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Effect of suckler cow genotype on energy requirements and performance in winter and subsequently at pasture

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Three experiments using a total of 62 Charolais (C) and 110 Beef × Holstein-Friesian (BF) spring-calving cows were carried out to determine the relative energy requirements of the genotypes. Cows were individually offered a restricted allowance of grass silage daily during the last 85 and 107 days pre partum in Experiments 1 and 2, respectively, and *ad libitum* grass silage during the last 93 days pre partum in Experiment 3. In all 3 experiments grass silage was offered *ad libitum* during the first 34 days of lactation. In Experiments 1 and 2, cows and calves were grazed together during the subsequent grazing seasons. When fed to appetite, silage dry matter intake was similar for both cow genotypes but was higher for the BF cows when expressed relative to live weight. For Experiments 1 and 2 combined, initial live weights and live weight changes to post-partum, over the indoor period and at pasture were 720 (s.e. 14.1), 613 (s.e. 8.4), –74 (s.e. 4.0), –63 (s.e. 2.7), –106 (s.e. 6.0), –89 (s.e. 4.0) and 120 (s.e. 7.0), 88 (s.e. 5.3) kg for C and BF cows, respectively. In Experiment 3 the corresponding initial live weights and live weight changes to post partum were 759 (s.e. 12.3), 659 (s.e. 9.1) and –63 (s.e. 4.9) and –52 (s.e. 3.5) kg. There was no effect of genotype on body condition score or adipose cell diameter or their changes. Plasma creatinine concentrations were higher ($P < 0.001$) in C cows than BF cows. It is concluded that the energy requirements of a 660 kg C cow are approximately equivalent to a 600 kg BF cow during late pregnancy.

Keywords: Energy requirements; genotype; intake; suckler cows

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Introduction

Suckler cows account for half of the total cow population in Ireland (Central Statistics Office, 2004). Traditionally suckler cow replacements were obtained from the dairy herd, comprising mostly early-maturing British beef breed crosses (Hereford and Angus). From a comparison of Limousin × Friesian and Hereford × Friesian cows (Drennan and McGee, 2004) it was concluded that feed intake, live weight and live weight changes and reproductive performance were similar, but the male progeny from the former had higher growth rate and killing-out rate resulting in a leaner carcass of heavier weight. Estimates of breed composition of the suckler herd illustrate that between 1992 and 1998 the proportion of Friesian decreased from 0.20 to 0.02, early-maturing breed crosses decreased from 0.51 to 0.46 and late maturing continental breed crosses increased from 0.29 to 0.52 (Drennan, 1999). Furthermore, over 0.87 of suckler cows were bred to a continental sire breed in 2002 (Irish Cattle Breeding Federation, 2003).

The increased proportion of suckler cows in the national herd, the replacement of Friesians by Holsteins in the dairy herd, which is undesirable from a beef point of view (McGee *et al.,* 2005), and a preference for home-bred animals to reduce costs and avoid introducing disease have led to increased retention of replacements from within the suckler herd. This is likely to result in more pure-bred cows that will be mainly Charolais, as it the most widely used sire breed.

In suckler calf-to-beef systems approximately 50 to 70% of the total energy requirement is used by the cow herd and obviously an even greater proportion in calf-to-weanling systems (Montano-Bermudez and Nielsen, 1990). Moreover, two-thirds to three-quarters of the total energy requirement of beef cows is used for maintenance alone (Montano-Bermudez and Nielsen, 1990; Petit *et al*., 1995), which is equivalent to almost half of the total energy requirements in suckler calf-to-beef production systems.

Although values vary between studies, the cost of grass silage is generally found to be greater than grazed grass and thus winter feed costs can account for a substantial proportion of the annual cost of feeding the cow (Drennan and McGee, 2004). If these costs can be reduced without decreasing performance, the profitability of a suckler beef enterprise should be significantly improved. Consequently, for economic reasons, the nutrition of the spring-calving suckler cow generally involves feed restriction and mobilisation of body reserves during the winter period and recovery of body reserves on the cheaper produced pasture (Petit *et al*., 1995).

The objective of the present studies was to determine the relative nutrient requirements of upgraded Charolais and Beef × Holstein-Friesian cows as suckler dams. The data reported in this paper concern feed intake, changes in cow live weight, body condition score, adipose cell size, blood metabolites, calving difficulty and calf birthweight. Calf immunity, milk yield and calf pre-weaning performance data are presented by McGee, Drennan and Caffrey (2005a and b).

Materials and Methods

Animals and general management

Spring-calving, upgraded Charolais (C) (seven-eighths or greater) cows were compared with first cross Beef (Hereford and Limousin) × Holstein-Friesian cows over three consecutive indoor winter-feeding periods (between December 1993 and April 1996) and the subsequent summer grazing period after the first two winters. The Hereford × Holstein-Friesian cows were older than the Limousin × Holstein-Friesian cows as the latter were used for annual replacements throughout the three experiments. Consequently, the proportion of Hereford × Holstein-Friesian cows in the BF category declined from 0.8 to 0.5 over the three experiments. Each year the cows were bred using two Charolais sires, one by artificial insemination and the second by natural mating over a 3-month period. Hereford × Holstein-Friesian and Limousin × Holstein-Friesian were grouped as a single type (BF) for all genotype comparisons.

During the winter indoor feeding period the diet consisted of grass silage (*ad libitum* or restricted) and a mineral vitamin supplement (60 g cow^{-1} day^{-1}). Cows were accommodated in individual tie-up stalls from which they were removed prior to parturition (generally 1 to 4 days in advance) and placed in straw-bedded calving pens. After parturition animals remained in the pens for a minimum of 4 days with the calf having free access to the dam. The early calving cows (approximately the first 50 to 70% of cows) were returned to the tie-up stalls with their calves placed behind them in individual pens. Calves had twice daily (approximately 0800 to 0900 and 1600 to 1630) access to their dams for suckling. These cows provided intake data for the period from post partum until turnout to pasture. Later-calving cows and their calves were grouped together with 2 to 4 cows per pen.

