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11 **DAIRY COW GENOTYPE AND METABOLIC STATUS**

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13 **A comparison of energy balance and metabolic profiles of the New Zealand and**

14 **North American strains of Holstein Friesian dairy cow**

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Abstract

The milk production, energy balance (EB), endocrine and metabolite profiles of 10 New Zealand Holstein-Friesian (NZ) cows and 10 North American Holstein-Friesian (NA) cows were compared. The NA cows had greater peak milk yields and total lactation milk yields (7387 vs. 6208 kg; s.e.d. = 359), lower milk fat and similar protein concentrations compared to the NZ cows. Bodyweight was greater for NA cows compared to NZ cows throughout lactation (596 vs. 544 kg; s.e.d. = 15.5), while body condition score (BCS) tended to be lower. The NA strain tended to have greater DMI (17.2 vs. 15.7 kg/d; s.e.d. = 0.78) for wk 1-20 of lactation, though DMI as a proportion of metabolic bodyweight was similar for both strains. There were no differences observed between the strains for the timing and magnitude of the energy balance (EB) nadir, interval to neutral EB, or mean daily EB for week 1-20 of lactation. Plasma concentrations of glucose and insulin were greater for NA cows during the transition period (d 14 *pre partum* to d 28 *post partum*). Plasma IGF-I concentrations were similar for the strains at this time, but NZ cows had greater plasma IGF-I concentration from d 29 to d 100 of lactation, despite similar calculated EB. In conclusion, the results of this study do not support the premise that the NZ strain has a more favourable metabolic status during the transition period. The results however indicate that NZ cows begin to partition nutrients towards body reserves during mid-lactation whereas NA cows continue to partition nutrients to milk production.

Keywords: Dairy cows, energy balance, nutrient partitioning, genetic selection

Introduction

Dairy cows typically enter a state of negative energy balance (NEB) *post partum*, when the combined energy requirements for maintenance and milk production exceed dietary energy intake. This energy deficit arises because cows generally achieve peak milk production at an earlier stage than maximal feed intake (Veerkamp, 1998). The shortfall in dietary intake is met by increased mobilization of body reserves in support of lactation, which occurs through coordinated adaptation of metabolism across several body tissues (Bauman, 2000).

The magnitude and duration of NEB is dependent on the direct and interactive effects of numerous factors including genotype, plane of nutrition, and body condition score (BCS) at calving. Consequently, there is considerable variation in the degree of energy deficit experienced by individual cows, both within and between studies. Genetic selection for increased milk yield has resulted in cows that are predisposed to more severe NEB, as the correlated response in feed intake to selection accounts for only approximately 45 to 65 percent of the increase in milk yield (Veerkamp, 1998). A negative genetic correlation consequently exists between BCS and genetic merit for milk yield (Berry et al., 2003).

There is compelling evidence of a negative genetic correlation between milk production and fertility performance (Hansen, 2000). Though the precise mechanisms remain unresolved, increasing negative energy balance (NEB) and altered partitioning of dietary energy have been cited as being detrimental to reproductive efficiency (Butler, 2003). This is further intimated by negative genetic correlations identified between body condition score (BCS) and fertility performance (Pryce et al., 2001).

Strain comparison studies in New Zealand and Ireland have reported lower milk volume, higher BCS throughout lactation and superior reproductive performance for the New Zealand (NZ) Holstein Friesian compared to North American (NA) Holstein Friesian (Harris and Kolver, 2001; Horan et al., 2005b). The NA strain has been selected for increased milk yield, body size and angularity in a production system based on year-round calving and high levels of concentrate supplementation, with little emphasis traits such as fertility. The NZ strain has been selected for increased milk solids yield and improved fertility and survival in a pasture-based production system (Horan et al., 2005a). The strain comparison model provides a framework for examining the effects of divergent genetic selection programmes within the Holstein Friesian on energy balance and nutrient partitioning. The objective of the current study was therefore to characterize the energy balance, nutrient partitioning and metabolic profiles of the NA and NZ strains, which differ in genetic merit for milk production.

Materials and Methods

Animals and experimental design

Two groups of 10 spring-calving, multiparous Holstein-Friesian cows were selected from the NA and NZ groups of the Moorepark strain comparison study (Horan et al., 2005a). The origins and establishment of the experimental groups from which the cows were selected have been previously described by Horan et al. (2005a). The North American (NA) strain was developed by mating the top 50% of cows in Moorepark (based on pedigree index for milk production) with 5 NA Holstein-Friesian sires, selected as the highest available in Ireland for pedigree index for milk production. The NZ strain were imported as embryos from New Zealand and

implanted into Holstein heifers. These embryos were generated by mating high genetic merit NZ Holstein-Friesian cows with 5 high genetic merit NZ Holstein-Friesian sires (based on Breeding Worth; the New Zealand genetic evaluation system). The experimental animals used in the current study were selected from the existing NA and NZ treatment groups involved in the Moorepark strain comparison study (Table 1). Mean calving dates were 25th February (s.d. 18 days) for the NA group and 2nd March (s.d. 17 days) for the NZ group.

Insert Table 1 Here

The cows were housed in a free-stall barn from 3 weeks prior to the expected calving date, with the treatment groups sharing common accommodation space. The cows were trained to use the Griffith Elder feeding system (Griffith Elder Ltd, Bury St Edmunds, Suffolk, UK). Forage and concentrate allocations were fed separately. Forage mangers were mounted on electronic load cells, while concentrates were dispensed through automatic feeders. Cows had *ad libitum* access to forage, which was offered to allow for feed refusals of at least 5%. Refusals were removed daily. The *pre partum* diet comprised *ad libitum* grass silage, with 2 kg per day of the lactating concentrate (Table 2) introduced from 2 weeks prior to the expected calving date. The *post partum* diet consisted of *ad libitum* grass silage and 8 kg of concentrate. From March 20th, all lactating cows were offered zero-grazed grass (*L. perenne spp)* supplemented with 4kg concentrate. Grass was harvested and fed each morning. The chemical composition of the grass silage and zero-grazed grass is reported in Table 3. Cows were turned out to pasture on July 30th and were offered high quality grazed grass (*L. perenne spp.)* plus 4 kg/day of concentrate. Cows remained at pasture day and night until mid-November, after which they were housed

at night. After December 1st, the cows were housed day and night. Animals were fed grass silage *ad libitum* when housed.

Insert Table 2 here

Insert Table 3 here

Samples and animal measurements

Milk yield (kg) was recorded daily at the morning and evening milkings using electronic milk meters (Dairy Master, Causeway, Co. Kerry, Ireland). Milk composition (fat, protein and lactose) was determined on two days per week from successive morning and evening milk samples by automated infra-red absorption analysis using a Milkoscan 605 (Foss Electric, Hillerod, Denmark). Solids-corrected milk (SCM) yield was calculated using the equation of Tyrell and Reid (1965). All cows were dried off on December 15th, resulting in mean lactation length of 290 days (s.d. 14 days) for the NA strain and 287 days (s.d. 16 days) for the NZ strain.

