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Effect of concentrate feeding level in winter and turnout date to pasture in spring on biological and economical performance of weanling cattle in suckler beef production systems

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Three experiments were carried out to determine the effects of supplementary concentrate feeding level (Low, LC; High, HC) to grass silage and/or turnout date to pasture in spring (Early, ET; Late, LT) for a second grazing season on performance to slaughter of spring-born, weaned beef calves (n=188). Experiment 1 comprised of two concentrate levels (0.5 and 1.5 kg/day). Experiment 2 comprised of two turnout dates (19 March, 9 April). Experiment 3 comprised of two concentrate levels (0.5 kg and 2.0 kg/day) and two turnout dates (22 March, 12 April). In Experiment 1, live-weight gain during the indoor winter period was 25 kg higher ($P<0.001$) for HC, whereas during the subsequent grazing season it was 17 kg higher ($P<0.05$) for LC resulting in similar ($P>0.05$) total live-weight gain for both treatments. In Experiment 2, live weight at turnout to pasture was 11 kg lower ($P<0.001$) for ET than LT, whereas 8 days after late turnout, it was 15 kg lower ($P<0.01$) for LT than ET. This difference in live weight was still evident 28 days later ($P<0.01$) but not ($P>0.05$), subsequently. In Experiments 1 and 2, live-weight gain during the finishing period and carcass weight, conformation and fat scores did not differ ($P>0.05$) between the treatments. In Experiment 3, at turnout to pasture, HC were 35 kg heavier ($P<0.001$) than LC, and ET were 12 kg lighter ($P<0.05$) than LT, whereas 8 days after late turnout, ET were 13 kg heavier ($P<0.05$) than LT. There was a concentrate level × turnout date interaction ($P<0.05$) for live weight at the end of the grazing season, whereby the LC, LT treatment were lighter than the other treatments, which did not differ. Live weight at slaughter and carcass weight did not differ ($P>0.05$) between the concentrate levels, whereas they were higher ($P<0.05$) for ET than LT. Economic and stochastic analysis of Experiment 3 indicated that, in the

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context of whole-farm systems, (i) feeding HC was dependent on date of sale such that only where progeny were sold at the start of the second grazing season, net farm margin (NFM) was increased, (ii) ET only increased NFM where progeny were retained through to finish and, (iii) taking progeny through to finish was more profitable than selling earlier in the animals' lifetime. In conclusion, subsequent compensatory growth at pasture diminishes the growth and economic advantage from concentrate supplementation or early turnout to pasture, of young late-maturing cattle.

Keywords: Beef cattle; bioeconomic modelling; compensatory growth; concentrate feeding level; spring grazing; stochastic analysis; turnout date

Introduction

Beef suckler cows comprise approximately half of the cow population in Ireland. Late-maturing continental breeds now account for over 75% of suckler cows, of which, 85% are bred to continental sire breeds (McGee 2012). These cows are predominantly spring-calving with their progeny frequently taken to finish at about 20 (heifers) and 24 (steers) months of age or greater (O'Donovan *et al*. 2010). They are operated within systems where grazed grass is the major dietary input. Thus, where progeny are taken through to slaughter, there are usually two grazing seasons and one or two indoor winter periods (e.g. Drennan and McGee 2009). In many instances, the production system may involve selling the progeny as live animals, including at the beginning (as yearlings) or end (at 1.5 years old) of the second grazing season.

The rationale for these grass-based production systems is the considerably lower comparative cost of grazed grass as a feedstuff (Finneran *et al.* 2011) together with its potentially high nutritive value and thus, high animal growth rate compared to diets offered indoors. Consequently, a short indoor feeding period in association with a long grazing season is desirable. However, under Irish conditions grass is normally available for grazing in situ for approximately 250 days per year (Mayne and O'Kiely 2005). The supply of grass herbage for grazing during late-winter, early-spring is generally limited by relatively low growth rates during this period and therefore, is often inadequate to meet the demand of grazing cattle until late spring, depending on stocking rate (Humphreys and O'Kiely 2006).

The herbage mass available to grazing livestock during spring can be increased if all the grassland on a farm, including the area destined for first harvest silage, is utilised during the first grazing rotation (O'Riordan, O'Kiely and Keane 1998; Humphreys and O'Kiely 2006). However, grazing spring swards designated for first cut silage may have negative effects on subsequent silage yield (Humphreys and O'Kiely 2006) and this needs to be quantified for suckler beef systems where both early- and late-harvest first-cut silage is produced (Drennan and McGee 2008, 2009). This is important considering the negative relationship between yield and cost of producing grass silage (Finneran *et al.* 2010). The effect of initial spring grazing date on dairy cow production in Ireland has been investigated widely (e.g. Roche *et al.* 1996; Sayers and Mayne 2001; Ferris, Gordon and Patterson 2001; Dillon *et al.* 2002; Kennedy *et al.* 2005, 2006, 2007), whereas there is little published information on this practice in beef cattle, especially within suckler beef production systems.

Improved profitability could derive from further increasing the proportion of grazed grass in the annual diet and by improving weight gain of weanlings during the first winter period. However, previous data from progeny of the dairy herd and from early-maturing beef crossbred cows have indicated that additional live-weight gain due to feeding supplementary concentrates with grass silage during the first winter is lost by compensatory growth during the subsequent (second) grazing season (Drennan 1979; Drennan and Harte 1979; Hornick *et al.* 2000; Keane 2002, 2005). There are little data published investigating such compensatory growth with late-maturing, continental breed cattle, especially in animals taken through to slaughter and even less on the economics of such practices on whole-farm profitability.