Cows and their progeny were blocked at pasture according to C, Hereford × Holstein-Friesian and Limousin × Holstein-Friesian genotype across four grazing systems each with 15 cows (McGee, Drennan and Caffrey, 1998). The swards consisted predominantly of perennial ryegrass and were rotationally grazed. All calves were abruptly weaned in autumn at 7 to 8 months of age. Details of all key dates are summarised in Table 1.

Experiment 1

At the start of the indoor winter feeding period, (99 (s.d. 22.9) days pre partum) fifty-four (21 C and 33 BF) cows were offered second-cut grass silage *ad libitum* (0.05 to 0.10 in excess of intake) for a 28-day period with individual voluntary intake of silage recorded over the last 14 days. Subsequently, they were offered a fixed level of second-cut grass silage (30 kg fresh weight) per day for the last 85 (s.d. 22.9) days of pregnancy. During the post-partum period cows were offered first-cut grass silage *ad libitum* for an average of 30 (s.d. 18.6) days until turnout to pasture. Intake was recorded post partum on the early-calving (11 C and 21 BF) cows. Samples of silage were taken twice

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

Item	Experiment		
	1	2	3
Indoor feeding commences	Dec 8	Nov 28	Nov 21
Restricted diet commences	Jan 6	Nov 28	–
Average calving date	Mar 17	Mar 14	Mar 21
Turnout to pasture			
Group 1	Apr 14	Apr 12	Apr 4
Group 2	May 5	Apr 25	–
Housing date	Nov 14 to Nov 25	Oct 28 to Nov 21	–

weekly for dry matter (DM) determination and composited on a 14-day basis for chemical analysis. The *in vivo* digestibility of the silage fed pre partum was determined using 12 Friesian steers blocked according to live weight and randomly assigned to two treatments. The treatments were silage at 0.95 or 0.70 of their *ad libitum* intake. The study consisted of an initial 8-day recording period on *ad libitum* silage followed by an 8-day treatment adaptation period and a further 12 days in the digestibility unit on the dietary treatments. The silage and faeces were collected and processed over 5 two-day periods according to the methods of Moloney and O'Kiely (1997).

Cow live weight was recorded prior to morning feeding at the start of the study and every two weeks thereafter throughout the indoor feeding period, within 20 h of parturition, at turnout to pasture, monthly at pasture and post housing at the end of the grazing season. Cow body condition score was assessed weekly throughout the indoor feeding period and additionally at the same time as live weight measurements. Body condition score was assessed using the Scottish and French methods as described by Lowman, Scott and Somerville (1976) and Agabriel *et al.* (1986), respectively. Body condition was also estimated from adipose cell diameter. A sample of rump adipose tissue was taken by biopsy at the level of the *gluteus medius* muscle and the mean adipose cell diameter (ACD) was measured after osmium tetroxide fixation as described by Robelin *et al.* (1986). In this case, cell diameter was calculated from the photographs using an *Adobe Photoshop* package and calibrated microtek scanner in conjunction with a *Delta-T-Scan Image Area* analysis package. The adipose samples were obtained 10 days after commencing the restricted dietary level, at turnout to pasture and following housing at the end of the subsequent grazing season. During the indoor feeding period two blood samples were obtained every 14 days, by jugular venipuncture, from each cow prior to morning feeding using a vacutainer containing lithium heparin and one containing sodium fluoride and potassium oxalate for blood metabolite analysis. Calving difficulty was assessed on a 5-point scale (1 = no assistance to 5 = caesarean section) (Drennan and McGee, 2004) and calf weight was recorded within 12 h of birth.

Experiment 2

Fifty nine cows (21 C and 38 BF; 49 of which were used in Experiment 1) were offered a fixed level (30 kg fresh weight) of second-cut grass silage per day for the last 107 (s.d. 21.2) days of pregnancy. Cows were offered first-cut grass silage *ad libitum* post partum until turnout to pasture after an average of 36 (s.d. 3.9) days. Silage intake for the period from parturition until turnout to pasture was recorded for 14 C and 26 BF cows. Feed sampling and analyses, cow live weight and body composition assessments and blood sampling were as described in Experiment 1.

Experiment 3

Fifty nine cows (20 C and 39 BF; 44 of which were used in Experiment 1 and 50 in Experiment 2) were offered second-cut grass silage *ad libitum* for the last 93 (s.d. 15.5) days of pregnancy. Data for the period from parturition until turnout to pasture were obtained on 13 C and 17 BF early-calving cows. These animals were offered first-cut grass silage *ad libitum* post partum until the experiment ended on 4 April. For the remaining animals, the experiment finished after parturition. Silage samples were collected three times, weekly; otherwise feed sampling was as described in Experiment 1. Cow live weight, and blood sampling were as described in Experiment 1 and body condition score was assessed every two weeks but ACD was not determined.