Samples of grass silage and concentrates offered were collected twice weekly for chemical analysis. Zero-grazed grass was sampled daily for dry matter; samples were bulked by week for composition analysis.

Cow body weight (kg) and BCS (Lowman et al., 1976) were recorded once weekly from 3 weeks before the expected calving date, immediately post-calving, and once weekly thereafter until the end of lactation. The dry cows were weighed before feeding in the morning and the lactating cows were weighed after morning milking, before feeding. Data were lost for pre-calving bodyweights and BCS owing to a technical failure in the recording system. Energy balance, bodyweight, and BCS profiles are therefore reported commencing from the week of calving

Blood samples were collected three times weekly (Monday, Wednesday, Friday) by coccygeal venipuncture for 2 weeks before expected calving date, daily from day of calving until day 14 *post partum*, and twice weekly (Monday, Thursday) from day 15 to day 100 *post partum*. Sampling took place after the morning milking and before feeding**.** Samples were collected into vials containing lithium heparin as an anticoagulant. The samples were immediately centrifuged at 2000 × g for 10 minutes. The plasma was decanted and stored at -20°C until analysis.

Laboratory procedures and analysis

The DM, NDF, crude fiber and CP of the forage and concentrate samples were analyzed as described by McNamara et al. (2003). Determination of *in vitro* dry matter digestibility (DMD) was carried out by near-infrared spectroscopy using a NIRsystems 6500 spectrophotometer (Perstorp Analytical Incorporated, Silver Springs, Maryland, USA). Silage pH was measured on the juice pressed from the silage using a glass electrode and a pH meter (Radiometer pHM2 standard pH meter-radiometer, Copenhagen). The organic matter digestibility of grass was determined as described by Morgan et al. (1994)

Blood plasma was analysed for glucose, non-esterified fatty acid (NEFA), and beta-hydroxybutyrate (BHBA) concentrations by enzymatic colorimetry, using appropriate kits and an ABX Mira autoanalyzer (ABX Mira, Cedex 4, France). Plasma insulin concentration was determined using a solid-phase fluoroimmunoassay (AutoDELFIA, PerkinElmer Life and Analytical Sciences, Turku, Finland). The inter- and intra-assay coefficients of variation were 14.7% and 6.4%, respectively. Circulating IGF-1 concentrations were quantified using a validated double-antibody radioimmunoassay, following ethanol:acetone:acetic acid (60:30:10) extraction as described by Enright et al. (1989). Recombinant human IGF-1 (supplied by R&D

Systems Europe, UK) was used for iodination and standards (iodine – 125 supplied by PerkinElmer (Unitech BD Ltd., Dublin, Ireland), as described by Spicer et al (1990). The rabbit anti-human IGF-I (AFP4892898) was obtained through the US National Hormone and Peptide Program (Dr A F Parlow, Scientific Director). Inter- and intra-assay coefficients of variation were 17.0 and 11.6%.

Energy balance

Energy balance was estimated as the difference between energy intake and the sum of energy for maintenance and milk production. The French Net Energy (NE) system was used (Jarrige, 1989). The NE content of the concentrates offered was determined using the NE values (UFL) of ingredients (INRAtion, 1999, version 2.7). One UFL is the NE content of 1 kg of air-dry standard barley for milk production (Jarrige, 1989). The NE value of the grass silage was calculated based on its *in vitro* DMD concentration (O'Mara et al., 1997). The NE value of the grass was determined according to Jarrige (1989).

The following equations were used to determine the energy required for maintenance and the energy output in milk:

Energy requirement for maintenance: (UFL/day) = 1.4 + 0.6 BW/100

UFL requirement for milk: (UFL/kg of milk) = 0.0054FC + 0.0031PC + 0.0028LC - 0.015; where BW = body weight, FC = fat concentration, PC = protein concentration and LC = lactose concentration all in g/kg.

Data handling and statistical analysis

Daily milk yield and DMI data were collapsed into weekly means, and EB values were similarly calculated as weekly means. Repeated measures analyses of genotype effects on DMI, milk yield, milk composition, plasma metabolites, insulin and IGF-I, energy balance, BCS and bodyweight were carried out using the MIXED procedure of SAS (SAS Institute, 1991). A first order autoregressive covariance structure was used. Genotype, time, and the interaction of genotype and time were included as fixed effects. Cow within genotype was included as a random effect. For illustrative purposes (Figure 4), body weight and BCS lines were smoothed using the LOESS procedure in SAS (SAS Institute, 1991).

Data for plasma analytes during daily blood sampling from day 1 to day 14 *post partum* were collapsed into four mean values (day 1 to 3 = day 3; day 4 to 7 = day 7; day 8 to 10 = day 10; day 11 to 14 = day 14), and into weekly mean values for *pre partum* samples and *post partum* samples collected from day 14 to 100 post-calving. This resulted in all cows having plasma analyte data for days -14, -7, 0, 3, 7, 10, 14, 21, 28, 35, 42, 49, 56, 63, 70, 84, 91, and 98 for statistical analysis. Plasma insulin, IGF-I and metabolite data were not normally distributed, and were log transformed prior to statistical analysis. Plasma analyte data for each cow was divided into 2 time periods (transition period from d 14 *pre partum* to d 28 *post partum*; post-transition period from d 29 to d 100 *post partum*) and the time periods were analyzed separately to accommodate the constant variance assumption of repeated measures analysis. Results for plasma analytes were back-transformed and are presented as geometric means (and 95% confidence intervals).

Results

Milk production and composition

The NA strain had a greater milk yield ($P < 0.01$) during week 1-20 of lactation, and tended to have a greater SCM yield ($P = 0.06$) compared to the NZ strain (Table 4). The NA strain had a higher ($P < 0.001$) peak milk yield, but peak SCM yield did not differ between the strains ($P = 0.39$). Mean daily SCM yield from wk 20 until the end of lactation was 18.8 kg and 15.1 kg ($P < 0.01$, s.e.d. 1.4 kg) for the NA and NZ strains, respectively.

Insert Table 4 here

Milk fat concentration over the full lactation was greater for NZ cows ($P < 0.01$), while milk protein concentration did not differ between the strains ($P = 0.33$). Total combined yield of milk fat and protein over the full lactation was 12.7% greater ($P = 0.03$) for the NA strain (Table 4). The NA strain produced 20.4% greater volume ($P < 0.01$) of milk over the full lactation compared to the NZ strain; total lactation SCM yield was 12.7% greater ($P = 0.04$) for the NA strain (Figure 1).