Therefore, the aims of the series of three experiments reported in this paper were to: Experiment 1: determine if live-weight gains made by late-maturing continental breed weanlings in response to feeding supplementary concentrate with grass silage during the first winter are lost by compensatory growth during the following grazing season and/or finishing period; Experiment 2: quantify if increasing the proportion of annual feed intake derived from grazed grass (and thus, reducing the intake of grass silage) by commencing the grazing season 3 weeks earlier, results in increased live-weight gain that is sustained through to finish; Experiment 3: determine if there are interactions between the effects studied in Experiments 1 and 2, and ultimately, to evaluate the impact of these effects on whole-farm profitability. An additional aim was to quantify the effect of grazing spring swards designated for first cut silage on subsequent yield and nutritive value of herbage and the economical implications of this on whole-farm profitability.

Materials and Methods

The study was conducted at the Animal & Grassland Research and Innovation Centre, Teagasc, Grange. The soil type and meteorological data recording was as described by Drennan and McGee (2009). Grass production was measured annually in a separate plot experiment as described by O'Riordan (1997) involving a cutting regime to a 4 cm stubble height on a 4-week cycle using an annual fertiliser nitrogen (N) input of 300 kg/ha.

Animals and management

Three separate experiments were carried out using single-suckled weaned calves from spring-calving (February–April) beef suckler cows taken through to slaughter. A total of 44 (18 male and 26 female), 72 (36 male and 36 female) and 72 (28 male and 44 female) animals were used in Experiments 1, 2 and 3, respectively. They were the progeny of Limousin × Holstein-Friesian (Experiment 1) and additionally, Simmental × (Limousin × Holstein-Friesian) (Experiments 2 and 3) cows. Mature cows were mated to Charolais sires and replacement heifers were bred to a Limousin sire. Male calves were castrated in August and all calves were weaned and housed indoors on 15 and 17 November, and 20 October in Experiments 1, 2 and 3, respectively. No concentrates were offered pre-weaning. After the first indoor winter period and application of treatments (see below), animals were reared on either an Intensive or Extensive grassland management systems study, as described by Drennan and McGee (2009). Key dates are summarised in Table 1.

Animals were assigned to blocks based on live weight, gender, cow genotype, cow

Table 1. Key dates for Experiments 1, 2 and 3

	Experiment		
	1	2	3
First silage harvest	26 May	17 May	25 May
Commence experimental winter feeding levels	20 December	18 November	25 November
Turnout date to pasture			
Early	Not applicable	19 March	22 March
Late	9 April	9 April	12 April
Commence winter finishing period			
Heifers	9 September	9 September	30 September
Steers	4 November	7 November	9 November
Slaughter date			
Heifers (~20 months)	31 October	7 November	9 November
Steers (~24 months)	(0.5) 28 January (0.5) 12 March	3 March	6 March

parity and grassland management system and, from within blocks, randomly allocated to the treatments.

Experimental treatments

The experimental treatments were as follows:

Experiment 1: During the first indoor winter experimental period (from 20 December to 9 April) two supplementary concentrate feed levels to grass silage – 0.5 (Low, LC) and 1.5 (High, HC) kg concentrate per head daily – were compared.

Experiment 2: At the end of the first indoor winter period (commenced on 18 November), during which a single supplementary concentrate feed level (1.0 kg per head daily) to grass silage was offered, two turnout dates to pasture in spring – Early (19 March, ET) and Late (9 April, LT) – were compared.

Experiment 3: During the first indoor winter experimental period, which commenced on 25 November, two supplementary concentrate feed levels to grass silage were offered and this was followed by two turnout dates to pasture, in a factorial experiment. The concentrate feeding levels were 0.5 kg (Low, LC) and 2.0 kg (High, HC) per head daily and the turnout dates to pasture were 22 March (Early, ET) and 12 April (Late, LT).

Winter indoor period

At the end of the first grazing season the weaned calves were accommodated in pens in a slatted floor house. During the winter indoor period, they were offered grass silage *ad libitum* (proportionately 0.05 to 0.1 in excess of daily intake) plus concentrate supplementation (as above). Concentrate offered in Experiments 1 and 2 comprised rolled barley 870 g, soya bean meal 68 g molasses 47 g and minerals/vitamins 15 g per kg fresh weight and that offered in Experiment 3 comprised rolled barley 430 g, molassed beet pulp 430 g, soyabean meal 80 g, molasses 45 g and mineral and vitamins 15 g per kg fresh weight. Concentrate was offered in one daily feed in the morning. Additionally, all animals received a high copper mineral/vitamin mixture at a rate of 20 g per head daily, spread over the silage. The animals assigned to the LT treatments in Experiments 2 and 3 continued to receive their concentrate and mineral/vitamin allowance in addition to grass silage *ad libitum* until turnout to pasture.

Grazing season

At the end of the indoor winter period animals were turned out to pasture for a second grazing season. The experimental area was a permanent grassland site. Animals assigned to the ET treatments in Experiments 2 and 3, grazed the paddocks designated for first cut silage harvesting. Grazing of the area designated for silage ended when the animals assigned to the LT treatment were turned out to pasture. Subsequently animals from both treatments grazed the designated grazing area together, within their assigned, Intensive or Extensive, grassland management system. The grazing area increased after silage harvesting when the subsequent regrowth became available.

The swards consisted predominantly of perennial ryegrass (*Lolium perenne*) and were rotationally grazed. Grassland management decisions were primarily based on visual assessment of herbage height and mass [i.e., equivalent to a mean compressed pre- and post-grazing sward height of ca. 12.0 and 6.0 cm, respectively, corresponding to ca. 1900 and 600 kg dry matter (DM)/ha] in order to provide high nutritive value pasture [i.e., *in vitro* DM digestibility (DMD) of ca. 760 g/kg] (Drennan and McGee 2009). Botanical composition was not measured but visually there was very little white clover (*Trifolium repens*) present.

