Alternative finishing strategies for Holstein-Friesian bulls slaughtered at 15 months of age

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The aim was to establish the optimum finishing strategy (FS) for dairy bulls slaughtered at 15 months. Sixty spring-born calves were assigned to one of four FS. The FS were split into two phases; pasture (PAS) from mid-August to housing (P1) and finished indoors on concentrates *ad libitum* plus straw for 209 d (P2). Treatment 1 (T1) was offered PAS in P1 and 800 g kg^{-1} barley (BAR), 140 g kg^{-1} soya bean meal (SBM), 40 g kg^{-1} molasses and 20 g kg^{-1} minerals (B) in P2. Treatments 2 (T2) and 3 (T3) were offered 3 kg dry matter (DM) of B per head daily at PAS. In P2, T2 was offered B while T3 was offered 400 g kg^{-1} BAR, 400 g kg^{-1} maize meal, 140 g kg^{-1} SBM, 40 g kg^{-1} molasses and 20 g kg^{-1} minerals (BM). In P1 treatment 4 (T4) was offered 3 kg DM of BM per head daily at PAS and 750 g kg^{-1} BAR, 140 g kg^{-1} SBM, 50 g kg^{-1} rumen protected fat, 40 g kg^{-1} molasses and 20 g kg^{-1} minerals in P2. Finishing strategy did not affect lifetime average daily gain or carcass conformation. Fat score tended (p=0.0514) to be greater for T3 than T1 and T4.

Key words: young bull, pasture, carcass weight, fat score

Introduction

Bull beef production systems have the potential to increase carcass output per hectare by slaughtering animals at a younger age and produce less greenhouse gas (GHG) emissions than steer beef systems (Nogalski et al. 2014, Murphy et al. 2017a). Currently, 13% of male animals are slaughtered as bulls in Ireland (Bord Bia 2016). Animals slaughtered at a younger age require concentrate intensive finishing diets to ensure an acceptable carcass at slaughter (O'Riordan et al. 2012). Although integrating a greater proportion of grazed grass in the diet reduced feed costs (Ashfield et al. 2014), intensive young bull production systems require high levels of concentrates to ensure optimum animal performance throughout the animal's lifetime.

Growth rate is a key driver of biological efficiency and profit in bull beef systems (Pettigrew et al. 2017). Male dairy calves managed in young bull systems in the UK are typically housed indoors on a concentrate intensive diet where little/no grazed grass is incorporated into the feed budget (Meat Promotion Wales 2014). In contrast, moderate levels of performance are common for male dairy calves at pasture during the first grazing season in Ireland which is attributed to the blueprint for the traditional 24 month steer production system (Keane and Allen 1998). Although such performance levels during the weaned calfhood stage are appropriate for steer systems, greater levels of performance are required throughout the animals' lifetime for young bull beef systems. When grazed pasture is incorporated into the diet during the first grazing season methods of increasing the nutritive value of the feed available to weaned calves assigned to young bull beef systems during summer and autumn is necessary to optimise performance (Pettigrew et al. 2017). Indeed, Pettigrew et al. (2017) reported that bulls grazing herb sward had superior growth rates than bulls grazing pasture and pasture supplemented with concentrates. Murphy et al. (2017b) also reported greater average daily gains (ADG), heavier calf housing weights and greater fat scores at slaughter for spring born male dairy calves offered greater levels of concentrate supplementation during the first season at pasture. However, Murphy et al. (2017b) also demonstrated that dairy bulls slaughtered at 15 months of age on a concentrate intensive finishing diet had inadequate carcass weight and fat score and concluded that greater levels of concentrate should be supplemented at pasture before housing or the finishing period should be greater than 200 days.

Carcass fat score is an integral component of carcass value (Bown et al. 2016) and Ladeira et al. (2016) stated that genetic factors, age at slaughter, growth rate and gender are parameters that influence the amount and composition of fat. Since young bulls are more efficient at converting nutrients to muscle than steers (Steen 1995) achieving the minimum requirement for fat score for bulls slaughtered at a younger age can be a challenge. However, De Smet et al. (2000) reported that increasing the energy density in the finishing diet increased carcass fat.

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Similarly, More O'Ferrall et al. (1989) showed that as the energy density of the diet increased, ADG, conformation score and kill-out proportion also increased while age at slaughter decreased. One avenue to increase the energy density of the finishing diet is by way of supplementation with energy dense ingredients such as maize and rumen protected fat (More O'Ferrall and Keane 1989, Nürnberg et al. 1998). Therefore the objective of this study was to establish the optimum finishing strategy for male dairy calves slaughtered at 15 months of age combining alternative supplementation strategies at pasture and energy density of the finishing ration.