Insert Figure 1 here

Dry matter intake, energy balance and feed efficiency

Mean DMI ($P = 0.07$) and net energy intake ($P = 0.08$) tended to be greater for NA compared to NZ cows (Figure 2) during wk 1-20 of lactation. When expressed as a percentage of metabolic bodyweight, however, the strains had similar ($P = 0.78$) mean daily DMI over the same time period (Table 5).

Insert Table 5 here

Insert Figure 2 here

The NA and NZ strains had similar mean daily calculated energy balance (EB) during week 1-20 (P = 0.95) of lactation (Figure 3). The strains also had a similar magnitude of EB nadir (P = 0.72). In addition, the timing of EB nadir (P = 0.77) and interval to neutral EB (P = 0.87) did not differ between the two strains (Table 5).

Insert Figure 3 here

The NA and NZ strains had similar milk yield per kg of DMI (P = 0.22), and similar output of milk energy per unit of net energy intake (P = 0.91), for week 1-20 of lactation (Table 5). Solids corrected milk yield as a proportion of metabolic bodyweight did not differ between the strains (P = 0.57).

Bodyweight and body condition score

The NA and NZ strains had similar BCS at the beginning of lactation (3.17 vs. 3.22, respectively; s.e.d = 0.18; P = 0.78). The strains had lost a similar amount of BCS by week 20 of lactation (0.65 vs. 0.55 respectively; s.e.d = 0.15; P = 0.53). Thereafter, the NZ strain began to increase in BCS whereas the NA strain did not, resulting in a greater BCS for NZ compared to NA by the end of lactation (2.85 vs. 2.43 respectively; s.e.d = 0.15; P = 0.02) Mean bodyweight across the full lactation was greater for NA compared to NZ cows (596 vs. 544 kg respectively; s.e.d = 21.9; P = 0.02) (Figure 4).

Insert Figure 4 here

Plasma insulin, IGF-I and metabolites

Mean plasma insulin concentration was higher (P = 0.01) for the NA strain during the transition period, and tended to be higher (P = 0.06) from d 29 until d 100 (Figure 5; Table 6). There were no differences between the strains in mean plasma concentrations of IGF-I in the transition period (P = 0.71). However, the NZ strain had higher (P = 0.04) plasma IGF-I concentrations from d 29 to d 100 of lactation (Figure 5; Table 6).

Insert Figure 5 here

Insert Table 6 here

Plasma glucose concentration was higher for the NA strain during the transition period (P = 0.01), but differences were not observed in the post-transition period (d 29 to d 100 of lactation) (P = 0.21) (Figure 6; Table 6). There were no differences observed between the strains in mean plasma NEFA concentration, either during the transition period (P = 0.29), or during the post-transition period (P = 0.99). Plasma BHBA concentration was higher for NZ compared to NA cows during the transition period (P = 0.02), but both strains had similar mean plasma BHBA concentrations during the post-transition period (P > 0.05).

Discussion

The primary objective of this study was to characterize the EB, nutrient partitioning and metabolic profiles of the NA and NZ strains, which differ in their

genetic merit for milk production, BCS and fertility performance (Horan et al., 2005b). The lack of difference between the EB profiles of the strains during early lactation was particularly interesting given the extensive reports of negative genetic relationships between milk yield and both EB and BCS (Berry et al., 2003; Veerkamp and Thompson, 1999).

In general, cows of higher genetic merit for milk yield have greater milk energy output in early lactation, which is met by a combination of increased DMI and body tissue mobilization (Bauman, 2000). The higher milk yield recorded for the NA cows in the present study is a result of more intensive genetic selection for milk yield compared to NZ cows (Kolver et al., 2000). Peak daily milk yield was higher for the NA strain as had been reported previously (Horan et al., 2005a), however peak yield did not differ between the groups when expressed as SCM. This was primarily due to the higher milk fat concentration of the NZ strain; mean milk protein concentration was not different between the groups. The NZ strain has previously exhibited higher milk fat and milk protein in pasture-based production systems (Horan et al., 2005a). Increasing fat and protein yield in a given volume of milk has been a key breeding objective in the New Zealand breeding programme for many years (Harris and Kolver, 2001). It can be therefore concluded that the strains experienced a comparable magnitude of milk energy demand at peak SCM production.

The NA strain had approximately 1.5 kg per day greater DMI, equivalent to 1.26 UFL of NE intake per day, compared to the NZ strain from wk 1-20 *post partum*. However, the daily energy requirements for milk and maintenance during this time were approximately 1.0 UFL and 0.30 UFL greater for the NA strain

318 respectively, resulting in similar EB profiles for the strains. The higher DMI of the
319 NA cows may be attributable to their greater bodyweight, as bodyweight is highly
320 correlated with DMI (Veerkamp and Thompson, 1999). The difference in bodyweight
321 between the strains is a direct result of divergent genetic selection objectives within
322 the strains' respective breeding programmes. The NA strain has been selected for
323 increased body size (Hansen, 2000), whereas bodyweight is afforded a negative
324 economic weighting in NZ selection indices (Harris et al, 1996).
325
326 Consistent with the EB results, the BCS profiles of the strains were not
327 different for weeks 1-20 of lactation. The profiles subsequently diverged however, as
328 the NZ cows began to increase BCS while the NA cows failed to gain BCS,
329 indicating that the NZ cows were in a more positive nutritional status during mid to
330 late lactation. Similarly McCarthy et al. (2007a) reported no difference in the rate of
331 BCS change between NA and NZ cows during early lactation, but a greater rate of
332 BCS accretion post nadir for NZ cows.
333
334 Differences in milk yield between high and low genetic merit cows are less on
335 a high grass diet because intake is limited by constraining factors in the diet such as
336 physical bulk, whereas on high concentrate diets, high genetic merit cows have the
337 advantage of higher DM intakes (Kennedy et al., 2003). The NA strain achieves a
338 lower proportion of potential DMI and milk yield in a pasture system compared to the
339 NZ strain, which is evidenced by its greater milk yield response to concentrate
340 supplementation (Horan et al., 2005a). Similarly, McCarthy et al (2007b) reported a
341 lower substitution rate of pasture for concentrate by the NA strain compared to the
342 NZ strain. This explains the greater milk yield response of NA cows to concentrate

supplementation, and demonstrates that the greater lactation energy demands of the NA strain are not satisfied by a predominantly pasture diet. Furthermore, the same study noted that despite their lower milk production, NZ cows spend a greater proportion of time grazing than NA cows and tend to increase grazing time when feed allowance is reduced, suggesting that the NZ strain may be more adapted to a grazing scenario (McCarthy et al., 2007b). The BCS profiles observed in the current study and similar strain comparisons (McCarthy et al., 2007a; Roche et al., 2006) indicate that the inability of the NA strain to meet energy demands from pasture persists through lactation. In contrast, the NZ strain is capable of ingesting sufficient energy for milk production and body tissue accretion from mid-lactation in a pasture-based system.

