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A comparison of energy balance and metabolic profiles of the New Zealand and North American strains of Holstein Friesian dairy cow

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22   **Abstract**

23   The milk production, energy balance (EB), endocrine and metabolite profiles of 10

24   New Zealand Holstein-Friesian (NZ) cows and 10 North American Holstein-Friesian

25   (NA) cows were compared. The NA cows had greater peak milk yields and total

26   lactation milk yields (7387 vs. 6208 kg; s.e.d. = 359), lower milk fat and similar

27   protein concentrations compared to the NZ cows. Bodyweight was greater for NA

28   cows compared to NZ cows throughout lactation (596 vs. 544 kg; s.e.d. = 15.5), while

29   body condition score (BCS) tended to be lower. The NA strain tended to have greater

30   DMI (17.2 vs. 15.7 kg/d; s.e.d. = 0.78) for wk 1-20 of lactation, though DMI as a

31   proportion of metabolic bodyweight was similar for both strains. There were no

32   differences observed between the strains for the timing and magnitude of the energy

33   balance (EB) nadir, interval to neutral EB, or mean daily EB for week 1-20 of

34   lactation. Plasma concentrations of glucose and insulin were greater for NA cows

35   during the transition period (d 14 *pre partum* to d 28 *post partum*). Plasma IGF-I

36   concentrations were similar for the strains at this time, but NZ cows had greater

37   plasma IGF-I concentration from d 29 to d 100 of lactation, despite similar calculated

38   EB. In conclusion, the results of this study do not support the premise that the NZ

39   strain has a more favourable metabolic status during the transition period. The results

40   however indicate that NZ cows begin to partition nutrients towards body reserves

41   during mid-lactation whereas NA cows continue to partition nutrients to milk

42   production.

43

44   **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).

70 Strain comparison studies in New Zealand and Ireland have reported lower milk

71 volume, higher BCS throughout lactation and superior reproductive performance for

72 the New Zealand (NZ) Holstein Friesian compared to North American (NA) Holstein

73 Friesian (Harris and Kolver, 2001; Horan et al., 2005b). The NA strain has been

74 selected for increased milk yield, body size and angularity in a production system

75 based on year-round calving and high levels of concentrate supplementation, with

76 little emphasis traits such as fertility. The NZ strain has been selected for increased

77 milk solids yield and improved fertility and survival in a pasture-based production

78 system (Horan et al., 2005a). The strain comparison model provides a framework for

79 examining the effects of divergent genetic selection programmes within the Holstein

80 Friesian on energy balance and nutrient partitioning. The objective of the current

81 study was therefore to characterize the energy balance, nutrient partitioning and

82 metabolic profiles of the NA and NZ strains, which differ in genetic merit for milk

83 production.

84

85 **Materials and Methods**

86 *Animals and experimental design*

87   Two groups of 10 spring-calving, multiparous Holstein-Friesian cows were

88 selected from the NA and NZ groups of the Moorepark strain comparison study

89 (Horan et al., 2005a). The origins and establishment of the experimental groups from

90 which the cows were selected have been previously described by Horan et al. (2005a).

91 The North American (NA) strain was developed by mating the top 50% of cows in

92 Moorepark (based on pedigree index for milk production) with 5 NA Holstein-

93 Friesian sires, selected as the highest available in Ireland for pedigree index for milk

94 production. The NZ strain were imported as embryos from New Zealand and

95   implanted into Holstein heifers. These embryos were generated by mating high

96   genetic merit NZ Holstein-Friesian cows with 5 high genetic merit NZ Holstein-

97   Friesian sires (based on Breeding Worth; the New Zealand genetic evaluation

98   system). The experimental animals used in the current study were selected from the

99   existing NA and NZ treatment groups involved in the Moorepark strain comparison

100   study (Table 1). Mean calving dates were 25th February (s.d. 18 days) for the NA

101   group and 2nd March (s.d. 17 days) for the NZ group.

102

103   ***Insert Table 1 Here***

104   The cows were housed in a free-stall barn from 3 weeks prior to the expected

105   calving date, with the treatment groups sharing common accommodation space. The

106   cows were trained to use the Griffith Elder feeding system (Griffith Elder Ltd, Bury

107   St Edmunds, Suffolk, UK). Forage and concentrate allocations were fed separately.

108   Forage mangers were mounted on electronic load cells, while concentrates were

109   dispensed through automatic feeders. Cows had *ad libitum* access to forage, which

110   was offered to allow for feed refusals of at least 5%. Refusals were removed daily.