Materials and methods

Animals and treatments

This study was conducted at the Teagasc Johnstown Castle Research Centre (52° 17' N, 6° 30' W) from February 2014 to June 2015. Sixty spring-born male Holstein-Friesian (HF) calves were purchased from commercial dairy farms and livestock marts and artificially reared on site similar to that described by Fallon (1992). Calves were generated from 23 artificial insemination (AI) bulls commonly available in Ireland and 4 stock bulls (sired 1 calf each) while 12 calves had an unrecorded HF sire. Mean date of birth and arrival age were 6 February 2014 and 23 (SD 6.6) days, respectively. Calves were turned out to pasture on 24 April and offered 1 kg dry matter (DM) per head daily of a calf ration (350 g kg^{-1} barley; 140 g kg^{-1} soya hulls; 120 g kg^{-1} soya; 100 g kg^{-1} rapeseed meal; 90 g kg^{-1} molasses; 80 g kg^{-1} flaked maize; 50 g kg^{-1} wheat distillers; 50 g kg^{-1} beef pulp and 20 g kg^{-1} minerals). Calves were rotationally grazed on a paddock system. Ivomec 1% injection (Merial Limited, Georgia, USA) was administered at 4, 8 and 12 weeks post-turnout to control internal parasites. On 12 August calves were randomly assigned to one of four finishing strategies blocked by date of birth, farm of origin and live weight. Live weight on 12 August and ADG from weaning to assignment of treatment were 177 (SD 22.3) kg and 0.84 (SD 0.143) kg, respectively.

The experimental overview is presented in Figure 1. The finishing regime comprised of alternative supplementation strategies at pasture (from 12 August to 3 November; P1) and contrasting energy density rations offered during the finishing period (P2). The finishing strategies included a pasture only diet in P1 followed by 800 g kg^{-1} barley, 140 g kg^{-1} soya bean meal, 40 g kg^{-1} molasses and 20 g kg^{-1} minerals (B) in P2 (T1), pasture plus 3 kg DM of B per head daily in P1 followed by B in P2 (T2), pasture plus 3 kg DM of B per head daily in P1 followed by 400 g kg^{-1} barley, 400 g kg^{-1} maize meal, 140 g kg^{-1} soya bean meal, 40 g kg^{-1} molasses and 20 g kg^{-1} minerals (BM) in P2 (T3) or pasture plus 3 kg DM of BM per head daily in P1 followed by 750 g kg^{-1} barley, 140 g kg^{-1} soya bean meal, 50 g kg^{-1} rumen protected fat (Megalac®, Volac International Limited, UK), 40 g kg^{-1} molasses and 20 g kg^{-1} minerals (BRPF) in P2 (T4).

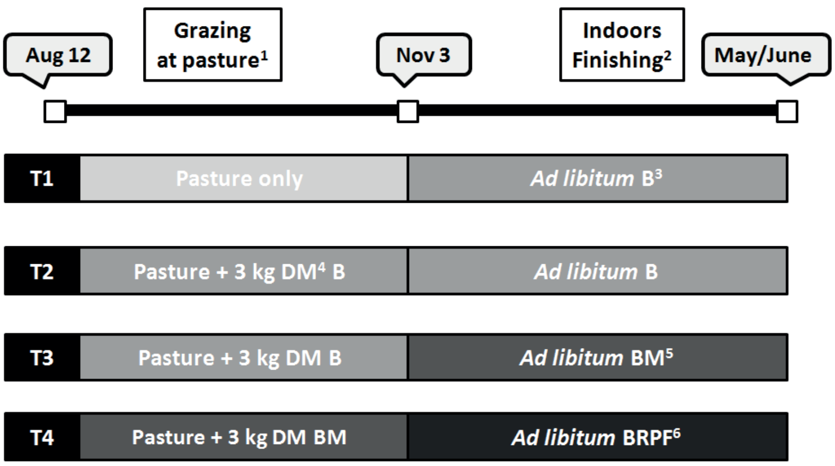

Fig. 1 Experimental overview of the treatments imposed in the study. [1]rotationally grazed at pasture from 12 August to housing on 3 November; [2]housed indoors on a slatted floor accommodation and offered a concentrate *ad libitum* diet from housing to slaughter; [3]800 g kg^{-1} barley, 140 g kg^{-1} soya bean meal, 40 g kg^{-1} molasses and 20 g kg^{-1} minerals; [4]dry matter; [5]400 g kg^{-1} barley, 400 g kg^{-1} maize meal, 140 g kg^{-1} soya bean meal, 40 g kg^{-1} molasses and 20 g kg^{-1} minerals; [6]750 g kg^{-1} barley, 140 g kg^{-1} soya bean meal, 50 g kg^{-1} rumen protected fat (Megalac®, Volac International Limited, UK), 40 g kg^{-1} molasses and 20 g kg^{-1} minerals.