The SCM yield of the NA cows was greater than NZ cows from approximately wk 20 until the end of lactation, coincident with the divergence of the BCS profiles of the strains. Similarly, Horan et al. (2006) observed that NA cows had a greater milk yield response to additional concentrate supplementation than NZ cows. Energy partitioning results in the current study were not confounded by pregnancy status as breeding was delayed due to a concurrent embryo collection study which prevented cows from becoming pregnant during the duration of the study. The divergence in the milk production and BCS profiles of the strains therefore indicates that the NA cows maintain preferential partitioning of nutrients to the mammary gland for a longer duration than NZ cows.

While it is well established that nutrient partitioning changes with stage of lactation (Kirkland and Gordon, 2001), the temporal change in the magnitude of

differences between the strains is an interesting feature of the present study. Genetic selection for increased milk yield has been associated with the shifting of homeorhetic controls, such that milk production is maximised from ingested nutrients and available body tissue reserves, particularly during early lactation (Bauman, 2000). However, the NA and NZ strains had a comparable degree of NEB and a similar propensity for body tissue mobilization during early lactation; differences in nutrient partitioning did not become manifest until after the time of peak milk energy demand. This implies that strain differences exist in the timescale of homeorhetic adaptations during lactation, with the NZ strain affording a greater metabolic priority to replenishment of body reserves at an earlier stage of lactation than the NA strain.

The NA cows had increased plasma insulin concentrations during the transition period, despite the similar calculated EB of the strains at this time. Differences in plasma insulin concentration, though statistically significant, were modest. In contrast, others have reported lower plasma insulin concentration for cows of higher genetic merit for milk yield (Gutierrez et al., 2006). The increased plasma glucose concentration for the NA cows was consistent with the observed differences in insulin concentrations.

The temporal patterns of plasma IGF-I concentration observed were similar to previous reports, with a decline at parturition and a gradual increase thereafter (McGuire et al., 1995). While the strains had similar plasma IGF-I profiles during the transition period, plasma IGF-I was higher for NZ cows from approximately d 30 of lactation. This occurred despite the similar EB profiles between the strains, and the higher plasma insulin concentrations in the NA cows.

Expression of the IGF-I gene in the liver is acutely responsive to nutritional status. The decline in IGF-I concentration at parturition is due to reduced expression of growth hormone receptor 1A (GHR-1A) and IGF-I mRNAs, coincident with a period of liver refractoriness to growth hormone (Radcliff et al., 2003). A several-fold increase in insulin has been shown to stimulate hepatic expression of GHR-1A and IGF-I mRNA (Butler et al., 2003; Rhoads et al., 2004). The higher insulin concentration for NA cows during the transition period in the current study may have been insufficient to elicit a detectable increase in plasma IGF-I concentration. Indeed, Radcliff et al (2006) showed that restricting DMI in early lactation decreased the rate of *post partum* increase in liver GHR mRNA and tended to reduce plasma IGF-I concentration, but had no effect on liver IGF-I mRNA. This indicates that post-transcriptional and/or post-translational mechanisms may also exert control on *post partum* IGF-I concentrations. Plasma IGF-I was higher for NZ cows from approximately day 30-100 of lactation, despite the similar EB profiles and lower circulating insulin concentrations compared to NA cows. Crooker et al. (2001) likewise showed that although *post partum* EB did not differ between cows of high and low genetic merit, plasma IGF-I was lower for the high genetic merit cows. Genetic selection for milk yield may therefore affect the somatotropic axis during early lactation independent of energy balance.

Gross energy efficiency may be defined as energy in the milk produced divided by the total energy intake (Brody, 1945). Gross efficiency is greater if calculated when cows are mobilizing body tissue in support of milk production, because the potential contribution of body reserves to milk energy output is not

418 considered (Veerkamp and Emmans, 1995). The strains had a similar degree of BCS
419 change over the first 20 weeks of lactation in the present study; the results thus
420 demonstrate that the NA and NZ strains have a similar level of milk production per
421 unit of energy intake or bodyweight, net of differences in body fat mobilization. This
422 is consistent with the review of Bauman et al. (1985), who stated that there is little
423 genetic variation in the partial efficiencies of metabolizable energy utilization for
424 maintenance or milk production. There is however a considerable degree of genetic
425 variation in gross efficiency, principally due to a dilution of maintenance
426 requirements for higher yielding cows (Veerkamp and Emmans, 1995). Similarly,
427 Yerex et al. (1988) showed that cows selected for lower bodyweight had lower
428 maintenance requirements, and consequently a higher gross efficiency than heavier
429 cows with similar levels of milk yield. In the present study, the lower milk
430 production of the NZ cows was offset by lower DMI and bodyweight to result in
431 similar milk production efficiencies for the strains.
432

Conclusions

This study compared the EB, metabolic profiles and nutrient partitioning of the NA and NZ strains of Holstein Friesian. The NZ strain had similar SCM yield, lower maintenance requirements and lower DMI in early lactation compared to the NA strain, resulting in no difference in EB between the strains. The similarity in early lactation EB of the strains was reflected in their respective metabolic and endocrine profiles during that time. The NZ cows began to replenish BCS at an earlier stage of lactation, and had greater plasma concentrations of IGF-I from approximately wk 4 of lactation. In conclusion, the results of this study do not support the premise that the NA cows experience a greater dietary energy deficit during the transition period due to their superior genetic potential for milk yield. The results do however indicate that NZ cows begin to partition nutrients towards body reserves during mid-lactation whereas NA cows continue to preferentially partition nutrients to milk for a longer duration *post partum*

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Table 1 *Genetic merit of the North American and New Zealand strains of Holstein Friesian based on predicted differences[2] and standard deviations (SD) for milk production, calving interval and survival*

Trait	Strain[1] NA	NZ
Milk (kg)	+ 210 (117)	+ 1 (157)
Fat (kg)	+ 6.2 (3.5)	+ 6.5 (5.0)
Protein (kg)	+ 7.4 (4.4)	+ 3.7 (4.0)
Fat (g/kg)	+ 0.10 (1.4)	+ 1.13 (0.62)
Protein (g/kg)	+ 0.40 (0.32)	+ 0.75 (0.43)
Calving interval (days)	+ 0.99 (1.98)	- 2.86 (1.53)
Survival (%)	+ 0.04 (0.29)	+ 1.14 (0.48)

[1]NA = North American Holstein Friesian; NZ = New Zealand Holstein Friesian

[2]All predicted differences obtained from the February 2004 international evaluations of the INTERBULL Animal Centre (Uppsala, Sweden).

