [AL] or grass silage* ad libitum *plus 5 kg DM of concentrates/head daily group [SC]) factorial arrangement of treatments. Average daily gain (ADG) during the grazing season was greater ($P < 0.01$) for HA than for LA. Consequently, HA bulls were 16 kg heavier at housing: 214 and 230 kg, respectively ($P < 0.05$). During the finishing period, ADG tended ($P = 0.09$) to be greater for LA than for HA. Carcass weight tended ($P = 0.08$) to be greater for HA than for LA. Fat score was greater for HA. Live weight at slaughter ($P < 0.001$) and carcass weight ($P < 0.001$) were 41 and 23 kg greater for AL than for SC, respectively. Conformation ($P < 0.05$) and fat score ($P < 0.05$) were greater for AL than for SC. The Grange Dairy Beef Systems Model simulated whole-farm system effects of the production systems. Net margin/head was greater for LA than for HA and greater for SC than for AL. Sensitivity analysis of finishing concentrate price, calf purchase price and beef price showed no re-ranking of the systems on a net margin basis. Although greater animal performance was observed from the higher plane of nutrition, overall profitability was lower.

Keywords

carcass weight • dairy bulls • finishing strategies • pasture • profitability

Introduction

The abolition of European Union (EU) milk quota and the targeted 50% increase in milk production by 2020 (Department of Agriculture, Food and the Marine [DAFM], 2010) is expected to have a dramatic effect on Irish dairy production. This is likely to result in a greater proportion of male dairy calves becoming available for beef production (European Commission, 2015). Traditionally, pasture-based steer production systems have incorporated a winter finishing period, whereby animals were finished at 24 mo of age on a grass silage *ad libitum* diet plus concentrates (Keane and Allen, 1998; McGee *et al.*, 2005). In practice, dairy steers account for 55% of total steer slaughterings and are finished during their third season at grass at 26–30 mo of age (O'Riordan and Cormican, 2015). More recently, there has been a significant increase in the proportion of bulls slaughtered, increasing from 3% in 2002 to 13% in 2015 (Irish Food Board [Bord Bia], 2016a). Prior to decoupling of support premia in 2003, bull beef production was generally less profitable than well-managed steer beef production, largely due to the higher premium-earning capacity of steers (Swinbank and Daugbjerg, 2006). Since then, the biological advantage of bulls compared to steers (superior growth rate, feed efficiency, carcass muscle proportion and the subsequent reduction in age at slaughter; Steen, 1995) has been exploited by beef producers.

A further consideration is that current UK market specifications stipulate that dairy bulls be slaughtered at <16 mo of age, achieve a minimum carcass weight of 270 kg and have conformation and fat scores of 'O=' and '2+' or greater, respectively (Dawn Meats, 2011). Given the importance of the UK market for Irish beef exports (Bord Bia, 2016b), it is essential that production blueprints meet these requirements. A shift from a 24-mo steer system to a more concentrate-intensive 15-mo bull beef system would result in an alteration to the finishing strategy and sale date. Increased levels of concentrate input during the finishing period, typically a concentrates *ad libitum* diet, are necessary to reach an acceptable live weight at slaughter at a younger age (O'Riordan *et al.*, 2011). While these concentrate-intensive production systems appear attractive from an output perspective, feed costs can be considerable and, consequently, the profitability of such systems can be marginal, particularly when feed costs are high (Ashfield *et al.*, 2014a). An economic modelling study by Ashfield *et al.* (2014a) reported that dairy

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bulls finished on concentrates *ad libitum* and slaughtered at 15 mo of age comprised the least profitable dairy calf-to-beef system investigated. Since grazed grass is a considerably cheaper feed source than grass silage or concentrates (Finneran *et al.,* 2010), incorporating grazed grass into the feed budget with strategic concentrate supplementation is of interest.

Typically, under Irish conditions, calves are pasture-grazed during the first season, and moderate levels of performance are achieved (Campion *et al.,* 2009). However, there is a paucity of available literature that evaluates concentrate supplementation at pasture for dairy calves. When animals are slaughtered at a younger age, concentrates constitute a larger proportion of the feed budget (O'Riordan *et al.,* 2011). Dairy calves slaughtered at a younger age may require additional concentrate supplementation during their first season at pasture to enhance animal performance at pasture (Campion *et al.,* 2009). Differences in alternative finishing strategies, including duration and diet, have been well documented (Sami *et al*., 2004; McGee *et al*., 2005). Binder *et al*. (1986) investigated differences in finishing diets and reported that grain-fed steers had a greater kill-out proportion, more intramuscular fat, greater conformation score and a whiter fat colour than forage-fed steers. Similarly, Cerdeño *et al*. (2006) reported that bulls finished with restricted feeding on concentrates had a lower fat score but produced meat of similar quality compared to bulls finished on a concentrates *ad libitum* diet. Although those studies examined alternative finishing strategies for dairy and dairy beef crossbred cattle, the ages at slaughter in those studies were greater than current market restrictions for bulls.