Finishing period

Near the end of the grazing season (Table 1), heifers were finished at pasture or alternatively finished indoors in a slatted floor house and offered grass silage *ad libitum* (Drennan and McGee 2009). In each instance they were offered approximately 3 kg fresh weight of a barley-based concentrate per head daily. At the end of the grazing season, steers were accommodated in a slatted floor house and were offered grass silage *ad libitum* plus approximately 4.0 kg fresh weight of a barley-based concentrate daily. In Experiment 3, slaughter data were available for only 16 of the 44 heifers (carcass weight was estimated for the missing heifers in each treatment using the mean kill-out proportion of corresponding animals that were slaughtered) as the others were used as breeding replacements.

Measurements

Animal live weight was recorded on two consecutive days at the start and end of the indoor feeding periods and just prior to slaughter with additional single day recordings at approximately monthly intervals in between. Live weight of all animals was also recorded 8 days following turnout of those assigned to the late grazing treatments. It was assumed that gut fill adjustment to the grass diet had largely occurred at this time point (Wright, Russel and Hunter 1986). At the end of the finishing period, animals were slaughtered in a commercial abattoir. After slaughter, hot carcass weight and weight of perinephric plus retroperitoneal fat (Experiments 1 and 3) were recorded. Carcasses were classified for conformation and fatness according to the European Union Beef Carcass Classification Scheme (Commission of the European Communities 1982). Kill-out proportion was calculated as the proportion of cold carcass weight (0.98 × hot carcass weight) to pre-slaughter live weight.

Intake of grass silage by weanlings during the indoor winter period was recorded over 42 days in Experiment 3. Measurement was on a pen basis, with pens within treatments located in different parts of the shed. Fresh silage was offered daily and refusals were removed each Friday. Daily feed intake was obtained by weighing the quantities of feed offered *ad libitum* and subsequent refusals over 4 consecutive days (Monday to Thursday) each week. For all three experiments, representative samples of grass silage offered, and refused (Experiment 3 only), were obtained and stored at –20 °C. Samples were processed and DM, pH, crude protein, and *in vitro* DMD, was determined as described by McGee, Drennan and Caffrey (2005).

For the early grazing period in Experiment 3, fourteen paddocks were used, with half of each paddock grazed and the remainder left ungrazed to simulate the area destined for silage harvest. Pre- and post-grazing herbage yield (above 4 cm) was determined on a minimum of four strips of grass (0.53 m wide, 4.5 m long) per paddock cut with a rotary blade lawnmower. The grass from each strip was weighed and sampled. Likewise, when animals had finished grazing a paddock, the sward height and yield was measured in the ungrazed half. Seven of the fourteen paddocks were harvested for silage on 20 May (representing early first-cut) and the remaining seven were harvested on 8 June (representing late first-cut) (Drennan and McGee 2009). Within 24 h prior to silage harvesting, the herbage yield in each paddock (grazed and ungrazed portions) was determined by cutting four, 4.5 m strips using a Haldrup mower. The grass from each strip was weighed and representative samples were obtained and stored at –20 °C. Samples were processed and DM, crude protein, ash, *in vitro* DMD, and digestible organic matter in the DM (DOMD) were determined as described by Owens, McGee and Boland (2008).

Statistical analysis

For Experiments 1 and 2, animal production data were subjected to an analysis of variance using the PROC GLM procedure of SAS (2003) with terms in the model for treatment and block. Animal production data for Experiment 3 were analysed as a 2 × 2 factorial arrangement of treatments, with terms in the model for concentrate level, turnout date, concentrate level × turnout date and block. Data pertaining to the effects of grazing and silage harvest date on herbage yield and nutritive value consisted of results for 7 plots, each with a 2 × 2 factorial arrangement of treatments. These data were analysed using a model with terms for grazing and harvest date and their interaction. All reported values are least square means, which were separated using the PDIFF option in SAS.

Economic and risk analysis

The Grange Beef Systems Model (GBSM), a whole-farm budgetary simulation model (Crosson *et al*. 2006; Crosson 2008), was used to simulate the impact of the feeding strategies implemented in Experiment 3 on whole-farm economic performance, expressed as net farm margin (NFM) (excluding direct farm support and environmental payments). To capture the range of production systems that typically occur on Irish farms and to quantify the capacity of these production systems to take advantage of supplementary concentrate feeding during the winter indoor period and compensatory growth found during the second grazing season, three production scenarios were investigated. These represented suckler beef production systems selling progeny at different stages in the animals life-cycle; immediately prior to LT (i.e., at the start of the second grazing season), immediately prior to housing at the end of the second grazing season, and at the end of the finishing period. The economic risk, defined as the degree of variation due to changes in the cost and price ratio (Perillat, Brown and

Cohen 2004) was evaluated for each scenario using the computer software, @Risk (Palisade 2006). Stochastic analysis was carried out using Monte Carlo assessment, which specifies a probability distribution for each sensitivity parameter. The values for parameters used in the model were chosen from their respective probability distribution for a large number of draws (10,000) to give estimates of the output distributions (Lien 2003). The general triangular probability distribution was chosen, and, therefore minimum, maximum and most likely prices for the relevant inputs and outputs were used (Table 2). In selecting the price range, the highest, lowest and mean prices observed between January 2008 and December 2012 were selected as the maximum, minimum and most likely prices, respectively (Bord Bia 2013; Central Statistics Office 2013). Furthermore, given the importance of sale price (either in the form of live animal sales or beef carcass sales) and concentrate price, sensitivity of NFM to these prices was carried out. Land was assumed to be owned and family labour was assumed to be freely available; thus, no imputed cost for these resources was included in the analysis.

