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A comparison of the feeding and grazing behaviour of primiparous Holstein-Friesian and Jersey×Holstein-Friesian dairy cows

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Food intake and feeding behaviour of Holstein-Friesian (HF) and Jersey×Holstein-Friesian (J×HF) dairy cows (14 primiparous cows of each genotype) were measured during a 54-day confinement period [cows offered a complete diet comprising conserved forage and concentrates; 66:34 dry matter (DM) basis], while herbage intakes and grazing behaviour were measured on three occasions during a 96-day grazing period. Throughout the experiment HF cows had a higher milk yield than J×HF cows ($P<0.05$), while fat+protein yield was unaffected by genotype. During the confinement period HF cows had a higher food intake than the J×HF cows ($P<0.01$), although DM intake/kg metabolic live weight (live weight$^{0.75}$) was unaffected by genotype. With the exception of the number of ruminating bouts/day ($P<0.05$), and idling time/day ($P<0.05$), both of which were highest with the J×HF cows, genotype had no significant effect on any of the feeding behaviours examined during the confinement period. Herbage intake did not differ between genotypes during the grazing period, although when expressed on a kg live weight$^{0.75}$ basis, intakes were highest with the J×HF cows ($P<0.05$). While the smaller J×HF cows had fewer grazing bouts per day ($P<0.01$), the mean duration of each grazing bout was longer ($P<0.001$), resulting in a longer total grazing time ($P<0.05$) and a greater number of grazing bites each day ($P<0.01$). The smaller crossbred cows had to 'work harder' during the grazing period to achieve the same intakes as the larger HF cows.

Keywords: crossbreeding; feeding behaviour; food intake; grazing behaviour

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Introduction

While the dairy sector within many developed countries continues to be dominated by the Holstein-Friesian breed, there has been a renewed interest in crossbreeding in recent years. One of the primary reasons for this is the decline in fertility traits associated with the Holstein breed (Royal *et al.* 2000). Interest in crossbreeding is normally highest within 'low input' milk production systems where grazed grass represents a high proportion of the diet. In fact, recent evidence suggests similar levels of milk production in Holstein-Friesian, Montbeliarde×Holstein-Friesian and Normande×Holstein-Friesian dairy cows (Walsh *et al.* 2008) within grassland-based milk production systems. Similarly, in a three-year study comparing the performance of Holstein-Friesian and Jersey×Holstein-Friesian dairy cows within grass-based milk production systems, there was no significant difference between genotypes for fat plus protein yield (Vance *et al.* 2013). Furthermore, fertility performance was substantially improved with the crossbred cows in the latter experiment.

Within grassland-based milk production systems the ideal cow is one that will consume large quantities of food per unit of bodyweight and efficiently convert this food into high value milk solids (Buckley, Holmes and Keane 2005). There is a common perception amongst dairy farmers that crossbred cows, and in particular the Jersey×Holstein-Friesian, are more vigorous feeders/grazers than purebred Holstein cows. Evidence does exist of differences between dairy cow strains, breeds and genotypes for food intake and feeding behaviour within both confinement and grazing environments. For example, within a confinement environment, Aikman, Reynolds and Beever (2008) observed Holstein cows to have higher eating rates than purebred Jersey cows, while the Jersey cows had a longer ruminating time. In addition, O'Driscoll, Boyle and Hanlon (2009) observed an increased number of bites per minute with Holstein-Friesian cows compared to Norwegian Red cows, while the latter had an increased number of feeding mastications each day. Within a grazing environment, Crawford (2002) reported that Norwegian Red cows grazed and ruminated for longer than Holstein-Friesian cows, while McCarthy *et al.* (2007) observed longer grazing times with New Zealand Holstein-Friesian dairy cows compared with both 'high durability' and 'high production' Holstein-Friesian strains. However, studies comparing the feeding and grazing behaviour of Holstein-Friesian and crossbred dairy cows are few. In one exception, Prendiville *et al.* (2010) reported no difference in food intake and few differences in grazing behaviour between Holstein-Friesian and Jersey×Holstein-Friesian cows. Within a confinement environment few studies have measured the food intake of Jersey×Holstein-Friesian dairy cows, while no studies have been identified in which the feeding behaviour of Holstein-Friesian and Jersey×Holstein-Friesian dairy cows were compared. Consequently this experiment was undertaken to examine food intake and feeding behaviour of Holstein-Friesian (HF) and Jersey×Holstein-Friesian (J×HF) crossbred dairy cows within a confinement environment, and the herbage intake and grazing behaviour of these two cow genotypes while grazing.

Materials and Methods

This experiment was conducted during 2008 at the Agri-Food and Biosciences Institute (AFBI) Hillsborough (54°27'N; 06°04'W). The experiment was 150 days in duration, and comprised a 54-day confinement period (7 May–29 June) followed by a 96-day grazing period (30 June–3 October).

Animals

The experiment involved 28 primiparous spring calving dairy cows, 14 HF and 14 J×HF dairy cows. The HF cows had a mean Predicted Transmitting Ability (PTA_{2010}) for fat+protein yield of 15.0 kg (s.d. 9.7), and were sired by a total of six Holstein-Friesian sires. The J×HF cows were the offspring of a breeding programme involving randomly selected Holstein-Friesian dams from the AFBI Hillsborough herd and three Jersey sires. Cows were separated into two 'genotype groups' at the start of the experiment (mean of 77 days calved) and remained in these groups for the duration of the experiment. At the start of the experiment (7 May) the HF and J×HF cows had a mean live weight of 512 and 421 kg, respectively, and a mean daily fat plus protein yield of 1.87 and 1.76 kg, respectively.