Supplementation of concentrates during the first season at pasture and alternative finishing strategies may have the potential to increase farm profit by improving calf performance at pasture and reducing the reliance on concentrates during the finishing phase. Therefore, the objectives of this study were to evaluate the effects of varying levels of concentrate supplementation during the first season at pasture and alternative finishing strategies on dairy bulls slaughtered at 15 mo of age and to conduct an economic appraisal of these production systems.

Materials and methods

This study was carried out at the Teagasc Johnstown Castle Research Centre (52°17′N, 6°30′W) on a permanent grassland sward of predominantly perennial ryegrass (*Lolium perenne*). The soil type was a mix of fine loamy with imperfect and moderate draining gley soils (Gardiner and Radford, 1980). Eighty-four spring-born dairy bull calves (51 Holstein-Friesian [HF] and 33 Jersey × HF [JEX]) were purchased from commercial dairy farms and artificially reared on site. Mean date of birth was 11 February 2011, and age at arrival was 18 d (s.d.: 8.3 d). Calves were reared artificially and offered 30 kg of milk replacer similar to that described by Fallon (1992). At weaning, calves were assigned to one of four treatments in a 2 (levels of concentrate supplementation during the grazing season: 1 kg [LA] or 2 kg [HA] DM/head daily) × 2 (finishing strategies: concentrates *ad libitum* (AL or grass silage *ad libitum* plus 5 kg DM of concentrates/head daily [SC]) factorial arrangement of treatments. Calves were assigned to treatment on 20 May, blocked by weaning weight, breed, farm of origin and date of birth. Calves were generated from 34 sires: 23 HFs and 11 Jerseys. Sixty-nine calves were sired by artificial insemination using sires commonly available in Ireland; four calves were sired by stock bulls (sired one calf each) and 11 calves had unknown sires.

Animal management

Calves were randomly assigned to one of three grazing groups within each concentrate supplementation level and managed on a rotational grazing system during the grazing season, as described by O'Donovan *et al*. (2002). Sward quality was maintained by using strip fencing with excess pasture removed as baled silage. Target pre- and post-grazing sward heights were 10 cm and 4 cm, respectively. Concentrate supplementation was offered in a single feed each morning. Calves were treated with Ivomec 1% injection (Merial Limited, Duluth, GA, USA) at 4, 8 and 12 wk after turnout to control internal parasites during the grazing season. Calves were pasture-grazed for 153 (s.d.: 14.2) d and housed on 3 November on slatted floor accommodation.

At housing, bulls were accommodated in replicated pens (three pens/treatment) until slaughter. Both AL and SC were gradually adapted to their finishing diets over a 21-d period. Fresh concentrates were offered daily to the AL group, and refusals were weighed back five times weekly. Straw was offered on an *ad libitum* basis to the AL group to ensure normal rumen function. Bulls in the SC treatment group were offered a grass silage *ad libitum* diet plus 5 kg DM/d of concentrate-based total mixed ration. Bulls were slaughtered after a 205 (s.d.: 15.1)-d finishing period. Bulls were selected for slaughter on one of three slaughter dates based on the date of birth on their animal passport to ensure that bulls were <16 mo (460 d; s.d.: 7.1 d) of age. The concentrate ration offered throughout the experimental period consisted of 580 g/kg barley, 260 g/kg beet pulp, 100 g/kg soya bean meal, 40 g/kg molasses and 20 g/kg minerals.

Body weight was recorded fortnightly throughout the study, using a 'Weigh Crate' (O'Donovan's Engineering, Cork, Ireland) and the 'Winweigh' software package (Tru-test Limited, Auckland, New Zealand). Average daily gain (ADG) was calculated for each bull using linear regression of live weight against recording date. Bulls were weighed at housing and again 4 d later in an attempt to reduce the variation caused by gut-fill. On the morning of slaughter, bulls were transported a distance of 63 km for approximately 50 min to a commercial slaughter plant and weighed in the lairage approximately 1 h before slaughter using a portable 'Platform Weigher' (O'Donovan's Engineering) to determine kill-out proportions.

Carcass assessment

Hot carcass weight was determined on each carcass immediately before video imaging analysis (VIA), and cold carcass weight was subsequently calculated (hot carcass weight × 0.98). Perinephric and retroperitoneal fat was removed from the left and right sides of each carcass, weighed and recorded. Carcass conformation and fat scores were mechanically assigned to each carcass side using the EU Beef Carcass Classification Scheme (Commission of the European Communities, 1982). Carcasses were classified on a continuous 15-point scale using a VIA carcass classification system (VBS2000; E+V Technology, Oranienburg, Germany). Carcass measurements were recorded on the right-hand side of each carcass, as described by De Boer *et al*. (1974). Carcasses were hung from the Achilles tendon and stored for 48 h at 4°C before being de-boned. Carcasses were divided into fore and hind quarters, as described by Keane and Allen (1998). On the right-hand side of each carcass, the 5th–10th ribs were removed from the pistola by cutting between the 10th and the 11th ribs. The *M. longissimus* area was traced and calculated using the Java image processing programme (Schneider *et al.,* 2012). The joint was then dissected into muscle (*M. longissimus* plus the other muscle proportion) and bone (including *ligamentum nuchae*).