111   The *pre partum* diet comprised *ad libitum* grass silage, with 2 kg per day of the

112   lactating concentrate (Table 2) introduced from 2 weeks prior to the expected calving

113   date. The *post partum* diet consisted of *ad libitum* grass silage and 8 kg of

114   concentrate. From March 20th, all lactating cows were offered zero-grazed grass (*L.*

115   *perenne spp)* supplemented with 4kg concentrate. Grass was harvested and fed each

116   morning. The chemical composition of the grass silage and zero-grazed grass is

117   reported in Table 3. Cows were turned out to pasture on July 30th and were offered

118   high quality grazed grass (*L. perenne spp.)* plus 4 kg/day of concentrate. Cows

119   remained at pasture day and night until mid-November, after which they were housed

120 at night. After December 1st, the cows were housed day and night. Animals were fed

121 grass silage *ad libitum* when housed.

122

123 ***Insert Table 2 here***

124 ***Insert Table 3 here***

125

126 *Samples and animal measurements*

127   Milk yield (kg) was recorded daily at the morning and evening milkings using

128 electronic milk meters (Dairy Master, Causeway, Co. Kerry, Ireland). Milk

129 composition (fat, protein and lactose) was determined on two days per week from

130 successive morning and evening milk samples by automated infra-red absorption

131 analysis using a Milkoscan 605 (Foss Electric, Hillerod, Denmark). Solids-corrected

132 milk (SCM) yield was calculated using the equation of Tyrell and Reid (1965). All

133 cows were dried off on December 15th, resulting in mean lactation length of 290 days

134 (s.d. 14 days) for the NA strain and 287 days (s.d. 16 days) for the NZ strain.

135   Samples of grass silage and concentrates offered were collected twice weekly

136 for chemical analysis. Zero-grazed grass was sampled daily for dry matter; samples

137 were bulked by week for composition analysis.

138   Cow body weight (kg) and BCS (Lowman et al., 1976) were recorded once

139 weekly from 3 weeks before the expected calving date, immediately post-calving, and

140 once weekly thereafter until the end of lactation. The dry cows were weighed before

141 feeding in the morning and the lactating cows were weighed after morning milking,

142 before feeding. Data were lost for pre-calving bodyweights and BCS owing to a

143 technical failure in the recording system. Energy balance, bodyweight, and BCS

144 profiles are therefore reported commencing from the week of calving

145   Blood samples were collected three times weekly (Monday, Wednesday,

146   Friday) by coccygeal venipuncture for 2 weeks before expected calving date, daily

147   from day of calving until day 14 *post partum*, and twice weekly (Monday, Thursday)

148   from day 15 to day 100 *post partum*. Sampling took place after the morning milking

149   and before feeding. Samples were collected into vials containing lithium heparin as an

150   anticoagulant. The samples were immediately centrifuged at $2000 \times g$ for 10 minutes.

151   The plasma was decanted and stored at -20°C until analysis.

152   *Laboratory procedures and analysis*

153   The DM, NDF, crude fiber and CP of the forage and concentrate samples were

154   analyzed as described by McNamara et al. (2003). Determination of *in vitro* dry

155   matter digestibility (DMD) was carried out by near-infrared spectroscopy using a

156   NIRsystems 6500 spectrophotometer (Perstorp Analytical Incorporated, Silver

157   Springs, Maryland, USA). Silage pH was measured on the juice pressed from the

158   silage using a glass electrode and a pH meter (Radiometer pHM2 standard pH meter-

159   radiometer, Copenhagen). The organic matter digestibility of grass was determined as

160   described by Morgan et al. (1994)

161   Blood plasma was analysed for glucose, non-esterified fatty acid (NEFA), and

162   beta-hydroxybutyrate (BHBA) concentrations by enzymatic colorimetry, using

163   appropriate kits and an ABX Mira autoanalyzer (ABX Mira, Cedex 4, France).

164   Plasma insulin concentration was determined using a solid-phase fluoroimmunoassay

165   (AutoDELFIA, PerkinElmer Life and Analytical Sciences, Turku, Finland). The inter-

166   and intra-assay coefficients of variation were 14.7% and 6.4%, respectively.

167   Circulating IGF-1 concentrations were quantified using a validated double-antibody

168   radioimmunoassay, following ethanol:acetone:acetic acid (60:30:10) extraction as

169   described by Enright et al. (1989). Recombinant human IGF-1 (supplied by R&D

170 Systems Europe, UK) was used for iodination and standards (iodine – 125 supplied by

171 PerkinElmer (Unitech BD Ltd., Dublin, Ireland), as described by Spicer et al (1990).

172 The rabbit anti-human IGF-I (AFP4892898) was obtained through the US National

173 Hormone and Peptide Program (Dr A F Parlow, Scientific Director). Inter- and intra-

174 assay coefficients of variation were 17.0 and 11.6%.

