A comparison of three contrasting systems of milk production for spring calving dairy cows

Final Report for AgriSearch in respect of the breed comparison component of Project D-29-06

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STRUCTURE OF REPORT

AgriSearch project D-29-06, ‘A comparison of three contrasting systems of milk production for spring calving dairy cows’ comprised two separate components: 1) a comparison of cow performance associated with three contrasting milk production systems, and 2) an evaluation of the performance of Holstein-Friesian and Jersey x Holstein-Friesian cows when managed on these three milk production systems. This report presents the final outcomes of the breed comparison component of the study.

The breed comparison component of the study encompassed two main parts: 1) a comparison of the performance of Holstein-Friesian and Jersey x Holstein-Friesian crossbred cows over three successive lactation, when managed on one of three contrasting grassland-based system of milk production: and 2) a single lactation study designed to examine the feeding and grazing behaviour of these two cow genotypes when managed within a confinement and grazing environment. The results of these two studies have now been fully written up, with results from both studies having been submitted for publication in refereed scientific journals.

This report begins with an ‘Executive summary’ which highlights key aspects of the studies, and this is followed by two papers which describe each of the studies in full. The report concludes with a summary of technology transfer articles and events associated with the projects.

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Executive summary

Experiment 1

A three year study was established to compare the performance of Holstein-Friesian (HF) and Jersey x Holstein-Friesian (J x HF) dairy cows when managed on one of three grassland-based systems of milk production. The experiment involved 28, 35 and 42 HF cows and 28, 32 and 32 J x HF cows (in Years 1, 2 and 3, respectively).

The three grassland-based systems were defined as low concentrate (LC), medium concentrate (MC) or high concentrate (HC). Post calving, cows were housed and offered grass silage, supplemented with 6.0, 8.0 and 10.0 kg concentrate/cow/day in systems LC, MC and HC, respectively. Across the three years of the study cows on LC had a mean turnout date of 14 February, while cows on systems MC and HC had a mean turnout date of 30 March. Throughout the summer grazing period concentrate feed levels were 0, 2.5 and 5.0 kg/cow/day. Full time housing occurred on 12, 6 and 6 November across three years in each of systems LC, MC and HC, respectively. From housing until drying off, cows on systems LC, MC and HC were offered 1.0, 2.0 and 3.0 kg concentrate/cow/day.

Total concentrate intakes with LC, MC and HC were 530, 1092 and 1667 kg/cow/lactation, respectively.

Dry matter intakes during the early lactation (pre-turnout) period were unaffected by genotype and were 14.7 and 14.8 kg DM/cow/day for HF and J x HF cows, respectively. Similarly, during the grazing periods there was no evidence of a difference in herbage intake between genotypes. Results from the grazing behaviour study highlight that the smaller J x HF cows modified their grazing behaviour to allow them to achieve similar herbage intakes as the larger Holstein-Friesian cows.

On average, HF cows produced 625 kg more milk than J x HF cows, while milk fat and protein concentrations were 5.8 and 2.9 g/kg higher with the J x HF cows. Fat plus protein yield was unaffected by genotype. Milk yield and fat plus protein yield were higher with systems MC and HC, than with LC. The results of the current study demonstrate that crossbreeding Holstein-Friesian dairy cows with Jersey sires will normally result in a loss in milk yield, but in most cases, no loss in the yield of milk constituents.

While the contribution of hybrid vigour to milk production performance cannot be identified within the current study, recent estimates of hybrid vigour within the literature (across a range of studies) for milk yield, milk fat content and milk protein content are 5.1%, 2.1% and 2.8%, respectively.

This difference in lactation milk production between the two genotypes was reflected in the different lactation curves observed, with peak yield for the HF cows (30.7 kg/day) being higher than for the J x HF cows (27.1 kg/day). In addition, the decline in daily milk yield was highest with the Holstein cows, indicating a less persistent lactation profile than for the J x HF cows. In terms of fat plus protein yield, neither peak yield, nor the rate of decline after the peak, differed between genotypes.

A key objective of this study was to compare the responses of the two cow genotypes to increasing concentrate levels. However, there was no significant genotype x system interaction for any of the milk production parameters examined (P>0.05). Thus within the range of concentrate levels examined, J x HF cows had the genetic potential to exhibit similar milk yield and milk constituent yield responses as pure bred HF cows. The implication of this is that crossbreeding may have a role within higher concentrate input systems of milk production, rather than being restricted to lower concentrate input systems.

The link between the intake of various fats and human health issues such as cardiovascular disease, cancer and obesity has prompted a renewed interest in the fatty acid content of milk. Within the current study genotype had relatively little effect on the concentrations of milk fatty acids. However, concentrations of short chain fatty acids (C4 – C14) and C18:0 tended to be higher with the J x HF cows, while concentrations of CLA, which has been reported to have anticarcinogenic properties, was higher in milk of HF cows. When the findings of this experiment are compared with those of other experiments, the results are by no mean consistent, and as such variations between individual sires within breed may be of greater importance than differences between breeds. The increasing CLA content of milk moving from system HC to system LC reflects the increasing proportion of pasture in the diet.

Jersey crossbred cows were on average 44 kg lighter than HF cows, while the J x HF cows had a 0.2 unit higher mean condition score than the HF cows. Despite these differences in actual live weight and condition score between the two genotypes, the condition score and liveweight change curves for the HF and J x HF cows followed strikingly similar trajectories throughout lactation, suggesting similar levels of tissue mobilisation in early lactation, and tissue gain in late lactation, between genotypes. There was no evidence of system having a significant effect on any body tissue parameter examined.

The similar trends in tissue mobilisation and deposition, and the similar nutrient intakes discussed earlier, help explain the similar milk energy outputs observed with the two cow genotypes. However, the smaller crossbred cows would be expected to have a maintenance energy requirement approximately 5.0 MJ/day lower than the larger HF cows, with this having the potential to support an extra one kilogram of milk, approximately. However, it was not possible to identify any clear milk performance benefits associated with this energy saving within the current study.

There was clear evidence of earlier resumption of cyclicity and improved fertility with the crossbred cows in the current study. For example, commencement of luteal activity and days to first observed heat occurred 3.4 and 8.8 days earlier, respectively, with the J x HF cows than with the HF cows. In addition, conception rate to first service, conception rate to first and second service and pregnancy rate at the end of the breeding season were 23, 29 and 16 percentage points higher with the J x HF cows, compared to the HF cows.

Previous studies have highlighted the association between negative energy balance, excessive tissue mobilisation during early lactation and reduced fertility performance. However the improved fertility performance with the J x HF cows within the current study occurred despite similar levels of condition score loss with the two genotypes. Hybrid vigour is likely to have been a significant contributor to the improved fertility performance observed with the crossbred cows. Thus, the findings of this experiment suggests that crossbreeding Holstein dairy cows with Jersey sires can provide an immediate opportunity to overcome some of the fertility problems widely reported with the Holstein breed.

Although concentrate inputs increased from 530 kg/cow with LC to 1667 kg/cow with HC, there was no evidence that fertility performance increased with increasing concentrate levels. In view of the absence of a system effect on BCS change in early lactation, and on concentrations of plasma non-esterified fatty acids (NEFA) and beta hydroxy-butyrate (BHB), it is perhaps unsurprising that fertility performance was unaffected by concentrate supplementation.

Somatic cell count was unaffected by genotype in the current study, with previous research suggesting that the effect of hybrid vigour on SCC is low. However, the proportion of cows with one or more cases of mastitis was approximately 45% higher with the HF cows.

There is a perception that Jersey crossbred dairy cows have improved hoof health compared to Holstein cows. Although not significant within the current study, there was a tendency for HF cows to have more cases of lameness. This may be due to Jersey and Jersey crossbred cows having harder hooves.

Experiment 2

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. There is a common perception that crossbred cows, and in particular the Jersey x Holstein-Friesian cross, are more vigorous feeders/grazers than purebred Holstein cows, although evidence to support this is limited.

This experiment was conducted to compare the food intake and feeding/grazing behaviour of Holstein-Friesian (HF) and Jersey x Holstein-Friesian (J x HF) dairy cows within a confinement environment, and whilst grazing. Food intake and feeding behaviour were measured during a 54-day confinement period (cows offered a complete diet comprising conserved forage and concentrates; 66:34 dry matter (DM) basis), and a 96-day grazing period (comprising three separate measurement periods: 28, 35 and 28 days in duration, respectively) when 2.0 kg concentrate/cow/day was offered. During the final week of each grazing measurement period herbage intakes were measured using the n-alkane technique, while grazing behaviour was recorded using grazing behaviour recorders. The study involved 14 primiparous dairy cows of each genotype.

HF cows had higher daily milk yields than J x HF cows (3.8 and 2.0 kg/day higher during the confinement period and the grazing period, respectively), while the J x 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 addition, HF cows were on average 73 kg heavier than J x HF cows, while the latter had a higher condition score.

Although few studies have compared food intakes of HF and J x HF dairy cows within a confinement situation, intakes of purebred Jersey cows are normally substantially lower than those of Holstein cows. During the confinement period HF cows consumed approximately 1.4 kg DM/day more than the J x HF cows, with the lower intakes of the crossbred cows appearing to be largely a function of their smaller body size. This was highlighted in that when intakes were expressed on a metabolic live weight basis ($LWT^{0.75}$) there was no difference in intakes between genotypes.

That the smaller crossbred cows in the current study were able to produce the same yield of fat + protein as the larger Holstein cows, despite having lower intakes, suggests an improvement in overall efficiency. Indeed, it is likely that there was an ‘energy saving’ associated with the lower maintenance requirement of the lighter crossbred cows, equivalent to approximately 8 MJ/day. This ‘energy saving’ would have had the potential to support the production of approximately 1.6 kg milk/day, and would account for the similar milk fat plus protein yield with the two genotypes, despite the crossbred cows having a lower food intake.

There were no significant differences between genotypes for any of the feeding behaviour parameters measured during the confinement period, with cows having a mean of 16 feeding bouts per day, and a mean feeding time of 384 minutes per day (measured at the open feed barrier using grazing behaviour recorders). In addition, when observed using time lapse video, genotype had no effect on time spent on any activity.

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 greater number of ruminating boli/day, but a shorter ruminating bout duration. The main driver of these effects is unclear, although it has been reported that ruminating boli regurgitated by Jersey cows were approximately 33% smaller than those produced by Holstein-Friesian cows.

Herbage intake, which is a function of time spent grazing x biting rate x herbage intake per bite, did not differ between genotypes during the grazing period in the current study despite the crossbred cows being approximately 70 kg lighter. This can be attributed to differences in grazing behaviour.

While the crossbred cows had fewer grazing bouts each day (9.3 vs 7.7), the duration of each grazing bout was on average 22.7 minutes longer (60.0 vs 82.7 minutes), and as such the crossbred cows grazed for longer each day (531 vs 582 minutes). In addition, while the number of bites per minute did not differ between the two genotypes (62 bites/minute), 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 (32910 vs

36346), and this allowed similar intakes to be achieved with the two breeds. The trend towards a lower bite mass with the crossbred cows may reflect anatomical constraints associated with the smaller animals, including both mouth and body size.

The higher herbage intakes (per kg metabolic live weight) of the J x 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, with previous research suggesting that Jersey cows had a larger gastrointestinal capacity than Holstein-Friesian cows. Nevertheless, the results of this experiment clearly demonstrated that differences in grazing behaviour existed between HF and J x 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.

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EXPERIMENT 1

Comparison of the performance of Holstein-Friesian and Jersey x Holstein-Friesian crossbred dairy cows within three contrasting grassland-based systems of milk production

1.0. Introduction

During the last few decades the Holstein-Friesian breed has become the dominant dairy cow breed on the majority of United Kingdom (UK) dairy farms, a reflection of the high level of efficiency of the breed for milk production. However, breeding programmes within the Holstein-Friesian breed have until recently largely focused on a single trait, namely milk production, and as such, dairy cow fertility, health and longevity have declined (Royal *et al.*, 2000). These factors, combined with increasing herd sizes and a trend towards reduced labour input per cow, has prompted interest in 'easy care cows'. In addition, milk composition at a national level within the UK is poorer in comparison to many other European countries (Dairy Co Datum, 2010). These factors, together with the downward pressure on producer returns, have resulted in a renewed interest in the role of crossbreeding. There is currently particular interest in the use of the Jersey breed within crossbreeding programmes, with this due in part to the high milk quality often reported for the breed (Rastani *et al.*, 2001; White *et al.*, 2001; Aikman *et al.*, 2006), and the perception that Jersey cattle are particularly well suited to grazing systems.

Evidence highlighting some of the benefits associated with crossbred cows already exists, with Jersey x Holstein-Friesian cows having been shown to produce similar yields of fat plus protein as Holstein-Friesian cows (Auldist *et al.*, 2007; Prendiville *et al.*, 2009). In addition, Thackaberry *et al.* (2009) reported higher conception rates to first service in Jersey x Holstein-Friesian cows compared with pure bred Holstein-Friesian cows. Nevertheless, most research on crossbreeding has been undertaken within low input grassland-based systems of milk production (Lopez-Villalobos *et al.*, 2000; Walsh *et al.*, 2008; Prendiville *et al.*, 2010b), although a relatively small number of UK farmers operate these systems. Few studies have examined crossbred cows within medium to high input systems, or indeed across a range of concentrate inputs. In one exception, which involved a comparison of Holstein-Friesian, Normande x Holstein-Friesian and Montbeliarde x Holstein-Friesian cows offered two concentrate feed levels (480 and 1020 kg/cow/lactation), Walsh *et al.* (2008) reported no significant genotype x system interaction for any of the milk production parameters examined. However, it appears that no studies have been conducted in which the performance of Holstein-Friesian and Jersey x Holstein-Friesian cows have been compared across a range of concentrate feed levels within a grassland-based milk production system.

Thus the objective of the current experiment was to compare the performance of Holstein-Friesian (HF) and Jersey x Holstein-Friesian (J x HF) dairy cows within three contrasting grassland-based milk production systems, with the primary difference between these systems being concentrate feed level.

2.0. Materials and Methods

This three year experiment was conducted at the Agri-Food and Biosciences Institute, Hillsborough (latitude 54˚27'N; longitude 06˚04'W) between January 2006 and December 2008. Cows of two genotypes were managed on one of three grassland-based milk production systems over three successive years.

2.1. Animals

The experiment involved 28, 35 and 42 HF cows and 28, 32 and 32 J x HF cows in each of Years 1, 2 and 3, respectively (Table 1). The HF cows had a mean predicted transmitting ability (PTA_{2005}) for fat plus protein yield of 17.1 (s.d. 11.6) kg and were sired by 19 Holstein-Friesian sires. The J x HF cows were the offspring of a breeding programme involving randomly selected Holstein-Friesian cows from the AFBI Hillsborough herd and Jersey sires of both Danish (n = 5) and New Zealand (n = 4) origin. During each of Years 1, 2 and 3, cows on the study were in lactations 1 and 2, 1 - 3 and 1 - 4, respectively. Mean calving dates were 28 January (s.d. 21.4 days), 9 February (s.d. 23.7 days) and 4 February (s.d. 24.0 days) in each of Years 1 – 3, respectively.

2.2. Overview of feed systems

Throughout the experiment cows were managed on one of three grassland-based systems of milk production, namely 'low concentrate' (LC), 'medium concentrate' (MC) and 'high concentrate' (HC). The guiding principles behind these systems were as follows: LC, to maximise milk production from grazed grass: MC, to maximise milk production from forage (grazed grass and conserved forage) and; HC, high reliance on concentrates and conserved forage. Key aspects of each of these systems are summarised in Table 2, with full details presented later.

Cows from each genotype were allocated to one of the three management systems within 36 hours of calving in Year 1, with genotype groups balanced across the systems according to calving date, parity, pre-calving live weight and body condition score, sire, and in the case of the HF cows, PTA_{2005} for fat plus protein yield. Cows remained on the same management system for the duration of the experiment, or until removed from the experiment. Cows that were removed during or at the end of Years 1 and 2 were replaced at the start of Years 2 and 3, respectively. Replacement animals were largely primiparous (with these also balanced across systems according to the traits described above), although on occasions multiparous cows were used as replacements.