Feed analysis

Grass and concentrate samples were collected weekly throughout the grazing season, with grass silage and concentrate samples collected weekly during the finishing period. Pre-grazing grass samples were collected for each rotation by cutting four quadrants (0.5 m × 0.5 m), representative of each plot, using an electric shears (Accu Grass Shears Comfortcut, Gardena Ltd., Ulm, Germany), as described by O'Donovan *et al*. (2002). All feed samples were duplicated. The first sample was oven-dried at 100°C for 24 h to determine the DM. The second sample was oven-dried at 40°C for 48 h and milled in a C & M Junior laboratory mill (South Hackensack, New Jersey); 1 mm sieve) for chemical analysis. Grass and concentrate samples were pooled on a fortnightly basis, while grass silage samples were pooled on a monthly basis. Concentrate samples were analysed for starch, crude protein and ash. Analysis was carried out for *in vitro* DM digestibility, *in vitro* organic matter digestibility, crude protein and ash for the grass silage samples. Grass samples were analysed for crude ash, crude protein, *in vitro* DM digestibility, *in vitro* organic matter digestibility and water-soluble carbohydrates. Analysis was performed as described by Owens *et al*. (2008). Neutral detergent fibre was determined for all samples using the Ankom method (F57; Ankom Technology, Macedon, NY, USA).

Economic analysis

Bioeconomic modelling was carried out using the Grange Dairy Beef Systems Model (Ashfield *et al.,* 2013), which is a whole-farm, single-year, static, deterministic simulation model that facilitates the technical and economic evaluation of grassland-based dairy calf-to-beef production systems. Biological performance from bulls in the current experiment was incorporated into the model. This included monthly live weight and concentrate DM intake (CDMI) data, carcass traits and housing requirements. Where data was not available from the current experiment, including those required to quantify variable costs (concentrate feed costs, fertiliser, silage, re-seeding, slurry, straw, milk replacer, veterinary services and medicine, interest on working capital, marketing and transport) and fixed costs (building maintenance, machinery operation, land improvements, interest, depreciation, car, telephone and electricity), these were based on data from Connolly *et al*. (2010), Central Statistics Office (CSO) (2015) and O'Donovan and O'Mahony (2011). Default parameters for the model are outlined in Table 1. The economic analysis was based on a 20 ha land area with 200 purchased calves. Calves were taken through to slaughter in production systems based on the experimental treatments of the current study. The model assumed that grass silage was offered to the AL group during the finishing period to maintain normal rumen function. Beef carcass price was the actual price received on the day of slaughter. Sensitivity analysis was carried out

Table 1. Assumptions used in the Grange Dairy Beef Systems Model

Item	Value
Calf price (€/head)	
Holstein-Friesian[1]	130
Jersey × Holstein-Friesian[1]	60
Milk replacer[2] (€/t)	2,124
Calf rearing concentrate[2] (€/t)	320
Finishing concentrate[2] (€/t)	300
Grass silage (€/t DM)	170
Mortality (%/yr)	
0–12 mo	5
13–24 mo	2

[1]Irish Farmers Journal (IFJ) (2011).
[2]Central Statistics Office (2015).
DM = dry matter.

to investigate the effects of a change in beef carcass price, calf purchase price and finishing concentrate price on the profitability of each of the systems. Land was assumed to be owned and family labour was assumed to be freely available; thus, no imputed costs for these resources were included in the analysis.

Statistical analysis

Normality of data distribution was tested using the UNIVARIATE procedure of SAS (Statistical Analysis System, version 9.3, 2011; SAS Institute Inc., Cary, NC, USA). The experimental unit was animal for all variables, except for CDMI during the finishing period, wherein pen was the experimental unit. Data was analysed using the MIXED procedure of SAS. Fixed effects for breed, concentrate supplementation level during the grazing season, finishing strategy and interactions were included in the model. Interactions were found to be non-significant and were subsequently removed from the model. Block was included as a random effect. Initial live weight at the beginning of the experimental period was included as a covariate. Least squares means were used in the procedure to compare differences between concentrate supplementation level during the grazing season and finishing strategy. The PDIFF option and Tukey's procedure were applied as appropriate to evaluate pairwise comparisons between the treatment means. Treatment effects were considered statistically significant when Type I error rate was <0.05. Least squares means are reported with standard error of the mean (s.e.) to facilitate interpretation of the treatment means.

Results

Feed analysis and estimates of CDMI

The chemical composition of the concentrate offered throughout the experimental period, the pasture offered during the grazing season and grass silage offered to the SC group during the finishing period are presented in Table 2. During the grazing season, the HA and LA groups consumed 325 and 161 kg DM of concentrates/head, respectively. CDMI during the finishing period was 78 kg DM/head greater (P < 0.001) for HA compared to that for LA, i.e. 1,283 and 1,205 kg DM, respectively. Similarly, CDMI during the finishing period was 442 kg greater (P < 0.001) for AL compared to that for SC, namely, 1,465 and 1,023 kg DM, respectively.