Confinement period

Throughout the confinement period the two genotype groups were housed in cubicle accommodation and offered a complete diet comprising forage and concentrates (66:34 DM basis), with the forage component of the diet comprising grass silage and maize silage (60:40 DM basis). The grass silage was produced from tertiary growth herbage (harvested on 16 October), while the maize silage was produced from a maize crop (variety Goldcob) which was harvested using a Kemper header (on 17 October). The maize crop was treated with a bacterial inoculant (Biotal solo maize) at harvesting. The ingredient composition of the concentrate offered (kg/t air dry basis), was as follows: barley, 186; wheat, 186; soya hulls, 115; citrus pulp, 116; soya bean, 160; rape seed meal, 160; molasses, 40 and minerals and vitamins, 37. The silage and concentrate components of the diet were mixed daily using a mixer wagon. Uneaten food was removed daily at 08:30 h and replaced with fresh food (offered *ad libitum* at proportionately 1.1 of the previous day's intake) at approximately 09:30 h. In addition, 0.5 kg of this concentrate was offered in the milking parlour during each of the morning and evening milkings.

The confinement period began with a 20-day dietary adjustment phase during which cows accessed their food via a post-and-rail type feed barrier. Thereafter, the two genotype groups were transferred to a Calan Gate (American Calan, Northwood, NH, USA) feeding system (which they had previously been trained to use) for a 20-day period. This 20-day period was divided into two ten-day sub-periods, with the pen order reversed during the second sub-period (days 11–20), with this deemed necessary as the two pens were not identical in layout. During this 20-day period each genotype group had access to seven Calan Gates, with each Calan Gate linked to an automatic cow identification system which allowed cows to gain access to a feed box mounted on a weigh scale. Calan Gates were used to record individual cow food intakes and feeding behaviour (number of feeding bouts per day, feeding bout duration, and DM intake per feeding bout) during the final five days of each 10-day sub-period (days 5–10, and days 15–20). In order to ensure that the two genotype groups acted independently of each other, groups were visually isolated at the feeding area using a wooden partition (from 60 cm above floor level to 170 cm above floor level). However, the layout of the house meant it was not possible to visually isolate cows whilst they were in the cubicle area.

After completion of this 20-day period, the two genotype groups were moved to two identical (but mirror image) pens (each with 16 cubicles) where they accessed food via a post-and-rail type feed barrier for a 14-day period. Each genotype group had a horizontal feed barrier space allowance of 600 cm. The move to these pens was necessary as it was not possible to fit grazing behaviour recorders to cows accessing food via Calan Gates due to the small access space associated with each gate. The two pens were visually isolated from each other (both the feeding and cubicle area) using wooden partitions, as described earlier.

During this 14-day period group intakes were calculated as the difference between the quantity of food offered at 09:30 h and the quantity of food remaining uneaten at 08:30 h the following day. During this period food intake patterns and rumination behaviours were recorded using grazing behaviour recorders, similar to those described by Rutter, Champion and Penning (1997), which recorded all jaw movements. Seven cows from each genotype were fitted with grazing behaviour recorders for two consecutive 23-h periods (day 6 and 7) with this repeated on the remaining seven cows from each genotype on day 9 and 10. Grazing behaviour recorders were fitted at approximately 15:30 h (after evening milking) and removed the following day at approximately 14:30 h (prior to evening milking). The data were subsequently analysed using 'Graze' analysis software (Rutter 2000).

Grazing period

Cows grazed a predominantly perennial ryegrass (*Lolium perenne*; cv. Aberstar and Aberzest) sward which was located on a clay-loam soil. Grazing commenced on 30 June, with each of the two genotype groups managed under a flexible rotational grazing system whereby fresh herbage was allocated to each group daily, after pm milking. Cows were offered a daily herbage allocation of approximately 18.0 kg DM/cow/day (measured above a height of 40 mm). This allocation was determined daily by cutting four quadrats (0.25 m^2) to approximately 40 mm above ground level from randomly selected sites across each grazing area using Gardina battery operated hand shearers (Accu 6; Kress and Kastner, Weiterstadt, Germany). Herbage harvested within each quadrat was collected, weighed and sub-sampled, and its DM content determined using a microwave oven (Sanyo Super Showerwave). The latter involved placing 50 g of chopped herbage on a ceramic plate, and drying for 3–5 min (with the power setting at 550 Watts), with the sample being mixed and checked for 'dryness' every minute. This process was then repeated for a series of decreasing time intervals (for example, 30 seconds, 20 seconds, 10 seconds), the duration of each depending on the 'touch dryness' of the sample after the previous drying period. The sample was weighed after each of these 'drying periods' until a constant weight was achieved, with care taken to avoid the sample igniting. Herbage DM yield above 4.0 cm was subsequently determined, and the appropriate area allocated daily. While it was not possible to graze the two genotype groups in visually isolated plots, a minimum distance of 30 m was maintained between groups at all times. Pre- and post-grazing grass heights were measured daily (40 measurements taken in a 'W' formation) using a rising plate meter (Jenquip, Feilding, New Zealand) within each genotype grazing area. During the grazing period cows were offered 2.0 kg/day of a 'grazing concentrate' (1.0 kg during each milking). The ingredient composition (kg/t air dry basis) of this grazing concentrate was as follows; barley, 190; maize, 190; sugar-beet pulp, 310; soya bean meal, 200; rape seed meal, 40; mineral and vitamins, 30; calcined magnesite, 10; and molaferm, 30.