Sward management and dietary analysis

In P1 pre- and post-grazing sward heights were measured using a rising plate meter (Jenquip, New Zealand). Pre-grazing herbage yields were determined on each paddock by cutting 4 quadrats (0.5 m × 0.5 m) representative of the herbage available, using an electric shears (Accu Grass Shears Comfortcut, Gardena Ltd, Germany) as described by O'Donovan et al. (2002). Herbage yield and pre- and post-grazing swards heights were used to estimate individual grass DM intake (GDMI). Pasture samples were collected weekly throughout P1, while concentrate samples were collected weekly throughout P1 and P2. Samples were duplicated. The first sample was oven dried at 100 °C for 24 hours for DM determination and discarded. The second sample was oven dried at 40 °C for 48 hours to determine the chemical composition. These samples were then milled through a 1 mm metal sieve (C & M Junior Laboratory Mill). Pasture and concentrate samples were pooled on a fortnightly basis. All samples were analysed for neutral detergent fibre (NDF), using the Ankom method (F57 Ankom Technology, Macedon, NY). The remainder of the analysis was as described by Owens et al. (2008). Pasture samples were analysed *in vitro* for DM and organic matter digestibility, crude ash, crude protein and water soluble carbohydrates. Concentrate samples were also analysed for starch, crude ash and crude protein. Chemical composition of the pasture and concentrates offered during the experimental period are presented in Table 1. Net energy values for grazed pasture and concentrate diets (Unit Fourragere Viande [UFV]) were estimated using the French NE system (INRA 1989) as modified by O'Mara (1996) for Irish conditions.

Table 1. Chemical composition of the feed offered during the experimental period

	Pasture[1]	B[2]	BM[3]	BRPF[4]
Dry matter (DM: g kg^{-1})	156 (SD[5] 4.3)	848 (SD 1.0)	847 (SD 1.0)	850 (SD 0.9)
Crude ash (g kg DM^{-1})	95.8 (SD 14.87)	63.3 (SD 10.98)	68.9 (SD 11.51)	81.3 (SD 7.83)
Crude protein (g kg DM^{-1})	233.9 (SD 38.43)	169.8 (SD 12.08)	156.5 (SD 9.10)	182.1 (SD 16.64)
Starch (g kg DM^{-1})	–	436.1 (SD 24.92)	468.8 (SD 14.08)	401.9 (SD 50.80)
Neutral detergent fibre (g kg DM^{-1})	487.6 (SD 42.25)	148.4 (SD 17.71)	120.9 (SD 3.68)	134.3 (SD 6.17)
DM digestibility (g kg DM^{-1})	758.4 (SD 30.76)	–	–	–
Organic matter digestibility (g kg^{-1})	749.4 (SD 32.69)	–	–	–
Water soluble carbohydrates (g kg DM^{-1})	124.9 (SD 62.19)	–	–	–
Unité Fourragère Viande (UFV; kg^{-1})	0.92	0.96	0.98	1.03

[1]Chemical composition of the pasture quality offered to treatment groups from 12 August to 3 November; [2]B consisted of 800 g kg^{-1} barley, 140 g kg^{-1} soya bean meal, 40 g kg^{-1} molasses and 20 g kg^{-1} minerals; [3]BM consisted of 400 g kg^{-1} barley, 400 g kg^{-1} maize meal, 140 g kg^{-1} soya bean meal, 40 g kg^{-1} molasses and 20 g kg^{-1} minerals; [4]BRPF consisted of 750 g kg^{-1} barley, 140 g kg^{-1} soya bean meal, 50 g kg^{-1} megalac®, 40 g kg^{-1} molasses and 20 g kg^{-1} minerals; [5]Standard deviation of the mean

Animal management

Calves were vaccinated against Infectious Bovine Rhinotracheitis (Rispoval IBR Marker-Live, Pfizer Animal Health, Cork, Ireland), Bovine Respiratory Syncytial Virus, Pasturella, Parainfluenza-3 virus (Bovipast RSP, Intervet, Schering-Plough Ltd., Wicklow, Ireland) and clostridial diseases (Covexin10, Schering-Plough Ltd.). Calves were housed on 3 November on a slatted floor accommodation and immediately adapted to a concentrate *ad libitum* diet over a 21 day period. Two weeks post-housing, Closamectin pour-on (Norbrook Laboratories Ltd.) was applied on the bulls. Bulls were divided into 3 pens (3.4 by 5 meters) within treatment, with 5 bulls per pen during the finishing period. Fresh concentrates were weighed into each pen daily and refusals were weighed back twice weekly.