Animal and carcass performance

At housing, HA were 16 kg heavier (P < 0.05) than LA as the ADG during the grazing season was 0.10 kg greater (P < 0.01) for HA (Table 3). Live weight at slaughter was similar for LA and HA, but the carcass weight tended (P = 0.08) to be greater for HA compared to that for LA. During the finishing period, the ADG tended (P = 0.09) to be greater for LA than for HA. Lifetime ADG and live weight/d of age were similar for HA and LA. However, carcass weight/d of age tended to be greater (P = 0.06) for HA than for LA. Kill-out proportion tended to be greater (P = 0.07) for HA than for LA. Conformation score and the perinephric and retroperitoneal fat, both absolute and expressed as a proportion of carcass weight, were similar for HA and LA. The HA treatment group had a 0.56 unit greater (P < 0.05) fat score compared to the LA group.

Live weight at housing was similar for AL and SC. Live weight at slaughter (P < 0.001) and carcass weight (P < 0.001) were 41 kg and 23 kg greater, respectively, for AL compared to the same for SC. ADG during the grazing season was similar for AL and SC, but ADG during the finishing period was 0.21 kg greater (P < 0.001) for AL than for SC. Lifetime ADG was 0.12 kg greater (P < 0.001) for AL than for SC. Consequently, both live weight (P < 0.001) and carcass weight (P < 0.001)/d of age were greater for AL than for SC. Kill-out proportion was similar for AL and SC. Conformation score (P < 0.05) and fat score (P < 0.06) were greater for AL than for SC. Perinephric and retroperitoneal fat was 2.39 kg heavier (P < 0.001) for AL than for SC. When expressed as per-kilogram carcass weight, perinephric and retroperitoneal fat was 15% greater for AL compared to that for SC (P < 0.01).

Carcass measurements

Carcass length (P = 0.09) tended to be greater for HA than for LA (Table 4). Carcass depth (P < 0.05) and leg length (P < 0.05) were greater for HA compared to the same for LA. Leg thickness, leg width and circumference of round were similar for LA and HA. Carcass length (P < 0.01) and leg thickness (P < 0.001) were greater for AL than for SC. Finishing strategy had no effect on carcass depth, leg length, leg width or circumference of round.

When expressed as a proportion of carcass weight, carcass measurements were unaffected by the level of concentrate supplementation during the grazing season. Relative to carcass weight, carcass length (P < 0.001), carcass depth (P < 0.001) and leg length (P < 0.001) were greater for SC than for AL. Similarly, leg thickness (P < 0.05), leg width (P < 0.001) and circumference of round (P < 0.001) were greater for SC than for AL when expressed as a proportion of carcass weight.

Composition of the rib joint

Concentrate supplementation level during the grazing season had no effect on the area of the *M. longissimus*, weight of the rib joint or composition of the rib joint (Table 5). The area of the *M. longissimus* was similar for AL and SC; however, the weight of the rib joint was 0.94 kg greater (P < 0.001) for AL compared to that for SC. The muscle proportion of the rib

Table 2. Chemical composition of the feed offered throughout the experimental period

	Grazed grass	Concentrate	Grass silage[1]
DM (%)	17.3	84.0	25.6
Crude ash (g/kg DM)	109.8	55.3	94.7
Crude protein (g/kg DM)	197.9	164.3	156.5
Starch (g/kg DM)	–	445.8	–
Neutral detergent fibre (g/kg DM)	456.8	137.9	492.7
DM digestibility (g/kg DM)	768.1	–	678.5
Organic matter digestibility (g/kg)	766.0	–	656.6
Water soluble carbohydrates (g/kg DM)	104.4	–	–

[1]Values for grass silage offered during the finishing period.
DM = dry matter.

Table 3. Effects of supplementation level and finishing strategy on body weight, average daily gain and carcass performance of dairy bulls

	Supplementation level[1] (S)		Finishing strategy[2] (F)		s.e.	Significance[3]	
	LA	HA	AL	SC		S	F
Initial weight (kg)	87	84	87	84	2.0	–	–
Housing weight (kg)	214	230	223	221	4.5	*	–
Live weight at slaughter (kg)	455	469	483	442	7.0	–	***
Carcass weight (kg)	230	240	247	224	3.9	0.0834	***
Average daily gains (kg)							
First season at pasture	0.78	0.88	0.84	0.82	0.024	**	–
Finishing period	1.28	1.21	1.35	1.14	0.028	0.0896	***
Lifetime gain	1.01	1.04	1.09	0.97	0.017	–	***
Live weight/d of age	0.99	1.02	1.05	0.96	0.015	–	***
Carcass weight/d of age	0.50	0.52	0.54	0.49	0.008	0.0616	***
Carcass performance							
Kill-out proportion (g/kg)	506	511	511	506	2.1	0.0696	–
Conformation score (1–15)	4.69	4.79	5.00	4.49	0.152	–	*
Fat score (1–15)	4.87	5.43	5.41	4.89	0.170	*	*
Perinephric + retroperitoneal fat (kg)	8.55	9.28	10.11	7.72	0.390	–	***
Perinephric + retroperitoneal fat/kg carcass weight (g/kg carcass)	37.1	38.4	40.8	34.6	1.52	–	**