During the grazing period herbage intakes were measured on three occasions (20 July–1 August, 24 August–5 September and 21 September–3 October) using the n-alkane technique (Mayes, Lamb and Colgrove 1986). On each occasion cows were dosed twice daily for 12 days (post milking) with a paper bung containing 500 mg of dotriacontane (C32-alkane), while faeces samples were collected from individual cows prior to each milking during the final six days. Faeces samples were stored at 4 °C until the final collection was complete, after which the 12 individual samples from each cow were bulked, and the bulked sample dried at 60 °C. During each of the three measurement periods, pluck samples of herbage were collected daily from within each grazing area (at 20 random locations). Herbage was sampled to a similar height as that to which the cows were observed to be grazing. Samples were immediately frozen at –20 °C and later freeze dried. A sample of the concentrate offered during each of the intake measurement periods was dried at 60 °C. Faeces, herbage and concentrate samples were subsequently milled and analysed for C32 and C33 n-alkane concentrations using the technique of Mayes *et al.* (1986), with recovery rates of C32 and C33 alkanes assumed as 0.857 and 0.853, respectively, as provided by Dillon (1993).

During each of the faeces collection periods, grazing behaviour was recorded using the grazing behaviour recorders described earlier. Seven cows from each genotype group were fitted with the recorders for two consecutive 23-h periods, commencing after evening milking. This process was then repeated with the seven remaining cows from each genotype group. Mean grazing behaviours were subsequently determined across the two measurement days for each cow. All jaw movements were analysed using 'Graze' analysis software described previously. Handling time was calculated as total grazing time plus total ruminating time, while idling time was calculated as the remaining time left each day.

Cow performance

Throughout the experiment cows were milked twice daily, between 05:00 and 06:30 h and between 14:00 and 15:30 h. Individual milk yields were recorded automatically during each milking while milk fat, protein and lactose concentrations were determined weekly on two consecutive (am and pm) samples using a Milkoscan (Model FT 120, Foss UK Ltd., Warrington, UK). Milk energy output was subsequently calculated as described by Tyrell and Reid (1965). Cow live weight was recorded after every milking and an average live weight calculated for each week. Condition score was assessed weekly using a five point scale (1=emaciated; 5=extremely fat) (Edmonson *et al.* 1989).

Feed chemical analysis

During the indoor period the silages offered were sampled daily and analysed for oven DM content, with fresh silage samples analysed twice weekly for gross energy (GE), nitrogen (N), pH, ammonia N and volatile components. Dried silage samples were retained and bulked for each 5-day period and analysed for acid detergent fibre (ADF), neutral detergent fibre (NDF), water soluble carbohydrates (WSC) and ash contents. In addition, dried maize silage samples were analysed for starch content. Concentrates offered during the indoor periods were sampled weekly and subsequently bulked for each 10-day period. Samples were oven dried and analysed for N, NDF, ADF and ash content. During the grazing period herbage pluck samples were taken twice weekly from within each of the grazing areas (at 20 random locations) and analysed for oven DM content. In addition, the metabolisable energy concentration of fresh grass was predicted using near infrared reflectance spectroscopy (NIRS) as described by Park *et al.* (1998) for grass silage, but using a calibration equation developed for fresh grass. Dried grass samples were subsequently bulked for each 7-day period and analysed for ADF, NDF, N, WSC and ash contents. Concentrates offered during the grazing period were sampled weekly and bulked for each 4-week period, and analysed for ADF, NDF, N and ash content. The feeds offered were analysed as described by Ferris *et al.* (1999), with the exception of GE content of fresh silage which was analysed as described by Porter (1992).

Statistical analysis

Data from this experiment were analysed using GenStat, Version 11.1 (Payne *et al.* 2008). The effect of cow genotype on mean milk output, milk composition, live weight and condition score data during the confinement period and during the grazing period were analysed using Analysis of Variance (ANOVA). Food intake and feeding behaviour data (measured using the Calan Gate feeding system) were averaged for each cow across the two measurement periods and the effect of cow genotype examined using ANOVA. The effect of genotype on feeding behaviours recorded using grazing behaviour recorders at the open feed barrier were averaged for individual cows across the two measurement days, and the mean data analysed using ANOVA. Herbage intake and grazing/ruminating behaviour data were analysed using Residual Maximum Likelihood (REML) analysis using a repeated measures mixed model. The model included the following terms as fixed effects: measurement period (1–3) + genotype (HF or J × HF) + measurement period × genotype, while cow and cow within measurement-period were included as random effects.

Results

Concentrates offered had mean crude protein (CP), NDF, ADF and ash content (g/kg DM) of 236, 92, 189 and 84, respectively (confinement period), and 228, 87, 174 and 97, respectively (grazing period). The chemical compositions of the silages and grazed grass offered during the experiment are presented in Table 1. The grass silage offered had an ammonia N content of 131 g/kg total n, a reflection of its late harvest date, while the maize silage offered had a DM and starch content of 353 g/kg and 257 g/kg DM, respectively. The herbage grazed had a mean CP and ME content of 187 g/kg DM and 11.1 MJ/kg DM, respectively.