2.2.1. Winter periods

Cows were transferred to cubicle accommodation within 36 hours of calving, and housed as a single group until the start of turnout. During the 'winter period', from calving until the start of turnout, all cows were offered diets comprising grass silage and concentrates. Throughout the experiment a common concentrate was offered to cows on all three systems, with the ingredient composition of this concentrate presented in Table 3. Changes in the availability and cost of some ingredients meant that the ingredient composition of the winter concentrate varied from year to year. Target concentrate intakes during the winter periods were 6.0, 8.0 and 10.0 kg/cow/day with systems LC, MC and HC, respectively. With system LC, the daily concentrate allowance was divided into two equal feeds each day, and offered via in-parlour feeders at each milking. Multiparous cows were offered their 6.0 kg daily concentrate allowance from calving onwards, while primiparous cows were offered 4.0 kg/cow/day during the first 10 days post calving, with this increasing to 6.0 kg/cow/day thereafter. With system MC, 1.0 kg of the daily concentrate allowance was offered during milking (0.5 kg at each milking), with the remaining 7.0 kg being offered through two out-of-parlour feed stations located within the cubicle house. The out-of-parlour component of the diet was 5.0 kg/cow/day for the first 10 days post calving, increasing to the full allowance of 7.0 kg/cow/day thereafter for both primiparous and multiparous cows. With system HC, 1.0 kg of the daily concentrate allowance was offered during milking (0.5 kg at each milking), while the remaining concentrate allocation was mixed with the silage part of the diet and offered in the form of a complete diet. Concentrates were incorporated into the mix at 9.5 kg/cow/day for each cow on this treatment, with the aim of achieving a total concentrate intake of approximately 10.0 kg/cow/day (including the in-parlour component).

A common silage was offered to cows on all systems during the first winter period of the study. However, during the second and third winter periods silages offered to cows on system LC differed from that offered to cows on systems MC and HC, cows on the latter two systems being offered a common silage. These differences arose as part of a systems comparison component of the experiment, whereby grazing and silage areas were integrated with system LC, but not with systems MC and HC.

Cows accessed the forage component of their diets (complete diet in the case of HC) via a Calan gate feeding system (American Calan, Northwood, NH, USA). Each Calan gate was linked to an automatic cow identification system, which allowed cows to gain access to a feed box mounted on a weigh scale (Griffith Elder, Bury St Edmunds, UK), thus allowing individual food intakes to be measured. Cows on each of systems LC, MC and HC accessed their food via separate boxes, with HF and J x HF cows within each system also having access to separate feed boxes. Cows of each genotype, within each system, were able to access any of a series of available feed boxes, with an average of three cows sharing each box. With all systems, the forage component of the diet (complete diet in the case of HC) was offered at proportionately 1.05 of the previous days intake. Uneaten food was removed from the feed boxes daily at approximately 08:30 hours and fresh food offered between 09:00 and 10:30 hours.

2.2.2. Transitional grazing period

An early spring turnout date was adopted with system LC to maximise the length of the grazing season. The duration of the daily grazing period increased from approximately two hours/day at the time of turnout, to approximately 12 hours/day by 30 March. During this period cows were allocated sufficient herbage to allow them to graze to a residual sward height of approximately 40 mm. In addition, during the non-grazing part of the day cows continued to be offered grass silage *ad libitum*, together with their full daily winter concentrate allocation (6.0 kg /cow/day).

With systems MC and HC the mean turnout date across the three years of the experiment was 7 April. Cows on these systems initially grazed for approximately eight hours/day (milking to milking) with this increasing to 12 hours/day by 14 April (mean date). When grazing commenced approximately half of the daily concentrate allocation was transferred from the out-of-parlour feeders (MC) and the complete diet mix (HC) to in-parlour feeders, and the overall daily concentrate feed levels reduced to 6.0 and 8.0 kg/cow/day (systems MC and HC, respectively). Concentrates remained at these levels until full turnout was achieved.

Approximately one week before full-time grazing commenced with all three systems, the ingredient composition of the concentrate offered was changed to a summer grazing concentrate (Table 3) which was offered throughout the entire grazing season in each of the three years of the experiment.

2.2.3. Main grazing season

Full-time turnout occurred on 10, 18 and 18 April (mean of the three years of the experiment) within systems LC, MC and HC, respectively. Once full-time turnout occurred, concentrate feed levels were reduced over a 10 - 15 day period to the target levels of 0.0, 2.5 and 5.0 kg/cow/day with systems LC, MC and HC, respectively. These concentrate feed levels were maintained throughout the main grazing periods, with the exception of system LC, where 1.0 - 2.0 kg/cow/day of the grazing concentrate was introduced into the diet during occasional periods of unfavourable weather conditions and grass shortages, and during the autumn grazing periods (from 26 September, 11 October, 4 September in years 1, 2 and 3, respectively). With systems LC, MC and HC, full-time grazing continued until 23, 19 and 19 October, respectively (mean across the three years of the experiment). Thereafter, cows grazed during the day, and were housed at night and offered grass silage as previously discussed.

2.3. Late lactation period

Full-time housing commenced on 12, 6 and 6 November (average across the three years) in each of systems LC, MC and HC, respectively. Post re-housing cows were again managed within a single group in cubicle accommodation. Grass silage (as described earlier) was offered to all cows, with cows on systems LC, MC and HC being offered 1.0, 2.0 and 3.0 kg concentrate/cow/day (winter period concentrates: Table 3) until drying-off.

2.4. Dry period

Cows with a body condition score of ≥2.50 were dried off either eight weeks pre-calving, or if average weekly milk yield fell below 5.0 kg/day. Cows with a body condition score of 2.25 or ≤2.00 were dried-off either 10 or 12 weeks pre-calving, respectively. During the dry period cows on all three systems were offered grass silage, with cows on systems MC and HC not receiving any concentrate supplementation. During Years 2 and 3 of the experiment, dry cows on system LC were offered 2.0 kg/cow/day of dry cow concentrate due to their low condition score. Throughout the dry period cows were supplemented with 100 g/cow/day of a dry cow mineral and vitamin mix. Cows that were non-pregnant remained on their experimental treatment for the same mean number of days as the pregnant cows within their experimental groups, after which they were removed from the experiment.

2.5. Culling

Cows that were removed from the experiment during the grazing season (as a result of health issues) were replaced with 'spare cows' until the end of that grazing season, in order to maintain a constant grazing group size (26 cows/group). Cows removed either during or at the end of Years 1 and 2 were replaced by new experimental cows at the start of the subsequent lactation.

2.6. Breeding programme

A 12-week breeding season was adopted within all three systems, commencing on 29 March (mean across three years) within systems MC and HC and approximately three weeks later with LC. The latter was adopted so that cows within system LC would begin to calve at the start of the grass growing season, thus allowing milk output from grazed grass to be maximised. A voluntary waiting period of a minimum of 42 days prior to the start of breeding was adopted with all cows. Throughout the experiment cows were bred via artificial insemination approximately 12 hours after visual observation of oestrus. Holstein-Friesian cows were bred to Holstein sires while J x HF cows were bred to Swedish-Red and White sires. Pregnancy was confirmed via rectal scanning at day 60 post insemination. Cows were not treated with any fertility drugs until they were a minimum of 52 days post calving. The exceptions to this were cows that displayed symptoms of uterine infections, in which case treatment was given as soon as the problem was identified. Cows which had not been observed on heat prior to day 52 post calving were inspected by a veterinary surgeon, and treated as appropriate.

2.7. Pasture Management

Although this paper examines the performance of the cows described in Table 1, these cows grazed as part of a larger group of cows (26 cows/system) during each of the three years of the study. Cows on system LC were managed on a flexible grazing system with fresh herbage (approximately 16 - 18 kg herbage DM/cow/day) being allocated to cows each day after evening milking, while cows on systems MC and HC were managed on a rotational paddock grazing system. With systems MC and HC, 21 x 0.23 ha and 21 x 0.184 ha paddocks, respectively, were initially established in a set paddock grazing system. For these systems the grazing season commenced with a 21-day grazing rotation, with additional paddocks being incorporated into the cycle as the season progressed.

Total N fertiliser application rates within the core grazing areas (across all systems) were 292 kg N/ha in Years 1 and 2, and 264 kg N/ha in Year 3. In order to maintain pasture quality, grass trimming (topping) was undertaken to a height of approximately 6.0 cm within all systems mid way through the grazing season.

2.8. Measurements

Cows were milked twice daily between 06:00 and 08:00 hours and between 15:00 and 17:00 hours, with milk yields recorded automatically at each milking. Milk fat, protein and lactose concentrations were determined weekly on two consecutive (morning and evening) milk samples (Milkoscan, Model FT 120, Foss UK Ltd., Warrington, UK) while milk somatic cell count (SCC) was determined monthly using a Fossomatic 360 (Foss Electric, Hillerød, Denmark). On four occasions (18 March, 20 May, 12 August and 29 September) during the final year of the experiment, while cows on all three systems were grazing full-time, milk was sampled during two consecutive milkings, bulked in proportion to yield, and subsequently analysed for milk fatty acid concentrations as described by Keady *et al.* (2000). In addition, milk progesterone concentrations were determined twice weekly (Monday and Friday; am samples) between calving and day 52 post calving for all cows during each of Years 1 - 3. Milk samples were preserved (Lactab Mark III, Thompson and Cooper Ltd., Lydney, UK) and stored at 4°C until analysed (within four weeks). Milk progesterone concentrations were determined using an enzyme-linked immuno-sorbent assay (ELISA) kit (Ridgeway Science Ltd., Gloucestershire, UK), based on the method of Sauer *et al.* (1986), as described in detail by McCoy *et al.* (2006). Interval to the commencement of luteal activity (LA) was defined as the interval from calving to the first of at least two consecutive increases in milk progesterone concentration above 3.0 ng/ml (Darwash *et al.*, 1997).

Cow live weight was recorded automatically after each milking and an average weekly live weight subsequently calculated. Body condition score of lactating cows was assessed weekly by two trained operators, on alternate weeks, using a five point scale (Edmonson *et al.*, 1989), where 1 = emaciated and 5 =

extremely fat. Locomotion score was recorded fortnightly by a single trained operator using a five point scale (Manson and Leaver, 1988), where 1 = no unevenness in gait or tenderness, and 5 = difficulty in walking and adverse effects on behaviour pattern. Blood samples were taken from the coccygeal vein of each cow between 06:30 and 08:30 hours at weeks 2, 4, 6, 8, 10 (± 3 days), 20, 30 and 40 (± 7 days) post calving. Blood plasma was recovered via centrifugation and stored at -20°C until analysed for β-hydroxybutyrate (BHB) and non-esterified fatty acids (NEFA) content (using a Wako kit, Wako Chemicals GMBH, Germany). Calving difficulty score was on a scale of 1 – 5, where 1 = unassisted calving and 5 = caesarean section (McEvoy *et al.,* 1995).

During periods when cows on each of the three systems were housed, individual food intakes were measured daily using the Calan gate feeding system, as described previously. During the grazing seasons herbage intakes were measured on three occasions during Year 2 (21 – 25 May, 9 – 13 July and 10 – 14 September) and on two occasions during Year 3 (26 – 30 May and 11 – 15 August), using the n-alkane technique (Mayes *et al.*, 1986). During a 12-day period cows were dosed twice daily, post milking, with a paper bung containing 500 mg of dotriacontane (C32 - alkane). During the final six days of each 12-day period, faeces samples were collected from individual cows twice daily prior to evening milking, and stored at 4°C. On completion of each 6-day sampling period, the 12 individual faeces samples for each cow were bulked, with bulked samples dried at 60°C. During the same 6-day period when faeces samples were collected, pre-grazing herbage ‘pluck’ samples were collected from within each genotypes grazing area (at 20 random locations). Herbage was sampled to a similar height as cows were observed to have grazed to during the previous day. Samples were immediately frozen at -20°C, and later freeze dried. In addition, a sample of concentrate offered during the intake measurement period 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 described by Dillon (1993). Throughout the grazing season, pre- and post-grazing sward heights were measured daily within each milk production system using a rising plate meter (Jenquip, New Zealand).

Throughout the study cows with health problems were treated by either a veterinary surgeon or by a member of Institute staff, as appropriate. All incidences of mastitis and lameness were recorded throughout the experiment with an incidence defined as one where antibiotic treatment was used.

2.9. Feed chemical analysis

Throughout the indoor periods of the experiment grass silages offered were sampled daily and analysed for DM content. In addition, on one occasion each week a fresh grass silage sample was analysed for concentrations of N and metabolisable energy (ME) using Near Infrared Reflectance Spectroscopy (NIRS), as described by Park *et al.* (1998). On one occasion each week a fresh sample of herbage was collected pre-grazing from the grazing areas associated with each of the systems and analysed for DM, N and ME content using NIRS as described by Park *et al.* (1998) for grass silage, but using calibration equations developed for fresh grass. Each one tonne batch of concentrates made during the study was sampled and the samples bulked for each 4-week period. Concentrate samples were analysed for DM and N concentrations as described by Ferris *et al.* (1999).

2.10. Statistical Analysis

Data from this experiment were analysed using GenStat Version 11.1 (Payne *et al.*, 2008), according to its 3 (milk production systems) x 2 (cow genotypes) factorial design. Milk fatty acid content was measured during Year 3 only, with the effects of genotype and feeding system on milk fatty acid content being analysed using repeated measures Residual Maximum Likelihood (REML) analysis. Data for herbage intake and total intake during each of the three measurement period in Year 2 and the two measurement period in Year 3 were analysed using ANOVA. The model used in the analysis of all other data from the experiment included year (n = 3), lactation number (lactation 1 or >1), cow (repeated measures), genotype and milk production system. Food intake (confinement periods), milk production, live weight and condition score (at fixed points during the lactation), fertility and health parameters were analysed using REML variance components analysis (continuous data) and regression analysis (binomial data). Weekly live weight and condition score data, and blood metabolite concentration data were analysed using repeated measures REML. The effects of genotype and management system on the shape of the milk yield and fat plus protein yield lactation curves was determined by fitting an exponential model curve (Wilmink, 1987) described as;

$$Yt = a + b \times e^{-0.05 \times t} + c \times t$$

Within this model *a*, *b* and *c* parameters relate to the intercept, the incline and the decline of the curve, respectively, while Yt describes milk production on day t. The effect of treatment on each of the coefficients (*a*, *b* and *c*) was examined using ANOVA, while peak yield and days to peak yield were derived for each individual cow using the exponential model described above and tested for significance.

3.0 Results

The common silage offered with all systems in Year 1 had a DM, crude protein (CP) and ME content of 309 g/kg, 146 g/kg DM and 11.8 MJ/kg DM, respectively. Equivalent values for silages offered with system LC were 286, 144 and 11.1 (Year 2) and 281, 128 and 11.0 (Year 3), respectively, while values for the common silage offered with systems MC and HC were 314, 133 and 11.0 (Year 2) and 261, 127 and 11.3, respectively. Concentrates offered during the winter and grazing periods had mean CP concentrations of 183 and 167 g/kg DM, respectively. Across the three years of the experiment, herbage offered within systems LC, MC and HC had a mean DM concentration of 177, 170 and 163 g/kg, a mean CP concentration of 164, 170 and 181 g/kg, and a mean ME concentration of 10.8, 10.7 and 10.9 MJ/kg DM, respectively. Mean pre- and post-grazing sward heights (across Years 1 – 3) were 9.9 and 6.0 cm for LC, 9.5 and 6.0 cm for MC and 9.5 and 5.7 cm for HC.

A total of 36 HF cows and 21 J x HF cows were culled during the course of the experiment. Reasons for culling were defined as infertility, mastitis, ‘legs and feet’ and ‘other’ (n = 29, 2, 3 and 3 for HF cows and n = 15, 0, 5 and 1 for J x HF cows, respectively). There were few significant interactions between dairy cow genotype and milk production system for parameters examined (P>0.05), and as such only the main effects have been presented within Tables 4 – 10. For parameters where interactions were observed, individual treatment values are given within the text.

3.1. Food Intake and milk production

The effect of dairy cow genotype and milk production system on DM intake during the periods when cows were housed is presented in Table 4. Mean daily DM intakes were 14.7 and 14.8 kg/day (early lactation, pre-turnout) and 13.0 and 12.6 kg/day (late lactation, post re-housing) for the HF and J x HF cows, respectively (P>0.05). The effect of system on early lactation DM intake has been presented for systems MC and HC only (intakes with LC were measured only briefly due to the early turnout dates adopted with this system). During the early lactation period, silage DM intake with system MC was higher than with system HC, while the reverse was observed with concentrate DM intake (P<0.001). Total DM intake was unaffected by system (P>0.05). Silage DM intake and total DM intake were unaffected by system during the late lactation period (P>0.05).

Herbage intake (as determined using the n-alkane technique) was unaffected by genotype during the three measurement periods in Year 2 and during the two measurement periods in Year 3 (P>0.05) (Table 5). Milk production system had a significant effect on herbage DM intake, with cows managed on system LC and MC having higher herbage intakes than cows managed on HC during the first measurement period in Year 2 (P<0.001) and during each of the measurement periods in Year 3. However, during the second and third measurement periods in Year 2, herbage intake of cows on HC was higher than for cows on LC (P<0.001). There was no significant genotype x system interaction for any of the food intake parameters examined during either the confinement or grazing periods (P>0.05).