Results

Total annual rainfall recorded at the centre for Experiments 1, 2 and 3 was 829, 981, and 938 mm, respectively. Corresponding annual duration of sunshine hours was 1,146, 1,129, and 1,224 and mean temperatures recorded at 50 mm below soil surface were 8.8, 9.5 and 9.6 °C. This compares with the 30-year average for rainfall, sunshine and temperature of 846 mm, 1,232 hours and 8.8 °C, respectively. Annual herbage yields (separate plot experiment) for Experiments 1, 2 and 3 were 12.2, 9.8 and 8.8 t DM/ha, respectively. This compares with the 12-year mean annual herbage production of 11.9 (s.d. 1.69) t DM/ha.

The chemical composition and *in vitro* DMD of the grass silage offered to the weanling cattle for each of the three experiments is presented in Table 3.

Experiment 1

At turnout to pasture, live weight was 23 kg lower (P<0.001) for LC compared to HC, whereas subsequently, there was no effect (P>0.05) of supplementary feed level on animal live weight (Table 4). During the indoor winter period, live-weight gain was 25 kg higher (P<0.001) for HC, whereas during the subsequent

Table 2. Price distributions used to evaluate the economic implications of turnout and concentrate feeding scenarios using production data from Experiment 3

Price	Minimum	Maximum	Most likely
Steer beef (R3; €/kg carcass)[1]	280	423	341
Heifer beef (R3; €/kg carcass) [1]	289	436	349
Cow beef (O3; €/kg carcass)[1]	223	369	286
Steer at turnout (€/kg live weight)[2]	144	268	196
Heifer at turnout (€/kg live weight)[2]	145	284	199
Steer at housing (€/kg live weight)[2]	155	193	173
Heifer at housing (€/kg live weight)[2]	157	266	196
Concentrate (€/t DM)[2]	246	355	293
Fertiliser; Calcium Ammonium Nitrate (€/t)[2]	236	413	326
Fertiliser; Urea (€/t)[2]	339	476	416

[1]Bord Bia (2013).
[2]Central Statistics Office (2013).

Table 3. Chemical composition and *in vitro* dry matter digestibility of grass silage (s.d.) offered to the weanling cattle in Experiments 1, 2 and 3

	Experiment		
	1	2	3
Dry matter (DM) (g/kg)	236 (17.0)	153 (9.2)	206 (20.4)
pH	3.8 (0.13)	4.3 (0.18)	4.0 (0.20)
Crude protein (g/kg DM)	149 (6.8)	180 (8.8)	162 (9.6)
In vitro DM digestibility (g/kg)	711 (15.3)	688 (22.0)	721 (23.6)

grazing season live-weight gain was 17 kg higher (P<0.05) for LC. This resulted in a similar (P>0.05) total live-weight gain for both treatments for the indoor winter period and grazing season combined. Subsequent live-weight gain during the finishing period, carcass weight and kill-out proportion, and carcass conformation and fat scores did not differ (P>0.05) between the two treatments.

Experiment 2

At turnout to pasture, live weight was 11 kg lower (P<0.001) for ET compared to LT, whereas at 8 days post late turnout, live weight was 15 kg lower (P<0.01) for LT than ET (Table 5). A difference in live weight was still evident 28 days later in May (P<0.01) after which, it diminished and was not different (P>0.05) between the treatments.

Table 4. Effect of supplementary concentrate feeding level with grass silage on live weight and carcass traits in Experiment 1

	Concentrate level		s.e.	Significance
	Low	High		
Live weight (kg)				
Initial weight	330	328	2.4	
Turnout to pasture	393	416	4.0	***
Housing	552	556	6.1	
Slaughter	624	621	6.6	
Live-weight gain (kg)				
Indoor winter period	63	87	3.3	***
Grazing season	158	141	5.1	*
Indoor winter + grazing season	221	228	5.8	
Housing to slaughter	73	67	4.0	
Total to slaughter	294	295	6.3	
Live-weight gain (g/day)				
Indoor winter period	570	794	29.6	***
Grazing season	897	790	32.2	*
Carcass traits				
Carcass weight (kg)	351	351	4.3	
Kill-out proportion (g/kg)	562	566	3.5	
Carcass conformation[1]	3.6	3.5	0.09	
Carcass fat[2]	4.2	4.2	0.09	

[1]Scale 1 to 5 (best conformation).
[2]Scale 1 to 5 (fattest).

Despite an additional 21 days indoors, animals on the LT treatment did not (P>0.05) achieve higher live-weight gain over the winter period. Live-weight gain to 8 days post late turnout was 16 kg higher (P<0.001) for ET compared to LT, whereas live-weight gain from 8 days post late turnout to housing was 9 kg higher (P=0.10) for LT. This resulted in a numerical difference in total live-weight gain from early turnout of 6 kg in favour of ET (P>0.05). Subsequent live-weight gain during the finishing period did not differ (P>0.05) between the two treatments. Carcass weight and carcass conformation and fat scores were similar (P>0.05) for both treatments, whereas kill-out proportion was higher (P<0.05) for LT compared to ET.

Experiment 3

Mean daily silage DM intake was lower (4.16 v. 4.54 kg, P<0.001) for HC compared to LC. At turnout to pasture, HC were heavier (P<0.001) than LC and LT were heavier (P<0.05) than ET (Table 6). However, at 8 days post late turnout, ET were heavier (P<0.05) than LT. There was a concentrate level × turnout date interaction (P<0.05) for live weight at housing at the end of the grazing season, whereby animals offered the low level of concentrate and turned out late were significantly lighter than the other treatments, which

Table 5. Effect of turnout date to pasture on live weight and carcass traits in Experiment 2