Mean pre-grazing sward heights during each of the three experimental grazing periods were 8.7 (s.d. 2.15), 9.1 (s.d. 2.38) and 7.5 (s.d. 3.20) cm for the HF cows and 9.0 (s.d. 3.10), 8.5 (s.d. 2.42) and 8.0 (s.d. 2.70) cm for the J × HF cows, respectively. Similarly, mean post-grazing sward heights were 5.4 (s.d. 1.57), 5.9 (s.d. 2.10) and 4.1 (s.d. 1.20) cm for the HF cows and 5.2 (s.d. 1.52), 5.5 (s.d. 1.68) and 4.3 (s.d. 2.15) cm for the J × HF cows, respectively. During each of the three grazing measurement periods mean daily rainfall was 7.8, 9.6 and 3.4 mm, respectively.

Milk production and milk composition

During the confinement period ($P<0.01$) and the grazing period ($P<0.05$), HF cows had a higher daily milk yield than J × HF cows, while J × HF cows produced milk

Table 1. Chemical composition of the silages (g/kg volatile corrected DM, unless stated otherwise) and grazed grass (g/kg DM, unless stated otherwise) offered during the experiment

	Confinement period				Grazed grass					
	GS	s.d.	MS	s.d.	30 June–1 Aug.	s.d.	2 Aug.–5 Sept.	s.d.	5 Sept.–3 Oct.	s.d.
Oven DM (g/kg)	185	37.4	336	11.8	159	22.3	151	31.5	160	33.7
Volatile corrected DM (g/kg)	198	35.3	353	5.4						
Crude protein	202	24.1	88	19.9	195	32.3	179	30.0	185	20.9
Ammonia-n (g/kg total n)	131	45.1	92	18.9						
pH	4.5	0.46	3.7	0.03						
Lactate	67	48.2	66	11.9						
Neutral-detergent fibre	518	22.3	546	22.0	509	14.1	506	27.1	509	19.4
Acid-detergent fibre	305	16.6	273	14.5	234	11.7	243	15.7	239	9.1
Water-soluble carbohydrates					69	47.9	81	71.4	75	58.1
Gross energy (MJ/kg DM)	18.1	9.54	19.3	9.97						
Metabolisable energy (MJ/kg DM)†					11.3	0.38	10.9	0.36	11.0	0.36
Starch			257	24.3						

† Determined using near infrared reflectance spectroscopy.
GS = grass silage; MS = maize silage; DM = dry matter.

with a higher milk fat content (P<0.01) (Table 2). The J×HF cows produced milk with a higher protein content than the HF cows during the grazing period (P<0.05). Genotype had no significant effect on milk fat plus protein yield during either the confinement or grazing period, although HF cows had a higher milk energy output than the J×HF cows during the confinement period (P<0.05). Holstein-Friesian cows were heavier than J×HF cows (P<0.001) throughout the experiment, while the J×HF cows had a higher condition score (P<0.05) than the HF cows during the confinement period.

Confinement period

During the confinement period, when cows accessed their food via Calan Gates, HF cows had a higher (P<0.05) daily food intake than J×HF cows (Table 3) although, genotype had no significant effect on any of the feeding behaviours examined. Group intakes at the open feed barrier were 19.1 and 17.6 kg DM/cow/day for the HF and J×HF cows, respectively. Of the feeding behaviours recorded using grazing behaviour recorders, the number of ruminating bouts/day was greater for the J×HF cows (P<0.05), while idling time (per day) was greater (P<0.05) with the HF cows. Genotype had no significant effect on any of the remaining behaviours examined at the open feed barrier.

Grazing period

During the grazing period there were significant genotype × measurement time (Table 4) interactions for grazing time (P<0.01), grazing prehensions/day (P<0.01) and idling time (P<0.05). During each of the three measurement times (1, 2, and 3) HF cows grazed for 575, 461 and 557 min/day, had 35,979, 28,660 and 34,092 grazing prehensions/day, and spent 459, 570 and 477 min/day idling, respectively. The J×HF cows grazed for 557, 557 and 631 min/day, had 32,662, 35,117 and 41,259 grazing prehensions/day, and spent 469, 439 and 473 min/day

Table 2. Effect of dairy cow genotype on milk production performance, mean live weight and mean condition score during the confinement and grazing periods

	Genotype		s.e.d.	Significance
	HF	J×HF		
Confinement period				
Milk yield (kg/day)	25.6	21.8	1.26	**
Fat content (g/kg)	41.2	45.9	1.51	**
Protein content (g/kg)	32.8	34.4	0.91	
Fat+protein yield (kg/day)	1.88	1.74	0.078	
Milk energy output (MJ/day)†	81	74	3.4	*
Live weight (kg)	515	439	16.5	***
Live weight$^{0.75}$ (kg)	108	96	2.6	***
Daily fat+protein yield (g/kg live weight$^{0.75}$)	17.5	18.1	0.87	
Condition score	2.4	2.6	0.08	*
Grazing period				
Milk yield (kg/day)	17.3	15.3	0.75	*
Fat content (g/kg)	43.3	48.4	1.53	**
Protein content (g/kg)	33.6	35.7	0.92	*
Fat+protein yield (kg/day)	1.33	1.28	0.030	
Milk energy output (MJ/day)†	56	53	2.2	
Live weight (kg)	492	419	15.4	***
Live weight$^{0.75}$ (kg)	104	93	2.5	***
Daily fat+protein yield (g/kg live weight$^{0.75}$)	12.8	13.9	0.52	*
Condition score	2.3	2.4	0.07	

†Milk energy content calculated according to Tyrell and Reid (1965). HF=Holstein-Friesian, J×HF=Jersey×Holstein-Friesian, * = P<0.05, ** = P<0.01, *** = P<0.001.

idling, respectively. There were no significant genotype×measurement time interactions for any of the other parameters examined, and as such only main effects are presented in Table 4.