Across the three years of the experiment mean days in milk (HF, 305; J x HF, 302) and concentrate feed levels (HF, 947; J x HF, 963 kg DM) did not differ between genotypes (P>0.05) (Table 6). Full lactation milk yields were higher with the HF cows compared with the crossbred cows (P<0.001), however genotype had no effect on solids corrected milk yield (P>0.05). Milk fat, protein (P<0.001) and lactose (P<0.05) concentrations were highest with the J x HF cows compared with the HF cows. Genotype had no significant effect on fat, protein and fat plus protein yields, or on milk energy output (P>0.05).

Full lactation concentrate intakes were 466, 961 and 1467 kg DM/cow with systems LC, MC and HC, respectively (P<0.001). Full lactation milk yield and solids corrected milk yield were lower with system LC than with either of systems MC or HC, with a similar trend observed for the yield of each of the milk constituents, and milk energy output (P<0.001). System had no effect on either milk fat or milk protein content (P>0.05). In addition, milk production system had no effect on mean SCC or log transformed SCC (P<0.05).

3.2. Lactation profiles

Parameters of the Wilmink curves (*a*, *b* and *c*) which describe the effect of genotype and system on daily milk yield and daily fat plus protein yield lactation curves are presented in Table 7, while actual lactation curves for the two genotypes are presented in Figures 1a and 1b, respectively. Genotype had a significant effect on the *a* and *c* parameters for milk yield and the *b* parameters for fat + protein yield (P<0.001), while system had a significant effect on the *a* and *b* parameters for milk yield (P<0.01) and the *a* (P<0.01) and *b* (P<0.05) parameters for fat + protein yield. Days to peak milk yield did not differ between the two genotypes (P>0.05), while days to peak fat plus protein yield were longer (P<0.01) for the crossbred cows. The HF cows had a higher (P<0.001) peak milk yield than the J x HF cows (30.7 and 27.1 kg/day, respectively), while peak fat + protein yield did not differ between genotypes (P>0.05). Days to peak milk yield was significantly lower with LC compared with either of systems MC or HC (P<0.001), while peak fat plus protein yield was unaffected by system (P>0.05). Peak fat plus protein yield was significantly higher with system HC, than with either of systems LC or MC (P<0.05).

Concentrations of short chain fatty acids (C4 – C14) and C18:0 were significantly higher with the J x HF cows compared with the HF cows (P<0.05), while the reverse was true for concentrations of C16:1, C18:1 and C18:2 fatty acids (P<0.05) (Table 8). Holstein-Friesian cows produced milk with a significantly higher conjugated linoleic acid (CLA) content than the crossbred cows (12.4 and 11.2 g/kg, respectively) (P<0.05). Concentrations of short chain fatty acids (C4 – C14) were lower with system LC than with either of systems MC or HC (P<0.05), while C17:0 and C18:1 followed the reverse trend (P<0.05). The concentration of CLA in milk decreased as concentrate supplementation increased, with concentrations being 13.3, 11.4 and 10.7 g/kg total fat with systems LC, MC and HC, respectively (P<0.001).

There was a significant genotype x system interaction for the following milk fatty acids: C15:0 (13.4, 12.4 and 13.2 g/kg for HF cows, and 12.1, 13.6 and 13.7 g/kg for J x HF cows, for systems LC, MC and HC respectively: P<0.001), C18:0 (91.0, 99.2 and 84.6 g/kg for HF cows, and 104.4, 94.8 and 101.2 g/kg for J x HF cows, for systems LC, MC and HC respectively: P<0.05), and CLA (14.9, 10.9 and 11.1 g/kg for HF cows, and 11.1, 11.6 and 10.4 g/kg for J x HF cows, for systems LC, MC and HC, respectively: P<0.01).

3.3. Tissue changes and blood metabolites

The HF cows had a higher mean live weight, live weight at calving, live weight at 100 and 200 days post calving, and at drying-off, compared with the J x HF cows (P<0.001), while the reverse was true for condition score (P<0.001, P<0.001, P<0.001, P<0.01 and P<0.05, respectively) (Table 9). At calving, 100 days post calving, 200 days post calving and drying-off, HF cows weighted 56, 44, 43 and 34 kg more than J x HF cows, respectively. Liveweight nadir was lowest with the J x HF cows (P<0.001) while liveweight loss to nadir was highest with the HF cows (P<0.05). Days to liveweight nadir and liveweight gain from nadir to drying-off was unaffected by genotype (P<0.05).

Milk production system had a significant effect on cow live weight at drying-off (P<0.01) and on liveweight gain from the nadir live weight to drying off (P<0.001), with both of these parameters being highest for cows on system HC.

System had no effect on any of the other live weight or condition score parameters examined. A significant ($P<0.001$) genotype x system interaction was observed for days to nadir live weight (18.6, 13.4 and 17.2 days for HF cows, and 15.1, 18.6 and 17.2 days for J x HF cows, on systems LC, MC and HC, respectively).

For each of the two genotypes, changes in live weight and condition score during the first 40 weeks of lactation are presented in Figures 2a and 2b, respectively. Based on a repeated measures analysis, there was a significant effect of genotype ($P<0.001$), system ($P<0.05$) and time ($P<0.001$) on live weight and body condition score, but no significant interactions between genotype and system or genotype and time ($P>0.05$).

Neither dairy cow genotype nor milk production system had a significant effect ($P>0.05$) on plasma NEFA and BHB concentrations ($P>0.05$). Plasma NEFA content decreased with time post-calving ($P<0.001$). There were no significant genotype x system or genotype x time interactions for plasma NEFA or BHB concentrations ($P>0.05$).

3.4. Fertility performance and cow health

While genotype had no effect on the proportion of cows with commencement of LA pre day 42 post-calving ($P>0.05$), J x HF cows had a shorter interval between calving and commencement of LA ($P<0.05$) (Table 10). In addition, days to first observed heat were fewer ($P<0.05$), while conception rate to first service ($P<0.01$), conception to first and second service ($P<0.001$), and pregnancy rate at the end of breeding season ($P<0.05$) were higher with the J x HF cows, than with the HF cows. There was no significant difference between genotype for mean number of services per cow or the interval from calving to conception ($P>0.05$). System of milk production had no significant effect on any of the fertility parameters examined within the current study, and there was no evidence of a genotype x system interaction for any parameter ($P>0.05$).

Across the three years of the study a larger proportion of HF cows were observed to have one or more cases of mastitis, compared to J x HF cows

($P<0.05$), while genotype had no significant effect on the mean locomotion score or the proportion of cows with one or more cases of lameness ($P>0.05$) (Table 10). The proportion of cows with one or more cases of lameness increased with increasing concentrate supplementation (0.04, 0.16 and 0.25 for systems LC, MC and HC, respectively; $P<0.01$) while milk production system had no effect on the proportion of cows with at least one case of mastitis or mean locomotion score ($P>0.05$). There was no significant genotype x system interactions observed for any of the cow health parameters examined. In addition, HF and J x HF cows had mean calving difficulty scores of 1.5 and 1.3 (SED, 0.08; $P<0.05$), respectively. Similarly, mean calf birth weights were 43.1 and 37.0 kg (SED, 0.82; $P<0.001$) for offspring of the HF and J x HF cows, respectively.

4.0. Discussion

This experiment was undertaken to compare the performance of HF and J x HF dairy cows within three contrasting milk production systems. While these systems differed in a number of ways, for example in relation to turnout date and grazing management, the predominant difference between systems was in concentrate feeding level. Cows managed on systems LC, MC and HC consumed on average 466, 961 and 1467 kg concentrate DM/lactation, respectively.

4.1. Food Intake

Few studies have compared the food intake of Holstein and crossbred dairy cows within a confinement environment. Within the current experiment food intakes were recorded during early lactation (prior to turnout) for cows managed on systems MC and HC. The early turnout date adopted within system LC precluded the use of the limited intake data from this system within the analysis. Dry matter intakes recorded during this very early lactation period were low (14.7 and 14.8 kg DM/cow/day for HF and J x HF cows, respectively), and were unaffected by genotype. These low intakes may reflect the young age structure of the experimental cows (mean lactation number 1.9), and the fact that intakes were recorded during the early lactation period prior to many cows achieving their full intake potential. That DM intake was not affected by genotype within the current experiment is in agreement with the findings of Heins *et al.* (2008a), who observed primiparous Holstein and Jersey x Holstein cows to have similar DM intakes (22.7 and 22.0 kg DM/cow/day, respectively) during the first 21 weeks of lactation. However, findings with regards to intakes have not always been consistent. For example, in two separate studies involving grass silage-based diets similar to those offered within the current study, intakes of Jersey crossbred cows were 0.9 kg/day higher than those of Holstein-Friesian cows (Xue *et al.*, 2010) and 1.4 kg/day lower than those of Holstein-Friesian cows (Vance *et al.,* 2010).

In line with the trends in DM intakes measured during the indoor periods, herbage intakes did not differ between genotypes during any of the three measurement periods in Year 2 (mean intake across the three periods, 11.7 and 11.8 kg DM/day in HF and J x HF cows, respectively) or the two measurement periods in Year 3 (mean intake across the two periods, 12.3 and 11.8 kg DM/day in HF and J x HF cows, respectively). In other grazing studies involving low levels of concentrates, Gonzalez-Verdugo *et al.* (2005), Prendiville *et al.* (2010a) and Vance *et al.* (2010) reported herbage DM intakes of Holstein-Friesian and Jersey x Holstein-Friesian cows to be similar, with mean intakes across these latter three studies being 15.9 and 15.2 kg DM/day, respectively. Vance *et al.* (2010) suggested that smaller J x HF cows modify their grazing behaviour to allow them to achieve similar herbage intakes as larger Holstein-Friesian cows. For example, these authors observed the Jersey x Holstein cows to have an increased grazing time and an increased number of grazing bites each day, compared with Holstein-Friesian cows.

While concentrate supplementation normally results in an increase in total DM intake (Ferris *et al.*, 2001), no such effect was observed during the early and late lactation confinement periods. This is likely a reflection of the relatively small differences in daily concentrate feed levels between systems. However, total DM intake during the grazing period increased with increased concentrate supplementation, while herbage DM intake remained relatively similar across feeding systems (mean intake across five measurement periods; 11.6, 12.4 and 11.6 kg DM/day for LC, MC and HC, respectively) suggesting that substitution effects were extremely small. While Bargo *et al.* (2002) reported a mean substitution rate (across 10 studies) of 0.39 kg herbage DM/kg concentrate DM (range, 0.02 – 0.71), substitution effects tend to be lowest where herbage allowances are low. The relatively low residual sward heights in this study (6.0, 6.0 and 5.7 cm for LC, MC and HC, respectively) suggest that cows were grazing tightly. Nevertheless, herbage intakes within this study tended to be lower than those measured in similar studies involving cows producing similar milk outputs (Prendiville *et al.,* 2010a).

4.2. Milk production and composition

Differences between HF and J x HF cows in terms of milk yield, milk composition and yield of milk constituents within the current study are in line with those reported previously within the literature. For example, within low input grass-based milk production systems Holstein-Friesian cows produced 241 kg (Lopez-Villalobos *et al.*, 2000) and 274 kg (Prendiville *et al.*, 2010b) more milk than Jersey crossbred cows, while milk fat and milk protein concentrations were on average 4.8 g/kg and 3.8 g/kg higher, respectively, with the Jersey crossbred cows. Within the current study HF cows produced on average 625 kg more milk than J x HF cows, while milk fat and protein concentrations were 5.8 and 2.9 g/kg higher with the J x HF cows. In agreement with the findings of the current study, Auldist *et al.* (2007), Prendiville *et al.* (2009) and Vance *et al.* (2010) reported no significant difference between Holstein-Friesian and Jersey x Holstein-Friesian dairy cows for fat plus protein outputs. Thus the results of the current study, in line with much of the literature, demonstrate that crossbreeding Holstein-Friesian dairy cows with Jersey sires will normally result in a loss in milk yield, but in most cases, no loss in the yield of milk constituents. While the contribution of hybrid vigour to milk production performance cannot be identified within the current study, recent estimates within the literature (across a range of studies) for milk yield, milk fat content and milk protein content are 5.1%, 2.1% and 2.8%, respectively (Lopez-Villalobos *et al.,* 2000; Van Raden and Sanders, 2003; Freyer *et al.,* 2008 and Prendiville *et al.,* 2010b).

This difference in lactation milk production between the two genotypes was reflected in the different lactation curves observed, with peak yield for the HF cows (30.7 kg/day) being higher than for the J x HF cows (27.1 kg/day). In addition, the decline in daily milk yield (*c*) was highest with the Holstein cows, indicating a less persistent lactation profile than for the J x HF cows. This is consistent with the findings of Hickson *et al.* (2006), who reported higher lactation persistency in pure bred Jersey dairy cows compared with Friesian dairy cows. Although there were subtle differences between genotypes in the shape of the fat plus protein yield lactation curve, neither peak yield, nor the rate of decline after the peak, differed between genotypes, with this reflected in the absence of a genotype effect on full lactation fat plus protein yield.

A key objective of this study was to compare the responses of the two cow genotypes to increasing concentrate feeding levels. While the HF cows might have been expected to exhibit a greater response to higher concentrate levels, no interaction between genotype and management system was observed for any of the milk production parameters investigated. While no studies have been identified in which the milk production response to concentrate supplementation has been compared in Holstein-Friesian and Jersey x Holstein-Friesian dairy cows, Kennedy *et al.* (2003) reported a significantly higher milk yield response in 'high' genetic merit Holstein-Friesian dairy cows (1.01 kg milk/kg concentrate DM) compared with 'low' genetic merit Holstein-Friesian dairy cows (0.74 kg milk/kg concentrate DM) when concentrate supplementation was increased from 376 kg/cow to 1540 kg/cow. Horan *et al.* (2005) reported a similar effect in a comparison involving Holstein-Friesian dairy cows selected for high levels of milk production and New Zealand Holstein-Friesian dairy cows. However, in agreement with the findings of the current experiment, Walsh *et al.* (2008) observed no genotype x feeding system interactions for milk production parameters in a comparison involving Holstein-Friesian, Montbeliarde, Normande, Norwegian Red, Montbeliarde x Holstein-Friesian and Normande x Holstein-Friesian dairy cows within grazing systems involving either 530 or 1030 kg concentrate/cow/lactation. Thus a key finding within the current study was that within the range of concentrate levels examined, J x HF cows had the genetic potential for milk production to exhibit similar milk yield and milk constituent yield responses as pure bred HF cows. The implication of this is that crossbreeding may have a role within higher concentrate input systems of milk production, rather than being restricted to lower concentrate input systems.

Nevertheless, the response to additional concentrate feeding within the current study was somewhat disappointing especially at the highest concentrate level. For example, while the production response to concentrate supplementation was substantial between systems LC and MC (1.38 kg milk and 0.14 kg fat plus protein/kg concentrate DM intake), the response between systems MC and HC was much lower (0.50 kg milk and 0.02 kg fat plus protein/kg concentrate DM intake), with differences between these systems (MC and HC) not being significant for any of the milk yield or milk constituent yield parameters investigated. Milk yield responses to concentrate supplementation within the literature are variable, with Bargo *et al.* (2002) reporting a mean response of 0.75 kg milk/kg concentrate DM intake (range, 0.06 to 1.56). The response of grazing dairy cow to concentrate supplementation is known to be influenced by many factors, including herbage allowance and composition, stage of lactation, and level and type of concentrate offered (Bargo *et al.*, 2003).

4.3. Milk fatty acid profile

The link between the intake of various fats and human health issues such as cardiovascular disease, cancer and obesity (Ip *et al.,* 1994; Hamazaki *et al.,* 2003; Lock and Bauman, 2004) has prompted a renewed interest in the fatty acid content of milk. Although a number of studies have examined the impact of cow genotype on milk fatty acid content, reports are often inconsistent. For example, while White *et al.* (2001) and Palladino *et al.* (2010) reported significantly higher concentrations of C16:0 with Jersey and Jersey crossbred cows (compared with Holstein-Friesian cows), respectively, no such effect was observed within the current study. Although the majority of saturated fats are considered to have harmful effects on human health, C18:0 is considered to have a neutralising effect on serum cholesterol levels. Within the current study C18:0 was higher in the milk of J x HF cows compared with HF cows, thus supporting the findings of a similar study undertaken by Vance (2011).