	Turnout date		s.e.	Significance
	Early	Late		
Live weight (kg)				
Initial weight	310	314	3.8	
At early turnout date	359	360	3.5	
At actual turnout date	359	370	3.3	*
8 days post late turnout	380	365	3.7	**
Housing	524	518	5.0	
Slaughter	609	599	6.9	
Live-weight gain (kg)				
Indoor winter period	49	56	3.2	
Early turnout to 8 days post late turnout	21	5	1.7	***
8 days post late turnout to housing	144	153	3.5	P=0.10
Early turnout to housing	165	159	4.1	
Grazing season	165	149	4.2	**
Indoor winter + grazing season	214	205	5.6	
Housing to slaughter	85	82	4.2	
Early turnout to slaughter	250	241	5.5	
Live-weight gain (g/day)				
Indoor winter period	403	394	25.2	
Actual grazing season	853	868	22.8	
Post late turnout to housing	880	934	21.4	P=0.08
Carcass traits				
Carcass weight (kg)	335	336	4.2	
Kill-out proportion (g/kg)	549	557	2.6	*
Carcass conformation[1]	3.3	3.1	0.03	
Carcass fat[2]	4.2	4.1	0.09	

[1]Scale 1 to 5 (best conformation).
[2]Scale 1 to 5 (fattest).

Table 6. Effect of supplementary concentrate feeding level and turnout date to pasture on live weight and carcass traits in Experiment 3

	Concentrate level (C)		Turnout date (T)		s.e.	Significance		
	Low	High	Early	Late		C	T	C × T
Live weight (kg)								
Initial	317	319	318	318	2.9			
At early turnout date	353	386	368	370	3.7	***		
At actual turnout date	356	391	368	380	3.8	***	*	
8 days post late turnout	367	394	387	374	3.6	***	*	
Housing	523	531	537	518	5.1		**	*1
Slaughter	598	607	611	594	5.5		*	
Live-weight gain (kg)								
Indoor winter period	39	73	50	62	2.0	***	***	
Early turnout to 8 days post late turnout	14	9	20	4	1.3	**	***	***2
8 days post late turnout to housing	156	138	150	144	4.1	**		
Early turnout to housing	171	146	170	147	4.4	***	***	*3
Grazing season	167	141	169	138	4.5	***	***	*4
Indoor + grazing season	206	213	219	200	4.7		**	*5
Housing to slaughter	75	75	74	76	3.0			
Early turnout to slaughter	246	221	243	224	4.9	**	**	
Live-weight gain (g/day)								
Indoor winter period	301	572	422	450	15.2	***		
Grazing season	954	800	913	842	25.2	***	P=0.05	
Carcass traits								
Carcass weight (kg)	327	333	336	323	3.4		*	
Kill-out proportion (g/kg)	546	545	547	545	3.3			
Carcass conformation[6]	3.1	3.2	3.1	3.2	0.12			
Carcass fat[7]	3.6	3.9	3.7	3.8	0.16			
Kidney and channel fat (kg)	7.3	7.9	7.6	7.6	0.52			

[1] = 541, 505, 533 and 531.
[2] = 26, 3, 13 and 5
[3] = 189, 151, 149, 144.
[4] = 190, 144, 149 and 132.
[5] = 222, 189, 216 and 211 for Low Early, Low Late, High Early and High Late treatments, respectively.
[6] Scale 1 to 5 (best conformation) [7] Scale 1 to 5 (fattest).

did not differ (Figure 1). Slaughter weight did not differ (P>0.05) between the concentrate levels, whereas slaughter weight was heavier (P<0.05) for ET compared to LT.

Live-weight gain over the indoor winter period was 34 kg higher (P<0.001) for HC compared to LC and 12 kg higher (P<0.001) for LT than ET. There were concentrate level × turnout date interactions for live-weight gain from turnout to 8 days post late turnout, from early turnout to housing, for the actual grazing season and for total indoor and grazing periods combined. These interactions were attributed to differences in magnitude of effects, whereby the difference in live-weight gain between the concentrate supplementation levels were much greater for ET compared to LT. Live-weight gain during the finishing period did not differ (P>0.05) between the treatments.

Daily live-weight gain during the indoor period was higher (P<0.001) for

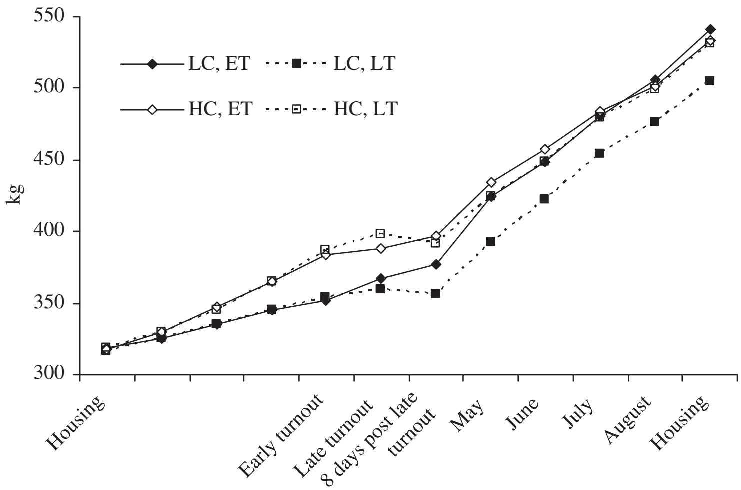

Figure 1. Effect of winter concentrate feed level (Low (LC) and High (HC)) and spring turnout date to pasture (Early (ET) and Late (LT)) on live weight in Experiment 3.

HC compared to LC, but did not differ (P>0.05) between the turnout dates. Subsequent daily live-weight gain during the grazing season was higher (P<0.001) for LC compared to HC, and higher (P=0.05) for ET than LT.

Carcass weight did not differ (P>0.05) between the levels of concentrate supplementation but was higher (P<0.05) for the ET compared to LT. Kill-out proportion and carcass conformation and fat scores and weight of kidney and channel fat did not differ (P>0.05) between the treatments.