Analytical procedures

The DM concentration of silage and faeces were determined by drying at 40 ^{o}C for 48 h in an oven with forced air circulation. The dried samples were ground through a 1 mm screen and analysed for dry matter digestibility (DMD) (Tilley and Terry, 1963), ash (muffle furnace at 550 ^{o}C), acid detergent fibre (ADF) and neutral detergent fibre (NDF) (Van Soest, 1963) and crude protein (Kjeldahl, N × 6.25). The gross energy (GE) concentration of wet silage (offered during the digestibility study) and faeces were determined using a Gallenkamp adiabatic bomb calorimeter. Silage juice extracts were used to determine pH. Expressed silage juice was also used to determine lactic acid concentration (O'Kiely and Moloney, 1994), volatile fatty acid composition (acetic, propionic and butyric acids) and ethanol concentration by gas liquid chromatography (Ranfft, 1973), residual water soluble carbohydrate concentration (Birch and Mwangelwa, 1974) and ammonia-N concentration using the Sigma Diagnostics method (171 UV) for plasma ammonia. Plasma albumin, beta-hydroxybutyrate (βHB), urea and creatinine were all measured using a Ciba-Corning Diagnostics 550 Express Clinical Chemistry Analyser and appropriate reagent kits (Randox Laboratories, Catalogue numbers AB 361, RB 1008, VR 221 and CR 52 for albumin, βHB, urea and creatinine, respectively). Plasma acetoacetate was determined using a modification of the method of Li *et al.* (1980) (J. Larkin, personal communication) but as concentrations were very low and negligible in some instances these data are not presented. Plasma glucose and non-esterified fatty acids (NEFA) were analysed using an Hitachi 705 clinical analyser and appropriate reagent kits (Randox Laboratories, GL 369 and FA 115 for glucose and NEFA, respectively).

Feed energy determination

Metabolisable energy (ME) of the silage was determined from its *in vitro* DMD using the following equation from MAFF (1984): ME (MJ/kg DM) = [(DMD (g/kg) – 61) × 0.011] + 3.2. Net energy (UFL(I)) of the silage was derived from *in vitro* DMD values using the feed tables published by O'Mara (1996).

Statistical analysis

For Experiments 1 and 2 combined, cow data were analysed using the PROC MIXED procedure of SAS (2001) for repeated measures with a model containing terms for genotype, experiment, genotype × experiment with effects for cow lactation number and calving date included as covariates. Cow data for Experiment 3 were analysed using PROC GLM (SAS, 2001) with a model containing terms for genotype and effects for cow lactation number and calving date included as covariates. The corresponding models for calf data also included terms for calf sex and sire of the calf. Least-squares means are reported with standard errors. Correlations were obtained using PROC CORR (SAS, 2001).

Results

Feed composition, digestibility and intake

The chemical composition of the silages offered pre and post partum in the three studies is presented in Table 2. *In vivo* digestibility of DM, organic matter (OM) and GE of the silage offered pre partum in Experiment 1, determined using steers fed at 0.95 and 0.75 of *ad libitum* intake, was unaffected by level of feeding. Digestibility coefficients (g/kg) for DM, OM, OM in

Table 2. Mean (s.d.) chemical composition and estimated energy value of silages offered pre- and post-partum in Experiments 1, 2 and 3

	Experiment 1		Experiment 2		Experiment 3	
Variable	Pre partum	Post partum	Pre partum	Post partum	Pre partum	Post partum
Dry matter (DM; g/kg)	220 (17.6)	234 (19.2)	194 (22.6)	217 (12.8)	262 (23.3)	208 (9.11)
pH	3.5 (0.12)	3.6 (0.00)	3.9 (0.41)	3.9 (0.08)	3.7 (0.22)	3.6 (0.08)
In vitro DM digestibility (g/kg)	633 (34.0)	740 (30.4)	639 (28.0)	751 (13.8)	686 (21.7)	767 (8.3)
Composition of DM (g/kg)						
Crude protein	130 (13.4)	148 (5.2)	147 (9.9)	154 (11.5)	136 (5.5)	154 (8.5)
Ash	100 (11.2)	92 (5.1)	84 (6.2)	88 (4.3)	86 (7.6)	85 (2.5)
Neutral detergent fibre	571 (55.4)	488 (49.4)	601 (24.1)	478 (21.7)	–	–
Acid detergent fibre	343 (29.2)	301 (28.3)	361 (14.0)	303 (13.2)	323 (15.7)	299 (12.0)
Lactic acid	136.1 (18.22)	148.6 (15.06)	123.8 (50.86)	129.5 (9.31)	88.7 (27.10)	150.4 (29.51)
Ethanol	5.4 (1.00)	5.9 (0.36)	8.3 (1.50)	9.4 (0.94)	4.1 (1.41)	6.1 (1.82)
Acetic acid	25.5 (4.68)	23.2 (3.57)	22.9 (5.48)	30.3 (3.21)	14.9 (3.16)	23.2 (1.29)
Propionic acid	1.9 (0.39)	0.8 (0.69)	2.2 (1.98)	0.8 (0.17)	0.8 (0.50)	0.8 (0.18)
Butyric acid	1.0 (0.84)	0.2 (0.23)	1.5 (2.43)	1.0 (0.25)	2.8 (2.98)	1.6 (1.20)
Residual WSC[a]	16.7 (1.74)	27.8 (11.59)	8.3 (5.19)	24.2 (4.37)	24.9 (10.94)	21.7 (1.86)
Ammonia-N (g/kg N)	77.4 (18.54)	84.3 (15.64)	98.4 (35.68)	63.7 (9.21)	81.7 (24.74)	85.5 (19.63)
Metabolisable energy (MJ/kg DM)	9.5	10.7	9.6	10.8	10.1	11.0
Net energy (UFL(I)[b]/kg DM)	0.70	0.84	0.71	0.85	0.78	0.87

[a] WSC = water soluble carbohydrates.
[b] UFL(I) – Unité fourragére lait (Ireland) (O'Mara, 1996).

the DM and GE were 670 and 655 (s.e. 7.6), 695 and 685 (s.e. 6.5), 628 and 618 (s.e. 5.9) and 661 and 648 (s.e. 20.1) for the 0.95 and 0.75 feeding level, respectively.