Concentrations of CLA, which has been reported to have anticarcinogenic properties in rats (Ip *et al.,* 1994) were higher in milk of HF cows than in the milk of J x HF cows within the current study. This was in line with the findings of White *et al.* (2001) who also reported higher concentrations of CLA in milk of Holstein cows compared with purebred Jersey cows. In contrast, Palladino *et al.* (2010) observed no difference between Holstein-Friesian, Jersey and Jersey x Holstein-Friesian cows for milk CLA content. The higher CLA concentrations reported by Palladino *et al.* (2010) compared to those within the current study, may reflect the overall higher concentrate supplementation levels within the current study. Previous studies have shown the CLA content of milk to increase as the proportion of pasture in the diet increases (Dewhurst *et al.,* 2006) with a similar effect observed within the current study. Thus while it is apparent that differences exist between genotypes for milk fatty acid content, results are by no mean consistent, and as such variations between individual sires within breed may be of greater importance than differences between breeds.

4.4. Body tissue change and blood metabolites

Within the current study Jersey crossbred cows were on average 44 kg lighter than HF cows, in line with the findings of Harris and Kolver (2001), Gonzalez-Verdugo *et al.* (2005), Auldist *et al.* (2007) and Heins *et al.* (2008a), (52 kg, 45 kg, 40 kg and 60 kg lighter, respectively). While Anderson *et al.* (2007) and Auldist *et al.* (2007) observed no difference in condition score between Holstein and Jersey crossbred cows, within the current study the J x HF cows had a 0.2 unit higher mean condition score than the HF cows. This agrees with the findings of Heins *et al.* (2008a) and Prendiville *et al.* (2009). Despite these differences in actual live weight and condition score between the two genotypes, the condition score and liveweight change curves for the HF and J x HF cows followed strikingly similar trajectories throughout lactation, although the HF cows lost an extra 11.0 kg live weight between calving and nadir. Nevertheless, these curves do suggest that levels of tissue mobilisation in early lactation, and tissue gain in late lactation, were similar between genotypes. In contrast, Walsh *et al.* (2008) reported a significant interaction between stage of lactation and dairy cow genotype for live weight and condition score change during lactation. For example, Holstein-Friesian cows had a higher condition score loss during the early lactation period than either Normande x Holstein-Friesian cows or Montbeliarde x Holstein-Friesian cows, while throughout the lactation Holstein-Friesian cows maintained a lower condition score than either of the other genotypes. However, Olson *et al.* (2010), Prendiville *et al.* (2009) and Heins *et al.* (2008a) reported similar liveweight change trends in Holstein-Friesian, Jersey and Jersey x Holstein-Friesian cows, thus supporting the findings of the current experiment, although Heins *et al.* (2008a) reported that condition score loss in early lactation plateaued earlier with Jersey x Holstein cows. The similar trends in tissue mobilisation with the two genotypes in the current study are supported by the similar trends in plasma NEFA and BHB concentrations (both considered indicators of adipose tissue breakdown).

The similar trends in tissue mobilisation and deposition, and the similar nutrient intakes discussed earlier, help explain the similar milk energy outputs observed with the two cow genotypes. In addition, the smaller crossbred cows would be expected to have a maintenance energy requirement approximately 5.0 MJ/day lower than the larger HF cows (Thomas, 2004), with this having the potential to support an extra one kilogram of milk (approximately). However it was not possible to identify any clear milk performance benefits associated with this energy saving within the current study. Nevertheless, milk energy output per kg live weight (0.126 and 0.136 MJ/kg, for HF and J x HF cows, respectively: SED, 0.0029: $P<0.001$) and milk energy output/kg live weight$^{0.75}$ (0.597 and 0.632 MJ/kg, for the HF and J x HF cows, respectively: SED, 0.0130: $P<0.01$) was higher with the crossbred cows suggesting that improved production efficiency did exist.

With the exception of increased liveweight gain from nadir to drying-off, and actual live weight at drying-off, both of which were highest with the HC system, there was no evidence of system having a significant effect on any body tissue parameter examined. Similarly, Walsh *et al.* (2008) reported higher liveweight gains (between weeks-13 to 44 of lactation) in a range of dairy cow genotypes managed on a high concentrate feeding system compared with those managed on a low concentrate feeding system. Furthermore, while none of Kennedy *et* *al.* (2002), Roche *et al.* (2006) or McCarthy *et al.* (2007) observed a significant difference for live weight and condition score loss in early lactation between feeding systems which differed in concentrate inputs, both live weight and condition score gain (post nadir) was highest in cows managed on high concentrate feeding systems, in line with the current study.

4.6. Cow fertility and health

There was clear evidence of earlier resumption of cyclicity and improved fertility with the crossbred cows in the current study. For example, commencement of LA and days to first observed heat occurred 3.4 and 8.8 days earlier, respectively, with the J x HF cows than with the HF cows. In addition, conception rate to first service, conception rate to first and second service and pregnancy rate at the end of the breeding season were 23, 29 and 16 percentage points higher with the J x HF cows, compared to the HF cows. These findings are in general agreement with those within the literature, with Auldist *et al.* (2007), Prendiville *et al.* (2008) and Thackaberry *et al.* (2009) observing higher conception rates to first service (mean: 22 percentage points higher) and Heins *et al.* (2008b) and Auldist *et al.* (2007) observing higher overall conception rates (mean: 10.5 percentage points higher) with Jersey crossbred cows. Improved fertility performance has also been observed in studies involving other crossbred genotypes. For example, Walsh *et al.* (2008) reported higher first service conception rates and higher overall pregnancy rates with Montbeliarde x Holstein-Friesian and Normande x Holstein-Friesian cows, compared with pure bred Holstein-Friesian cows.

Previous studies have highlighted the association between negative energy balance, excessive tissue mobilisation during early lactation and reduced fertility performance (Veerkamp *et al.*, 2003). For example, Pryce *et al.* (2001) suggested that cows which are genetically predisposed to loose more body condition between weeks 1 - 10 of lactation will have increased days to first observed heat, increased days to first service, and longer calving intervals. However the improved fertility performance with the J x HF cows within the current study occurred despite similar levels of condition score loss with the two genotypes, and the absence of evidence from blood metabolite data that the two genotypes differed in terms of levels of metabolic stress experienced. While there is some evidence that pure bred Jersey cows tend to have higher levels of fertility performance than pure bred Holstein-Friesian cows (Grosshans *et al.*, 1997; Washburn *et al.*, 2002), hybrid vigour is likely to have been a significant contributor to the improved fertility performance observed with the crossbred cows. Hybrid vigour for fertility parameters is normally positive, with Lopez-Villalobos (1998) reporting a mean hybrid vigour of 5.8 days for each of interval from calving to conception and for ‘days open’ (across 11 studies). Thus, the findings of this experiment suggests that crossbreeding Holstein dairy cows with Jersey sires can provide an immediate opportunity to overcome some of the fertility problems widely reported with the Holstein breed.

Although concentrate inputs increased from 466 kg DM/cow with LC to 1467 kg DM/cow with HC, there was no evidence that fertility performance increased with increasing concentrate levels. In view of the absence of a system effect on BCS change in early lactation, and on concentrations of plasma NEFA and BHB, it is perhaps unsurprising that fertility performance was unaffected by concentrate supplementation. Similar effects have been observed in previous studies (Buckley *et al.*, 2000; Snijders *et al.*, 2001; Horan *et al.*, 2004). For example, within the latter study Horan *et al.* (2004) observed no difference in conception rates to first service, conception to first and second service and overall pregnancy rates, when concentrate feed levels increased from 366 kg/cow to 1452 kg/cow.

Most studies have reported no difference between Holstein-Friesian and Jersey x Holstein-Friesian cows for mean SCC (Heins *et al.*, 2008b; Prendiville *et al.*, 2010b). This is perhaps not surprising when we consider that purebred Jersey cows often have either similar (Washburn *et al.*, 2002; Sewalem *et al.*, 2006; Prendiville *et al.*, 2010b) or higher (Berry *et al.*, 2007) SCC’s than pure bred Holstein cows. In addition, benefits of hybrid vigour on SCC appear to be low, with VanRaden and Sanders (2003) reporting levels of hybrid vigour for SCC in Holstein, Jersey and Guernsey crossbred cows to be low and unfavourable, while Prendiville *et al.* (2010b) observed no evidence of hybrid vigour for SCC in Jersey crossbred cows.

While SCC was unaffected by genotype in the current study, the proportion of cows with one or more cases of mastitis was approximately 45% higher with the HF cows. In contrast, Prendiville *et al.* (2010b) reported no difference between Holstein-Friesian and Jersey x Holstein-Friesian cows for the proportion of cows having at least one case of mastitis.

There is a perception that Jersey crossbred dairy cows have improved hoof health compared to Holstein cows. Although not significant within the current study, there was a tendency for HF cows to have more cases of lameness. Indeed, Logue *et al.* (1994) reported that Jersey x Holstein cows had a lower incidence and prevalence of lameness than pure bred Holstein cows, as well as having lower sole lesion scores. Furthermore, studies comparing hoof health of pure bred Jersey cows to that of a second breed suggest Jersey cows to have improved hoof health (Alban, 1995; Huang *et al.*, 1995; Boelling *et al.*, 2001). This may be due to Jersey and Jersey crossbred cows having harder hooves. For example, in a small scale study Leithbridge and Margerison (2008) reported that the force needed to puncture the hooves of Jersey x Friesian cows was significantly higher than for the hooves of pure bred Friesian cows, and this could make the former more resilient to challenges of the hoof.

5.0. Conclusions

While J x HF cows produced less milk than HF cows, improved compositional quality with the former meant that fat plus protein yield was unaffected by genotype. There was no evidence of a genotype x environment interaction for any of the milk production parameters examined, suggesting that J x HF cows may have a role within higher concentrate input systems. The Jersey crossbred cows had improved fertility performance, despite there being no difference between genotypes for live weight and condition score change throughout lactation. Although SCC did not differ between genotypes, mastitis incidence was lowest with the Jersey crossbred cows. While concentrate supplementation improved milk production, fertility performance was unaffected by additional concentrate supplementation.

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7.0. References

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Table 1 Number of cows of each genotype on the experiment during each of Years 1, 2 and 3

	Genotype				Milk Production System					
	HF		J x HF		LC		MC		HC	
	Primiparous	Multiparous	Primiparous	Multiparous	HF	J x HF	HF	J x HF	HF	J x HF
Year 1	21	7	21	7	9	9	9	10	10	9
Year 2	12	23	8	24	11	11	13	11	11	10
Year 3	9	33	9	23	14	11	13	12	15	9

HF, Holstein-Friesian; J x HF, Jersey x Holstein-Friesian
LC, Low Concentrate; MC, Medium Concentrate; HC, High Concentrate

Table 2 Overview of the three experimental systems examined

	Low Concentrate (LC)	Medium Concentrate (MC)	High Concentrate (HC)
Winter feeding period	Grass silage supplemented with 6.0 kg concentrate/cow/day (via in-parlour feeders)	Grass silage supplemented with 8.0 kg concentrate/cow/day (via out-of-parlour feeders)	Grass silage supplemented with 10.0 kg concentrate/cow/day (mixed with silage in a complete diet)
Grazing period	Early turnout in spring. Flexible grazing system (daily herbage allocation of 20.0 kg dry matter/cow/day). Minimum concentrate supplementation	Later turnout in spring. Rotational paddock grazing system. Concentrate feed level approximately 2.5 kg/cow/day	Later turnout in spring. Rotational paddock grazing system. Concentrate feed level approximately 5.0 kg/cow/day
Late lactation period	Grass silage and 1.0 kg concentrate/cow/day	Grass silage and 2.0 kg concentrate/cow/day	Grass silage and 3.0 kg concentrate/cow/day

Table 3 Ingredient composition of concentrate feed stuffs offered during the indoor winter periods and summer grazing periods

	Indoor winter period		Summer grazing period	
	Years 1 & 2	Year 3	Year 1	Years 2 & 3
Barley	140	140	100	190
Wheat	140	140		
Maize meal			280	190
Unmolassed sugar beet pulp	100	100	310	310
Citrus pulp	100	100		
Maize gluten feed	120	190		
Distillers grains (maize)	120			
Soya bean meal	100	110	200	200
Rape meal	120	160	40	40
Megalac	14	14		
Vitamins and minerals	22	22	30	30
Calcined magnesite	4	4	10	10
Molaferm	20	20	30	30

Table 4 Effect of dairy cow genotype and management system on food intake (kg DM/cow/day) during the periods when cows were housed (early lactation and late lactation)

	Genotype (G)				System (S)				
	HF	J x HF	SED	Sig	LC	MC	HC	SED	Sig
Early lactation (Year 1 – 3) ‡									
Grass Silage[1]	7.1	7.2	0.27	NS	-	7.8	6.5	0.27	***
Concentrates[1]	7.4	7.4	0.22	NS	-	6.5	8.3	0.22	***
Total Intake[1]	14.7	14.8	0.44	NS	-	14.7	14.8	0.44	NS
Late Lactation (Years 1 and 2) †									
Grass Silage[1]	11.4	11.0	0.43	NS	11.6	11.3	10.6	0.53	NS
Concentrates[1]	1.7	1.7	0.03	NS	1.0	1.6	2.4	0.04	***
Total Intake[1]	13.0	12.6	0.43	NS	12.6	12.9	13.0	0.53	NS

HF, Holstein-Friesian; J x HF, Jersey x Holstein-Friesian; LC, Low Concentrate; MC, Medium Concentrate; HC, High Concentrate
‡, calving until start of turnout, †, full-time housing until drying off
[1], kg dry matter/cow/day

Table 5 Effect of dairy cow genotype and management system on intakes (kg DM/cow/day) during the grazing period in Years 2 and 3, as measured using the n-alkane technique

	Genotype (G)				System (S)				
	HF	**J x HF**	**SED**	**Sig**	**LC**	**MC**	**HC**	**SED**	**Sig**
Year 2									
First measurement period (21st – 25th May)									
Grass Intake[1]	11.3	11.4	0.45	NS	11.8[a]	12.0[a]	10.3[b]	0.56	***
Total Intake[1]	13.5	15.6	0.45	NS	11.8[a]	14.2[b]	14.7[b]	0.56	***
Second measurement period (23rd – 27th July)									
Grass Intake[1]	11.3	11.2	0.30	NS	9.5[a]	12.1[b]	12.1[b]	0.40	***
Total Intake[1]	13.5	13.4	0.30	NS	9.5[a]	14.3[b]	16.5[c]	0.37	***
Third measurement period (24th – 28th Sept)									
Grass Intake[1]	12.6	12.7	0.42	NS	12.0[a]	11.9[a]	13.8[b]	0.52	***
Total Intake[1]	14.8	14.8	0.42	NS	12.0[a]	14.1[b]	18.2[c]	0.52	***
Year 3									
First measurement period (26th – 30th May)									
Grass Intake[1]	13.6	12.9	0.48	NS	13.6[a]	14.3[a]	11.9[b]	0.61	***
Total Intake[1]	15.8	15.1	0.48	NS	13.6[a]	16.5[b]	16.3[b]	0.61	***
Second measurement period (11th – 15th August)									
Grass Intake[1]	11.0	10.7	0.56	NS	11.2[a]	11.7[a]	9.7[b]	0.70	*
Total Intake[1]	13.2	12.9	0.56	NS	11.2[a]	13.9[b]	14.0[b]	0.70	***

HF, Holstein-Friesian; J x HF, Jersey x Holstein-Friesian; LC, Low Concentrate; MC, Medium Concentrate; HC, High Concentrate
[abc], means with the same superscripts, within rows, are not significantly different
[1], kg dry matter/cow/day

Table 6 Effect of dairy cow genotype and management system on 'days in milk', total lactation concentrate intake, total lactation milk production and mean somatic cell count (mean of Years 1, 2 and 3)

	Genotype (G)				System (S)				
	HF	J x HF	SED	Sig	LC	MC	HC	SED	Sig
Days in milk	305	302	4.6	NS	299	304	307	5.6	NS
Concentrate intake (kg DM)	947	963	25.0	NS	466[a]	961[b]	1467[c]	30.7	***
Milk yield (kg)	6252	5627	175.2	***	5399[a]	6084[b]	6336[b]	215.3	***
Milk composition (g/kg)									
Fat	42.0	47.8	0.73	***	44.3	45.9	44.5	0.90	NS
Protein	33.0	35.9	0.34	***	34.1	34.6	34.6	0.42	NS
Lactose	45.9	46.3	0.20	*	45.9	46.1	46.3	0.24	NS
Milk solids yield (kg)									
Fat	261	269	8.1	NS	238[a]	278[b]	280[b]	10.0	***
Protein	206	202	5.6	NS	183[a]	210[b]	219[b]	6.9	***
Fat + protein	467	471	13.4	NS	421[a]	488[b]	498[b]	16.5	***
Solids corrected milk yield (kg)[1]	6264	6186	177.7	NS	5599[a]	6458[b]	6618[b]	218.4	***
Milk energy output (GJ)[2]	19.6	19.4	0.56	NS	17.5[a]	20.2[b]	20.7[b]	0.68	***
Mean SCC (000/ml)	218	173	36.7	NS	175	195	219	45.3	NS
Mean SCC (000/ml log^{10})	2.17	2.14	0.055	NS	2.13	2.18	2.14	0.068	NS