634 **Table 2** *Ingredient and chemical composition of concentrate supplement fed*

635 *throughout the study*

Ingredient	Value
Barley (g/kg)	200
Beet pulp (g/kg)	220
Maize gluten (g/kg)	170
Rapeseed meal (g/kg)	210
Soybean meal (g/kg)	140
Lard (g/kg)	30
Di-calcium phosphate (g/kg)	15
Limestone flour (g/kg)	7
Salt (g/kg)	5
Calcined magnesite (g/kg)	3
Chemical Composition	
Dry matter (g/kg)	871[1] ± 32
Crude protein (g/kg DM)	186 ± 71
Neutral detergent fibre (g/kg DM)	256 ± 20
Ash (g/kg DM)	91 ± 3
Starch (g/kg DM)	182 ± 15
Net energy (UFL/kg)[2]	1.0
NE_L (Mcal/kg)[3]	1.7

636 [1] Mean ± standard deviation

637 [2] Estimated based on net energy values for ingredients (INRAtion, 1999, version 2.7).

638 [3] Estimated based on 1 UFL = 1.7 Mcal/kg (Vermorel, 1989)

639 **Table 3** *Chemical composition of grass silage and zero-grazed grass*[1]

Variable	Grass silage	Zero-grazed grass
Dry matter (DM), (g/kg)	273 ± 53	172 ± 22
Crude protein (g/kg DM)	117 ± 9	155 ± 31
Neutral detergent fibre (g/kg DM)	589 ± 27	390 ± 23
Acid detergent fibre (g/kg DM)	368 ± 23	-
Ash (g/kg DM)	58.3 ± 8	78.7 ± 8
Dry matter digestibility[2] (g/kg)	697 ± 40	-
Organic matter digestibility (g/kg DM)	630 ± 33	813 ± 17
pH	4.11 ± 0.36	-
Net energy [3,4] (UFL/kg DM)	0.79	0.99
Net energy [5] (Mcal/kg DM)	1.34	1.68

640 [1] Values reported are means ± standard deviation

641 [2] Estimated using near-infrared spectroscopy

642 [3] The net energy value of silage was calculated from its *in vitro* DMD concentration (O'Mara *et al.*,
643 1997)

644 [4] The net energy value of grass was determined according to Jarrige (1989)

645 [5] Estimated based on 1 UFL = 1.7 Mcal/kg (Vermorel, 1989)

646

647 **Table 4** *Effect of strain[1] of Holstein Friesian on milk production and composition*

Variable	NA	NZ	s.e.d.[2]	P-value
Week 1-20 of Lactation				
Milk yield (kg/day)	30.9	26.8	1.1	<0.01
Solids corrected milk[3] (SCM) yield (kg/day)	29.6	27.7	1.0	0.06
Milk fat content (g/kg)	42.0	47.7	1.8	<0.01
Milk protein content (g/kg)	32.4	32.5	0.6	0.97
Peak Milk yield (kg)	37.6	32.7	1.1	<0.001
Peak SCM yield (kg)	38.0	36.6	1.6	0.39
Total Lactation[4]				
Milk yield (kg)	7280	6045	362	<0.01
SCM (kg)	6816	6048	342	0.04
Milk fat content (g/kg)	40.2	43.9	1.2	<0.01
Milk protein content (g/kg)	33.5	34.1	0.6	0.33
Total fat + protein yield (kg)	533	473	27	0.03

648 [1] NA= North American Holstein Friesian; NZ= New Zealand Holstein Friesian

649 [2] SED = Standard error of difference

650 [3] Calculated as described by Tyrell and Reid (1965)

651 [4] Mean lactation length was 287d for NZ and 290d for NA strain

652 **Table 5** *Effect of strain on Energy Balance and Feed Intake*

Variable	NA[1]	NZ[1]	s.e.d.[2]	P-Value
Dry Matter and Energy Intake wk1-20				
Dry matter intake (DMI) (kg / d)	17.2	15.7	0.78	0.07
Net energy intake (UFL /d)	16.8	15.5	0.70	0.08
DMI as proportion of MBW[3] (%)	14.3	14.1	0.71	0.78
Energy Balance (EB)				
EB wk 1-20 (UFL[4] / d)	-1.80	-1.84	0.66	0.95
Nadir EB (UFL / d)	-6.88	-7.31	1.20	0.72
Interval to nadir EB (days)	10.3	10.6	1.84	0.77
Interval to neutral EB (days)	72	73	9.5	0.87
Milk Production Efficiency wk1-20				
Milk yield per kg DMI (kg)	1.86	1.75	0.08	0.22
UFL milk per UFL intake (UFL)	0.84	0.85	0.12	0.91
SCM[5] as proportion of MBW (%)	17.7	18.1	0.71	0.57

653 [1] NA= North American Holstein Friesian; NZ= New Zealand Holstein Friesian

654 [2] s.e.d. = Standard error of difference

655 [3]MBW = Metabolic bodyweight, calculated as $B^{0.75}$, where B=bodyweight (kg)

656 [4]1 UFL = Net energy for lactation equivalent of 1 kg standard air-dry barley (Jarrige, 1989)

657 [5]SCM = Solids Corrected Milk

Table 6 *Effect of strain on plasma concentrations[1] of insulin, IGF-I and metabolites*

Variable	NA[2]	NZ[2]	Mean ratio[3]	P-value
Transition Period[4]				
Insulin (uIU/mL)	4.39 (3.82, 5.16)	3.32 (2.86, 3.82)	1.33 (1.08, 1.65)	0.01
IGF-I (ng/mL)	56.8 (49.4, 66.7)	59.2 (51.4, 68.7)	0.96 (0.78, 1.19)	0.71
Glucose (Mmol/L)	3.50 (3.39, 3.63)	3.29 (3.16, 3.39)	1.07 (1.01, 1.12)	0.01
NEFA (Mmol/L)	0.34 (0.28, 0.41)	0.39 (0.33, 0.47)	0.85 (0.66, 1.11)	0.29
BHB (Mmol/L)	0.63 (0.57, 0.70)	0.77 (0.69, 0.87)	0.82 (0.70, 0.96)	0.02
Post Transition[4]				
Insulin (uIU/mL)	4.66 (4.06, 5.42)	3.86 (3.35, 4.44)	1.21 (0.99, 1.48)	0.06
IGF-I (ng/mL)	77.5 (67.4, 90.0)	97.5 (83.9, 112.2)	0.80 (0.65, 0.99)	0.04
Glucose (Mmol/L)	3.25 (3.19, 3.35)	3.32 (3.25, 3.42)	0.98 (0.95, 1.01)	0.21
NEFA (Mmol/L)	0.17 (0.14, 0.20)	0.17 (0.14, 0.20)	1.00 (0.78, 1.29)	0.99
BHB (Mmol/L)	0.46 (0.41, 0.51)	0.44 (0.39, 0.48)	1.05 (0.92, 1.21)	0.45