[1]Concentrate supplementation level during the grazing season; LA = 1 kg DM of concentrates/head daily; HA = 2 kg DM of concentrates/head daily.
[2]Finishing strategy; AL = concentrates *ad libitum*; SC = grass silage plus 5 kg DM of concentrates/head daily.
[3]Interactions between concentrate supplementation level during the grazing season and finishing strategy were found to be non-significant and thus were omitted.

joint was 13% greater for AL than for SC ($P < 0.001$). The proportion of bone in the rib joint was similar for both finishing strategies.

Concentrate supplementation level during the grazing season had no effect on the area of the *M. longissimus*, weight of the rib joint or the muscle and bone proportions of the rib joint when expressed as a proportion of carcass weight. Scaled to carcass weight, the area of the *M. longissimus* was greater ($P < 0.05$) for SC than for AL. However, rib weight tended ($P = 0.05$) to be greater for AL than for SC. Although no difference was observed between AL and SC for bone proportion of the rib joint relative to carcass weight, the muscle proportion of the rib joint relative to carcass weight was greater for AL than for SC ($P < 0.05$).

Economics

Increasing the level of concentrate supplementation during the grazing season resulted in a gross output value greater by €45 (Table 6). However, concentrate feed costs and total variable costs increased by €110/head and €93/head,

Table 4. Effects of supplementation level and finishing strategy on absolute carcass measurements and as a proportion of carcass weight

	Supplementation level[1] (S)		Finishing strategy[2] (F)		s.e.	Significance[3]	
	LA	HA	AL	SC		S	F
Absolute carcass measurements (cm)							
Carcass length	125	127	128	125	0.6	0.0946	**
Carcass depth	45	46	45	45	0.3	*	–
Leg length	65	66	66	66	0.4	*	–
Leg thickness	24	24	25	23	0.3	–	***
Leg width	42	43	43	42	0.3	–	–
Circumference of round	109	110	110	109	0.6	–	–
Carcass measurements expressed as a proportion of carcass weight (mm/kg carcass)							
Carcass length	5.50	5.35	5.23	5.62	0.074	-	***
Carcass depth	1.96	1.92	1.86	2.02	0.032	-	***
Leg length	2.86	2.80	2.71	2.95	0.036	-	***
Leg thickness	1.04	1.02	1.00	1.05	0.013	-	*
Leg width	1.86	1.81	1.76	1.91	0.024	-	***
Circumference of round	4.77	4.65	4.51	4.90	0.057	-	***

[1]Concentrate supplementation level during the grazing season; LA = 1 kg DM of concentrates/head daily; HA = 2 kg DM of concentrates/head daily.
[2]Finishing strategy; AL = concentrates *ad libitum*; SC = grass silage plus 5 kg DM of concentrates/head daily.
[3]Interactions between concentrate supplementation level during the grazing season and finishing strategy were found to be non-significant and thus were omitted.

Table 5. Effects of supplementation level and finishing strategy on the rib joint and its composition

	Supplementation level[1] (S)		Finishing strategy[2] (F)		s.e.	Significance[3]	
	LA	HA	AL	SC		S	F
M. longissimus area (cm^2)	60.89	62.45	62.81	60.52	1.23	-	–
Weight of rib joint (kg)	6.71	6.91	7.28	6.34	0.146	-	***
Composition of rib joint (kg)							
Muscle	4.90	5.10	5.36	4.64	0.112	-	***
Bone	1.93	1.90	1.96	1.87	0.043	-	–
Expressed as a proportion of carcass weight							
M. longissimus area (cm^2/kg carcass)	0.27	0.26	0.26	0.27	0.004	-	*
Weight of rib joint (g/kg carcass)	29.1	28.7	29.5	28.4	0.42	-	0.0523
Composition of rib joint (g/kg carcass)							
Muscle	2.1	2.1	2.2	2.1	0.03	-	*
Bone	8.4	8.0	8.0	8.4	0.02	-	–

[1]Concentrate supplementation level during the grazing season; LA = 1 kg DM of concentrates/head daily; HA = 2 kg DM of concentrates/head daily.
[2]Finishing strategy; AL = concentrates *ad libitum*; SC = grass silage plus 5 kg DM of concentrates/head daily.
[3]Interactions between concentrate supplementation level during the grazing season and finishing strategy were found to be non-significant and thus were omitted.

respectively. Thus, gross margin was €48/head greater for LA than for HA. Total fixed costs were similar for both levels of concentrate supplementation and, therefore, the net margin was greater by €49/head for LA compared to that for HA.