Straw was available on an *ad libitum* basis to maintain normal rumen function. Clean fresh water was available. Bulls were finished over a 209 (SD 8.5) day period and slaughtered at 478 (SD 6.6) days of age. Bulls were selected for slaughter on three different sale dates based on the date of birth on their animal passport to ensure that they were 15 months of age at slaughter.

Bulls were weighed fortnightly throughout the experiment using a 'Weigh Crate' (O'Donovan's Engineering, Cork, Ireland) and the 'Winweigh' software package (Tru-test Ltd., Auckland, New Zealand). Average daily gain during the pre-experimental period (24 April to 11 August), P1 and P2 were calculated using linear regression of live weight against recording date for each bull. Bulls were weighed at housing and again 4 days later in an attempt to correct for the variation caused by gut-fill. On the morning of slaughter, bulls were transported 63 km to a commercial slaughter plant and weighed in the lairage approximately 1 hour pre-slaughter using a portable 'Platform Weigher' (O'Donovan's Engineering, Cork, Ireland).

Ultrasonic and live animal measurements

Ultrasonic muscle and subcutaneous fat depth were recorded on the right hand side of each carcass using a Dynamic Imaging Ultrasound Scanner (Concept IMCV with 3.5 MHZ head) at 18 (SD 8.5) and 79 (SD 8.5) days pre-slaughter. Subcutaneous fat depth was calculated as the mean of four points on the rump, four points at the 13th rib and three points at the third lumbar. *Longissimus dorsi* muscle depth was measured at the 3rd lumbar from the top of the bone to the bottom of the back fat layer. Simultaneously, live animal measurements were recorded and expressed as a proportion of live weight (De Boer et al. 1974). Chest depth and pelvic width were measured using a callipers (Mantax Black Callipers, Haglof, Sweden), while height at withers, chest circumference and length of back were recorded using a fibreglass measuring tape.

Carcass assessment

Post-slaughter carcass weight was determined for each bull (hot carcass weight × 0.98). Perinephric and retroperitoneal fat was weighed and recorded from both sides of each carcass. Video imaging analysis carcass classification system (VBS 2000, E+V, Germany) mechanically assigned each carcass side a carcass conformation and fat score on a 15 point scale using the EU Beef Carcass Classifications Scheme (EC 2006). 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 at 4 °C. After 48 hours carcasses were divided into fore and hind quarters. Ultimate pH and temperature were recorded at the 10th rib from the *M. longissimus thoracic* prior to deboning using a combined pH and temperature meter (Hanna Model HI 9125, Hanna Instruments, Bedfordshire, UK) and a penetration glass pH probe (Hanna Model FC231D, Hanna Instruments, Bedfordshire, UK). The 5th to 10th rib joint was removed from the right hand side of each carcass. The area of the *M. longissimus* was traced at the 10th rib and the area was determined using the Java image processing programme (Schneider et al. 2012). The rib joint was separated into muscle (*M. longissimus* plus other muscle) and bone (including *ligamentum nuchae*).

Statistical analysis

The PROC UNIVARIATE procedure of SAS (Statistical Analysis System, version 9.3; SAS Institute Inc., Cary, NC, USA, 2011) was used to test the normality of data distribution. Animal was the experimental unit for all variables, with the exception of feed intake and efficiency where pen was the experimental unit. Data were analysed using a randomised mixed model analysis of variance with the PROC MIXED procedure of SAS. Finishing strategy was included as fixed effect in the model. Least square means and standard error of the mean were used to discern the differences between treatment means and to interpret the results.

Results

Estimated individual DM intakes

The quantity of pasture offered was similar for all treatment groups (Table 2). During the finishing period, concentrate DM intake (CDMI) was lowest for T3, greatest for T2 and intermediate for both T1 and T4 (p<0.01). Total CDMI (P1 and P2) was lowest for T1 and greatest for T2, both T3 and T4 were intermediate (p<0.001).

Animal and carcass performance

Average daily gain during P1 (Table 3) was greatest for T4, lowest for T1 and intermediate for T2 and T3 (p<0.05) but live weight at housing was similar for all treatment groups. During P2, ADG was similar for all treatment groups. Consequently, live weight at slaughter and carcass weight (Table 4) were similar irrespective of finishing strategy. Finishing strategy did not affect lifetime ADG, live weight per day of age or carcass weight per day of age.