HF, Holstein-Friesian; J x HF, Jersey x Holstein-Friesian; LC, Low Concentrate; MC, Medium Concentrate; HC, High Concentrate
[1] Solids corrected milk yield (kg/day) = 0.0123 Fat + 0.00656 Solids not Fat – 0.0752 x (milk yield) (Tyrrell and Reid, 1965);
Where Solids Not Fat = Protein + Lactose + Ash : Ash assumed as 7.1 g/kg
[2] Milk energy output = 0.0386 Fat + 0.0205 Solids not Fat – 0.236 x (Milk Yield) (Tyrrell and Reid, 1965)
[abc] means with the same superscripts, within rows, are not significantly different
SCC, Somatic Cell Count

Table 7 Effect of dairy cow genotype and management system on fitted parameters (*a*, *b* and *c*) of Wilmink curves describing lactation curves for milk yield and milk fat plus protein yield, and on estimates of peak yield and days to peak yield

		Genotype (G)				System (S)				
		HF	J x HF	SED	Sig	LC	MC	HC	SED	Sig
Milk yield (kg/day)	*a*	35.3	31.9	0.77	***	31.7[a]	34.2[b]	34.7[b]	0.94	**
	b	-13.4	-15.5	1.91	NS	-9.5[a]	-16.5[b]	-17.4[b]	2.34	**
	c	-0.091	-0.080	0.0031	***	-0.087	-0.087	-0.083	0.0038	NS
Milk fat + protein yield (kg/day)	*a*	2.35	2.40	0.064	NS	2.32[a]	2.29[a]	2.52[b]	0.079	**
	b	-0.24	-0.83	0.170	***	-0.24[a]	-0.65[b]	-0.71[b]	0.208	*
	c	-0.006	-0.006	0.0002	NS	-0.006	-0.005	-0.005	0.0003	NS
Days to peak yield		40.2	44.2	2.46	NS	35.8[a]	43.4[b]	47.3[b]	3.05	***
Peak milk yield (kg/day)		30.7	27.1	0.65	***	27.8	29.2	29.7	0.81	NS
Days to peak fat + protein yield		35.6	44.1	2.88	**	34.9	43.4	41.3	3.58	NS
Peak fat + protein yield (kg/day)		2.12	2.11	0.067	NS	2.08[a]	2.03[a]	2.23[b]	0.083	*

HF, Holstein-Friesian; J x HF, Jersey x Holstein-Friesian; LC, Low Concentrate; MC, Medium Concentrate; HC, High concentrate
[abc] means with the same superscripts, within rows, are not significantly different

Table 8 Effect of dairy cow genotype and management system on milk fatty acid concentrations (g/kg of milk fat identified) (mean of three sampling periods during Year 3)

	Genotype (G)				**System (S)**				
	HF	**J x HF**	**SED**	**Sig**	**LC**	**MC**	**HC**	**SED**	**Sig**
C4 – C14	298.7	310.9	5.10	*	295.7[a]	308.6[b]	310.0[b]	0.63	*
C14:1	16.1	15.2	0.73	NS	15.5	15.6	15.9	0.89	NS
C15:0	13.1	13.2	0.26	NS	13.0	13.1	13.3	0.32	NS
C15:1	3.05	2.95	0.087	NS	3.09	2.94	2.98	0.107	NS
C16:0	300.5	299.2	4.80	NS	293.8	303.5	302.1	5.91	NS
C16:1	18.7	17.0	0.75	*	18.5	16.8	18.3	0.92	NS
C17:0	6.63	6.61	0.151	NS	6.94[a]	6.46[b]	6.47[b]	0.185	*
C17:1	2.40	2.19	0.141	NS	2.52	2.19	2.16	0.175	NS
C18:0	93.0	99.7	2.83	*	99.2	95.9	94.1	3.48	NS
C18:1	210.9	199.5	5.11	*	216.6[a]	199.4[b]	199.7[b]	6.29	*
C18:2	14.3	13.3	0.42	*	12.2[a]	13.0[a]	16.2[b]	0.51	***
C18:3	7.9	8.0	0.26	NS	8.4	7.7	7.7	0.32	NS
C20:0	0.32	0.48	0.010	NS	0.51	0.32	0.36	0.120	NS
C20:1	0.53	0.45	0.071	NS	0.42[a]	0.67[b]	0.39[a]	0.088	**
[1]CLA	12.4	11.2	0.54	*	13.3[a]	11.4[ab]	10.7[b]	0.66	***

HF, Holstein-Friesian; J x HF, Jersey x Holstein-Friesian; LC, Low Concentrate; MC, Medium Concentrate; HC, High Concentrate
[1] CLA, Conjugated Linoleic Acid
[abc], means with the same superscripts, within rows, are not significantly different

Table 9 Effect of cow genotype and management system on live weight and condition score parameters during the lactation (mean of Years 1, 2 and 3)

	Genotype (G)				System (S)				
	HF	**J x HF**	**SED**	**Sig**	**LC**	**MC**	**HC**	**SED**	**Sig**
Live weight (kg)									
Mean	513	469	8.5	***	483	488	502	10.4	NS
At calving	547	491	9.7	***	515	513	539	12.0	NS
At day-100 post-calving	494	450	8.6	***	469	467	479	10.5	NS
At day-200 post-calving	507	464	8.7	***	477	486	494	10.7	NS
At drying off	549	515	9.9	***	514[a]	530[ab]	553[b]	12.2	**
Nadir	471	428	8.2	***	449	446	453	10.1	NS
Loss to nadir	74.7	63.7	5.02	*	65.9	66.8	74.9	6.16	NS
Days to nadir	16.4	17.0	1.08	NS	16.8	16.0	17.2	1.33	NS
Gain from nadir to drying off	80.1	88.1	4.51	NS	65.4[a]	85.3[b]	101.6[c]	5.53	***
Condition Score									
Mean	2.33	2.50	0.047	***	2.37	2.39	2.48	0.058	NS
At calving	2.68	2.87	0.046	***	2.80	2.72	2.81	0.057	NS
At day-100 post-calving	2.34	2.53	0.055	***	2.40	2.41	2.49	0.067	NS
At day-200 post-calving	2.26	2.41	0.050	**	2.29	2.33	2.38	0.061	NS
At drying off	2.24	2.38	0.065	*	2.25	2.25	2.42	0.079	NS

HF, Holstein-Friesian; J x HF, Jersey x Holstein-Friesian; LC, Low Concentrate; MC, Medium Concentrate; HC, High Concentrate
[abc] means with the same superscripts, within rows, are not significantly different

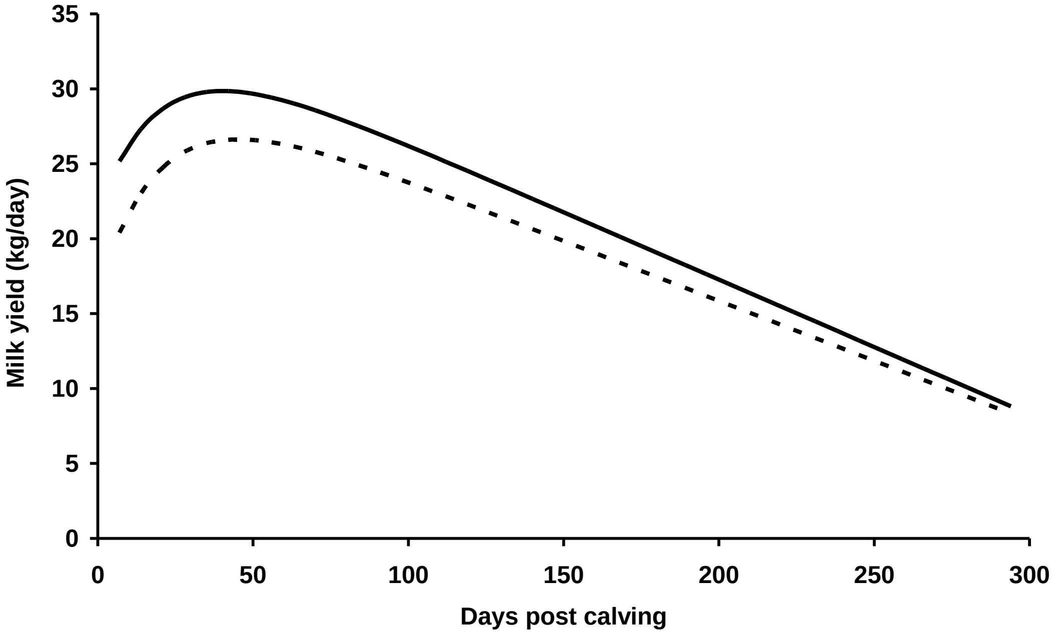
Table 10 Effect of dairy cow genotype and management system on cyclicity, reproductive performance and health parameters (mean of Years 1, 2 and 3)

	Genotype (G)				System (S)				
	HF	**J x HF**	**SED**	**Sig**	**LC**	**MC**	**HC**	**SED**	**Sig**
Pre day-42 post calving									
Proportion of cows displaying LA	0.80	0.90	0.063	NS	0.88	0.78	0.88	0.077	NS
[1]Interval to commencement of LA (days)	27.0	23.6	1.49	*	24.8	26.8	24.4	1.86	NS
[1]Peak progesterone at first rise (ng/ml)	27.2	28.3	2.09	NS	26.6	27.4	29.3	2.63	NS
Fertility performance (proportional basis unless stated otherwise)									
Days to first observed heat	50.5	41.7	3.71	*	41.1	47.7	49.6	4.54	NS
Conception to first service (proportion)	0.35	0.58	0.080	**	0.50	0.47	0.37	0.098	NS
Conception to first and second service (proportion)	0.52	0.81	0.077	***	0.71	0.62	0.62	0.095	NS
Pregnancy rate at end of breeding season (proportion)	0.73	0.89	0.064	*	0.80	0.79	0.82	0.079	NS
Mean number of services per cow	2.0	1.8	0.18	NS	1.7	2.0	2.0	2.22	NS
Interval from calving to conception (days)[2]	97.5	90.1	5.23	NS	96.0	87.7	97.6	6.35	NS
Health parameters									
Proportion of cows with at least one case of mastitis	0.29	0.16	0.067	*	0.25	0.20	0.28	0.082	NS
Proportion of cows with at least one case of lameness	0.19	0.11	0.057	NS	0.04	0.16	0.25	0.070	**
Mean locomotion score	2.6	2.6	0.02	NS	2.6	2.6	2.6	0.02	NS

HF, Holstein-Friesian; J x HF, Jersey x Holstein-Friesian; LC, Low Concentrate; MC, Medium Concentrate; HC, High Concentrate
[1] for cows displaying luteal activity (LA); [2], for cows that became pregnant

Figure 1 Effect of dairy cow genotype (HF, ———; J x HF, **-------**) on the lactation profile for daily milk yield (a) and daily fat plus protein yield (b) (mean across systems LC, MC and HC during Years 1, 2 and 3)

(a)



(b)

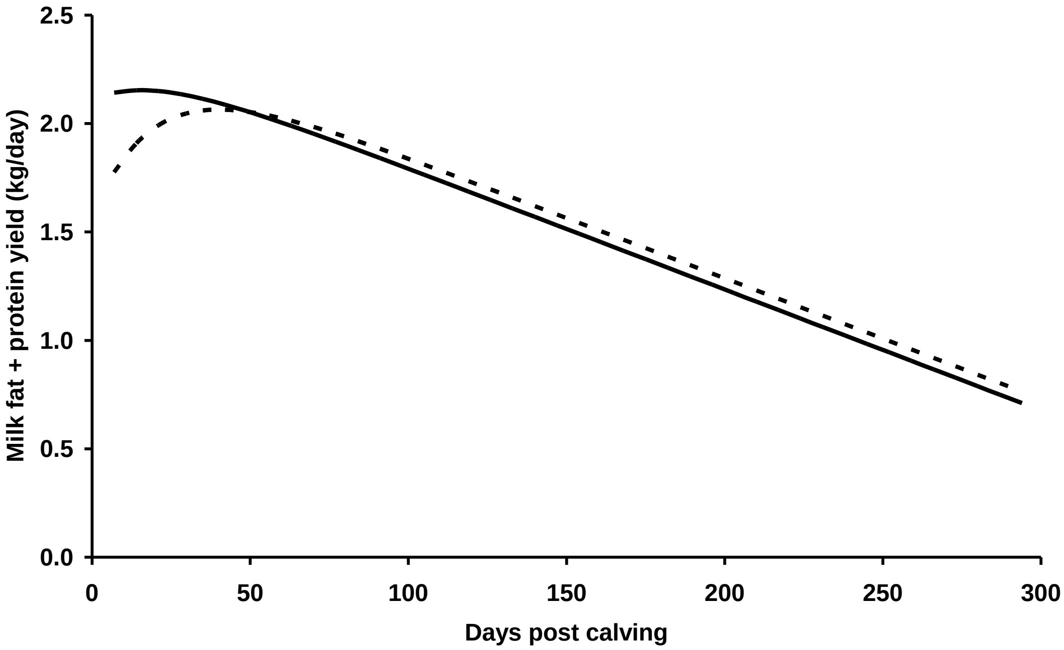
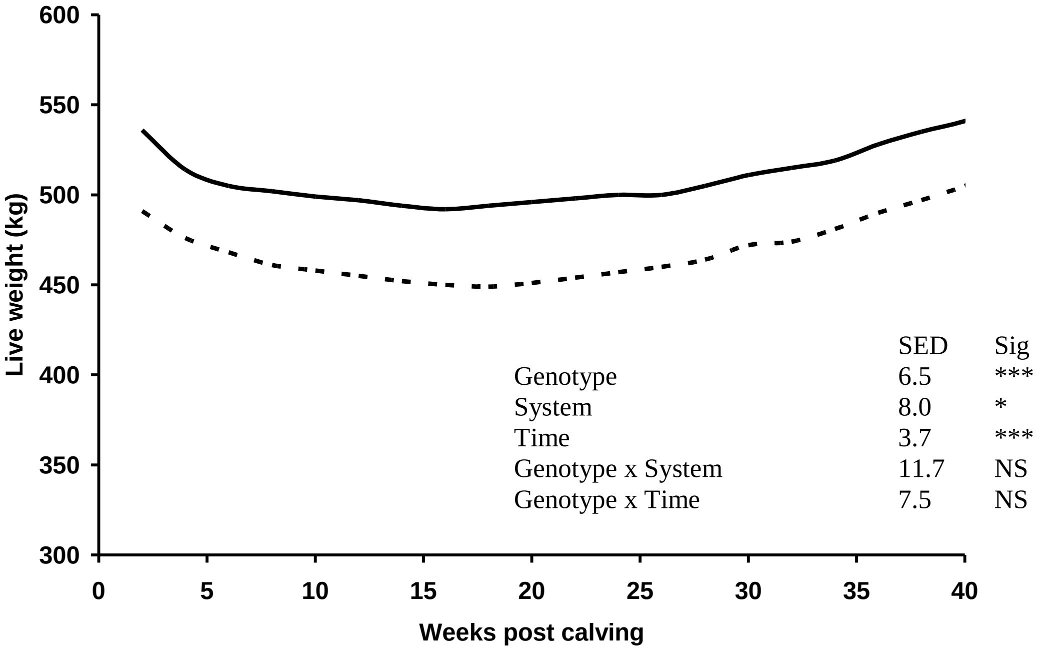


Figure 2 Effect of dairy cow genotype (HF, ———; J x HF, -------) on (a) cow live weight and (b) condition score changes during the first 40 weeks of lactation (mean of each two week period during Years 1, 2 and 3)

(a)



(b)