Beef price received was €0.08/kg greater ($P < 0.05$) for AL than for SC. Concentrate feed costs were €162/head greater for AL than for SC. Consequently, concentrate feed costs represented 72% and 65% of the total variable costs for AL and SC, respectively. Other feed costs (grazed grass and grass silage) were €17/head greater for SC than for AL. The remaining variable costs were similar for AL and SC. The total cost to produce a kilogram of beef carcass was €0.29/kg

Table 6. Economic appraisal (€/head, with the exception of beef carcass price) of dairy bulls slaughtered at 15 mo of age

Production systems	**LA[1]**	**HA[2]**	**AL[3]**	**SC[4]**
Beef carcass price (€/kg carcass)	3.77	3.83	3.84	3.76
Livestock sales	869	914	941	842
Calf purchase price	100	100	100	100
Gross output value	769	814	841	742
Variable costs				
Concentrates	553	643	679	517
Other feedstuff	122	121	114	130
Veterinary and medical	61	61	61	61
Other	90	93	94	89
Total variable costs	826	919	949	796
Gross margin	(57)	(105)	(108)	(54)
Total fixed costs	131	133	134	130
Net margin	(189)	(238)	(242)	(185)
Sensitivity analysis				
Impact on margin/head (€)				
Calf purchase price (±€10/head)	9.50	9.50	9.50	9.50
Finishing concentrate price (±€10/t)	14.30	15.30	17.40	12.20
Beef price (±€0.10/kg)	23.00	23.90	24.50	22.40

[1]1 kg DM of concentrates/head daily during the grazing season.
[2]2 kg DM of concentrates/head daily during the grazing season.
[3]Finished on concentrates *ad libitum*.
[4]Finished on grass silage *ad libitum* plus 5 kg DM of concentrates/head daily.
DM = dry matter.

greater for AL compared to that for SC, i.e. €4.43 and €4.14/kg carcass, respectively. Gross margin/head was €54 greater for SC compared to that for AL; however, both finishing strategies returned negative gross margins.

Taking the varying levels of concentrate supplementation and finishing into account, net margins/head were negative for all systems (Figure 1). The differential between the highest and lowest net margin/head was €107. Dairy bulls in the LA treatment group finished in the SC treatment group returned a net margin of –€159/head, while bulls in the HA treatment group finished in the AL treatment group returned a net margin of –€266/head. Figure 1 also shows that when concentrate costs as a proportion of total variable reduces, the net margin increases.

Sensitivity analysis showed that an increase in calf purchase price of €10/head reduced the net margin by €9.50 (Table 6). When concentrate feed costs increased by €10/t, the financial loss was €5.20 greater for AL than for SC. When beef price increased by €0.10/kg, net margin increased by 10% and 12% for AL and SC, respectively.

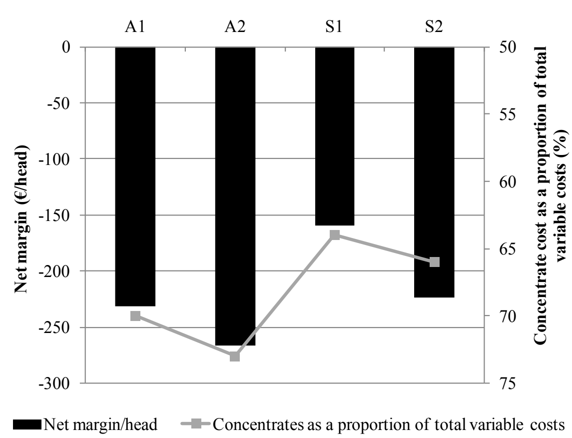

Figure 1. Effects of production system on the net margin/head and the concentrate costs as a proportion of total variable costs of dairy bulls (*ad libitum* concentrates finished and offered 1 kg DM of concentrates during the grazing season (A1); *ad libitum* concentrates finished and offered 2 kg DM of concentrates during the grazing season (A2); finished on silage plus 5 kg DM of concentrates and offered 1 kg DM of concentrates during the grazing season (S1); finished on silage plus 5 kg DM of concentrates and offered 2 kg DM of concentrates during the grazing season (S2)). DM = dry matter.

Discussion

Finishing male cattle as bulls at <16 mo of age meets the required UK market specification for bull beef (Matthews, 2011); however, no study has been undertaken to investigate the impacts of alternative production strategies designed to meet this specification or, consequently, to assess the financial feasibility of such production strategies. To address this lack of information, this study assessed the impact of varying levels of concentrate supplementation during the grazing season, alternative finishing strategies and the overall farm profitability of these systems using performance data from dairy bulls.