[1] Geometric Means (95% Confidence interval in parentheses)

[2] NA = North American Holstein Friesian; NZ = New Zealand Holstein Friesian

[3] Ratio of geometric means (95% Confidence interval in parentheses)

[4] Transition = d 15 *pre partum* to d 28 *post partum*; Post transition = d 29 to 100 *post partum*

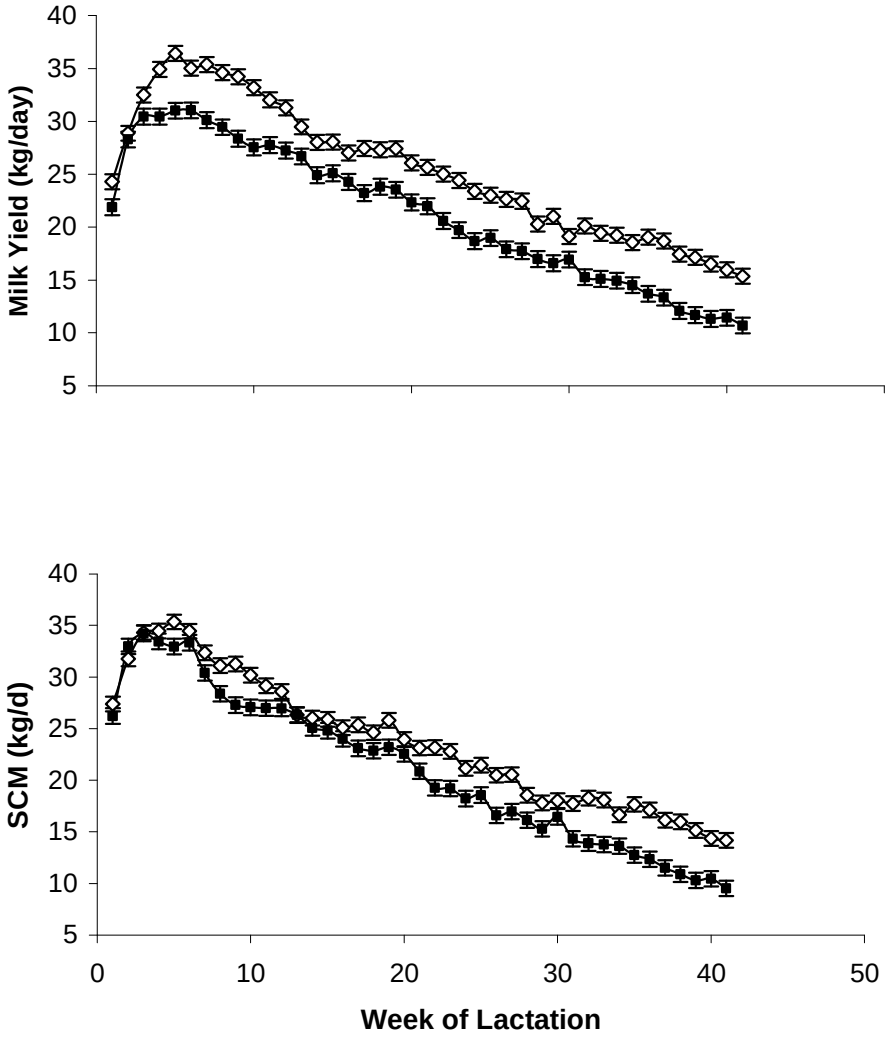

Milk Yield (kg/day)
40
35
30
25
20
15
10
5
SCM (kg/d)
40
35
30
25
20
15
10
5
0
10
20
30
40
50
Week of Lactation

Figure 1.

674 **Figure 1.** Effect of strain of Holstein-Friesian on milk yield and solids-corrected milk yield (SCM) (◊
675 = North American Holstein Friesian; ■ = New Zealand Holstein Friesian). The P values for the effects
676 of strain, week and interaction between strain and week on mean daily milk yield were 0.002, <0.001
677 and 0.96, respectively. The s.e.d. was 1.18 kg/day. The P values for the effects of strain, week and
678 interaction between strain and week on mean daily SCM yield were 0.04, <0.0001 and 0.98,
679 respectively. The s.e.d. was 1.05 kg/day.
680

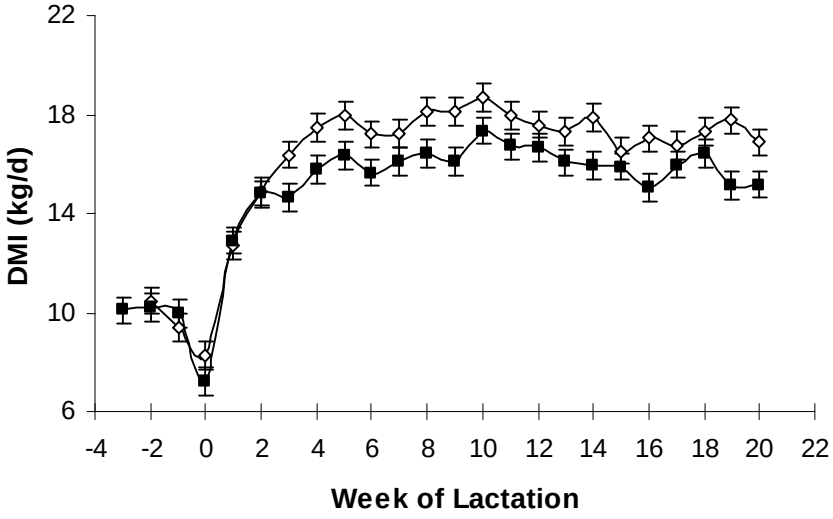

22
18
14
10
6
DMI (kg/d)
-4
-2
0
2
4
6
8
10
12
14
16
18
20
22
Week of Lactation

Figure 2.

699 **Figure 2.** Effect of strain of Holstein-Friesian on dry matter intake (◊ = North American Holstein
700 Friesian; ■ = New Zealand Holstein Friesian). The P-values for the effects of strain, week and
701 interaction between strain and week on daily dry matter intake from wk 1 until wk 20 *post partum* were
702 0.07, <0.001 and 0.90, respectively. The s.e.d. was 0.8 kg/day.