Herbage yield at silage harvesting was lower (P<0.001) for swards grazed in Spring compared to those not grazed, but the *in vitro* DMD and DOMD of the herbage was higher (P<0.01) (Table 7). There was no effect (P>0.05) of spring grazing on crude protein or ash concentrations of the herbage.

Economic and risk analysis

The effect of concentrate feeding level on NFM was dependent on sale date such that where progeny were sold at the start of the second grazing season, the end of

Table 7. Herbage yield, chemical composition and nutritive value for four treatments

Silage harvest date	Early (20 May)		Late (8 June)		s.e.	Significance	
Spring grazing treatment	Grazed	Ungrazed	Grazed	Ungrazed		Harvest date	Grazing
Yield at closure of grazed plots (kg/ha DM)	1,066	2,236	1,035	2,198	217.6		***
Days to harvest	49	49	68	68			
Yield at harvest (kg/ha DM)	3,236	4,966	5,756	6,562	198.1	***	***
Crude protein (g/kg DM)	167	162	131	132	3.7	***	
Ash (g/kg DM)	80	81	75	75	1.6	*	
Dry matter digestibility(g/kg)	794	772	734	692	7.0	***	**
Digestible organic matter in the DM (g/kg)	739	701	684	635	8.9	***	**

the second grazing season or were taken though to finish, HC increased, decreased or had no effect, respectively, on NFM (Table 8).

The effect of turnout date on NFM was also dependent on sale date; where sale date was at the start or end of the grazing season NFM was slightly greater for LT; however, where progeny were taken through to finish the opposite effect was found. Date of sale had a considerable impact on NFM with the lowest margin where progeny were sold at the start of the grazing season and the highest margin where progeny were retained through to finish. Significant variation in NFM was found with the level of variation greater for earlier sale dates. However, despite the large variation in NFM, no scenarios showed negative NFM at the 5% level. A notable aspect of the results was the sensitivity of the scenarios to animal sale price. The sensitivity to sale price was much greater where sale date was delayed until later in the animal's life.

Discussion

Effect of concentrate supplementation on animal performance

Live-weight gain responses by continental crossbred weanlings to additional supplementary concentrate offered during the indoor period were subsequently largely lost due to compensatory growth at pasture. A compensation index (the additional live-weight gain during re-alimentation at pasture by animals previously offered the low concentrate level divided by the additional live-weight gain in winter by those offered the high concentrate level – Hornick *et al.* 2000) of 0.68 was obtained for Experiment 1. The equivalent value in Experiment 3 for cattle turned out "late" was 0.35, whereas it was 1.21 for those turned out "early". Other studies with yearling cattle turned out to pasture have found compensation values ranging from 0.24 to 0.80 (Ferrer Cazcarra and Petit 1995; Kyne, Drennan and Caffrey 2001; Keane 2005; Marren *et al.* 2013); compensation indexes of greater than 1.00, as achieved here, are

Table 8. Effect of date of sale, supplementary concentrate feeding level and turnout date to pasture on net farm margin (€/ha) in Experiment 3

			Net farm margin (€/ha)				Sensitivity analysis	
Sale date	Concentrate feeding[1]	Turnout date[2]	Mean	Standard Deviation	5% Confidence Interval	95% Confidence Interval	Sale price (€)[3]	Concentrate price (€)[4]
Start of	Low	Early	268	110.7	90	455	77	2.20
second	Low	Late	299	109.3	122	481	76	3.03
grazing	High	Early	269	116.8	80	467	80	5.65
season	High	Late	324	118.2	138	526	81	6.09
End of	Low	Early	382	68.5	271	498	151	2.66
second	Low	Late	369	67.2	262	483	144	3.51
grazing	High	Early	314	312.7	204	426	149	5.36
season	High	Late	353	66.5	245	467	149	5.88
End of	Low	Early	405	90.7	258	557	158	6.27
finishing	Low	Late	396	85.8	257	540	152	6.91
period	High	Early	407	90.2	262	559	157	8.29
	High	Late	389	89.4	245	543	156	9.36

[1]Concentrate feeding level during the first winter, low = 0.5 kg/d, high = 2.0 kg/d.
[2]Turnout date to pasture for the second grazing season, Early = 22 March, Late = 12 April.
[3]Impact of 10c/kg change in live animal or beef carcass price on net margin per hectare.
[4]Impact of €10/t change in concentrate price on net margin per hectare.

unusual (Hornick *et al*. 2000). The extent of compensation is largely a function of the initial weight (age) of the animal, previous nutritional level, and degree and length of the winter restriction relative to the length of the subsequent grazing season (or recovery period) (Drennan and Harte 1979; Keane 2002), factors which varied substantially across experiments.

An additional 1 kg live weight per 4.4 kg and 5.5 kg of extra concentrate offered to the high concentrate groups was obtained at the end of the winter period in Experiments 1 and 3, respectively. These values are intermediate to previous responses of 3.8 kg (Keady *et al.* 2004) and 6.3 kg (Kyne *et al.* 2001) who evaluated 0 kg and 1.5 kg and, 0.5 kg and 1.5 kg concentrate daily, respectively, as supplements to grass silage with similar cattle. Silage DM intake relative to body weight in Experiment 3 concurs with the findings of Kyne *et al*. (2001) and the substitution rate of 0.29 kg grass silage DM intake per kg concentrate DM is consistent with previous comparable studies (McGee 2005). Disparities between experiments in animal live weight responses to supplementation can be primarily attributed to differences in the quantity of concentrates and the nutritive value of the grass silage offered (McGee 2005) but also, growth potential of the cattle.