Total DM intake was unaffected by genotype, while total DM intake per kg live weight$^{0.75}$ was highest with the J×HF cows (P<0.05) (Table 4). Grazing time (P<0.01), total grazing prehensions/day (P<0.01) and the mean duration of each grazing bout (P<0.001) were significantly higher for the J×HF cows than for the HF cows, while HF cows had a greater number of grazing bouts/day (P<0.01) and a higher grass intake per minute (P<0.05) than the J×HF cows. There were no differences between genotypes for any of the ruminating behaviours observed.

There was a significant effect of measurement time for a number of the grazing parameters measured, including grass and total DM intake (P<0.001), grazing time (P<0.001) and the total number of grazing prehensions/day (P<0.001), with these being highest during measurement time 3 (Table 4). There were also differences observed between measurement times for time spent ruminating (P<0.01), total ruminating mastications/day (P<0.05), handling time (P<0.001) and total mastications/day (P<0.05), with the minimum value for each of these parameters observed during measurement time 2.

Discussion

Milk production performance

In agreement with the findings of previous studies (Anderson *et al.* 2007; Auldist *et al.* 2007; Heins *et al.* 2008; Prendiville, Pierce

Table 3. Effect of dairy cow genotype on food intake and feeding behaviour during the confinement period, as recorded at Calan gates and at an open feed barrier

	Genotype		s.e.d.	Significance
	HF	J×HF		
Feeding behaviour (Calan gates)				
Total DM intake (kg/day)	18.5	17.1	0.67	*
Total DM intake/kg live weight$^{0.75}$ (kg/day)	0.17	0.18	0.005	
Total feeding time (min per day)	248	236	18.0	
Feeding time per kg DM consumed (min)	13.5	13.7	0.99	
Number of feeding bouts (per day)	16.1	16.0	1.04	
Mean duration of each feeding bout (min)	16.1	15.2	1.13	
DM consumed per feeding bout (kg)	1.22	1.11	0.084	
Eating rate (g DM/min)	77.3	75.6	5.53	
Feeding behaviour (open feed barrier)				
Total DM intake (kg/day)	19.1	17.6		
Total feeding time (min/day)	386	382	15.2	
Number of feeding bouts (per day)	12.3	12.8	1.14	
Mean duration of each feeding bout (min)	35	31	3.8	
Number of feeding mastications (per day)	24,390	22,731	1629.9	
Feeding mastication (per min)	63	60	3.0	
Ruminating time (min/day)	456	496	28.6	
Ruminating bouts (per day)	16.9	25.1	3.07	*
Ruminating bout duration (min)	29.7	22.2	4.23	
Ruminating mastication (per day)	31,066	33,976	2532.2	
Ruminating mastication (per min)	67	68	2.3	
Ruminating boli (per day)	545	625	50.0	
Boli per ruminating bout	35	27	4.8	
Ruminating mastications per boli	57	56	3.5	
Boli per minute	1.2	1.3	0.07	
Idling time (min/day)	538	473	27.1	*

HF = Holstein-Friesian; J×HF = Jersey×Holstein-Friesian; DM = dry matter. * = $P < 0.05$.

and Buckley, 2009) HF cows had higher daily milk yields than J×HF cows (3.8 and 2.0 kg/day higher during the confinement and grazing period, respectively), while the J×HF cows produced milk with a higher fat and protein content. The overall effect within this study was that genotype had no significant effect on fat plus protein yield, in common with the findings of Auldist *et al.* (2007) and Prendiville *et al.* (2009). Within the current study HF cows were on average 74 kg heavier than J×HF cows, with this difference considerably greater than differences in live weight recorded by Auldist *et al.* (2007), Heins *et al.* (2008) and Prendiville *et al.* (2009) (50, 33 and 42 kg, respectively), although the latter studies involved both primiparous and multiparous cows. The higher condition scores of the J×HF cows in the current study are in agreement with the findings of Prendiville *et al.* (2009).

Food intake and feeding behaviour during the confinement period

In order to measure individual cow intakes and detailed feeding behaviours for individual cows, measurements were undertaken at a Calan Gate feeding system and at an open feed barrier. Differences

Table 4. Effect of dairy cow genotype and measurement period on herbage intake and grazing behaviour