175

176 *Energy balance*

177 Energy balance was estimated as the difference between energy intake and the

178 sum of energy for maintenance and milk production. The French Net Energy (NE)

179 system was used (Jarrige, 1989). The NE content of the concentrates offered was

180 determined using the NE values (UFL) of ingredients (INRAtion, 1999, version 2.7).

181 One UFL is the NE content of 1 kg of air-dry standard barley for milk production

182 (Jarrige, 1989). The NE value of the grass silage was calculated based on its *in vitro*

183 DMD concentration (O'Mara et al., 1997). The NE value of the grass was determined

184 according to Jarrige (1989).

185 The following equations were used to determine the energy required for

186 maintenance and the energy output in milk:

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

188 UFL requirement for milk: (UFL/kg of milk) = $0.0054FC + 0.0031PC + 0.0028LC -$

189 0.015; where BW = body weight, FC = fat concentration, PC = protein concentration

190 and LC = lactose concentration all in g/kg.

191

192 *Data handling and statistical analysis*

193   Daily milk yield and DMI data were collapsed into weekly means, and EB

194   values were similarly calculated as weekly means. Repeated measures analyses of

195   genotype effects on DMI, milk yield, milk composition, plasma metabolites, insulin

196   and IGF-I, energy balance, BCS and bodyweight were carried out using the MIXED

197   procedure of SAS (SAS Institute, 1991). A first order autoregressive covariance

198   structure was used. Genotype, time, and the interaction of genotype and time were

199   included as fixed effects. Cow within genotype was included as a random effect. For

200   illustrative purposes (Figure 4), body weight and BCS lines were smoothed using the

201   LOESS procedure in SAS (SAS Institute, 1991).

202   Data for plasma analytes during daily blood sampling from day 1 to day 14

203   *post partum* were collapsed into four mean values (day 1 to 3 = day 3; day 4 to 7 =

204   day 7; day 8 to 10 = day 10; day 11 to 14 = day 14), and into weekly mean values for

205   *pre partum* samples and *post partum* samples collected from day 14 to 100 post-

206   calving. This resulted in all cows having plasma analyte data for days -14, -7, 0, 3, 7,

207   10, 14, 21, 28, 35, 42, 49, 56, 63, 70, 84, 91, and 98 for statistical analysis. Plasma

208   insulin, IGF-I and metabolite data were not normally distributed, and were log

209   transformed prior to statistical analysis. Plasma analyte data for each cow was divided

210   into 2 time periods (transition period from d 14 *pre partum* to d 28 *post partum*; post-

211   transition period from d 29 to d 100 *post partum*) and the time periods were analyzed

212   separately to accommodate the constant variance assumption of repeated measures

213   analysis. Results for plasma analytes were back-transformed and are presented as

214   geometric means (and 95% confidence intervals).

215

216   **Results**

217   *Milk production and composition*

218   The NA strain had a greater milk yield (P < 0.01) during week 1-20 of

219   lactation, and tended to have a greater SCM yield (P = 0.06) compared to the NZ

220   strain (Table 4). The NA strain had a higher (P < 0.001) peak milk yield, but peak

221   SCM yield did not differ between the strains (P = 0.39). Mean daily SCM yield from

222   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

223   the NA and NZ strains, respectively.

224

225   ***Insert Table 4 here***

226

227   Milk fat concentration over the full lactation was greater for NZ cows (P < 0.01),

228   while milk protein concentration did not differ between the strains (P = 0.33). Total

229   combined yield of milk fat and protein over the full lactation was 12.7% greater (P =

230   0.03) for the NA strain (Table 4). The NA strain produced 20.4% greater volume (P <

231   0.01) of milk over the full lactation compared to the NZ strain; total lactation SCM

232   yield was 12.7% greater (P = 0.04) for the NA strain (Figure 1).

233

234   ***Insert Figure 1 here***

235

236   *Dry matter intake, energy balance and feed efficiency*

237   Mean DMI (P = 0.07) and net energy intake (P = 0.08) tended to be greater for

238   NA compared to NZ cows (Figure 2) during wk 1-20 of lactation. When expressed as

239   a percentage of metabolic bodyweight, however, the strains had similar (P = 0.78)

240   mean daily DMI over the same time period (Table 5).