Table 2. Effects of finishing regime on pre-and post-grazing sward heights and estimated individual dry matter intake (DMI) on Holstein-Friesian bulls slaughtered at 15 months of age

	T1[1]	T2[2]	T3[3]	T4[4]	SEM[5]	*p* value
Herbage:						
Available herbage (kg DM ha^{-1})	1056	990	990	1075	145.0	0.9596
Estimated individual GDMI[6] (kg DM head^{-1})	5.4	3.6	3.6	4.1	0.54	0.2108
Concentrates (kg DM head^{-1}):						
Concentrate intake during the first season at pasture	0^{a}	212^{b}	212^{b}	211^{b}		<0.001
Estimated individual concentrate DMI during finishing	1673^{ab}	1774^{b}	1578^{a}	1655^{ab}	34.8	<0.01
Total concentrate DMI	1673^{a}	1986^{b}	1790^{ac}	1866^{bc}	34.8	<0.001

[1]No supplementation at pasture and finished on an ad libitum B (800 g kg^{-1} barley, 140 g kg^{-1} soya bean meal, 40 g kg^{-1} molasses and 20 g kg^{-1} minerals); [2]Supplemented with 3 kg DM per head daily of B at pasture and finished on ad libitum B; [3]Supplemented with 3 kg DM per head daily of B at pasture and finished on ad libitum BM (400 g kg^{-1} barley, 400 g kg^{-1} maize meal, 140 g kg^{-1} soya bean meal, 40 g kg^{-1} molasses and 20 g kg^{-1} minerals). [4]Supplemented with 3 kg DM per head daily of BM at pasture and finished on ad libitum BRPF (750 g kg^{-1} barley, 140 g kg^{-1} soya bean meal, 50 g kg^{-1} megalac®, 40 g kg^{-1} molasses and 20 g kg^{-1} minerals)'; [5]Standard error of the mean; [6]Grass dry matter intake

Table 3. Effects of finishing regime on the animal and carcass performance of Holstein-Friesian bulls slaughtered at 15 month of age

	T1[1]	T2[2]	T3[3]	T4[4]	SEM[5]	*p* value
Initial live weight (12 Aug; kg)	175	181	173	181	6.1	0.7628
Live weight at housing (kg)	247	256	263	270	7.9	0.2065
Live weight at slaughter (kg)	546	572	554	552	15.0	0.5952
Average daily gains (ADG; kg):						
ADG (August-November)	0.90^{a}	0.96^{ab}	1.07^{ab}	1.10^{b}	0.047	<0.05
ADG during finish	1.56	1.55	1.47	1.40	0.052	0.1331
Lifetime ADG	1.16	1.22	1.19	1.22	0.036	0.4925
Live weight per day of age	1.14	1.20	1.16	1.15	0.031	0.5386
Carcass weight per day of age	0.59	0.62	0.60	0.59	0.017	0.5181
Ultrasound and animal measurements (79 days pre slaughter):						
Muscle depth (mm)	57.3	56.8	57.2	55.3	1.35	0.6907
Fat depth (mm)	2.05	2.27	2.29	2.23	0.044	0.1744
Height at withers (mm kg^{-1})	2.81	2.71	2.69	2.71	0.061	0.5173
Length of back (mm kg^{-1})	2.58	2.61	2.64	2.59	0.262	0.9540
Chest circumference (mm kg^{-1})	3.95	3.83	3.90	3.86	0.080	0.7568
Chest depth (mm kg^{-1})	1.44	1.41	1.40	1.42	0.030	0.7802
Pelvic width (mm kg^{-1})	1.07	1.04	1.05	1.04	0.019	0.5116
Ultrasound and animal measurements (pre-slaughter measurements):						
Muscle depth (mm)	61.6	57.9	60.4	59.2	1.17	0.1999
Fat depth (mm)	2.39	2.77	2.62	2.43	0.152	0.2077
Height at withers (mm kg^{-1})	2.48	2.40	2.44	2.43	0.054	0.7485
Length of back (mm kg^{-1})	2.47	2.47	2.61	2.53	0.051	0.2415
Chest circumference (mm kg^{-1})	3.71	2.66	3.73	3.69	0.073	0.9397
Chest depth (mm kg^{-1})	1.32	1.32	1.32	1.34	0.025	0.9607
Pelvic width (mm kg^{-1})	1.01	1.00	1.00	0.99	0.020	0.8871