	Genotype (G)		s.e.d.	Significance	Measurement time (T)			s.e.d.	Significance	G×T	
	HF	J×HF			1	2	3			s.e.d.	Significance
Grass DM intake (kg/day)	15.3	14.6	0.63		14.2	13.4	16.4	0.57	***	1.04	
Total DM intake (kg/day)	17.0	16.3	0.63		15.9	15.1	18.1	0.48	***	0.87	
Total DM intake/kg live weight$^{0.75}$	0.15	0.16	0.006	*	0.14	0.14	0.18	0.005	***	0.009	
Grazing time (min/day)	531	582	18.9	**	566	509	594	16.7	***	28.4	**
Grazing bites per min	62	62	1.4		61	63	64	1.9		2.7	
Grazing mastications (per day)	5192	4914	794.4		5973	4170	5017	749.7		1243.0	
Grazing prehensions (per day)	32,910	36,346	1393.0	**	34,320	31,889	37,676	1387.0	***	2249.0	**
Grazing bouts (per day)	9.3	7.7	0.45	**	9.4	8.0	8.1	0.80		1.16	
Mean duration of grazing bout (min)	60.0	82.7	4.69	***	62.5	74.4	77.1	7.40		10.78	
Grass intake per min (g DM)	29	26	1.5	*	26	27	29	1.7		2.5	
Grass intake per bite (g DM)	0.47	0.42	0.030		0.44	0.44	0.46	0.033	**	0.047	
Ruminating time (min/day)	350	360	21.1		377	324	363	16.8	**	30.1	
Ruminating bouts (per day)	18.8	19.6	2.06		21.7	19.0	16.8	2.14		3.41	
Ruminating bout duration (min)	20.8	21.1	2.46		20.2	19.3	23.3	1.91		3.47	
Ruminating mastications (per day)	21,939	22,248	1586.0		23,345	20,347	22,589	1162.0	*	2173.0	
Ruminating boli (per day)	457	408	77.5		479	351	467	85.4		133.3	
Boli per ruminating bout	26.4	23.6	4.57		25.4	20.6	28.9	4.79		7.61	
Handling time (min/day)	896	961	37.7		971	832	982	35.6	***	59.0	
Idling time (min/day)	502	460	34.3		464	504	475	30.7		52.0	*
Total mastications (per day)	27,992	28,089	2019.0		30,158	25,480	28,483	1440.0	**	2732.0	

HF=Holstein-Friesian; J×HF= Jersey×Holstein-Friesian; G×T=genotype×measurement time. * = P<0.05, ** = P<0.01.

in food intakes between the two feeding systems were numerically small (mean of 0.6 kg DM/cow/day), with this supporting the findings of Ferris *et al.* (2006) that method of offering food (Calan Gates vs. open feed barrier) has no effect on total daily DM intake. However, total feeding time was numerically 142 min longer at the open feed barrier compared to the Calan Gates, due to the fact that a maximum of seven cows were able to feed through the seven available Calan Gates at any one time, while the 600 cm of feed space (42.8 cm/cow) available at the open feed barrier allowed approximately ten cows to feed at any one time. In addition, Ferris *et al.* (2006) observed an increased frequency of agonistic behaviour between non-feeding and feeding animals when cows were offered food via a Calan Gate feeding system compared to an open feed barrier. As a result of these two factors, cows offered feed via the Calan Gate system are likely to have had an increased rate of eating. This is in agreement with the observations of Ferris *et al.* (2006), while the capacity of dairy cows to increase intake rates so as to maintain intakes when feed space allowance is severely restricted has recently been confirmed by O'Connell *et al*. (2010). Nevertheless, as both genotypes were managed identically within each of the feeding systems, the comparison of the two cow genotypes, which was the primary objective of this study, remains valid.

Although few studies have compared food intakes of HF and J×HF dairy cows within a confinement situation, intakes of Holstein cows are normally higher than those of purebred Jersey cows. For example, daily DM intakes of Holstein cows were 3.7, 5.9 and 6.9 kg higher than those of Jersey cows in confinement studies reported by Blake, Custodio and Howard (1986), Rastani *et al.* (2001) and Aikman *et al.* (2008), respectively. However, within the current study the HF cows consumed approximately 1.4 kg DM/day more than the J×HF cows when individual cow intakes were measured using the Calan Gates, while intakes of HF cows were numerically 1.5 kg DM/day more than for the J×HF cows when group intakes were measured at the open feed barrier. Although the current study did not include purebred Jersey cows, previous workers have observed heterosis for food intake in studies involving Jersey crossbred cows. For example, Olson, Cassell and Hanigan (2010) observed heterosis for net energy intake within a confinement situation of 5.7%, while within a grazing situation Prendiville *et al.* (2010) observed daily grass DM intakes of Jersey crossbred cows to be 0.25 kg higher than that of the breed parent mean. Indeed, Heins *et al.* (2008) and Vance *et al*. (2012) observed no difference in food intake between Holstein and Jersey×Holstein dairy cows during the first 146 days of lactation, and throughout the entire lactation, respectively, with heterosis likely to have been a contributing factor to these similar intakes. Nevertheless, it is likely that the lower intakes of the crossbred cows in the current study is largely a function of their smaller body size, as when expressed on a metabolic live weight basis there was no difference in intake between genotypes.