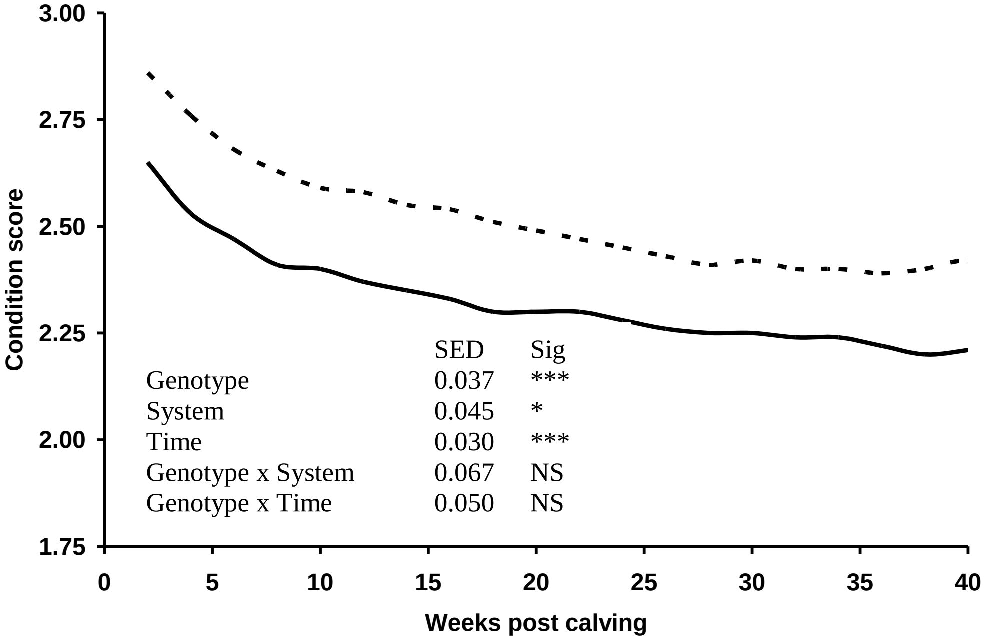
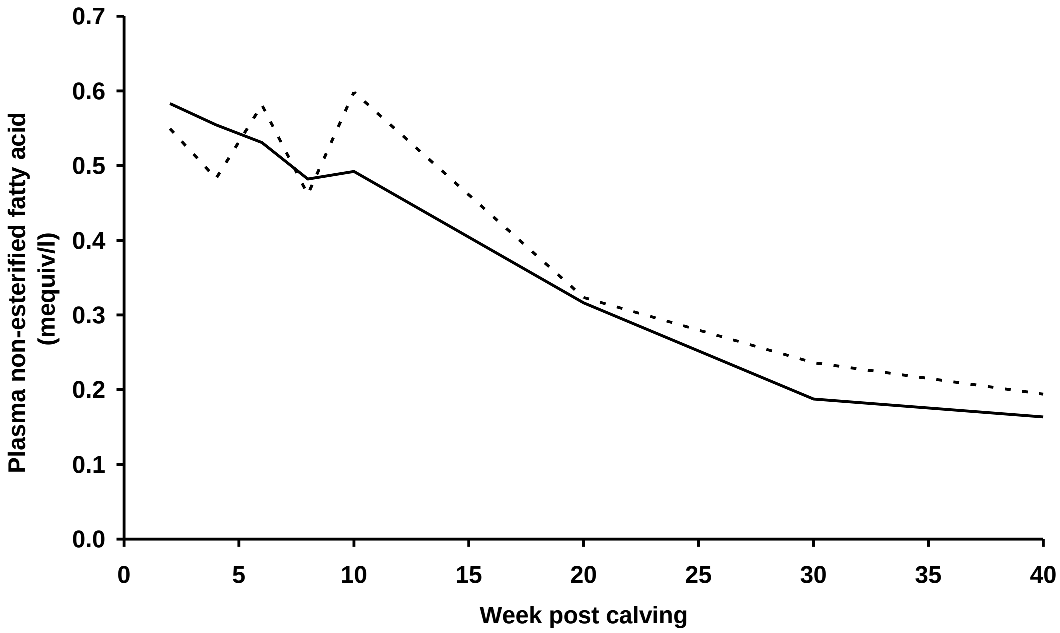
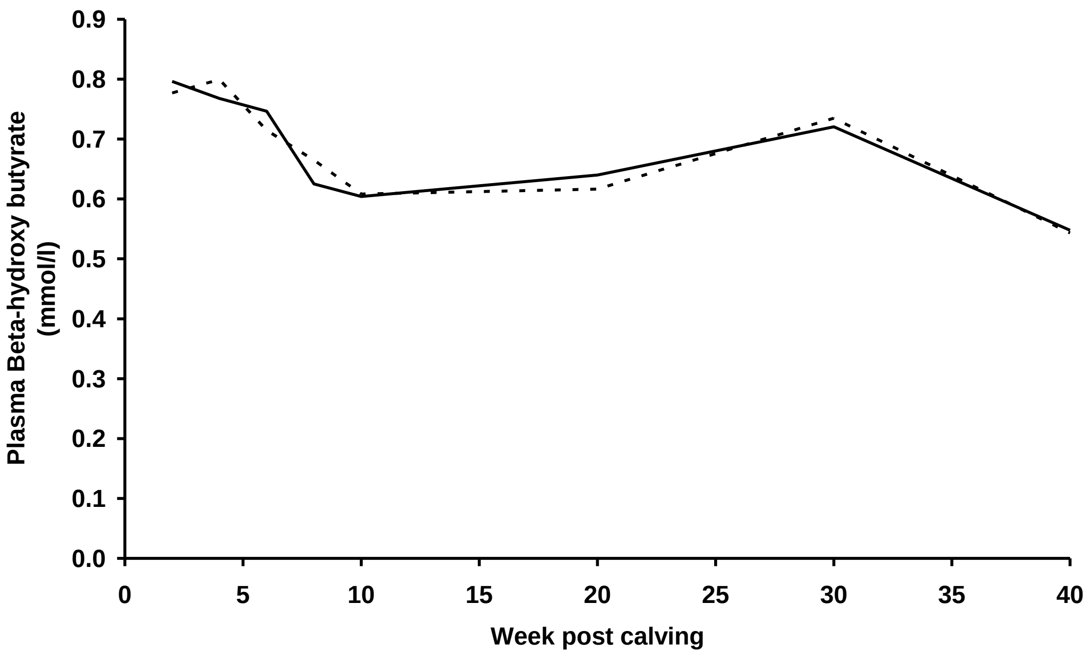


Figure 3 Effect of dairy cow genotype (HF, ———; J x HF, -------) on plasma (a) non-esterified fatty acids and (b) beta-hydroxy butyrate concentrations during the first 40 weeks post-calving (mean of Years 1, 2 and 3)

(a)



(b)



EXPERIMENT 2

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

1.0 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, health and longevity traits associated with the Holstein breed (Royal *et al.*, 2000; Mayne *et al.*, 2002). Interest in crossbreeding is normally highest within 'low input' milk production systems where forage (grazed and conserved) represents a high proportion of the diet. In fact, recent evidence suggests similar levels of milk production in Holstein-Friesian, Montbeliarde x Holstein-Friesian and Normande x 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 x 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.*, 2009). 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 *et al.,* 2005). There is a common perception amongst dairy farmers that crossbred cows, and in particular the Jersey x Holstein-Friesian cross, 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 *et al.* (2008) observed higher eating rates (g dry matter (DM)/min) with Holstein-Friesian cows while ruminating time was highest with purebred Jersey cows. In addition, O'Driscoll *et al.* (2009) observed higher biting rates (bites/minute) with Holstein-Friesian cows while the total number of feeding mastications each day was highest with Norwegian Red cows. 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 x Holstein-Friesian cows. Within a confinement environment few studies have measured the food intake of Jersey x Holstein-Friesian dairy cows, while no studies have been identified in which the feeding behaviour of Holstein-Friesian and Jersey x Holstein-Friesian dairy cows were compared. Consequently this experiment was undertaken to examine the food intake and feeding/grazing behaviour of Holstein-Friesian (HF) and Jersey x Holstein-Friesian (J x HF) crossbred dairy cows within both a confinement environment and while grazing.

2.0 Materials and Methods

This experiment was conducted during 2008 at the Agri-Food and Biosciences Institute, Hillsborough (54˚27'N; 06˚04'W). The experiment was 176 days in duration, and comprised a 54-day confinement period (7 May – 29 June: first confinement period), a 96-day grazing period (30 June – 3 October: grazing period), followed by a second 26-day confinement period (4 October – 29 October: second confinement period) (Table 1).

2.1 Animals

The experiment involved 28 spring calving dairy cows, 14 HF and 14 J x HF dairy cows (F1). 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 x HF cows were the offspring of a breeding programme involving randomly selected Holstein-Friesian dams from the AFBI Hillsborough herd and three Jersey sires. All cows were primiparous, and had mean calving dates of 28 (HF) and 11 (J x HF) February, respectively. At the commencement of the experiment (7 May) cows were separated into two ‘genotype groups’ and they remained in these groups for the duration of the experiment. At this point HF and J x HF cows were a mean of 68 and 85 days calved, respectively, had a mean live weight of 512 and 421 kg, respectively, and a mean daily milk yield of 23.6 and 22.5 kg, respectively.

2.2 First confinement period (7 May to 29 June)

Throughout the first confinement period cows were offered a complete diet comprising forage and concentrate (66:34 DM basis), with the forage component of the diet comprising grass silage and maize silage (60:40 DM basis). The grass silage offered during this period was harvested on 16 October from the tertiary growth of a perennial ryegrass-based sward, while the maize silage offered was harvested on 17 October. 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 meal, 160; molasses, 40 and minerals and vitamins, 37. The silage and concentrate components of the diet were mixed daily using a complete diet mixer wagon (Redrock, Co. Armagh, Northern Ireland). In addition, 0.5 kg of this concentrate was offered in the milking parlour during each of the morning and evening milkings.

During the first 20 days of the experiment (dietary adjustment phase) cows accessed their experimental diets via a post-and-rail type feed barrier. Thereafter, during two 10-day experimental periods cows accessed their feed via a Calan Gate (American Calan, Northwood, NH, USA) feeding system (which cows had previously been trained to use). Each Calan gate was linked to an automatic cow identification system which allowed cows to gain access to a feed box mounted on a weigh scale, thus allowing individual feed intakes and feeding behaviour to be measured. Each group had access to seven Calan Gates thus enabling proportionately 0.5 of animals to gain access to the feed at any one time. Uneaten food was removed from the feed boxes at 08:30 hours daily and replaced with fresh food (offered *ad libitum* at proportionately 1.1 of the previous days intake) at approximately 09:30 hours.

Throughout the two 10-day periods during which feed intakes were recorded, cows were managed in cubicle accommodation with each genotype group having access to 20 cubicle beds (220 cm long and 125 cm wide). 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. During the second 10-day period, the pen order was reversed, with this deemed necessary as the two pens were not identical in layout.

After completion of these two 10-day periods, the two genotype groups were moved to two identical (but mirror image) pens where they accessed food via a post-and-rail type feed barrier for a 14-day period. 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 feed space associated with the gates), or to video record cows within the part of the house fitted with Calan Gates (due to a low roof). Each pen was fitted with 16 cubicles configured in three rows. The two pens were visually isolated from each other (both the feeding and cubicle area) using wooden partitions, as described earlier. In addition, a partition extended 100 cm outside of the pen, at the feed barrier to ensure genotype groups remained visually isolated while accessing food. Each genotype group had access to 600 cm of feed barrier space, approximately 43 cm of feed barrier space per cow. This was designed to enable approximately half of the cows within each group to access food at any one time.

2.3 Grazing period (30 June to 3 October)

Cows commenced grazing on 30 June, and following a five day adaptation period, cows completed three grazing periods (28, 35 and 28 days in duration, respectively). Adverse weather conditions during the second grazing period (13 – 19 August) necessitated housing cows fulltime for one week, thus the length of this period was increased to 35 days. During the five day adaptation period to grazing, concentrates offered in the milking parlour during the first confinement period were replaced with 2.0 kg/cow/day of a ‘grazing concentrate’ (1.0 kg being offered in the parlour during each milking). Cows remained on this level of concentrate feeding throughout the grazing period. 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 meal, 40; mineral and vitamins, 30; calcined magnesite, 10; and molaferm, 30.

The experimental grazing area was located on a clay-loam soil, while the sward grazed was approximately one year old and was predominantly perennial ryegrass (*Lolium perenne*; cv. Aberstar and cv. Aberzest). Each of the two genotype groups were managed under a flexible rotational grazing system, with fresh herbage being allocated to each group daily, after pm milking. Cows were offered a daily herbage allocation of 18.0 kg DM/cow/day (measured above a height of 40 mm) with the area offered each day determined 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, with the sub-sample dried to a constant weight using a microwave oven for determination of DM content. 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. Midway through the grazing period, the grazing area was trimmed to a residual height of approximately 60 mm after each grazing was complete.

2.4 Second confinement period (10 October – 29 October)

Cows were rehoused on the 4 October and offered grass silage produced from the secondary re-growth of a perennial ryegrass-based sward until the experiment was complete. In addition, cows were supplemented with 3.0 kg concentrate/cow/day, offered in two equal feeds during the morning and evening milking. The ingredient composition of the concentrate offered (kg/t air dry basis) was; barley, 180; wheat, 180; citrus pulp, 103; soya hulls, 103; soya bean, 189; rape meal, 178; Megalac, 15; minerals, 22; and molasses, 30. During this period cows were housed in the same pens and accessed food via the same Calan Gate feeding system described earlier. Following a six-day adaptation period to the silage-based diets, cows completed two 10-day experimental periods, as described previously, with the pen order again being reversed between the first and second 10-day periods.

3.0 Measurements

Throughout the experiment cows were milked twice daily, between 05:00 and 06:30 hours and between 14:00 and 15:30 hours. 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).

Cow live weight (LWT) was recorded after every milking and an average LWT calculated for each week. Condition score was assessed weekly using a five point scale (1 = emaciated; 5 = extremely fat) (Edmonson *et al.*, 1989).

3.1 Confinement periods

During the periods when cows accessed their feed via the Calan Gate feeding system, food intake and feeding behaviours recorded during days 6 – 10 of each 10-day measurement period were statistically analysed. Within the current study separate meals were defined when the time interval between the end of one feeding period and the start of a second feeding period was greater than six minutes (Patterson *et al.*, 1998). The Calan Gate feeding system allowed total DM intake, number of meals per day, meal duration, and DM intake per meal to be determined daily for each individual cow.

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

In addition, the behaviour of each genotype group was recorded using video cameras suspended from the roof of the cow shed (24-hour time lapse mode) during days 7, 9, 11 and 13 of the 14-day period. The entire area of each pen, including the cubicles, passageways and feed barriers, were observed using two cameras per pen (Panasonic CCD cameras, WV-CP410) connected to four individual video recorders (Panasonic, AG-TL300). A waterproof crayon was used to place a personalised fluorescent mark on the back of each cow so as to aid identification. Videos were subsequently observed and the behaviour (five behaviours identified) of each individual cow recorded at 10-minute intervals as follows: feeding (defined as head completely through the feed barrier), queuing to feed (defined as standing directly behind cows that are feeding and facing the feed barrier), standing in cubicles (either two feet or four feet in cubicle), standing in passageway/drinking, and lying. The total time (minutes) that individual animals spent engaged in each of these five activities each day was calculated as the number of observations per day for that activity (averaged across the four observation days) multiplied by ten.

3.2 Grazing periods

During the grazing period herbage intakes were measured on three occasions using the n-alkane technique (Mayes *et al.*, 1986). During the last 12 days of each of the three measurement periods, cows were dosed twice daily, post milking, with a paper bung containing 500 mg of dotriacontane (C32-alkane).

During the final six days of each measurement period, faecal samples were collected from individual cows prior to each milking. Faecal 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 the final six days of each measurement period, pluck samples of herbage were collected daily from within each grazing area (at 20 random locations). Herbage was sampled to a similar height as cows were observed to be grazing to. 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. Faecal, 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 described 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 group were fitted with the recorders for two consecutive 24-hour periods, commencing after evening milking. This process was then repeated with the seven remaining cows from each genotype group. Mean grazing behaviours across the two measurement days were subsequently determined.

Within each of the two genotype grazing areas, pre-grazing herbage mass (>40 mm) was determined twice weekly prior to the recording week and daily during the recording week of each period. Herbage mass was determined by cutting four strips (approximately 7.0 m long x 0.91 m wide) to approximately 40 mm above ground level from four randomly selected sites across each grazing area using a reciprocating knife-bar mower (Agria, Moeckmuehl, Germany). Herbage harvested within each strip was collected, weighed and sub-sampled, with the sub-sample oven dried overnight at 85°C for determination of DM content. In addition, 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.

3.3 Feed chemical analysis

During the indoor periods 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 nitrogen 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 at 80°C for 48 hours and analysed for N, NDF, ADF, GE and ash contents. During the grazing period herbage pluck samples were taken twice weekly from within each of the grazing areas (x 20 random locations) and analysed for oven DM content. Dried grass samples were subsequently bulked for each seven day period and analysed for ADF, NDF, N, WSC and ash contents. 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. Concentrates offered during the grazing periods were sampled weekly and subsequently bulked for each measurement period, and analysed for ADF, NDF, N, GE and ash contents. 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).