[1]No supplementation at pasture and finished on an ad libitum B (800 g kg^{-1} barley, 140 g kg^{-1} soya bean meal, 40 g kg^{-1} molasses and 20 g kg^{-1} minerals); [2]Supplemented with 3 kg DM per head daily of B at pasture and finished on ad libitum B; [3]Supplemented with 3 kg DM per head daily of B at pasture and finished on ad libitum BM (400 g kg^{-1} barley, 400 g kg^{-1} maize meal, 140 g kg^{-1} soya bean meal, 40 g kg^{-1} molasses and 20 g kg^{-1} minerals). [4]Supplemented with 3 kg DM per head daily of BM at pasture and finished on ad libitum BRPF (750 g kg^{-1} barley, 140 g kg^{-1} soya bean meal, 50 g kg^{-1} megalac®, 40 g kg^{-1} molasses and 20 g kg^{-1} minerals)'; [5]Standard error of the mean

Kill-out proportion and carcass conformation score (Table 4) were similar for all treatment groups. Carcass fat score tended (p=0.0514) to be greater for T3 than T4 and T1 while T2 was intermediate. On an absolute basis perinephric and retroperitoneal fat tended (p=0.0526) to be greater for both T3 and T4 than T1, while T2 was intermediate.

When expressed as a proportion of carcass weight perinephric and retroperitoneal fat was greatest for T4 and lowest for T1 with both T2 and T3 intermediate ($p<0.05$). Ultimate pH and temperature were similar across all treatment groups.

Table 4. Effects of finishing regime on ultrasound measurements, animal and carcass measurements and ultimate pH and ultimate temperature of Holstein-Friesian bulls slaughtered at 15 months of age

	T1[1]	T2[2]	T3[3]	T4[3]	SEM[5]	*p* value
Carcass performance:						
Carcass weight (kg)	283	296	288	281	8.4	0.5680
Kill-out proportion (g kg^{-1})	518	517	521	509	3.5	0.1191
Conformation score (1–15)	5.53	5.47	5.64	5.38	0.296	0.9504
Fat score (1–15)	5.33^{a}	6.13^{ab}	6.45^{b}	5.46^{a}	0.315	0.0514
Perinephric and retroperitoneal fat (kg)	8.58^{a}	9.82^{ab}	11.15^{b}	11.37^{b}	0.785	0.0526
Perinephric and retroperitoneal fat (g kg carcass^{-1})	30.44^{a}	32.90^{ab}	38.84^{ab}	39.92^{b}	2.275	<0.05
Ultimate pH (0–14)	5.67	5.66	5.74	5.68	0.052	0.7396
Ultimate temperature (°C)	4.37	4.41	4.38	4.15	0.148	0.5747
Carcass measurements (mm kg carcass^{-1}):						
Carcass length	4.72	4.64	4.65	4.86	0.116	0.5237
Carcass depth	1.62	1.61	1.63	1.76	0.050	0.1160
Leg length	2.56	2.45	2.46	2.75	0.110	0.2137
Leg width	1.61^{ab}	1.51^{a}	1.55^{ab}	1.65^{b}	0.039	0.0551
Leg thickness	1.02	0.96	0.99	0.99	0.030	0.5233
Circumference of round	4.14	4.01	4.0	4.22	0.030	0.2781

[1]No supplementation at pasture and finished on an ad libitum B (800 g kg^{-1} barley, 140 g kg^{-1} soya bean meal, 40 g kg^{-1} molasses and 20 g kg^{-1} minerals); [2]Supplemented with 3 kg DM per head daily of B at pasture and finished on ad libitum B; [3]Supplemented with 3 kg DM per head daily of B at pasture and finished on ad libitum BM (400 g kg^{-1} barley, 400 g kg^{-1} maize meal, 140 g kg^{-1} soya bean meal, 40 g kg^{-1} molasses and 20 g kg^{-1} minerals); [4]Supplemented with 3 kg DM per head daily of BM at pasture and finished on ad libitum BRPF (750 g kg^{-1} barley, 140 g kg^{-1} soya bean meal, 50 g kg^{-1} megalac®, 40 g kg^{-1} molasses and 20 g kg^{-1} minerals)'; [5]Standard error of the mean

Ultrasonic, animal and carcass measurements

Finishing strategy had no effect on subcutaneous fat depth or l*ongissimus dorsi* muscle depth (Table 3). Carcass measurements expressed as a proportion of carcass weight; carcass length, carcass depth and leg length were unaffected by treatment. However, leg width scaled to carcass weight tended ($p=0.06$) to be greater for T4 than T2, with both T1 and T3 intermediate. Relative to carcass weight, leg thickness and circumference of round were similar across all finishing strategies.