That the smaller crossbred cows in the current study were able to produce an equal yield of fat+protein as the larger Holstein cows, despite having a lower intake, suggests an improvement in overall efficiency. This is further highlighted when milk fat+protein yield per 100 kg live weight is calculated, with respective values for the HF and J×HF cows being 0.36 and 0.40 kg, respectively. A similar trend (with a difference of the same order of magnitude), was observed by Prendiville *et al.* (2010) in a grazing experiment involving these two genotypes, although in the latter study milk solids yield/kg of herbage intake with the crossbred cows was also significantly higher than the mid parent mean. While these authors suggested that this increase in efficiency may be due in part to the increased number of mastications per unit of intake observed with the crossbred cows, and a resulting change in particle size and improved digestibility, feeding mastications/kg intake was similar with each of the two genotypes within the current study. Indeed, Xue *et al*. (2011) observed that these two genotypes digested their food and utilised the digested energy with similar levels of efficiency. The exception to this was 'heat production as a proportion of metabolisable energy intake', which was significantly higher for the Holstein cows, thus suggesting a lower metabolic efficiency for the latter. However, within the current study it is likely that there was 'energy saving' associated with the lower maintenance requirement of the lighter crossbred cows. For example, according to the current UK rationing system for dairy cows (Agnew *et al*. 2004), the crossbred cows (76 kg lighter) would have had a maintenance energy requirement approximately 8 MJ/day lower than that of the Holstein cows. This 'energy saving' would have had the potential to support the production of approximately 1.6 kg milk/day, and it is very likely that this is the main reason for the similar yield of fat plus protein observed with the two genotypes, despite the crossbred cows having a lower food intake.

The feeding behaviour of HF and J×HF cows does not appear to have been compared previously within a confinement system. However, the current study provides no evidence that feeding behaviour of the two genotypes differed, irrespective of where measurements were undertaken (Calan Gate or open feed barrier). In similar studies in which the feeding behaviour of different cow genotypes was compared, Aikman *et al.* (2008) reported similar total feeding time for Holstein-Friesian and Jersey dairy cows (360 and 382 min/day, respectively), while O'Driscoll *et al.* (2009) observed that the time spent feeding, the number of feeding bouts per day and the mean bout length was similar for Holstein-Friesian and Norwegian Red dairy cows. The lower intakes of the J×HF cows in the current study may be due to a number of non significant trends in feeding behaviours having an overall significant effect when multiplied together, or due to the J×HF cows having a lower intake per bite. While data from the confinement period do not allow the latter to be examined, there was a trend towards a lower intake per bite with the J×HF cows in the subsequent grazing period. It is also worth noting that mean feeding time measured using the grazing behaviour recorders within this study was similar to the mean feeding time recorded using time lapse video recorders on days 7, 9, 11 and 13 within the current study, namely 372 min/day (Vance 2011). This finding suggests that grazing behaviour recorders can be used to accurately measure feeding behaviour within a confinement system, a less time consuming process than using video observations.

Cows of different genotypes have been observed to have different ruminating times in some studies [623 and 538 min for Holstein-Friesian and Jersey dairy cows, respectively: Aikman *et al.* (2008)] but not in others [610 and 585 min/day for Holstein-Friesian and Norwegian Red dairy cows, respectively: O'Driscoll *et al.* (2009)]. The difference in the former study is likely due to the Jersey cows having a lower intake than the Holstein cows. The significantly higher number of ruminating bouts with the crossbred cows in the current study was accompanied by a trend towards a longer ruminating time and a greater number of ruminating boli/day but a shorter ruminating bout duration. In addition, idling time was lower with the J×HF cows. The main driver of these effects and associated trends is unclear, although Aikman *et al.* (2008) reported that ruminating boli regurgitated by Jersey cows were approximately 33% smaller than those produced by Holstein-Friesian cows. In addition, Aikman *et al.* (2008) suggested that Jersey cows were more efficient at reducing feed particle size compared to Holstein-Friesian cows, and this might contribute to a higher rate of food passage through the gastrointestinal tract.

Herbage intake and grazing behaviour

The ideal cow for a grazing system is one which will consume large quantities of grazed herbage per unit of live weight, and efficiently convert this herbage into high yields of milk solids per unit of live weight (Buckley *et al.* 2005). While there is anecdotal evidence that crossbred cows, especially Jersey crossbred cows, are 'more efficient' grazers than purebred Holstein cows, few studies have compared herbage intakes and grazing behaviour of these two genotypes. Although purebred Jersey cows have been observed to have lower grass intakes than Holstein-Friesian cows [18%, 18% and 13% lower in studies by L'Huillier, Parr and Bryant (1988), Mackle *et al.* (1996) and Prendiville *et al.* (2010), respectively] intakes of Jersey×Holstein cows did not differ from those of Holstein cows (13.9 vs. 13.3 kg DM/cow/day: 16.7 vs. 15.9 kg DM/cow/day) in studies by Gonzalez-Verdugo, Magofke and Mella (2005) and Prendiville *et al.* (2010), respectively. In common with the latter two studies, herbage intakes did not differ between genotypes during the grazing period in the current study.

Herbage intake is a function of time spent grazing×biting rate×herbage intake per bite (Spedding, Large and Kydd 1966). While many studies have examined the effects of sward and environmental factors on grazing behaviour (for example, Rook, Huckle and Penning 1994; McGilloway *et al.* 1999), the effect of cow genotype has received less attention. That intakes did not differ between genotypes within the current study, despite the crossbred cows being approximately 70 kg lighter, reflects the similar outputs of milk solids with each of the two genotypes, with these similar intakes facilitated by differences in grazing behaviour. For example, while the crossbred cows had fewer grazing bouts each day, the duration of each grazing bout was on average 22.7 min longer, and as such the crossbred cows grazed for longer each day. In addition, while the number of bites per min did not differ between the two genotypes (62 bites/min), and the crossbred cows tended to have a lower intake per bite, the longer grazing time with the crossbreds resulted in a greater number of grazing bites per day (32,910 vs. 36,346), and this allowed similar intakes to be achieved with the two genotypes. Thus it would appear that the smaller J×HF cows had to work harder in order to achieve similar herbage intakes, thus concurring with the findings of Prendiville *et al.* (2009).