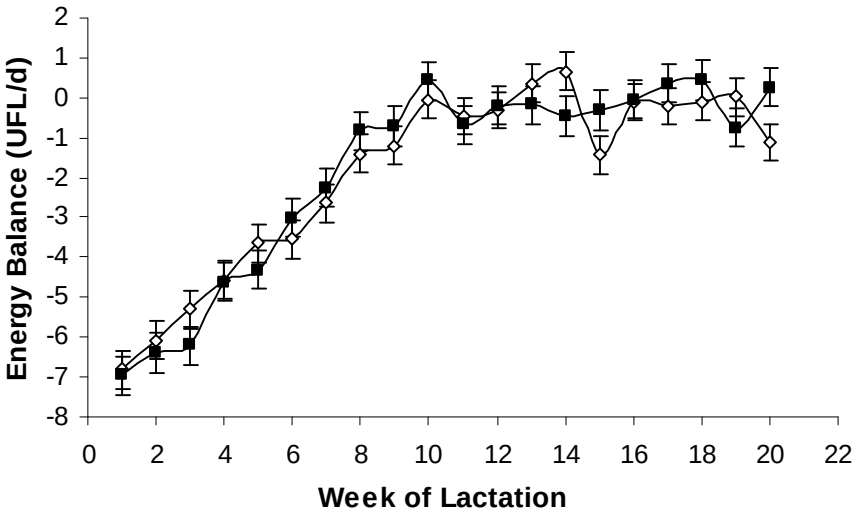

Energy Balance (UFL/d)
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
0
2
4
6
8
10
12
14
16
18
20
22
Week of Lactation

Figure 3.

720 **Figure 3.** Effect of strain of Holstein-Friesian on energy balance (◊ = North American Holstein
721 Friesian; ■ = New Zealand Holstein Friesian) from wk 1 to 20 of lactation. The P values for the effects
722 of strain, week and interaction between strain and week were 0.95, <0.001 and 0.94, respectively. The
723 s.e.d. was 0.6 UFL/day.

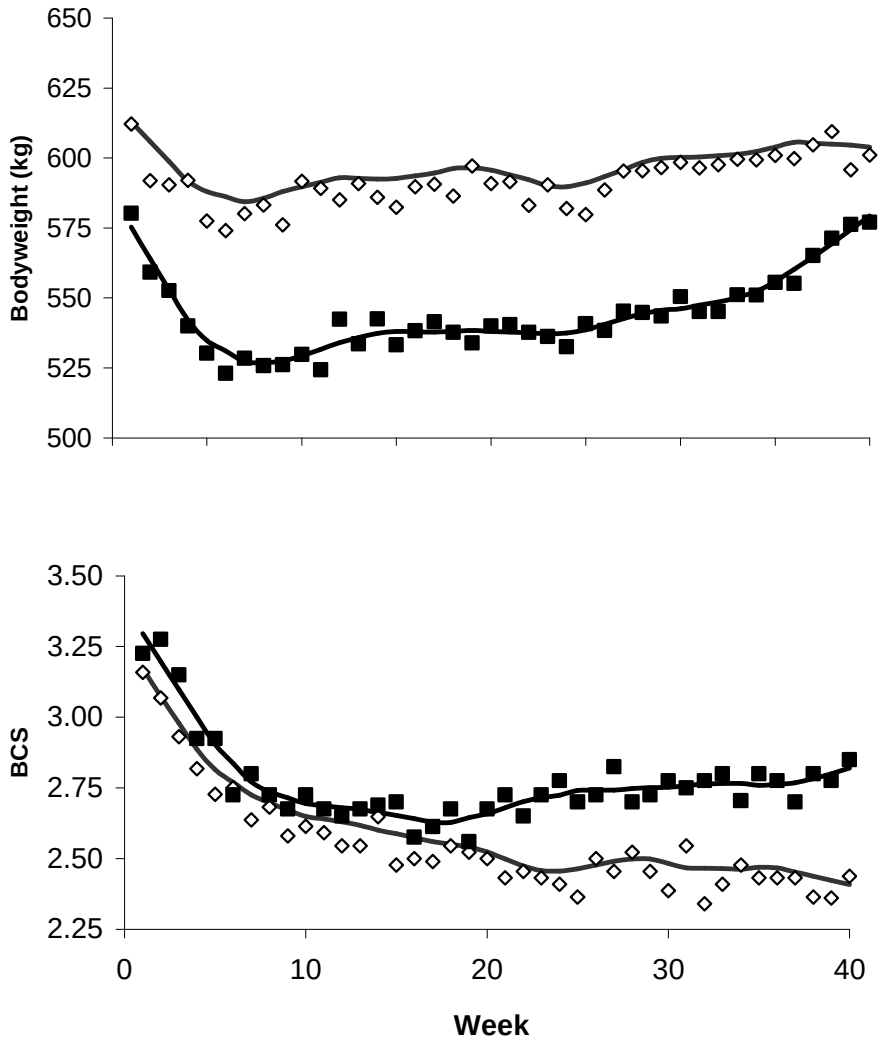

650
625
600
575
550
525
500
Bodyweight (kg)
3.50
3.25
3.00
2.75
2.50
2.25
BCS
0
10
20
30
40
Week

Figure 4.

Figure 4. Effect of strain of Holstein-Friesian on body condition score (BCS) and bodyweight (◊ = North American Holstein Friesian; ■ = New Zealand Holstein Friesian). The P values for the effects of strain, week and interaction between strain and week on weekly BCS were 0.16, <0.001 and 0.009, respectively. The s.e.d. was 0.08 BCS units. The P values for the effects of strain, week and interaction between strain and week on weekly bodyweight were 0.02, <0.001 and 0.57, respectively. The s.e.d. was 15.5 kg. Figures are presented with LOESS-smoothed lines for illustrative purposes.