Discussion

A high level of animal performance is required throughout the animal's lifetime to achieve the minimum carcass weight (270 kg) and fat score (equivalent to 6 in the present study) for dairy bulls slaughtered at 15 months of age. Numerous studies have shown that an ADG of 1.4 kg can be achieved for dairy and dairy × beef bulls finished on a concentrate intensive diet (Keane and Fallon 2001, Murphy et al. 2017a and b). However, achieving high levels of animal performance during the grazing season to optimise animal performance during the calfhood stage can prove difficult. Kelly et al. (2013) recommended a minimum live weight of 240 kg at 35 weeks of age as the necessary target for male dairy calves to be considered for the 15 month bull production system. Achieving the minimum requirement for fat score has also been cited as an issue for young bull beef production (Kirkland et al. 2007, O'Riordan et al. 2012). Therefore, refining blueprints for concentrate supplementation at pasture during the first grazing season and altering the composition of the finishing diet for the 15 month bull production system may improve animal performance and fat score.

Calf performance

Although this does ensure that animal performance is optimised, the profitability of the system can be marginal particularly if concentrate price is high. It is well recognised that increasing the proportion of grazed grass in an animal's feed budget reduces the costs of production (Crosson et al. 2009). In dairy calf to beef production systems in Ireland, calves are typically pasture grazed with strategic concentrate supplementation during defined periods; from turnout to early May and mid-September to housing, and moderate levels of performance are achieved (Campion et al. 2009). Murphy et al. (2017b) concluded that male dairy calves offered grazed grass during the calfhood stage and slaughtered at 15 months of age should be either finished on a concentrate intensive diet for greater than 200 days (i.e. reduce the length of the grazing season) or allocated increased levels of concentrate supplementation at pasture before concentrate intensive indoor finishing. The latter proposal could maintain animal performance by counteracting the deterioration in pasture quality in the latter stage of the grazing season. Animal performance of T1 at pasture in the current study was greater than anticipated. This may have been a consequence of the greater than expected herbage quality available as highlighted by the chemical composition; DM digestibility and organic matter digestibility. Consequently live weight at calf housing for T1 was greater than that reported previously by Campion et al. (2009) and Murphy et al. (2017b) where calves were offered 2 kg DM per day; 210 kg and 230 kg, respectively. Calves in T4 in the present study had greater ADG at pasture than T1. Murphy et al. (2017b) reported that male dairy calves supplemented with additional levels of concentrates (2 kg DM and 1 kg DM of concentrate per head daily) throughout the first season at pasture were 17 kg heavier at calf housing. Subsequent carcass performance from Murphy et al. (2017b) reported that male dairy calves supplemented with greater levels of concentrates tended to have heavier carcasses with greater fat scores than those offered lower levels of concentrate supplementation. The greater carcass weight for calves supplemented at pasture was not observed in the present study. This was largely attributed to the greater ADG of T1 at pasture. In the current study live weight at housing was positively correlated with carcass weight (R^2=0.65).

Finishing phase

During the finishing phase in the current study, ADG was greater than that previously reported for dairy bulls slaughtered at 15 months of age. Murphy et al. (2017b) reported an ADG of 1.34 kg for dairy bulls finished on a concentrate *ad libitum* diet while Keane and Fallon (2001) achieved an ADG of 1.36 kg for bulls finished over a 10 month period on a concentrate *ad libitum* diet. Conformation score of HF bulls in the current study was similar to that reported in previous studies (Keane and Fallon 2001, Alberti et al. 2008). This is consistent with the findings of Guerrero et al. (2013), who reported that a finishing period of 145 days removed differences that were influenced by production system pre-finishing. Guerrero et al. (2013) reported no difference in carcass weight, kill-out proportion or conformation score between Gascon bulls managed under intensive and extensive conditions pre-finishing. However, differences in fat score were evident. Irrespective of treatment group all finishing strategies achieved the required carcass weight and conformation scores in the present study.