241

242   ***Insert Table 5 here***

243   ***Insert Figure 2 here***

244

245   The NA and NZ strains had similar mean daily calculated energy balance

246   (EB) during week 1-20 (P = 0.95) of lactation (Figure 3). The strains also had a

247   similar magnitude of EB nadir (P = 0.72). In addition, the timing of EB nadir (P =

248   0.77) and interval to neutral EB (P = 0.87) did not differ between the two strains

249   (Table 5).

250

251   ***Insert Figure 3 here***

252

253   The NA and NZ strains had similar milk yield per kg of DMI (P = 0.22), and

254   similar output of milk energy per unit of net energy intake (P = 0.91), for week 1-20

255   of lactation (Table 5). Solids corrected milk yield as a proportion of metabolic

256   bodyweight did not differ between the strains (P = 0.57).

257

258   *Bodyweight and body condition score*

259   The NA and NZ strains had similar BCS at the beginning of lactation (3.17 vs.

260   3.22, respectively; s.e.d = 0.18; P = 0.78). The strains had lost a similar amount of

261   BCS by week 20 of lactation (0.65 vs. 0.55 respectively; s.e.d = 0.15; P = 0.53).

262   Thereafter, the NZ strain began to increase in BCS whereas the NA strain did not,

263   resulting in a greater BCS for NZ compared to NA by the end of lactation (2.85 vs.

264   2.43 respectively; s.e.d = 0.15; P = 0.02) Mean bodyweight across the full lactation

265   was greater for NA compared to NZ cows (596 vs. 544 kg respectively; s.e.d = 21.9;

266   P = 0.02) (Figure 4).

267

268   *Insert Figure 4 here*

269

270   *Plasma insulin, IGF-I and metabolites*

271   Mean plasma insulin concentration was higher (P = 0.01) for the NA strain

272   during the transition period, and tended to be higher (P = 0.06) from d 29 until d 100

273   (Figure 5; Table 6). There were no differences between the strains in mean plasma

274   concentrations of IGF-I in the transition period (P = 0.71). However, the NZ strain

275   had higher (P = 0.04) plasma IGF-I concentrations from d 29 to d 100 of lactation

276   (Figure 5; Table 6).

277

278   *Insert Figure 5 here*

279   *Insert Table 6 here*

280

281   Plasma glucose concentration was higher for the NA strain during the

282   transition period (P = 0.01), but differences were not observed in the post-transition

283   period (d 29 to d 100 of lactation) (P = 0.21) (Figure 6; Table 6). There were no

284   differences observed between the strains in mean plasma NEFA concentration, either

285   during the transition period (P = 0.29), or during the post-transition period (P = 0.99).

286   Plasma BHBA concentration was higher for NZ compared to NA cows during the

287   transition period (P = 0.02), but both strains had similar mean plasma BHBA

288   concentrations during the post-transition period (P > 0.05).

289

290   **Discussion**

291   The primary objective of this study was to characterize the EB, nutrient

292   partitioning and metabolic profiles of the NA and NZ strains, which differ in their

293   genetic merit for milk production, BCS and fertility performance (Horan et al.,

294   2005b). The lack of difference between the EB profiles of the strains during early

295   lactation was particularly interesting given the extensive reports of negative genetic

296   relationships between milk yield and both EB and BCS (Berry et al., 2003; Veerkamp

297   and Thompson, 1999).

298

299   In general, cows of higher genetic merit for milk yield have greater milk

300   energy output in early lactation, which is met by a combination of increased DMI and

301   body tissue mobilization (Bauman, 2000). The higher milk yield recorded for the NA

302   cows in the present study is a result of more intensive genetic selection for milk yield

303   compared to NZ cows (Kolver et al., 2000). Peak daily milk yield was higher for the

304   NA strain as had been reported previously (Horan et al., 2005a), however peak yield

305   did not differ between the groups when expressed as SCM. This was primarily due to

306   the higher milk fat concentration of the NZ strain; mean milk protein concentration

307   was not different between the groups. The NZ strain has previously exhibited higher

308   milk fat and milk protein in pasture-based production systems (Horan et al., 2005a).

309   Increasing fat and protein yield in a given volume of milk has been a key breeding

310   objective in the New Zealand breeding programme for many years (Harris and

311   Kolver, 2001). It can be therefore concluded that the strains experienced a

312   comparable magnitude of milk energy demand at peak SCM production.