Level of concentrate supplementation during the grazing season

Typically, calves in Ireland are managed at pasture during the first season, during which moderate levels of performance (0.70–0.80 kg/d) are achieved (Campion *et al.,* 2009). However, in the UK and continental Europe, young bull production systems are usually operated as indoor confinement systems, wherein concentrate inputs are high from an early age, with limited proportions of grazed grass included in the diet (Grundy *et al.,* 2000; Nogalski *et al.,* 2014). The findings of the current study are consistent with previous research in which calves grazing under Irish conditions exhibited moderate levels of performance during the grazing season (Campion *et al.,* 2009). The potential to further increase the ADG, from weaning to 9 mo of age, through high concentrate input diets also exists. Keane (2001) reported that HF calves in a barley beef production system gained 1.32 kg/d from 12 wk to 9 mo of age when fed indoors on concentrates *ad libitum*. Calves supplemented with lower levels of concentrate supplementation at pasture showed reduced performance in the current study, but the profitability of the system increased due to savings on feed, which is consistent with the findings of Crosson *et al*. (2009). Utilising pasture in a 15-mo bull production system can reduce the overall costs of production, but this also presents the challenge of achieving the required market specifications. Although numerous studies have investigated the effects of calf nutrition on performance during the finishing period, many of those studies focussed on the influence of pre-weaning nutrition (Arthington *et al.,* 2005; Wolcott *et al.,* 2010). Wolcott *et al*. (2010) reported that suckled Shorthorn calves weaned at 259 d of age were 17 kg heavier at the start of the finishing period and had 18 kg greater carcass weight at 23 mo of age compared to those weaned at 123 d of age. Arthington *et al*. (2005) reported similar ADG results during the finishing period, United States Department of Agriculture (USDA) grade yields and marbling scores for Brahman × British steers weaned at 89 or 300 d of age. A review by Berge (1991) reported that at a fixed carcass weight, the initial differences in body composition during calfhood (5–11 mo of age) were generally not significant at slaughter. This is consistent with the findings of Keane and Drennan (1983), who reported that male Friesian calves supplemented with 1.8 kg DM/head daily at pasture were 45 kg heavier than those offered pasture only at 7 mo of age, but carcass weight, kill-out proportion and the conformation and fat scores were similar. In the present study, HA calves were 16 kg heavier at housing, yet live weight at slaughter was similar for both groups, while kill-out proportion and carcass weight tended to be greater for HA and carcass fat score was greater for HA compared to those for LA. The differences in performance of calves between the Keane and Drennan study (1983) and the present study may be attributed to the age at slaughter. Keane and Drennan (1983) studied animals slaughtered at 22 mo of age, which would have facilitated compensatory growth over an extended period, compared to the approach used in the current study.

Finishing strategy

Carcass weights of bulls in both finishing strategies in the current study were below target market specifications. The performance of male dairy cattle finished on various finishing strategies has been well documented (Keane and Fallon, 2001; Keane *et al*., 2006). The findings from the current study are consistent with previous reports, in which animals finished on high concentrate diets had greater ADG, live weight at slaughter and carcass weight, conformation and fat scores compared to animals finished on a combination of grass silage *ad libitum* plus concentrates (Keane and Fallon, 2001; Keane *et al.,* 2006). In the present study, ADG during the finishing period for bulls finished on concentrates *ad libitum* was similar to the report of Keane and Fallon (2001), wherein HF bulls (9–11 mo of age), gained up to 1.4 kg/d on a high concentrate diet. Grundy *et al*. (2000) also reported that dairy beef crossbred bulls finished on concentrates *ad libitum* for approximately 200 d achieved an ADG of 1.43 kg. Consistent with the present study, Keane and Allen (1998) reported an ADG during the finishing period of 1.18 kg for Charolais × dairy bulls finished on grass silage plus concentrates, whereby the proportion of concentrates constituted up to 55% of total DM intake. However, bulls in that study were finished over a 12-mo period and slaughtered at 19 mo of age. Similarly, McGee *et al*. (2005) reported an ADG during the finishing period of 1.04 kg for Holstein, Friesian and Charolais × dairy bulls finished over a 10-mo period on a grass silage *ad libitum* diet supplemented with 6 kg of concentrates/head daily.

In the present study, the AL group gained an additional 39 kg live weight during the finishing period compared to the SC group, which resulted in an additional 23 kg carcass weight. Similarly, Keane and Fallon (2001) reported an additional

49 kg live weight at slaughter, which resulted in additional 34 kg greater carcass weight for bulls finished on concentrates *ad libitum* compared to those on grass silage *ad libitum* plus 6 kg of concentrates/head daily. Sami *et al*. (2004) also reported that live weight at slaughter and carcass weights were 48 and 35 kg greater for Simmental bulls finished for 100 d on maize silage plus 3.73 kg DM of concentrates/d compared to those on maize silage plus 0.89 kg DM of concentrates/d, respectively. Previous research (Keane and Fallon, 2001; Keane *et al.,* 2006) has shown that animals finished on a high concentrate diet had a greater kill-out proportion compared to those finished on a forage and concentrate diet. Keane and Fallon (2001) reported a 13 g/kg greater kill-out proportion for bulls finished on concentrates *ad libitum* compared to those on a grass silage *ad libitum* diet supplemented with 6 kg of concentrates. Similarly, Keane *et al*. (2006) reported a 10 g/kg greater kill-out proportion for dairy and dairy beef crossbred steers finished on concentrates *ad libitum* compared to those on grass silage plus concentrates (ratio 25:75 on a DM basis). The greater kill-out proportion in those studies could be explained by differences in diet composition, where a forage diet would increase gut fill to a greater degree than a high concentrate diet (Kirkland *et al.,* 2007).