Ad libitum DM intakes of silage pre partum in Experiment 1 (over a 14-day period) and Experiment 3 (Figure 1) were similar (P > 0.05) for both genotypes (Table 3). When expressed relative to live weight intake was higher (P < 0.001) for BF cows. *Ad libitum* DM intake of silage post partum was not significantly different between genotypes but was higher (P < 0.001) for BF cows when expressed relative to weight.

Cow live weight and body composition

The effects of cow genotype on live weight, body condition score and ACD are presented in Table 4. At the start of the indoor winter feeding period in all 3 experiments, C cows were heavier by over 100 kg than BF cows (P < 0.001). For Experiments 1 and 2 combined there was no effect of genotype on live-weight loss pre partum. There was a genotype × experiment interaction (P < 0.05) for live-weight loss to post-partum reflecting the fact that there was no effect of genotype in Experiment 1 while in Experiment 2 live-weight loss was significantly greater (–72 vs. –50 kg) for C cows than BF cows.

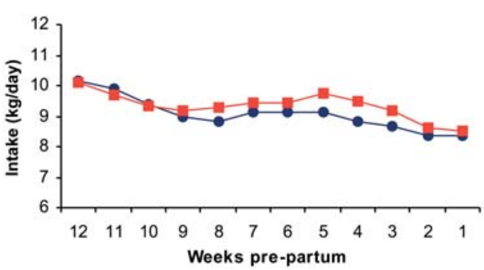

Figure 1: Silage dry matter intake of Charolais (–●–) and Beef × Holstein-Friesian (–■–) cows pre-partum (Experiment 3).

Compared to BF cows, C cows had a higher (P < 0.05) live-weight loss over the indoor winter period and subsequently a higher (P < 0.01) live-weight gain at pasture. In Experiment 3, live-weight gain pre partum was lower (P < 0.05) and live-weight loss to post partum (P = 0.07) and over the indoor winter feeding period higher for C cows than BF cows.

There was no significant effect of cow genotype on body condition score at the start of the winter indoor feeding period in any of the experiments using either the Scottish (Table 4) or French scoring method (not presented). The results from both body condition score methods were highly correlated (*r* = 0.74 to 0.85, P < 0.001). Body condition scores were lower when determined by the French method than by the Scottish method, particularly when cows were in poor body condition. Compared to BF cows, C cows had a greater body condition score loss prepartum in Experiments 1 and 2 combined (P = 0.08) and in Experiment 3 (P < 0.05) (Table 4). Body condition score loss over the indoor winter feeding period and body condition score gain at pasture did not differ significantly between genotypes using either scoring method. Similarly, there was no significant difference between the cow genotypes in ACD or ACD changes over the winter indoor feeding period or subsequently at pasture.

Plasma metabolite concentrations

Plasma metabolite concentrations are presented in Figure 2. In all 3 experiments creatinine concentrations were significantly higher in C cows than BF cows both pre- and pre partum. In both genotypes the concentrations of creatinine increased (P < 0.001) pre partum and decreased (P < 0.001) pre partum.

For Experiments 1 and 2 combined, C cows had significantly higher plasma NEFA concentrations pre partum than BF

Table 3. Daily silage dry matter (DM) and energy intake (s.e.) pre and post partum for Experiments 1 and 2 combined and Experiment 3

	Experiments 1 and 2 combined			Experiment 3		
	Charolais	Beef × Friesian	Significance	Charolais	Beef × Friesian	Significance
Intake pre partum						
Ad libitum						
DM (kg/day)	8.5 (0.17)[a]	8.6 (0.14)[a]		9.3 (0.21)	9.4 (0.15)	
DM relative to live weight (g/kg)	11.7 (0.32)[a]	14.0 (0.26)[a]	***	12.2 (0.27)	14.0 (0.19)	***
Metabolisable energy (MJ/day)	–	–		93.3 (2.08)	94.6 (1.54)	
Net energy[b] (UFL(I)/day)	–	–		7.2 (0.16)	7.3 (0.12)	
Restricted						
DM (kg/day)	6.2 (0.05)	6.2 (0.03)		–	–	
Metabolisable energy (MJ/day)	59.1 (0.43)	59.1 (0.28)		–	–	
Net energy[b] (UFL(I)/day)	4.3 (0.03)	4.3 (0.02)		–	–	
Intake post partum						
DM (kg/day)	9.5 (0.17)	9.3 (0.13)		9.3 (0.20)	9.2 (0.18)	
DM relative to live weight (g/kg)	15.2 (0.33)	17.4 (0.24)	***	12.9 (0.37)	15.4 (0.32)	***
Metabolisable energy (MJ/day)	102.0 (1.88)	99.7 (1.45)		101.7 (2.22)	101.3 (1.92)	
Net energy[b] (UFL(I)/day)	8.1 (0.15)	7.9 (0.12)		8.1 (0.18)	8.0 (0.15)	

[a] Intake recorded over 14-day period prior to feed restriction.
[b] UFL(I) – Unité fourragére lait (Ireland) (O'Mara, 1996).