313

314   The NA strain had approximately 1.5 kg per day greater DMI, equivalent to

315   1.26 UFL of NE intake per day, compared to the NZ strain from wk 1-20 *post*

316   *partum*. However, the daily energy requirements for milk and maintenance during

317   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

343   supplementation, and demonstrates that the greater lactation energy demands of the

344   NA strain are not satisfied by a predominantly pasture diet. Furthermore, the same

345   study noted that despite their lower milk production, NZ cows spend a greater

346   proportion of time grazing than NA cows and tend to increase grazing time when feed

347   allowance is reduced, suggesting that the NZ strain may be more adapted to a grazing

348   scenario (McCarthy et al., 2007b). The BCS profiles observed in the current study

349   and similar strain comparisons (McCarthy et al., 2007a; Roche et al., 2006) indicate

350   that the inability of the NA strain to meet energy demands from pasture persists

351   through lactation. In contrast, the NZ strain is capable of ingesting sufficient energy

352   for milk production and body tissue accretion from mid-lactation in a pasture-based

353   system.

354

355   The SCM yield of the NA cows was greater than NZ cows from

356   approximately wk 20 until the end of lactation, coincident with the divergence of the

357   BCS profiles of the strains. Similarly, Horan et al. (2006) observed that NA cows had

358   a greater milk yield response to additional concentrate supplementation than NZ

359   cows. Energy partitioning results in the current study were not confounded by

360   pregnancy status as breeding was delayed due to a concurrent embryo collection

361   study which prevented cows from becoming pregnant during the duration of the

362   study. The divergence in the milk production and BCS profiles of the strains therefore

363   indicates that the NA cows maintain preferential partitioning of nutrients to the

364   mammary gland for a longer duration than NZ cows.

365

366   While it is well established that nutrient partitioning changes with stage of

367   lactation (Kirkland and Gordon, 2001), the temporal change in the magnitude of

368   differences between the strains is an interesting feature of the present study. Genetic

369   selection for increased milk yield has been associated with the shifting of

370   homeorhetic controls, such that milk production is maximised from ingested nutrients

371   and available body tissue reserves, particularly during early lactation (Bauman, 2000).

372   However, the NA and NZ strains had a comparable degree of NEB and a similar

373   propensity for body tissue mobilization during early lactation; differences in nutrient

374   partitioning did not become manifest until after the time of peak milk energy demand.

375   This implies that strain differences exist in the timescale of homeorhetic adaptations

376   during lactation, with the NZ strain affording a greater metabolic priority to

377   replenishment of body reserves at an earlier stage of lactation than the NA strain.

378

379   The NA cows had increased plasma insulin concentrations during the

380   transition period, despite the similar calculated EB of the strains at this time.

381   Differences in plasma insulin concentration, though statistically significant, were

382   modest. In contrast, others have reported lower plasma insulin concentration for cows

383   of higher genetic merit for milk yield (Gutierrez et al., 2006). The increased plasma

384   glucose concentration for the NA cows was consistent with the observed differences

385   in insulin concentrations.

386

387   The temporal patterns of plasma IGF-I concentration observed were similar to

388   previous reports, with a decline at parturition and a gradual increase thereafter

389   (McGuire et al., 1995). While the strains had similar plasma IGF-I profiles during the

390   transition period, plasma IGF-I was higher for NZ cows from approximately d 30 of

391   lactation. This occurred despite the similar EB profiles between the strains, and the

392   higher plasma insulin concentrations in the NA cows.

393

394   Expression of the IGF-I gene in the liver is acutely responsive to nutritional

395   status. The decline in IGF-I concentration at parturition is due to reduced expression

396   of growth hormone receptor 1A (GHR-1A) and IGF-I mRNAs, coincident with a

397   period of liver refractoriness to growth hormone (Radcliff et al., 2003). A several-fold

398   increase in insulin has been shown to stimulate hepatic expression of GHR-1A and

399   IGF-I mRNA (Butler et al., 2003; Rhoads et al., 2004). The higher insulin

400   concentration for NA cows during the transition period in the current study may have

401   been insufficient to elicit a detectable increase in plasma IGF-I concentration. Indeed,

402   Radcliff et al (2006) showed that restricting DMI in early lactation decreased the rate

403   of *post partum* increase in liver GHR mRNA and tended to reduce plasma IGF-I

404   concentration, but had no effect on liver IGF-I mRNA. This indicates that post-

405   transcriptional and/or post-translational mechanisms may also exert control on *post*

406   *partum* IGF-I concentrations. Plasma IGF-I was higher for NZ cows from

407   approximately day 30-100 of lactation, despite the similar EB profiles and lower

408   circulating insulin concentrations compared to NA cows. Crooker et al. (2001)

409   likewise showed that although *post partum* EB did not differ between cows of high

410   and low genetic merit, plasma IGF-I was lower for the high genetic merit cows.

411   Genetic selection for milk yield may therefore affect the somatotropic axis during

412   early lactation independent of energy balance.