The trend towards a lower bite mass with the crossbred cows may reflect anatomical constraints with the smaller animals, including both mouth and body size (Rook 2000). Differences in grazing behaviour have been observed between cow genotypes in previous studies. For example, Linnane *et al.* (2004) and McCarthy *et al.* (2007) observed North American Holstein-Friesian cows to have a greater number of bites per minute than New Zealand Holstein-Friesian cows, while McCarthy *et al.* (2007) observed that the latter grazed for longer each day. Similarly, Crawford (2002) observed that Norwegian Red cows grazed for longer than Holstein-Friesian cows, although daily herbage intake, herbage intake per bite and the number of grazing bites per day did not differ between breeds. In contrast to the findings of the current study, Prendiville *et al.* (2010) reported similar grazing times, grazing bites per day and herbage intakes per bite with Holstein-Friesian and Jersey×Holstein-Friesian dairy cows. The shorter grazing times in the current study, compared to those reported by Prendiville *et al*. (2010), is reflected in a lower herbage intake, and this is likely due to cows of both genotypes in the current study being offered a common rate of 2.0 kg concentrate/day, and being primiparous.

The higher intakes of both genotypes during the third measurement time are somewhat unexpected in view of the lower milk yields and lower fat plus protein yield during this period. However, unfavourable weather conditions experienced during the first and second measurement time (mean daily rainfall, 7.8 and 9.6 mm/day, respectively) are likely to have had a detrimental effect on grazing behaviour and herbage intake during these periods. For example, mean duration of grazing time during the first and second measurement periods were 28 and 85 min/day less than during the third measurement period, while cows had 5787 fewer bites during the second measurement period compared to the third. A similar pattern was observed for ruminating behaviour, with time spent ruminating and the number of ruminating mastications being significantly lower during the second measurement period than during the third. The impact of weather conditions on grazing behaviour has been noted previously, with Hinch, Thwaites and Lynch (1982) observing that dairy cow grazing time was reduced by approximately 60 min per day during periods of inclement weather. That a significant genotype×measurement time interaction was observed for total daily grazing time, the number of grazing bites each day and total idling time each day may suggest that crossbred cows are more capable of maintaining normal grazing behaviour during periods of adverse weather, compared to HF cows.

Although differences between breeds in time spent ruminating have been observed within a grazing environment (420 and 371 min/day for Norwegian Red and Holstein-Friesian cows, respectively: Crawford 2002), the mean time spent ruminating did not differ between genotypes within the current study. Indeed, in common with the findings of Prendiville *et al.* (2010), none of the ruminating behaviours examined differed between the HF and crossbred cows. This reflects the similar food intakes and milk energy outputs observed with the two genotypes in the current study, and supports the observation by O'Connell *et al.* (2000) of longer ruminating times being associated with increased food intakes.

The higher herbage intakes (per kg live weight$^{0.75}$) of the J×HF cows in the current study suggests a higher intake capacity compared to the HF cows. This may be explained in part by differences in size of the gastrointestinal tract. For example, Smith and Baldwin (1974) reported that Jersey cows had a larger gastrointestinal capacity than Holstein-Friesian cows, while more recently Lewis, Thackaberry and Buckley (2011) observed that as a proportion of live weight, Jersey and Jersey crossbred cows had a larger rumen-reticulum, abomasum and total gastrointestinal tract than Holstein cows. Nevertheless, the results of this experiment clearly demonstrated that differences in grazing behaviour existed between HF and J×HF cows, and it was this modified behaviour, which reflects a greater 'grazing drive', that allowed the smaller crossbred cows to compete with the larger Holstein cows in terms of herbage intakes. The overall benefit of this greater grazing drive in terms of production performance is less clear. For example, the lower live weight of the J×HF cows during the grazing period (73 kg) would have resulted in a lower maintenance energy requirement (approximately 8.0 MJ/day lower). However, as already discussed, milk energy output did not differ between genotypes, nor did the J×HF cows appear to partition this 'saved' energy to body condition gain. This may reflect the fact that although intakes were not significantly different between genotypes, intakes were numerically (0.7 kg DM) lower with the J×HF cows (approximately 8.5 MJ/day lower ME intake), while in addition, the crossbred cows are likely to have expended additional energy due to their longer grazing times. Nevertheless, this finding does not detract from the smaller size of the crossbred cows making them highly suitable for grazing systems, or the many functional trait benefits that are increasingly being demonstrated with crossbred cows (Vance *et al*. 2012, 2013).

Conclusions

The smaller size, and associated lower intakes, or trends towards lower intakes, with the J×HF cows appears to have been largely compensated for by the lower maintenance energy requirements of the crossbred cows. As a consequence, fat plus protein yield did not differ between genotypes during either the confinement or grazing periods. Genotype had little effect on feeding behaviour within the confinement environment; however, within the grazing environment the crossbred cows modified their grazing behaviour to achieve high herbage intakes, suggesting an improved 'grazing drive'. When expressed on a metabolic live weight basis the J×HF cows had a higher DM intake per kg live weight$^{0.75}$, with this facilitated by an increased time spent grazing and a greater number of grazing bites per day.

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