Table 4. Cow live weight and changes, body condition score and changes, adipose cell diameter and changes, calving difficulty score and calf birth weight (s.e.) in Experiments 1 and 2 combined, and Experiment 3

	Experiments 1 and 2 combined			Experiment 3		
	Charolais	Beef × Friesian	Significance	Charolais	Beef × Friesian	Significance
Live weight (kg)						
Initial	720 (14.1)	613 (8.4)	***	759 (12.3)	659 (9.1)	***
Change pre partum	–3 (3.1)	–5 (2.0)		14 (4.38)	28 (3.24)	*
Change to within 20 h post partum	–74 (4.0)	–63 (2.7)	*[a]	–63 (4.9)	–52 (3.5)	P = 0.07
Change over winter	–106 (6.0)	–89 (4.0)	*	–100[b] (6.7)	–91[b] (5.9)	
Change turnout to housing	111 (4.8)	94 (3.9)	**	–	–	
Condition score[c]						
Initial	3.30 (0.122)	3.35 (0.077)		3.20 (0.138)	3.19 (0.102)	
Change pre partum	–0.84 (0.074)	–0.68 (0.060)	P = 0.08	–0.40 (0.095)	–0.11 (0.070)	*
Change to within 20 h post partum	–1.14 (0.056)	–1.12 (0.052)		–0.64 (0.108)	–0.55 (0.078)	
Change over winter period	–1.01 (0.084)	–1.06 (0.063)		–0.36[b] (0.132)	–0.43[b] (0.118)	
Change turnout to housing	0.86 (0.084)	1.01 (0.077)		–	–	
Adipose cell diameter (μm)						
Initial	125.0 (3.34)	128.9 (2.10)		–	–	
Change over winter period	–14.6 (3.31)	–9.5 (2.16)		–	–	
Change turnout to housing	12.0 (3.51)	8.9 (2.79)		–	–	
Calving difficulty score	1.4 (0.17)	1.6 (0.12)		1.5 (0.24)	1.5 (0.17)	
Calf birth weight (kg)	47.2 (1.21)	45.6 (0.77)		48.0 (1.34)	46.7 (0.99)	

[a] Genotype × Experiment interaction.
[b] Early-calving cows only.
[c] (Lowman *et al*., 1976).

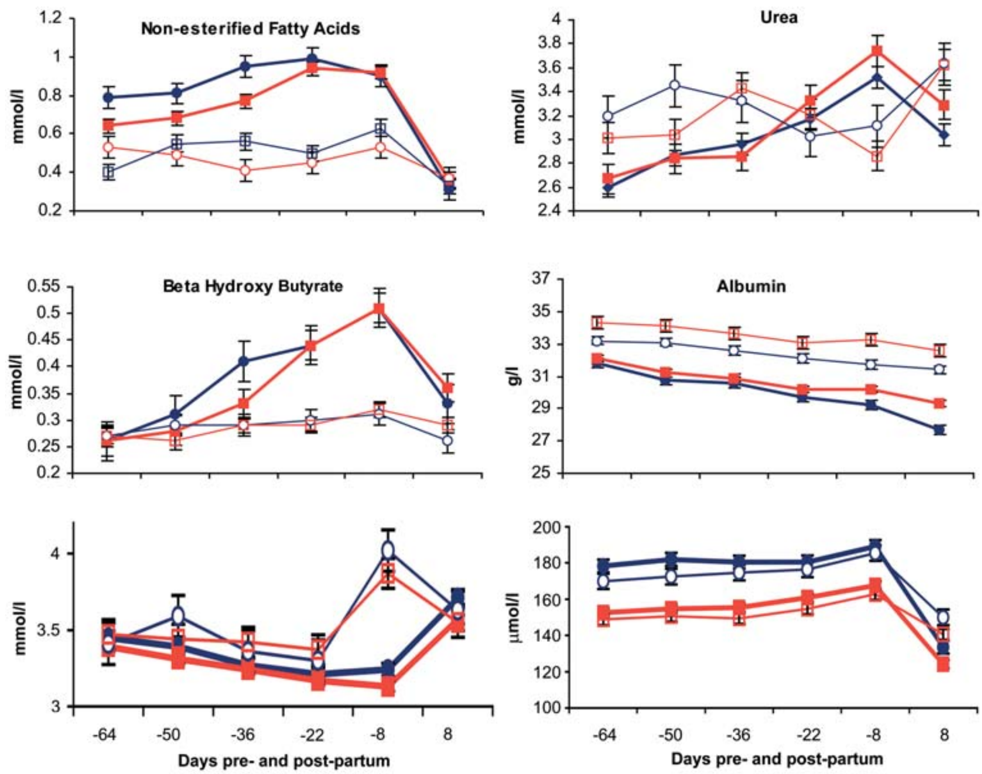

Figure 2: Plasma metabolite concentrations pre and post partum in Charolais (C) and Beef × Holstein-Friesian (BF) cows for Experiments 1 and 2 combined (C = —●—; BF = —■—) and Experiment 3 (C = —○—; BF = —□—). Vertical bars represent s.e.

cows but there was no significant difference between genotypes post partum. In both genotypes the concentrations of plasma βHB, NEFA and urea increased (P < 0.001) while concentrations of plasma glucose and albumin levels decreased (P < 0.001) post partum. During the post-partum period, the concentrations of plasma βHB, NEFA, urea and albumin decreased (P < 0.001) and glucose concentrations increased (P < 0.001) in both genotypes. In Experiment 3, plasma albumin concentrations were higher (P < 0.001) for BF cows than C cows both pre and post partum. In both genotypes the concentrations of plasma albumin decreased (P < 0.001) and βHB increased (P < 0.05) post partum.

There was no effect (P > 0.05) of genotype on calving difficulty or calf birthweight (Table 4).

Discussion

Silage digestibility and DM intake

All silages were well preserved, as indicated from pH values and ammonia concentrations. The silages offered pre- and post-partum had low and high digestibilities, respectively. The absence of an effect of level of feeding on silage digestibility is in accord with the results of previous studies in which all-forage diets were offered (Russel and Wright, 1983a; Ortiques *et al.*, 1993). This contrasts with diets containing concentrates, where digestibility declines as feeding level is increased (Chillard *et al.*, 1995).