In the current study, carcass conformation and fat scores were greater for AL compared to the same for SC. Sami *et al*. (2004) reported greater carcass conformation and fat scores for Simmental bulls finished on maize silage supplemented with 3.73 kg DM of concentrates compared to those finished on maize silage plus 0.89 kg DM concentrates. Similarly, Keane and Fallon (2001) reported greater carcass conformation and fat scores for HF bulls finished on concentrates *ad libitum* compared to those finished on grass silage supplemented with 3 kg of concentrates DM/head daily. However, Cerdeño *et al*. (2006) reported similar carcass conformation scores with greater fat scores for 10-mo-old Limousin crossbred bulls finished on concentrates *ad libitum* compared to those on alfalfa hay supplemented with 4 kg of concentrates/head daily over a 60-d period. The similar conformation score for bulls described by Cerdeño *et al*. (2006) may be due to the shorter finishing period (60 d) compared to that in the current study.

Economics

The optimum production system is one that returns a profit by efficiently utilising grazed grass, farm facilities and labour. Economic analysis in the present study showed that net margins were negative for both finishing strategies. The cost to produce 1 kg of beef was 1.15 and 1.10 times that of the beef price for the AL and SC groups, respectively. Previously, Ashfield *et al*. (2014b) reported that feed costs represented 74% of the total variable costs across a range of dairy calf-to-beef production systems. Although the utilisation of grazed grass is central to increasing profitability (Crosson *et al.,* 2009), the 15-mo bull production system is dependent on high levels of concentrate input. Consequently, the proportion of grazed grass in the feed budget is limited. In the current study, 35% and 38% of the total lifetime weight gain was estimated to come from grazed grass for AL and SC, respectively. Although beef carcass price is typically greater in May and June (DAFM, 2015) when spring-born bulls finished at 15 mo of age are slaughtered, the profitability of the system was still negative. Results from the current study also indicated that fluctuations in calf purchase price do not result in re-ranking between the finishing strategies. However, it is clear that AL is more susceptible to changes in concentrate price than SC, while changes in beef price have the largest effects on the profitability for all systems.

Keane and Fallon (2001) showed that HF bulls, 9–11 mo of age, had the capacity to grow up to 1.4 kg/d when finished on a high concentrate diet (270 kg live weight gain over a 200-d finishing period in the context of a 15-mo bull production system). Therefore, to achieve a carcass weight of 270 kg, i.e. an approximate live weight at slaughter of 520 kg in a 15-mo bull production system, the ADG during the grazing season must be greater than that achieved in the current study to ensure that housing weight at the end of the grazing season is approximately 250 kg. This is supported by Kelly *et al*. (2013), who reported that a minimum live weight of 240 kg at 35 wk of age would be necessary for dairy bulls to be considered for the 15-mo bull production system. To ensure that these targets are achieved, calves could be supplemented with greater levels of concentrate supplementation at pasture or housed earlier to prolong the finishing period, to ensure that the target live weight at slaughter is achieved. However, both alternatives would increase the costs of production. That aside, assuming that calves were supplemented with 1 kg of concentrates during the grazing season, finished on a concentrates *ad libitum* diet and achieved the target carcass weight (270 kg), a net loss of €149/head would be incurred at the assumed concentrate price.

From a practical perspective, alternative production system(s) would be required on a farm to complement the 15-mo bull production system as modest levels of grazed pasture and grass silage are required. However, Ashfield *et al*. (2014b) reported that combining production systems for male dairy calves did not improve the utilisation of the grass grown or the profit. Although animal performance of bulls slaughtered at 15 mo of age could be optimised by utilising high levels of grazed pasture via the incorporation of a leader–follower system and/or strategic supplementation with concentrates during periods of reduced pasture quality, results from the current study indicate that alternatives to the 15-mo bull production system, such as the 19-mo bull or 24-mo steer production systems (Ashfield *et al.,* 2014b), should be considered for male dairy calf-to-beef production.

Conclusion

Results from this study indicate that calves supplemented with high levels of concentrates at pasture were heavier at housing, but net margin was greater for calves supplemented with lower levels of concentrates. The superior biological performance of animals finished on a higher plane of nutrition was confirmed in this study. The target market specifications were not achieved for any of the systems examined, and all treatments failed to return a positive net margin. Therefore, at the prices assumed in this study, alternative production systems to the 15-mo bull production system should be considered for male dairy calves.

Acknowledgements

This project (11/SF/322, "BullBeef") was funded by the Irish Department of Agriculture, Food and the Marine's competitive research programmes. The authors also wish to acknowledge the technical support of Brendan Swan and the farm staff at the Teagasc Johnstown Castle Research Centre for the care and husbandry of the animals.

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