413

414   Gross energy efficiency may be defined as energy in the milk produced

415   divided by the total energy intake (Brody, 1945). Gross efficiency is greater if

416   calculated when cows are mobilizing body tissue in support of milk production,

417   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)

625   [1]NA = North American Holstein Friesian; NZ = New Zealand Holstein Friesian

626   [2]All predicted differences obtained from the February 2004 international evaluations of the

627   INTERBULL Animal Centre (Uppsala, Sweden).

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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 $\pm$ 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)

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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

658   **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

659   [1] Geometric Means (95% Confidence interval in parentheses)

660   [2] NA = North American Holstein Friesian; NZ = New Zealand Holstein Friesian

661   [3] Ratio of geometric means (95% Confidence interval in parentheses)

662   [4] Transition = d 15 *pre partum* to d 28 *post partum*; Post transition = d 29 to 100 *post partum*

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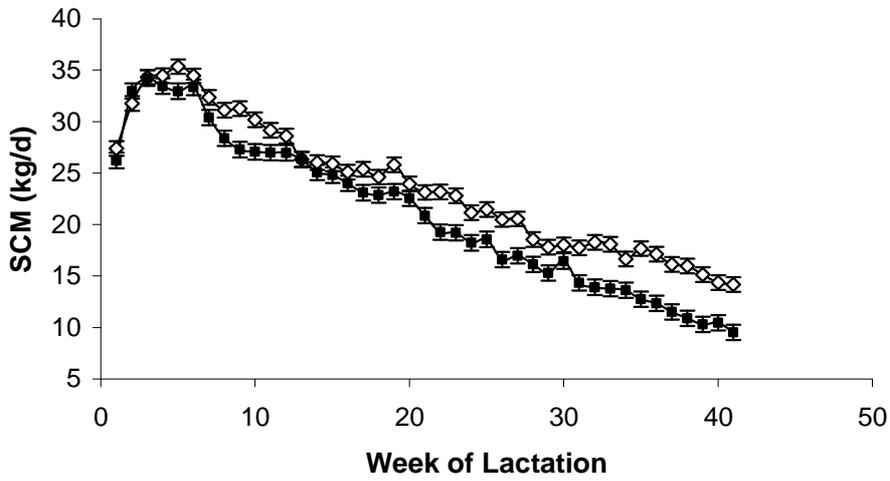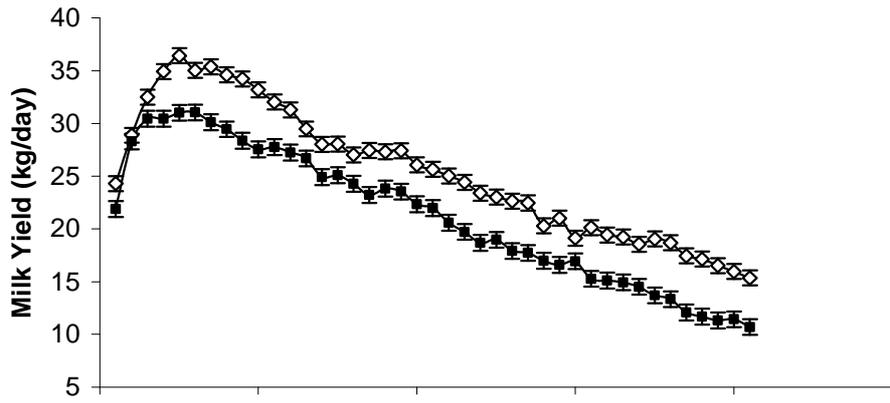
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673   Figure 1.

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.

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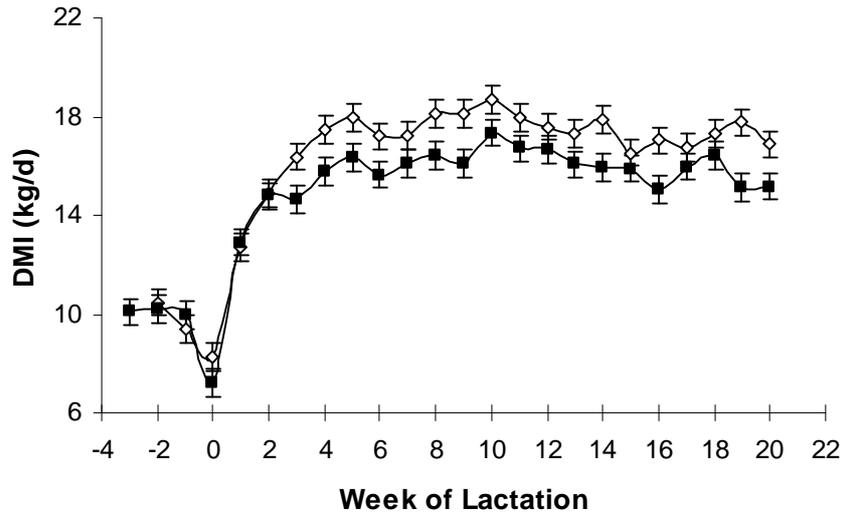
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698   Figure 2.