Despite the difference of over 100 kg in live weight between the two cow genotypes, absolute *ad libitum* intakes during pregnancy in Experiments 1 and 3, were similar. While intake increases with size within breed or beef-cow type (Petit *et al.*, 1992) there are breed differences in intake. Geay and Micol (1989) reported a proportionately 0.06 and 0.10 lower intake for purebred Charolais bulls compared to Charolais × Friesian/Holstein and Friesian/ Holstein bulls, respectively. Similarly, Keane (1995) reported that the intake of Charolais × Friesian steers was proportionately 0.04 lower than Friesian steers and 0.07 lower than Holstein steers at a fixed weight. Thus, the dairy proportion of the BF cows would be expected to increase intake by about 5% thereby partially explaining the lack of a significant difference observed in the present study. The decline in silage intake pre partum in Experiment 3 agrees with previous reports in dairy (Ingvartsen, Andersen and Foldager, 1992) and beef (Petit *et al.,* 1995) cows but not with the study of Drennan and Bath (1976). In all three experiments silage intake post partum was similar for both genotypes despite the higher milk yield (McGee *et al.,* 2005b) of the BF cows. The similarity in grass silage intake capacity of both genotypes has important feeding and economic implications. The voluntary forage intake of beef cows ranges from less than 15 to more than 25 g DM per kg live weight (Petit *et al.*, 1992). The low *ad libitum* intake of grass silage relative to live weight in the present study (means of 11.7 to 14.0 and 12.9 to 17.4 g DM per kg live weight in mid-late pregnancy (low DMD silage) and early lactation (high DMD silage), respectively) is in accord with previous reports offering unwilted grass silage of moderate DM to suckler cows (Drennan and McGee, 2004).

Cow energy requirements

The large live-weight difference between the genotypes reflects the large mature size of the Charolais breed compared to the Hereford, Limousin or Friesian breeds. Using published figures from current feeding systems, maintenance requirements based on the recorded live weights would be approximately 8 to 10% (about 6.7 MJ of ME per day) greater for the C cows than the BF cows (INRA, 1989; AFRC, 1993; NRC, 2000). Despite the sizeable disparity in live weight between the genotypes, the live-weight loss pre partum (Experiments 1 and 2 combined) was similar for both genotypes (difference of 2 kg) and the difference (11 kg) in live-weight loss to post partum, while statistically significant, was relatively small. In Experiment 3, when cows were fed to appetite, the differences between the genotypes in live-weight loss prepartum (14 kg) and to post partum (11 kg) were again relatively small although intakes were numerically higher for the lighter BF cows. These results suggest that the energy requirements of the heavier C cows are only marginally greater.

While the energy content of body weight loss varies depending on its composition, which largely reflects cow body condition (Wright and Russel, 1984; Agabriel and Petit, 1987) and the magnitude of the weight loss (Petit and Agabriel, 1993) it is reasonable to assume that mobilisation of subcutaneous fat was the primary mechanism in both genotypes, considering the good body condition score at the start of the winter indoor period. Using the dietary energy value of approximately 27 MJ of

ME per kg live-weight loss (Russel and Wright 1983a; Petit *et al.*, 1992) the 11 kg higher weight loss of the C cows to within 20 h post-partum averaged over the three experiments equates to an additional 297 MJ of ME or 3.1 MJ of ME per day. When adjusted for differences in daily ME intake (zero in Experiments 1 and 2 combined and –1.3 MJ in Experiment 3) this means that an extra 2.8 MJ of ME per day was required by the C cows for the additional 100 kg live weight. While acknowledging that the methodology used is subject to cumulative errors this value is only 0.4 of the additional theoretical requirements based on live weight. Consequently, in this study the energy requirement of a 600 kg BF cow was approximately equivalent to that of a 660 kg C cow in late pregnancy. This difference in energy requirement may be partially ascribed to the proportion of dairy breed in the crossbred. The maintenance energy requirements of dairy breeds and beef × dairy genotypes are approximately 0.20 (Taylor, Thiessen and Murray, 1986; Solis *et al.*, 1988) and 0.10 (Thompson *et al.,* 1983) greater respectively, than beef breeds.

The ability of suckler cows to replenish the body reserves, mobilised over the winter period, during the subsequent grazing season was clearly evident. The greater live-weight gain at pasture by the C cows compared to the BF cows may be partly attributed to the lower milk yield of the former (McGee *et al.,* 2005b) but may also be due to the fact that C cows lost more live weight during the winter period and thus exhibited a compensatory-like growth at pasture (Drennan and Bath, 1976; Agabriel and Petit, 1987; Drennan and McGee, 2004).

The changes in ACD diameter over the winter and subsequently at pasture in Experiments 1 and 2 reflected the changes in cow body condition score in accord with other studies (Ortiques *et al.*, 1993; Agabriel *et al.,* 1995).

Blood metabolites

The significant decrease in plasma glucose pre partum and the concomitant increase in plasma NEFA and βHB pre partum in both C and BF cows indicated that both genotypes were mobilising body fat during this period. The changes in the three metabolites broadly agree with previous findings where underfed or more severely restricted animals had lower glucose concentrations and higher NEFA and βHB concentrations than adequately fed or better fed animals (Russell and Wright, 1983b; Sinclair, Broadbent and Hutchinson, 1994). The fact that plasma creatinine concentrations were significantly higher in C cows pre partum and decreased in both genotypes post partum, thus closely paralleling changes in live weight, agrees with previous reports that creatinine reflects muscle mass (Istasse *et al.,* 1990). As creatinine is a by-product of the breakdown of creatine and phosphocreatine, an energy storage compound in muscle, the increase in plasma creatinine concentration pre partum implies that both genotypes were also mobilising muscle tissue. This is substantiated by the concomitant decrease in plasma albumin concentrations (Sykes, 1978). Furthermore, as all cows were offered the same restricted level of silage throughout the pre-partum period in Experiments 1 and 2, dietary supplies of urea should be relatively constant, thus the increase in plasma urea concentrations pre partum may also indicate that body protein was being mobilised and used as an energy precursor. Therefore, body tissue mobilisation consisted of lipolysis and muscle tissue breakdown. In general, the changes in blood metabolites over time observed in Experiments 1 and 2 combined were not as evident in Experiment

3. This may be attributed to the fact that silage allowance was restricted in the former case, thus resulting in a greater mobilisation of body reserves coupled with minimised variation in dietary influences related to sampling.