Effect of early turnout to pasture on animal performance

About 0.05 of the total annual yield of herbage DM accumulates during the period November to early-March at Teagasc, Grange. Turnout of livestock to pasture in spring has to be delayed until grass growth begins and sufficient herbage has accumulated to meet animal demand. Additionally, grazing conditions, which are largely dictated by the prevailing soil and weather conditions, must be adequate. Grass growth commences rapidly at this site ca. mid-March (Drennan and McGee 2008), which largely reflects recorded ambient soil temperatures. Considering that a grass growing day is classified as a day where soil temperature is >5 ˚C at 9.00 am (O'Donovan *et al.* 2010), it is not surprising that earlier growth at this site is not readily stimulated by advanced application of fertiliser N (O'Kiely and O'Riordan 2003), or by use of contrasting perennial ryegrass cultivars (Humphreys and O'Kiely 2006). Consequently, the early turnout dates used in this study reflect what is feasible for the location and the difference between the dates replicate realistic commercial targets. Clearly, extending the duration between turnout dates would magnify any treatment effects – for example, the difference between turnout dates used by Steen (2002) was 6 weeks (14 Mar v. 2 May) – but as turnout date to pasture in seasonal grass-based systems should be approximately aligned with prevailing on-farm grass supply, an excessively large interval between dates is impractical.

Caution is necessary in interpreting changes in live weight following turnout to pasture. Cattle previously offered a grass silage-based diet to appetite and subsequently turned out to pasture experience a reduction in live weight associated with the transition, mainly due to changes in gut fill, which can vary according to concentrate feed level. Marren *et al.* (2013) reported that yearling bulls, offered grass silage *ad libitum* and supplemented with either, 2, 4 or 6 kg of concentrates daily during the winter period, had reductions in live weight 2 days following turnout to pasture of 16, 19 and 27 kg, respectively. Consequently, recording live weight after a sufficient time period to allow for gut fill adjustment is necessary.

Cattle turned out to pasture three weeks earlier in both Experiments 2 and 3 were ca. 14 kg heavier 8 days after the late turnout date. In Experiment 2 the difference in live weight declined to a non-significant 6 kg by the end of the grazing season, equivalent to a compensation index of 0.56 thus, reducing the advantage of early turnout. In contrast, in Experiment 3 there was an interaction between treatments whereby for the HC animals, the difference in live weight at housing declined to only 2 kg, which is similar to Experiment 2, whereas for the LC animals it increased to 36 kg in favour of ET. This demonstrated that where nutrient restriction during the indoor winter period occurred over a longer period (i.e., LC, LT) animal live-weight gain at pasture is lower, whereas conversely, when the duration and/or severity of the restriction is not great (i.e., LC, ET) live-weight gain is higher (compensation) (Figure 1). Drennan and Harte (1979) also found that compensatory growth is reduced following prolonged under-nutrition. Using comparable treatments to this study, Kyne *et al.* (2001) found no interactions but this may be partly attributable to the comparatively higher growth (558 v. 301 g/day) during the winter of animals offered the low supplementation level in that experiment. Overall, this suggests that when live-weight gain of late-maturing continental weanling cattle is low during the indoor winter period (ca. 300 g/day in this study), compensatory growth during the subsequent grazing season is curtailed if the duration of that level of restriction is prolonged (proportionately 0.18 in this instance), i.e., turned out to pasture late, but not if turned out early.

With the exception of the LC, LT treatment in Experiment 3, collectively these results and those of previous (O'Riordan *et al.* 1998; Kyne *et al.* 2001) and more recent studies (Gould *et al.* 2011a; O'Riordan, Keane and McGee 2011a; O'Riordan *et al.* 2011b) that have examined the effect of earlier (3 to 4 weeks) turnout date to pasture in spring on live-weight gain of yearling beef cattle previously offered grass silage-based diets show that, after allowing for changes in gut fill, in the immediate weeks following turnout to pasture of the late turnout groups, cattle turned out to pasture earlier gained between 5 and 16 kg more live weight. This is largely a manifestation of the difference in growth rate obtained on a lower (grass silage-based) compared to a higher (grazed grass) nutritive value diet over a duration of 3 to 4 weeks. These differences in live weight change were initially evident as a significant divergence in absolute live weight in some (O'Riordan *et al.* 1998, 2011a, b) but not all (Kyne *et al.* 2001; Gould *et al.* 2011a) studies. However, in all studies cited, there were no significant differences between turnout dates in absolute live weight of cattle at the end of the grazing season. Collectively, this suggests that there are only transitory benefits in performance (live weight) of beef cattle from early turnout to pasture in spring. These findings contrast with dairy cow systems where the improvement in animal performance (increased milk production; Dillon *et al.* 2002) from providing access to grazed pasture in early spring, compared to animals indoors on grass silage-based diets, is captured immediately. Additionally, the variance associated with recording animal live weight is greater than that of recording milk production.

The absence of a difference in carcass weight between the two turnout dates in Experiment 2 is similar to the findings of Kyne *et al.* (2001) who reported a non-significant 1.8 and 4.7 kg of carcass in heifers slaughtered at 20 months and steers slaughtered at 24 months of age, respectively, in favour of the early turnout treatments. The significant effect of turnout date on carcass weight in Experiment 3 (acknowledging the limited heifer carcass data available) is largely a reflection of the effect of the LC, LT.

Effect of spring grazing on subsequent herbage yield and quality

O'Riordan *et al.* (1998) showed that previous grazing of the silage sward caused a greater reduction in grass yield at earlier than at later silage harvest dates, or in other words, the shorter the interval between spring grazing and silage harvesting the greater the negative impact of grazing on herbage yield. The reduction in yield of herbage for silage harvesting of 0.35 and 0.12 for the early and late harvest dates, respectively, concurs with this and the corresponding values of 0.24 and 0.06 reported by Kyne *et al.* (2001). Similarly, Gould *et al.* (2011a) found that early grazing (from 19 March to 9 April) reduced yield of herbage harvested for silage on 2 June by 0.25.