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.
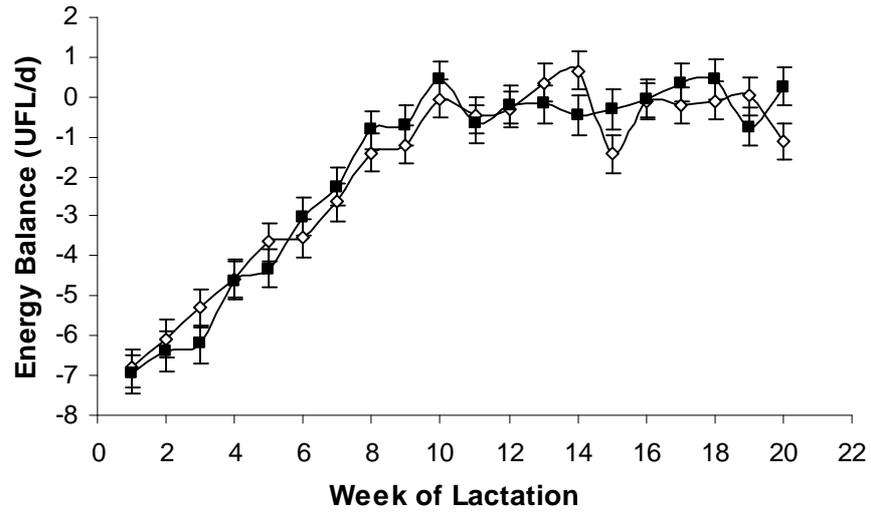
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719   Figure 3.

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.

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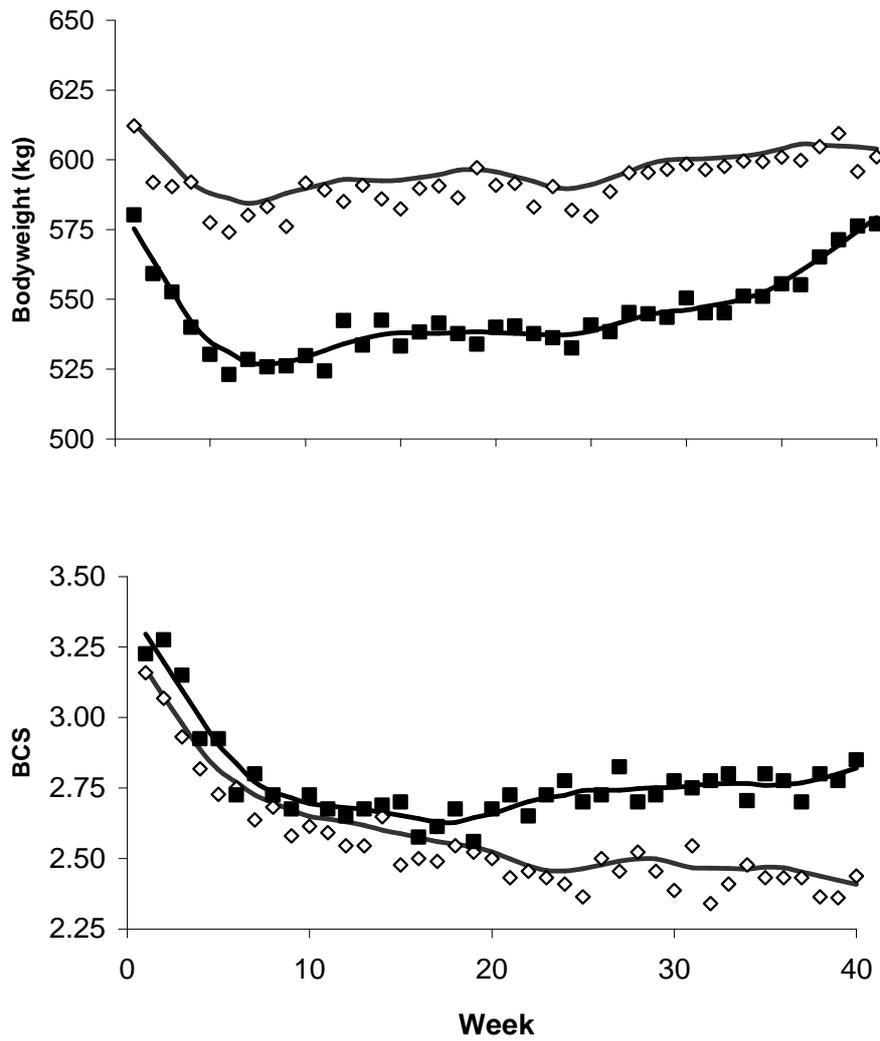
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734   Figure 4.