In conclusion, although C cows were 100 kg heavier than BF cows voluntary silage intake pre and post partum was similar for both genotypes and it is estimated that the energy requirement of a 600 kg BF cow is approximately equivalent to a 660 kg C cow in late pregnancy.

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References

Agabriel, J. and Petit, M. 1987. Recommandations alimentaires pour les vaches allaitantes. *Bulletin Technique*, C.R.Z.V., Theix I.N.R.A. **70:** 153–166.

Agabriel, J., Giraud, J.M., Petit, M., Barboiron, C., Coulaud, G. and Decuq, F. 1986. Determination et utilisation de la note d'etat d'engraissement en elevage allaitant. *Bulletin Technique*, C.R.Z.V. Theix I.N.R.A. **66:** 43–50.

Agabriel, J., Petit, M., Ollier, A. and Chilliard, Y. 1995. Effects of underfeeding on body reserves variations and on energy efficiency of lactating Charolais cows. *Annales de Zootechnie* **44:** 317.

AFRC (Agricultural and Food Research Council). 1993. "Energy and Protein Requirements of Ruminants". An advisory manual prepared by the AFRC Technical Committee on Responses to Nutrients. CAB International, Wallingford, UK.

Birch, G.G. and Mwangelwa, O.M. 1974. Calorimetric determination of sugars in sweetened condensed milk products. *Journal of the Science of Food and Agriculture* **25:** 1355–1362.

Central Statistics Office 2004. *Livestock Survey*, Statistical Release, December 2003, CSO Dublin, 4 pages.

Chilliard, Y., Doreau, M., Bocquier, F. and Lobley, G.E. 1995. Digestive and metabolic adaptations of ruminants to variations in food supply. In: "Recent developments in the Nutrition of Herbivores". (ed. M. Journet, E. Grenet, M-H. Farce, M. Theriez and C. Demarquilly). *Proceedings of the IVth International Symposium on the Nutrition of Herbivores,* INRA, Editions, Paris, pages 329–360.

Drennan, M.J. 1999. "Breed Composition of the Irish Cattle Herd", Beef Production Series No. 22, Teagasc, Dublin, ISBN 1 84170 140 8, 26 pages.

Drennan, M.J. and Bath, I.H. 1976. Single-suckled beef production 3. Effect of plane of nutrition during late pregnancy on cow performance. *Irish Journal of Agricultural Research* **15:** 157–168.

Drennan, M.J. and McGee, M. 2004. Effect of suckler cow genotype and nutrition level during the winter on voluntary intake and performance and on the growth and slaughter characteristics of their progeny. *Irish Journal of Agricultural and Food Research* **43:** 185–199.

Geay, Y. and Micol, D. 1989. Growing and finishing cattle. In: "Ruminant Nutrition, Recommended Allowances & Feed Tables". (ed. R. Jarrige), INRA and John Libbey Eurotext, London Paris, 121–152.

Ingvartsen, K.L., Andersen, H.R. and Foldager, J. 1992. Effect of sex and pregnancy on feed intake capacity of growing cattle. *Acta Agriculturae Scandinavica, A, Animal Science* **42:** 40–46.

INRA (L'Institute National de la Research Agronomique). 1989. "Ruminant Nutrition, Recommended Allowances & Feed Tables". (ed. R. Jarrige), INRA and John Libbey Eurotext, London Paris, 389 pages.

Irish Cattle Breeding Federation. 2003. "Irish Cattle Breeding Statistics 2003". (ed. A. Cromie) ISSN 1649–0991, 24 pages.

Istasse, L., Van Eenaeme, C., Gabriel, A., Clinquart, A., Maghuin-Rogister, G. and Bienfait, J.M. 1990. The relationship between carcass characteristics, plasma hormones and metabolites in young fattening bulls. *Veterinary Research Communications* **14:** 19–26.

Keane, M.G. 1995. "Feed Efficiency in Beef Production". Technical Bulletin Issue. No.5, R & H Hall: 8 pages.

Li, P.K., Lee, J.T., MacGillivray, M.H., Schaefer, P.A. and Siegel, J.H. 1980. Direct, fixed-time kinetic assays for beta-hydroxybutyrate and acetoacetate with a centrifugal analyzer or a computer-backed spectrophotometer. *Clinical Chemistry* **26**: 1713–1717.

Lowman, B.G., Scott, N.A. and Somerville, S.H. 1976. "Condition scoring of cattle". Bulletin no. 6

(Revised edition), East of Scotland College of Agriculture, 31 pages.

McGee, M., Drennan, M.J. and Caffrey, P.J. 1998. Milk yield and calf performance of suckler cows on different grazing systems. *Irish Journal of Agricultural and Food Research* **37:** 117–118.

McGee, M., Keane, M.G., Neilan, R., Moloney, A.P. and Caffrey, P.J. 2005. Production and carcass traits of high dairy genetic merit Holstein, standard dairy genetic merit Friesian and Charolais × Holstein-Friesian male cattle. *Irish Journal of Agricultural and Food Research* **44:** 215–231.