3.4 Statistical analysis

Data from this experiment was analysed using GenStat, Version 11.1 (Payne *et al.*, 2008). Data describing milk output, milk composition, live weight and condition score during each period (first confinement period, grazing period and second confinement period) were analysed using ANOVA. The effect of dairy cow genotype on food intake and feeding behaviour (measured using the Calan Gate feeding system) was analysed using repeated measures REML analysis with the model including the fixed effect of genotype (HF and J x HF) and measurement period (n = 2). Feeding behaviours recorded using grazing behaviour recorders, and video observation data ('first confinement period') were averaged for individual cows across all measurement days (grazing behaviour recorders, n = 2; video observation data, n = 4), and the mean data analysed using AVOVA. Herbage intake and grazing/ruminating behaviour was analysed using repeated measures REML analysis with the model including the fixed effects of genotype (HF and J x HF) and measurement period (n = 3), with the interactions between genotype and measurement period examined.

4.0 Results

Concentrates offered had mean crude protein (CP), NDF, ADF and ash contents (g/kg DM) of 236, 92, 189 and 84, respectively (first confinement period), 228, 87, 174 and 97, respectively (grazing period), and 236, 96, 192 and 79, respectively (second confinement period). The chemical compositions of the silages and grazed grass offered during the experiment are presented in Table 2. Due to the moderate quality (ammonia-N content, 131 g/kg total N) of the grass silage available during the 'first confinement period' (mid October harvest date), maize silage was incorporated into the complete diet to improve its nutritive value. The maize silage offered had a DM and starch content of 353 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.

During the grazing period the mean pre-grazing herbage mass (>40 mm) was 2620 (s.d. 481.5) and 2636 (s.d. 370.0) kg DM/ha for the HF and J x HF cows, 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 x 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 x HF cows, respectively. During each of the three grazing measurement periods mean daily rainfall was 7.8, 9.6 and 3.4 mm, respectively.

4.1 Milk production and milk composition

During the first confinement period (P<0.01), the grazing period (P<0.05), and the second confinement period (P<0.05), HF cows had a higher daily milk yield than J x HF cows, while J x HF cows produced milk with a higher milk fat content (first confinement period, P<0.01; grazing period, P<0.01; second confinement period, P<0.001) (Table 3). The J x HF cows produced milk with a higher protein content than the HF cows during the grazing period (P<0.05) and second confinement period (P<0.001). Genotype had no significant effect on milk fat plus protein yield (P>0.05) during any of the three measurement periods, although HF cows had a higher milk energy output than the J x HF cows during the first confinement period (P<0.05). Holstein-Friesian cows were heavier than J x HF cows (P<0.001) throughout the experiment, while the J x HF cows had a higher condition score (P<0.05) than the HF cows during the two confinement periods.

4.2 First confinement period

During the first confinement period, when cows accessed their food via Calan Gates, HF cows had a higher (P<0.05) daily food intake than J x HF cows (18.5 and 17.1 kg DM/cow/day, respectively) (Table 4) although, genotype had no significant effect on any of the feeding behaviours examined (P>0.05). Group intakes at the ‘open feed barrier’ were 19.1 and 17.6 kg DM/cow/day for the HF and J x HF cows, respectively. Of the feeding behaviours recorded using grazing behaviour recorders, the number of ruminating bouts was greater for the J x HF cows (P<0.05), while idling time was greater (P<0.05) with the HF cows. Genotype had no significant effect on any of the remaining behaviours examined (P>0.05). In addition, genotype had no significant effect on time spent on any of the behaviours observed using time lapse video, namely feeding, queuing to feed, lying in cubicles, standing in cubicles or standing in passageways/drinking (P>0.05).

4.3 Grazing Period

During the grazing period there were significant genotype x period interactions for grazing time (P<0.01), grazing prehensions/day (P<0.01) and idling time (P<0.05). During each of periods 1, 2, and 3 HF cows grazed for 575, 461 and 557 minutes/day, had 35979, 28660 and 34092 grazing prehensions/day, and spent 459, 570 and 477 minutes/day idling, respectively. The J x HF cows grazed for 557, 557 and 631 minutes/day, had 32662, 35117 and 41259 grazing prehensions/day, and spent 469, 439 and 473 minutes/day idling, respectively. There were no significant genotype x period interactions for any of the other parameters examined, and as such only main effects are presented in Table 5.

Total DM intake was unaffected by genotype (P>0.05), while total DM intake per kg metabolic live weight ($LWT^{0.75}$) was highest with the J x HF cows (P<0.05) (Table 5). 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 x 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 x HF cows. There were no differences between genotypes for any of the ruminating behaviours observed (P>0.05).

There was a significant effect of period 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 period 3 (Table 5). There were also differences observed between periods 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).

4.4 Second Confinement period

During the second confinement period total DM intake (P<0.001), mean feeding bout duration (P<0.01) and DM intake/feeding bout (P<0.001) were higher with the HF cows than with the J x HF cows (Table 6). The J x HF cows had a greater number of feeding bouts/day than the HF cows (P<0.05), although, none of DM intake/kg $LWT^{0.75}$, total feeding time or eating rate differed between genotypes (P>0.05).

5.0 Discussion

Maximising nutrient intakes in order to promote high levels of milk production is a primary objective within most dairy production systems. While nutrient intakes are strongly influenced by the cows energy requirements and the nutrient concentration of the food on offer (Grant and Albright, 2000), intakes are also influenced by feeding behaviour (Albright, 1993). Many factors affect the feeding behaviour of a cow including environment, management, animal health and social factors (DeVries and von Keyserlingk, 2005). In addition, previous studies have suggested a genetic component to a cows feeding behaviour (Linnane *et al.,* 2004; O'Driscoll *et al.,* 2009). The aim of this experiment was to compare the food intake and feeding/grazing behaviour of HF and J x HF dairy cows within a confinement environment and while grazing.

5.1 Milk production performance

In agreement with the findings of previous studies (Anderson *et al.*, 2007; Auldist *et al.*, 2007; Heins *et al.*, 2008; Prendiville *et al.*, 2009) HF cows had higher daily milk yields than J x HF cows (3.8, 2.0 and 1.3 kg/day higher during the first confinement period, the grazing period and the second confinement period, respectively), while the J x 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 73 kg heavier than J x HF cows. This difference was considerably greater than that recorded by Auldist *et al.* (2007), Heins *et al.* (2008) and Prendiville *et al.* (2009), namely 50, 33 and 42 kg, respectively, although the latter studies involved both primiparous and multiparous cows. The higher condition scores of the J x HF cows in the current study are in agreement with the findings of Prendiville *et al.* (2009).

5.2 Food intake and feeding behaviour during the confinement periods

As already explained, experimental requirements dictated that intakes and feeding behaviour be measured at both a Calan gate feeding system and at an open feed barrier. However, differences in food intakes between the two feeding systems were relatively small (mean of 0.6 kg DM/cow/day), with this supporting the findings of Ferris *et al.* (2006) that the method of offering food (Calan gates *vs* open feed barrier) had no effect on total daily DM intake. However, total feeding times were numerically 142 minutes longer at the open feed barrier compared to the Calan gates, with this indicating a higher rate of intake with the latter, again supporting the findings of Ferris *et al.* (2006). This may have been due to an inadequate feed space allowance at the Calan gates, or perhaps an issue of comfort. With regards the latter, Huzzey *et al.* (2006) reported that cows spent significantly more time feeding each day when managed on a 'post-and-rail' type feed barrier as opposed to a 'head locking' feed barrier system, and suggested that the former provided less of a barrier between the cow and the feed thus making feeding more comfortable. Nevertheless, as both genotypes were managed identically within each of the feeding systems, the genotype comparison remains valid.

During the first confinement period HF cows consumed approximately 1.4 kg DM/day more than the J x HF cows when individual cow intakes were measured using the Calan Gates, and 1.5 kg DM/day more when group intakes were measured at the 'open feed barrier'. While intakes of both genotypes were substantially lower during the second confinement period (compared to the first), a reflection of the lower milk yields of cows during this late lactation period, intakes of HF cows remained higher than those of the J x HF cows.

Although few studies have compared food intakes of HF and J x HF dairy cows within a confinement situation, intakes of purebred Jersey cows are normally substantially lower than those of Holstein 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 *et al.* (1986), Rastani *et al.* (2001) and Aikman *et al.* (2008), respectively. As there appears to be no literature evidence of heterosis with regards to food intake, intakes of crossbred cows might be expected to be intermediate between those of the two purebred parent breeds. Indeed Schwager-Suter *et al.* (2001) observed net energy intakes of Jersey x Holstein-Friesian cows (presented in graphical form for the first 30 weeks of lactation) to be intermediate between those of purebred Holstein and purebred Jersey cows. However in contrast, Heins *et al.* (2008) observed no difference in food intake between Holstein and Jersey x Holstein dairy cows during the first 146 days of lactation (22.7 and 22.0 kg/day, respectively), while Xue *et al.* (2010) observed intakes of Jersey x Holstein crossbred cows to be higher than those of purebred Holstein cows. In this latter study there was no difference in live weight between the two cow genotypes, while the crossbred cows had a higher milk energy output. Nevertheless, the lower intakes of the crossbred cows in the current study appear to be largely a function of their smaller body size, as when intakes were expressed on a metabolic live weight basis ($LWT^{0.75}$) there was no difference in intakes 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 lower intakes, suggests an improvement in overall efficiency. Although it is possible that this may be due in part to differences in metabolic efficiency between the genotypes, Xue *et al*. (2010) 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 with the Holstein cows, thus suggesting a lower metabolic efficiency with the latter. Within the current study it is likely that there was an '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 (Feed into Milk: Thomas, 2004) the 76 kg lower live weight of the crossbred cows during the first confinement period within this experiment would have resulted in 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 would account for the similar milk fat plus protein yield with the two genotypes, despite the crossbred cows having a lower food intake.

While the feeding behaviour of HF and J x HF cows within a confinement system does not appear to have been compared previously, the effect of dairy cow breed on feeding behaviour has been examined in a number of studies. For example, O'Driscoll *et al.* (2009) observed that the time spend feeding, number of meals per day and number of feeding bites per day was similar for Holstein-Friesian and Norwegian Red dairy cows. In addition, Aikman *et al.* (2008) reported similar total feeding time with Holstein-Friesian and Jersey dairy cows (360 and 382 minutes/day, respectively). Similarly, within the current study there were no significant differences between genotypes for any of the feeding behaviour parameters measured during the first confinement period, with cows having a mean of 16 feeding bouts per day, and a mean feeding time of 384 minutes per day (measured at the open feed barrier using grazing behaviour recorders), the latter remarkably similar to the values reported by Aikman *et al.* (2008). 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 observed using time lapse video recorders (372 minutes/day). This finding demonstrates 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. Feeding times recorded at the Calan gate system in the current study (mean of 242 minutes/day) were similar to those recorded by Elizalde and Mayne (2009) for Holstein-Friesian cows (253 minutes/day) when offered food via a Calan gate system. There is no obvious explanation for the small but significant differences in feeding behaviour observed between the two genotypes during the second indoor period, with the differences in the number of feeding bouts/day and the duration of each feeding bout being the opposite of what was observed during the grazing period.

There is increasing interest in 'time budgets' of dairy cows, and especially time spent lying, with some anecdotal evidence suggesting that increasing lying times are associated with increased blood flow to the mammary gland (Metcalf et al., 1992; Rulquin and Caudal, 1992) in turn resulting in higher milk yields (Davis and Collier, 1985). However the results of the current study clearly demonstrated that during the period when cows were managed at the 'open feed barrier' genotype had no effect on time spent on any of the activities observed using time lapse video observations. In one of the few similar comparisons, Roca-Fernandez *et al.* (2010) observed no difference in standing and lying times in Holstein-Friesian and Jersey x Holstein-Friesian dairy cows within a confinement environment (based on direct observations), although observations in this study excluded the period from 22:00 hours to 07.00 hours and from 14:00 hours to 16:00 hours. Lying times within the current study (mean of 693 minutes/day) were similar to those recorded in previous studies, namely 684 and 702 minutes/day (Wechsler *et al.,* (2000), Cook *et al.,* (2005), respectively).

Rumination, which can be defined as the regurgitation of reticulorumen ingesta via a boli, to the mouth of a ruminant animal, its remastication, salivation and subsequent swallowing back into the rumen (Welch, 1982), is essential for adequate reduction of food particle size in order to facilitate digestion. Cows of different genotypes have been observed to have different ruminating times in some studies (623 and 538 minutes for Holstein-Friesian and Jersey dairy, respectively: Aikman *et al.,* 2008) but not in others (610 and 585 minutes/day for Holstein-Friesian and Norwegian Red dairy cows, respectively: O'Driscoll *et al.,* 2009). These differences between studies are likely driven by intakes with the Jersey cows having a much lower intake than the Holstein cows in the former study.

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 greater number of ruminating boli/day, but a shorter ruminating bout duration. In addition, idling time was lower with the J x 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 in terms of feed particle size reduction than Holstein-Friesian cows, and this might contribute to a higher rate of food passage from the gastrointestinal tract.

5.3 'Grazing Period'

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 *et al.* (1988), Mackle *et al.* (1996) and Prendiville *et al.* (2010), respectively) intakes of Jersey x 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 *et al.* (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 x biting rate x herbage intake per bite (Spedding *et al.*, 1966). While many studies have examined the effects of sward and environmental factors on grazing behaviour (for example, Rook *et al.*, 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, can be attributed to differences in grazing behaviour. For example, while the crossbred cows had fewer grazing bouts each day (9.3 vs 7.7), the duration of each grazing bout was on average 22.7 minutes longer (60.0 vs 82.7 minutes), and as such the crossbred cows grazed for longer each day (531 vs 582 minutes). In addition, while the number of bites per minute did not differ between the two genotypes (62 bites/minute), 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 (32910 vs 36346), and this allowed similar intakes to be achieved with the two breeds. The trend towards a lower bitemass 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 take 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 (646 and 662 minutes per day), grazing bites per day (40,672 and 39,859) and herbage intakes per bite (0.42 g) with Holstein-Friesian and Jersey x Holstein-Friesian dairy cows, respectively. The shorter grazing time observed in the current study is reflected in a lower herbage intake, and this is likely due to the fact that cows in the current study were primiparous, and were offered 2.0 kg concentrate/day. Concentrate feeding has been shown to reduce grazing time (Bargo *et al.*, 2003; McCarthy *et al.*, 2007). Kennedy *et al.* (2008) reported similar grazing times to those recorded within the current study (549 minutes/day) when grazing cows were offered 3.0 kg of concentrate per day.

The higher intakes of both genotypes during the third measurement period 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 periods (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 minutes/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 *et al.* (1982) observing that dairy cow grazing time was reduced by approximately 60 minutes per day during periods of inclement weather. That a significant genotype x period interaction was observed for total grazing time each day, 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 minutes/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 supports the similar intakes observed with the two genotypes, with O'Connell *et al.* (2000) observing that longer ruminating times were associated with increased food intakes.

The higher herbage intakes (per kg $LWT^{0.75}$) of the J x 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, with Smith and Baldwin (1974) reporting that Jersey cows had a larger gastrointestinal capacity than Holstein-Friesian cows. Nevertheless, the results of this experiment clearly demonstrated that differences in grazing behaviour existed between HF and J x 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 x 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 x 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 x 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.

6.0 Conclusions

The smaller size, and associated lower intakes, or trends towards lower intakes, with the J x 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 x HF cows had a higher DM intake per kg $LWT^{0.75}$, with this due to an increased time spent grazing and a greater number of grazing bites per day.