The nutritive value of herbage at both silage harvest dates was increased with early grazing. Grazing swards in spring that are subsequently harvested for first-cut silage can result in a higher *in vitro* DMD of the herbage at harvest (O'Riordan *et al.* 1998) and in the conserved grass (Humphreys and O'Kiely 2006), although the difference is not always significant (Kyne *et al.* 2001; Gould *et al.* 2011a). The degree to which spring grazing enhances subsequent digestibility of herbage may be attributed to management practices the previous autumn. For example, an early autumn closing date (which may be a result of inclement grazing conditions) can decrease the *in vitro* DMD of herbage because of higher proportions of dead material, and to a lesser extent, a higher proportion of stem, compared with closing swards later in autumn (Hennessy *et al.* 2006). In that case, spring grazing can have a large positive effect on DMD of grass harvested for silage (O'Riordan *et al.* 1998). Spring grazing may also result in additional ensilability and conservation benefits and thus, crops that are easier to preserve as silage provided that adequate fermentable substrate is available (Humphreys and O'Kiely 2007). Likewise, early spring grazing has been shown to improve herbage digestibility in subsequent grazing rotations (Kennedy *et al.* 2006, 2007).

Consequently, for successful integration of early grazing into seasonal beef production systems, the decrease in the quantity of grass harvested (net energy basis) for conservation must not be greater than the reduction in animal requirements associated with the shorter indoor winter period.

Economic and risk analysis

The appropriate level of concentrate feeding during the first winter was largely dependent on date of sale. Where progeny were sold at the start of the second grazing season, a higher level of meal feeding can be justified as this is captured in heavier sale live weight and consequently, higher animal value. However, where sale was delayed until after a season at pasture, the effect of compensatory growth at pasture for progeny fed lower levels of concentrate during the first winter eliminated most of the live weight advantage gained by those fed higher levels of concentrate and correspondingly, NFM was greater for the low concentrate feeding regime.

At the end of the first winter, early turnout to pasture resulted in greater NFM only where progeny were taken through to slaughter. For systems selling progeny earlier in the animal's life early turnout was found to decrease NFM. These results must be viewed in the context of the data presented in Table 7, showing the effect of spring grazing on silage harvest yields and digestibility. There was a considerable reduction in silage yield where the silage area was grazed in spring with the associated increase in silage digestibility small by comparison. Therefore, from a whole-farm system perspective, silage area required was greater and the remaining area available for grazing was reduced. To compensate for the smaller grazing area, fertiliser application rates for grazing were increased. The combination of greater silage area and higher fertiliser application rates increased costs substantially. Similarly, Finneran *et al*. (2012) found that grazing of the silage sward in spring did not provide any economic benefit when the nutritional value of the silage was not limiting animal productivity under a non-grazed strategy. Although the results obtained here would appear to contradict those of Crosson, McGee and Drennan (2009), who found that NFM increased by €1.17/ha for each day that turnout to pasture for yearling cattle was advanced, the earlier analysis was framed in the context of earlier turnout onto grazing area and did not simulate grazing of silage area.

In relation to the production systems modelled, selling progeny as finished cattle was most profitable. The relatively low NFM where progeny were sold at the start of the second grazing season suggests yearling sale values do not adequately offset the over-wintering costs incurred and that a season at pasture, where high levels of live-weight gain can be achieved at relatively low-cost, is thus, more profitable. The carcass value for the period from which the data were taken (January 2008 to December 2012) adequately rewarded the costs incurred during finishing and therefore, NFM was greater for systems taking cattle through to finish than those selling cattle at the end of the second grazing season. However, sensitivity analysis indicates that this system is highly sensitive to the prevailing beef price.

Monte Carlo simulation permitted the assessment of the impact of price uncertainty on net farm margin. This analysis highlighted the significant impact that the price fluctuations experienced in the 5-year period, January 2008 to December 2012 had on economic performance. In particular, these results indicate that relatively modest price changes can change the ranking of production systems selling at the end of the second grazing and taking progeny through to finish. It would require more extreme changes in output prices for the production system selling progeny at the start of the second grazing season to return a higher margin than either alternative sale dates.

Additional considerations

Initial turnout date to pasture in spring is largely dependent on interactions between many factors including soil type, weather, grass growth, sward management and grazing conditions (O'Riordan *et al.* 1998). For example, Hennessy *et al.* (2006) showed substantial differences in relation to grass growth in favour of a site with free-draining acid brown earth with a sandy loam to loam texture in the south of Ireland compared to this site (north-east), an imperfectly drained brown earth, with a loam to clay loam texture, and a high base status. As a result, the degree to which early turnout to pasture can be easily exploited will vary substantially, and especially, according to geographical location but also from year to year in relation to meteorological conditions. Consequently, flexibility in grazing management is required. This may include using strategies such as "on-off" grazing, whereby animals are given restricted access time to pasture daily (O'Riordan *et al.* 1998; Gould *et al.* 2010, 2011b).

It is acknowledged that in locations with free-draining soils, higher soil temperatures and, with higher grass growth and grass covers earlier in spring, the advantage in favour of early turnout to pasture is likely to be increased. This is because animals can be turned out to pasture earlier than in the current experiments, and therefore, the negative effect of spring grazing on yield of herbage harvested for silage at a fixed harvest date, diminishes.

Conclusion

Subsequent compensatory growth at pasture diminished the growth advantage from concentrate supplementation of grass silage or early turnout to pasture, of young late-maturing continental crossbred cattle. Grazing the designated silage harvesting area reduced herbage yield but increased its nutritive value. Allowing cattle to graze early in spring will reduce requirements for grass silage (and concentrates), and slurry storage and spreading. However, in the context of whole-farm systems, under the conditions of this study early turnout to pasture in spring increased net farm margin only where progeny were taken through to finish. Similarly, additional concentrate supplementation improved net farm margin only where progeny were sold at the start of the second grazing season.

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