McGee, M., Drennan, M.J. and Caffrey, P.J. 2005a. Effect of suckler cow genotype on cow serum immunoglobulin (Ig) levels, colostrum yield, composition and Ig concentration and subsequent immune status of their progeny. *Irish Journal of Agricultural and Food Research* **44:** 173–183.

McGee, M., Drennan, M.J. and Caffrey, P.J. 2005b. Effect of suckler cow genotype on milk yield and pre-weaning calf performance. *Irish Journal of Agricultural and Food Research* **44:** 185–194.

MAFF (Ministry of Agriculture, Fisheries and Food). 1984. "Energy allowances and feeding systems for ruminants". Reference Book 433, HMSO, London.

Montano-Bermudez, M. and Nielsen, M.K. 1990. Biological efficiency to weaning and to slaughter of crossbred beef cattle with different genetic potential for milk. *Journal of Animal Science* **68:** 2297–2309.

Moloney, A.P. and O'Kiely, P. 1997. Digestibility, nitrogen retention and plasma metabolite concentrations in steers offered whole-crop wheat silage-based rations. *Irish Journal of Agricultural and Food Research* **36:** 135–144.

NRC (National Research Council). 2000. "Nutrient requirements of beef cattle". Update 2000. Seventh Revised Edition 1996. National Academy Press, Washington D.C., 232 pages.

O'Kiely, P. and Moloney, A.P. 1994. Silage characteristics and performance of cattle offered grass silage made without an additive, with formic acid or a partially neutralised blend of aliphatic organic acids. *Irish Journal of Agricultural and Food Research* **33:** 25–39.

O'Mara, F. 1996. "A Net Energy System for Cattle and Sheep". Department of Animal Science and Production, University College Dublin.

Ortigues, I., Petit, M., Agabriel, J. and Vermorel, M. 1993. Maintenance requirements in metabolizable energy of adults, nonpregnant, nonlactating Charolais cows. *Journal of Animal Science* **71:** 1947–1956.

Petit, M. and Agabriel, J. 1993. Etat corporel des vaches allaitantes charolaises: signification, utilisation pratique et relations avec la reproduction. *Productions Animales* **6:** 297–302.

Petit, M., Garel, J.P., D'Hour, P. and Agabriel, J. 1995. The use of forages by the beef cow herd. In: "Recent developments in the Nutrition of Herbivores". (ed. M. Journet, E. Grenet, M-H. Farce, M. Theriez and C. Demarquilly). *Proceedings of the IVth International Symposium on the Nutrition of Herbivores,* INRA, Editions, Paris, pages 473–496.

Petit, M., Jarrige, R., Russel, A.J.F. and Wright, I.A. 1992. Feeding and nutrition of the suckler cow. In: "Beef Cattle Production, World Animal Science", (ed. R. Jarrige, and C. Beranger), C5, Elsevier, Amsterdam, pages 191–208.

Ranfft, K. 1973. Gas chromatography of short chain acids in ruminal fluids. *Archives Tierernahrung* **23:** 343.

Robelin, J., Agabriel, J., Barboiron, C., Jailler, R., Cuylle, G. and Moins, G. 1986. Estimation de l'etat d'engraissement des bovins vivants a partir de la taille des cellules adipeuses. *Bulletin Technique C.R.Z.V. Theix I.N.R.A*. **66:** 37–41.

Russel, A.J.F. and Wright, I.A. 1983a. Factors affecting maintenance requirements of beef cows. *Animal Production* **37:** 329–334.

Russel, A.J.F. and Wright, I.A. 1983b. The use of blood metabolites in the determination of energy status in beef cows. *Animal Production* **37:** 335–343.

Sinclair, K.D., Broadbent, P.J. and Hutchinson, J.S.M. 1994. The effect of pre- and post-partum energy and protein supply on the blood metabolites and reproductive performance of single- and twin-suckling beef cows. *Animal Production* **59:** 391–400.

Solis, J.C., Byers, F.M., Schelling, G.T., Long, C.R. and Greene, L.W. 1988. Maintenance requirements and energetic efficiency of cows of different breed types. *Journal of Animal Science* **66:** 764–773.

Sykes, A.R. 1978. An assessment of the value of plasma urea nitrogen and albumin concentrations as monitors of the protein status of sheep. In: "The Use of Blood Metabolites in Animal Production", (ed. D. Lister). British Society of Animal Production, Occasional Publication No. 1, pages 143–154.

Statistical Analysis Systems Institute 2001. SAS/STAT. The SAS system for windows, Release 8.02, SAS Institute Inc., Cary, NC, USA.

Taylor, St. C.S., Thiessen, R.B. and Murray, J. 1986. Inter-breed relationship of maintenance efficiency to milk yield in cattle. *Animal Production* **43:** 37–61.

Thompson, W.R., Meiske, J.C., Goodrich, R.D., Rust, J.R. and Byers, F.M. 1983. Influence of body composition on energy requirements of beef cows during winter. *Journal of Animal Science* **56:** 1241–1252.

Tilley, J.M.A. and Terry, R.A. 1963. A two-stage technique for the *in vitro* digestion of forage crops. *Journal of the British Grassland Society* **18:** 104–111.

Van Soest, P.J. 1963. Use of detergents in the analysis of fibrous feeds. III. A rapid method for the determination of fibre and lignin. *Journal of the Association of Official Analytical Chemists* **46:** 829–835.

Wright, I.A. and Russel, A.J.F. 1984. The composition and energy content of empty body-weight change in mature cattle. *Animal Production* **39:** 365–369.

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