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Table 1 Overview of the three experimental periods

Period	Dates	Description of period	Duration of periods
'First confinement period'	7 May to 29 June	Dietary adjustment	20 days
		Measurement periods	2 x 10 days and 1 x 14 days
'Grazing period'	30 June to 3 October	Transition period	5 days
		Measurement periods	1 x 28 days, 1 x 35 days and 1 x 28 days
'Second confinement period'	4 October to 29 October	Transition period	6 days
		Measurement periods	2 x 10 days

Table 2 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

	First Confinement Period				**Grazed Grass**						**Second Confinement Period**	
	GS	**s.d.**	**MS**	**s.d.**	**P 1**	**s.d.**	**P 2**	**s.d.**	**P 3**	**s.d.**	**GS**	**s.d.**
Oven DM (g/kg)	185	37.4	336	11.8	159	22.3	151	31.5	160	33.7	267	33.6
Volatile corrected DM (g/kg)	198	35.3	353	5.4							274	18.3
Crude Protein	202	24.1	88	19.9	195	32.3	179	30.0	185	20.9	140	14.7
Ammonia-N (g/kg total N)	131	45.1	92	18.9							90	44.4
pH	4.5	0.46	3.7	0.03							4.1	0.18
Lactate	67	48.2	66	11.9							95	21.4
Acetate	44	25.6	27	1.4							21	6.6
Propionate	4	3.1	3	0.9							2	1.0
Neutral-detergent fibre	518	22.3	546	22.0	509	14.1	506	27.1	509	19.4	628	37.7
Acid-detergent fibre	305	16.6	273	14.5	234	11.7	243	15.7	239	9.1	359	18.0
Ash	148	19.1	39	1.4	100	5.6	93	9.8	100	7.9	99	16.3
Water-Soluble Carbohydrates	6	0.8			69	47.9	81	71.4	75	58.1	27	7.4
Gross Energy (MJ/kg DM)	18.1	9.54	19.3	9.97							18.3	7.58
†Metabolisable energy (MJ/kg					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; P1, Period One; P2, Period Two; P3, Period Three; DM, Dry Matter

Table 3 Effect of dairy cow genotype on milk production performance, mean live weight and mean condition score during each of the three experimental periods

	Genotype			
	HF	J x HF	s.e.d.	Sig.
First indoor period (7 May – 29 June)				
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	NS
Fat + protein yield (kg/day)	1.88	1.74	0.078	NS
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 LWT$^{0.75}$)	17.5	18.1	0.87	NS
Condition score	2.4	2.6	0.08	*
Grazing period (30 June – 3 October)				
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	NS
Milk energy output (MJ/day)†	56	53	2.2	NS
Live weight (kg)	492	419	15.4	***
Live weight$^{0.75}$ (kg)	104	93	2.5	***
Daily fat + protein yield (g/kg LWT$^{0.75}$)	12.8	13.9	0.52	*
Condition score	2.3	2.4	0.07	NS
Second indoor period (4 October – 29 October)				
Milk yield (kg/day)	10.2	8.9	0.57	*
Fat content (g/kg)	43.9	51.2	1.65	***
Protein content (g/kg)	35.3	39.5	0.97	***
Fat + protein yield (kg/day)	0.80	0.80	0.045	NS
Milk energy output (MJ/day)†	33.1	32.3	1.87	NS
Live weight (kg)	528	457	14.6	***
Live weight$^{0.75}$ (kg)	110	99	2.3	***
Daily fat + protein yield (g/kg LWT$^{0.75}$)	7.3	8.1	0.45	NS
Condition score	2.2	2.3	0.06	*

HF, Holstein-Friesian; J x HF, Jersey x Holstein-Friesian
†, milk energy content calculated according to Tyrell and Reid (1965)

Table 4 Effect of dairy cow genotype on food intake and feeding behaviour during the first confinement period as recorded using Calan gates, grazing behaviour recorders† and time lapse video recorders‡

	Genotype			
	HF	J x HF	s.e.d.	Sig.
Feeding Behaviour (Calan Gates)				
Total DM intake (kg/day)	18.5	17.1	0.67	*
Total DM intake/kg Liveweight$^{0.75}$ (kg/day)	0.17	0.18	0.005	NS
Total feeding time (minutes per day)	248	236	18.0	NS
Feeding time per kg DM consumed (minutes)	13.5	13.7	0.99	NS
Number of feeding bouts (per day)	16.1	16.0	1.04	NS
Mean duration of each feeding bout (minutes)	16.1	15.2	1.13	NS
DM consumed per feeding bout (kg)	1.22	1.11	0.084	NS
Eating rate (g DM/minute)	77.3	75.6	5.53	NS
Feeding Behaviour (Open Feed Barrier†)				
Total DM intake (kg/day)	19.1	17.6		
Total feeding time (minutes/day)	386	382	15.2	NS
Number of feeding bouts (per day)	12.3	12.8	1.14	NS
Mean duration of each feeding bout (minutes)	35	31	3.8	NS
Number of feeding mastications (per day)	24390	22731	1629.9	NS
Feeding mastication (per minute)	63	60	3.0	NS
Ruminating time (minutes/day)	456	496	28.6	NS
Ruminating bouts (per day)	16.9	25.1	3.07	*
Ruminating bout duration (minutes)	29.7	22.2	4.23	NS
Ruminating mastication (per day)	31066	33976	2532.2	NS
Ruminating mastication (per minute)	67	68	2.3	NS
Ruminating boli (per day)	545	625	50.0	NS
Boli per ruminating bout	35	27	4.8	NS
Ruminating mastications per boli	57	56	3.5	NS
Boli per minute	1.2	1.3	0.07	NS
Idling time (minutes/day)	538	473	27.1	*
Idling mastications (per day)	1320	1592	235.1	NS
Main activities (Open Feed Barrier‡)(minutes per day)				
Feeding	374	369	28.5	NS
Queuing to feed	3	3	1.3	NS
Lying on cubicles	682	704	26.6	NS
Standing in cubicles	93	111	10.8	NS
Standing in passageways/drinking	65	54	7.6	NS

HF, Holstein-Friesian; J x HF, Jersey x Holstein-Friesian; DM, Dry Matter

Table 5 Effect of dairy cow genotype and measurement period (P1, P2 and P3) on herbage intake and grazing behaviour

	Genotype				Period					G x P	
	HF	J x HF	s.e.d.	Sig	P1	P2	P3	s.e.d.	Sig.	s.e.d	Sig
Grass DM intake (kg/day)	15.3	14.6	0.63	NS	14.2	13.4	16.4	0.57	***	1.04	NS
Total DM intake (kg/day)	17.0	16.3	0.63	NS	15.9	15.1	18.1	0.48	***	0.87	NS
Total DM intake/kg Live weight$^{0.75}$	0.15	0.16	0.006	*	0.14	0.14	0.18	0.005	***	0.009	NS
Grazing time (minutes/day)	531	582	18.9	**	566	509	594	16.7	***	28.4	**
Grazing bites per minute	62	62	1.4	NS	61	63	64	1.9	NS	2.7	NS
Grazing mastications (per day)	5192	4914	794.4	NS	5973	4170	5017	749.7	NS	1243.0	NS
Grazing prehensions (per day)	32910	36346	1393.0	**	34320	31889	37676	1387.0	***	2249.0	**
Grazing bouts (per day)	9.3	7.7	0.45	**	9.4	8.0	8.1	0.80	NS	1.16	NS
Mean duration of grazing bout (minutes)	60.0	82.7	4.69	***	62.5	74.4	77.1	7.40	NS	10.78	NS
Grass intake per minute (g DM)	29	26	1.5	*	26	27	29	1.7	NS	2.5	NS
Grass intake per bite (g DM)	0.47	0.42	0.030	NS	0.44	0.44	0.46	0.033	**	0.047	NS
Ruminating time (minutes/day)	350	360	21.1	NS	377	324	363	16.8	**	30.1	NS
Ruminating mastications (per day)	21939	22248	1586.0	NS	23345	20347	22589	1162.0	*	2173.0	NS
Ruminating boli (per day)	457	408	77.5	NS	479	351	467	85.4	NS	133.3	NS
Ruminating bouts (per day)	18.8	19.6	2.06	NS	21.7	19.0	16.8	2.14	NS	3.41	NS
Ruminating bout duration (minutes/day)	20.8	21.1	2.46	NS	20.2	19.3	23.3	1.91	NS	3.47	NS
Boli per ruminating bout	26.4	23.6	4.57	NS	25.4	20.6	28.9	4.79	NS	7.61	NS
Handling time (minutes/day)	896	961	37.7	NS	971	832	982	35.6	***	59.0	NS
Idling time (minutes/day)	502	460	34.3	NS	464	504	475	30.7	NS	52.0	*
Idling mastications (per day)	852	959	152.2	NS	855	1005	856	163.5	NS	257.5	NS
Total mastications (per day)	27992	28089	2019.0	NS	30158	25480	28483	1440.0	**	2732.0	NS

HF, Holstein-Friesian; J x HF, Jersey x Holstein-Friesian
P1, Period One; P2, Period Two; P3, Period Three; G x P, Genotype x Period

Table 6 Effect of dairy cow genotype on food intake and feeding behaviour during the 'second confinement period' (measured using Calan Gates)

	Genotype			
	HF	J x HF	s.e.d.	Sig.
Total DM intake (kg/day)	14.8	12.9	0.51	***
Total DM intake/kg live weight$^{0.75}$ (kg)	0.13	0.13	0.004	NS
Total feeding time (minutes/day)	271	254	13.4	NS
Feeding time per kg DM consumed (minutes)	18.3	20.1	1.14	NS
Number of feeding bouts (per day)	14.9	16.6	0.72	*
Mean duration of each feeding bout (minutes)	18.3	15.6	0.92	**
DM consumed per feeding bout (kg)	1.0	0.8	0.06	***
Eating rate (g DM/minute)	56	51	3.2	NS

HF, Holstein-Friesian; J x HF, Jersey x Holstein-Friesian
DM, Dry Matter

TECHNOLOGY TRANSFER ASSOCIATED WITH THE PROJECT

REFEREED PUBLICATIONS

Vance, E.R., Ferris, C.P., Elliott, C.T. and Kilpatrick, D.J. (2011) A comparison of the feeding and grazing behaviour of primiparous Holstein-Friesian and Jersey x Holstein-Friesian dairy cows. Irish Journal of Agriculture and Food Research (Submitted).

Vance, E.R., Ferris, C.P., Elliott, C.T. and Kilpatrick, D.J. (2011) Comparison of the performance of Holstein-Friesian and Jersey x Holstein-Friesian crossbred dairy cows within three contrasting grassland-based systems of milk production. Livestock Science (Submitted)

PUBLICATIONS IN CONFERENCE/SEMINAR PROCEEDINGS

Vance, E.R., Ferris, C.P., Murray, R.J.S. and Elliott, C.T. (2009) The effect of cow genotype and milk production system on the fatty acid composition of milk. Proceedings of Agricultural Research Forum of the Irish Grassland and Animal Production Association, Tullamore, Ireland. March 2009, Page 114.

Vance, E.R., Ferris, C.P., Elliott, C.T. and Kilpatrick, D.K. (2009) Reproductive performance of Holstein-Friesian and jersey x Holstein-Friesian crossbred dairy cows on three contrasting spring calving milk production systems. Proceedings of Agricultural Research Forum of the Irish Grassland and Animal Production Association, Tullamore, Ireland. March 2009, Page 139.

Vance, E.R. Ferris, C.P., Elliott, C.T. and Kilpatrick, D.J. (2009) The performance of Holstein-Friesian and Jersey x Holstein-Friesian crossbred cows on three grassland-based systems of milk production. The British Grassland Society Ninth Research Conference, 8^{th} – 9^{th} September 2009, Harper Adams University College, Shropshire.

Vance, E.R., Ferris, C.P., Elliott, C.T. and Kilpatrick, D.J. (2010) Food intake and feeding behaviour of Holstein-Friesian and Jersey x Holstein-Friesian crossbred dairy cows. In: Advances in Biosciences - Food, Feed, Energy and Fibre from Land. Proceedings of the British Society of Animal Science and the Agricultural Research Forum, April 2010, Belfast, p 141.

Ferris, C.P. and Vance, E.R. (2010) The performance of Jersey crossbred cows within grassland-based milk production systems. In: Making Progress through research-a seminar for specialists (Dairy genetics and heifer management). Proceedings of an AgriSearch seminar held at the Agri-Food and Biosciences Institute Hillsborough, 28 June 2010. pp 28 – 55.

FARMERS/INDUSTRY MEETINGS/PRESS RELEASES

13 February 2007: Update on dairy research, with a focus on breeding studies. Ballymoney Dairy Discussion Group.

8 November 2010 Cookstown Dairy Discussion group: Crossbreeding – is it an option worth considering?

Ferris, C.P. and Vance, E.R. (2010) Jersey crossbred cows perform well in AFBI Hillsborough study. United News, June 2010.

VISITORS TO HILLSBOROUGH (Key presentations)

28-Apr-06	Mr Vaughan Templeton, Nuffield Scholar, N. Zealand	Overview of environmental issues and grazing research. New Spring Systems study.
01-May-06	Richard Dewhurst, Lincoln University, NZ.	Overview of P, labour and breed comparison studies
12-Jun-06	Mr Kevin McDonald, Dexcel, N. Zealand	Overview of environmental and breed comparison research
16-Jun-06	On-farm grass monitoring group	Overview of new Spring Systems study
20-Jun-06	UDF, Council members	P, NRF and labour studies. New Spring Systems study
03-Jul-06	Mrs Clare Cooper, NZ postgraduate student	Once day milking, Spring Systems, NRF
15-Aug-06	Prof. Wayne Kellog, University of Arkansas	Breed comparison, barriers studies, Labour studies
12-Sep-06	Cheshire Grassland Society (Mr D Hughes)	Spring systems, P, NRF
04-Oct-06	Mr James and Chris Hill, Australia	NRF, Spring systems, Barriers, Labour
20-Oct-06	Mr Friefrich Fuhrer, Mr Peter Kreuzhuber, Mr Jim Hamilton, Fleckvieh Austria	NRF and Jersey crossbreds
23-Nov-06	Third year Greenmount students	NRF and crossbreeding, including Spring systems
27-Feb-07	Caledon dairy discussion group	Barriers, NRF, Spring systems
08-Mar-07	Jack Kennedy, IFJ	Barriers, spring systems, NRF
26-Mar-07	J. Thompsons Group	Barriers, Spring Systems, NRF
03-Apr-07	Mr Paul McGill, New Zealand Farmer	Breed comparison studies, Barriers, Systems
06-Jun-07	Association of Veterinary Practioners in Northern Ireland	NRF study, Jersey crossbred study

07-Jun-07	Ardglass Dairy farmers	Systems study
12-Jun-07	The Cowboys, Scottish dairy farmers	Spring Systems, NRF cows
13-Jun-07	DARD dairy advisors	Spring Systems
14-Jun-07	Dr Chris Grainger, Ellenbank	Jersey x
15-Jun-07	Dairy levy collectors body	AgriSearch research
26-Jun-07	Frank Wright	Systems, Breeds, P
26-Jun-07	Scottish Farmers	Breeds/Systems
27-Jun-07	Hybrid Dairy group, Cornwall	Systems/Breeds
27-Jun-07	AgriTech Group	Systems/Breeds
04-Jul-07	Dr Lewis McClinton	Overview of breed research programme
17-Jul-07	Dairy Hygiene Inspectorate	NRF and Spring Systems study
05-Sep-07	Kingshay/Farm Gate Nutrition	P, Systems, Jx, NRF
06-Dec-07	CAFRE Students	NRF, Crossbreeding
11-Dec-07	Adrain Caine Consultant + farmers	NRF, Crossbreeding
23-Jan-08	Ardglass Dairy discussion group	Systems update
05-Feb-08	BOCM Pauls, Technical Forum (Brian Martin)	NRF, Systems, Barriers
04-Apr-08	Prof John Comerford	P, Breeds
09-Jun-08	AgriSearch Council	Sustainable dairy systems
26-Aug-08	Enniskillen dairy farmers	NRF, Jersey crossbreds
04-Sep-08	Mid and West Wales Agriculture Discussion Group	P and breeds/crossbreeding
10-Sep-08	Hugh Black + 6 dairy farmers	Overview, P, breeds, barriers
03-Oct-08	Navan Grazing Group	Spring systems/NRF
06/05/2009	Black lion dairy discussion group, Meath	Crossbreeding/NRF
29/06/2009	BGS Summer tour	Crossbreeding-climate change
01/07/2009	Wicklow Dairy Farmers	Crossbreeding/Grazing/P
28/09/2009	IFA Study group	Overview, welfare, crossbreeding and Phosphorus

30/09/2009	Farmers from Welsh Borders and Shropshire	Norwegian cows, crossbreeding
28/10/2009	AFBI Board	Crossbreeding-GHG
18/11/2009	Dairy Science Forum	Crossbreeding
19/11/2009	Grass profit Check Farmers	Crossbreeding
24/11/2009	Andy Dodd, DairyCo	Crossbreeding
20/01/2010	United Feeds Rep.	Norwegian cows, crossbreeding, environmental issues
28/01/2010	YFC Ulster Livestock Seminar	Dairying - its not all black and white
03/02/2010	Navan dairy farmers	Jersey crossbreeding, NRF and environmental issues
24/02/2010	AFBI Board meeting visit	Sustainable dairy systems
26/03/2010	Grass Check farmers and advisors	Crossbreeding, environment
06/06/2011	Narberth Grassland Society, Pembrokeshire	Crossbreeding and environmental research
20/06/2011	North Wales farmers, organised by Dairy Co/DARD	Crossbreeding and environmental research
21/06/2011	United Dairy Farmers, Area Councils A and B	Introduction and crossbreeding
22/06/2011	United Dairy Farmers, Area Councils C and D	Introduction and crossbreeding