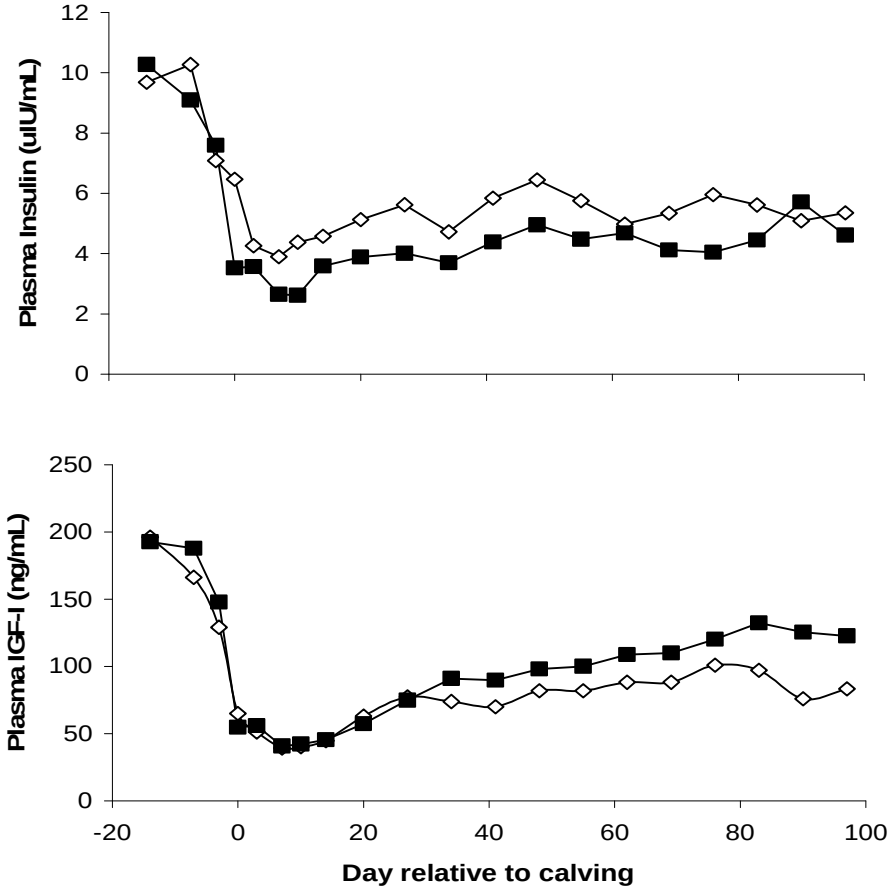
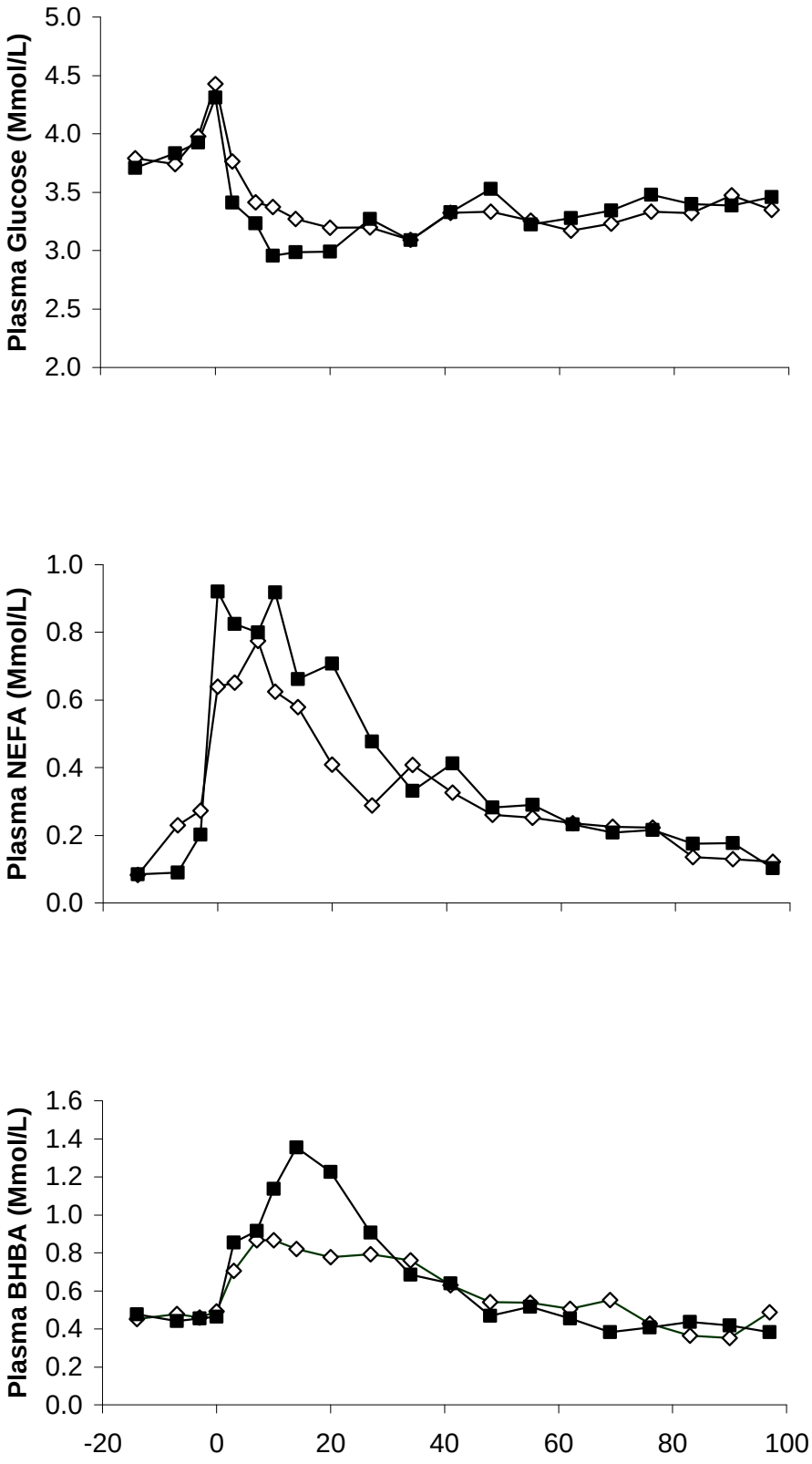

Plasma Insulin (uIU/mL)
12
10
8
6
4
2
0
Plasma IGF-I (ng/mL)
250
200
150
100
50
0
-20
0
20
40
60
80
100
Day relative to calving

Figure 5.

Figure 5. Effect of strain of Holstein-Friesian on plasma insulin and IGF-I concentrations (◊ = North American Holstein Friesian; ■ = New Zealand Holstein Friesian). The P-values for the effect of strain on insulin concentration were 0.01 and 0.06 for the transition period (2 wk *pre partum* to d 28 *post partum*) and post transition period (d 29 to d 100 *post partum*), respectively. The P-values for the effect of strain on IGF-I concentration were 0.71 and 0.04 for the transition and post-transition periods, respectively. There were no significant strain-by-time interactions observed for either insulin or IGF-I across the entire experimental period ($P > 0.05$).



761

762 Figure 6.

Figure 6. Effect of strain of Holstein-Friesian on plasma glucose, non-esterified fatty acid (NEFA) and beta-hydroxybutyrate concentrations (◊ = North American Holstein Friesian; ■ = New Zealand Holstein Friesian). The P-values for the effect of strain on glucose concentration were 0.01 and 0.21 for the transition period (2 wk *pre partum* to d 28 *post partum*) and post transition period (d 29 to d 100 *post partum*), respectively. The P-values for the effect of strain on NEFA concentration were 0.29 and 0.99 for the transition and post-transition periods, respectively. The P-values for the effect of strain on BHBA concentration were 0.02 and 0.45 for the transition and post-transition periods, respectively. There were no significant strain-by-time interactions observed for glucose, NEFA or BHBA concentrations across the entire experimental period ($P > 0.05$).