The increased androgen activity of bulls compared to steers resulted in greater muscle but lower fat deposition (Sillence 2004). Consequently, achieving an adequate fat cover for bulls can be difficult particularly when slaughtered at a younger age. Previously Prendiville et al. (2012) reported that fat score increased as age at slaughter increased for dairy bulls slaughtered at 15, 19 and 22 months of age, respectively. However, current UK market specifications dictate that dairy bulls be slaughtered at less the 16 months of age and achieve a fat score of 6 or greater (Dawn Meats 2011). Fat scores achieved in the current study were consistent with that previously reported for dairy bulls finished on high concentrate or concentrate *ad libitum* diets (Kirkland et al. 2007, Murphy et al. 2017a). The energy density of the finishing diet in the present study increased from 0.96 (UFV) kg^{-1} (B) to 0.98 UFV kg^{-1} (BM) to 1.03 UFV kg^{-1} (BRPF) to evaluate the effects on fat score. The greater UFV value of maize meal (1.06 UFV kg^{-1}) compared to rolled barley (0.99 UFV kg^{-1}; INRA 1989) suggests that maize based rations may have the potential to enhance fat deposition during the finishing period.

Results from the present study showed that carcass fat score and perinephric and retroperitoneal fat were similar for T1 and T2. However, T3 had a 1.12 unit greater carcass fat score and 2.57 kg more perinephric and retroperitoneal fat than T1. Consistent with the findings of Keane (2008), results from the present study showed no difference in live weight at slaughter, carcass weight or fat score for dairy bulls finished on T2 or T3. Similarly, Lenehan et al. (2015) reported no difference in fat scores for suckler bulls finished on *ad libitum* barley and maize meal based rations. However, estimated individual concentrate DMI during the finishing period was 196 kg greater for T2 than T3. This is consistent with the findings of Lenehan et al. (2015), who reported lower concentrate intakes for continental bulls offered 426 g kg^{-1} barley, 426 g kg^{-1} maize meal, 70 g kg^{-1} soya bean meal, 50 g kg^{-1} molasses and 28 g kg^{-1} than bulls offered 862 g kg^{-1} barley, 60 g kg^{-1} soya bean meal, 50 g kg^{-1} molasses and 28 g kg^{-1}.

Interestingly, perinephric and retroperitoneal fat was 2.79 kg greater for T4 than T1 but carcass fat score was similar for both groups. This highlights differences in the deposition of fat between T1 and T4. Previously Steen (1995) reported that Friesian cattle exhibited greater deposition of internal fat than Limousin × Friesian and Belgian Blue × Friesian which would have made a major contribution to the lower efficiency of carcass and lean gains. This could explain the similar carcass performance of the treatment groups in the current study. De Smet et al. (2000) demonstrated that increasing the energy density of the finishing ration for beef bulls, through beef tallow supplementation, resulted in greater carcass fat scores while Gillis et al. (2004) and Sutter et al. (2000) reported no difference in fat score for beef heifers and dairy bulls finished with or without RPF supplementation, respectively.

Variation was apparent within each of the finishing strategies for carcass performance. Although supplementing concentrates at pasture (T2, T3 and T4) did increase the proportion of bulls that achieved the required carcass fat score compared those unsupplemented at pasture (T1), variation within treatment was also apparent. The proportion of bulls that achieved the target fat score was 0.33, 0.73, 0.82 and 0.50 for T1, T2, T3 and T4, respectively. Similarly, the proportion of bulls that achieved target carcass weight for T1, T2, T3 and T4 were 0.73, 0.87, 0.82 and 0.64, respectively while the proportion of bulls that attained the target conformation score was 0.80, 0.80, 0.91 and 0.79 for T1, T2, T3 and T4, respectively. However, combining these performance parameters to present the proportion of bulls that achieved the current UK market specifications (Dawn Meats 2011) highlighted that 0.27, 0.53, 0.55 and 0.43 for T1, T2, T3 and T4, respectively, achieved performance targets. This highlights the difficulty in achieving the required carcass weight and carcass conformation and fat scores for dairy bulls slaughtered at 15 months even when lifetime ADG was in excess of 1.15 kg for all treatment groups.

Conclusion

The results of this study indicated that there is a role for pasture in the production of 15 month dairy bull beef. However, excellent grassland management is central to the successful integration of grazed grass in the 15 month bull production system. Across all finishing strategies a live weight at housing of approximately 250 kg or greater was achieved. Despite all treatments realising the required age at slaughter, carcass weight and conformation score specifications, only T2 and T3 achieved the required fat score. No difference in animal performance or feed efficiency was observed between T2 and T3. However despite high levels of animal performance of T1 and T4, a large proportion of carcasses did not achieve the required market specifications (Dawn Meats 2011). Thus the recommended blueprint of production to achieve the current UK market specifications requires dairy bulls be supplemented with 3 kg DM of a barley based concentrate per head daily at pasture from mid-August to housing followed by indoor finishing on an *ad libitum* B or BM based rations for 200 days.

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