735   **Figure 4.** Effect of strain of Holstein-Friesian on body condition score (BCS) and bodyweight ($\lozenge$ =

736   North American Holstein Friesian; ■ = New Zealand Holstein Friesian). The P values for the effects of

737   strain, week and interaction between strain and week on weekly BCS were 0.16, <0.001 and 0.009,

738   respectively. The s.e.d. was 0.08 BCS units. The P values for the effects of strain, week and interaction

739   between strain and week on weekly bodyweight were 0.02, <0.001 and 0.57, respectively. The s.e.d.

740   was 15.5 kg. Figures are presented with LOESS-smoothed lines for illustrative purposes.
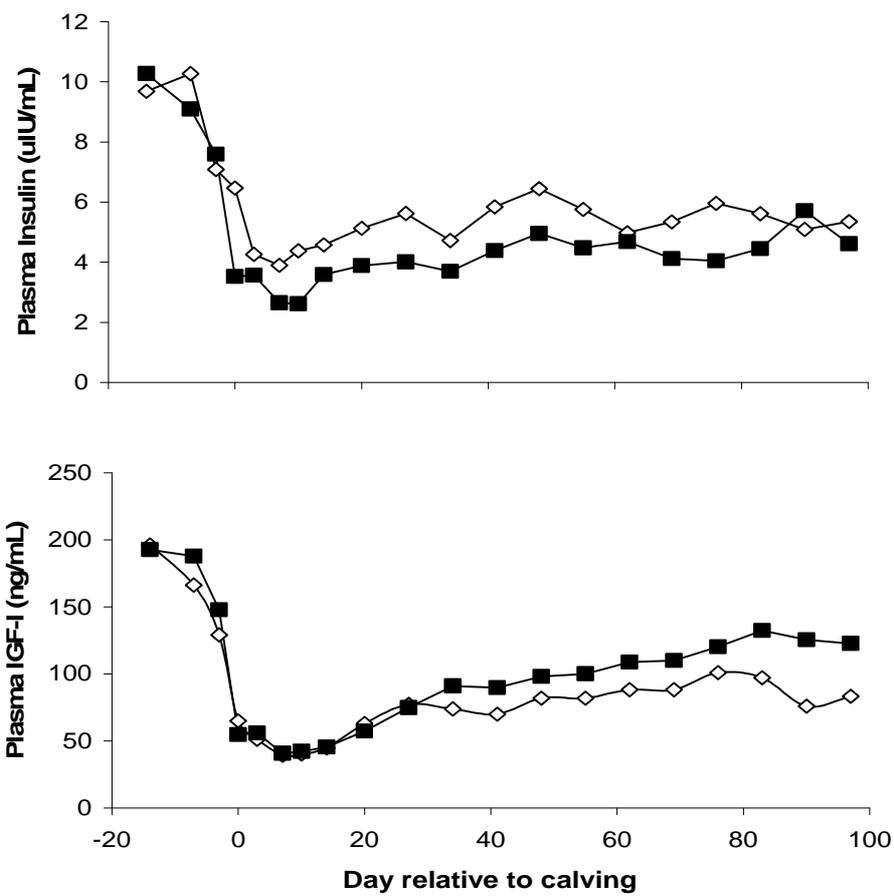
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752   Figure 5.

753 **Figure 5.** Effect of strain of Holstein-Friesian on plasma insulin and IGF-I concentrations (◊ = North

754 American Holstein Friesian; ■ = New Zealand Holstein Friesian). The P-values for the effect of strain

755 on insulin concentration were 0.01 and 0.06 for the transition period (2 wk *pre partum* to d 28 *post*

756 *partum*) and post transition period (d 29 to d 100 *post partum*), respectively. The P-values for the effect

757 of strain on IGF-I concentration were 0.71 and 0.04 for the transition and post-transition periods,

758 respectively. There were no significant strain-by-time interactions observed for either insulin or IGF-I

759 across the entire experimental period (P > 0.05).

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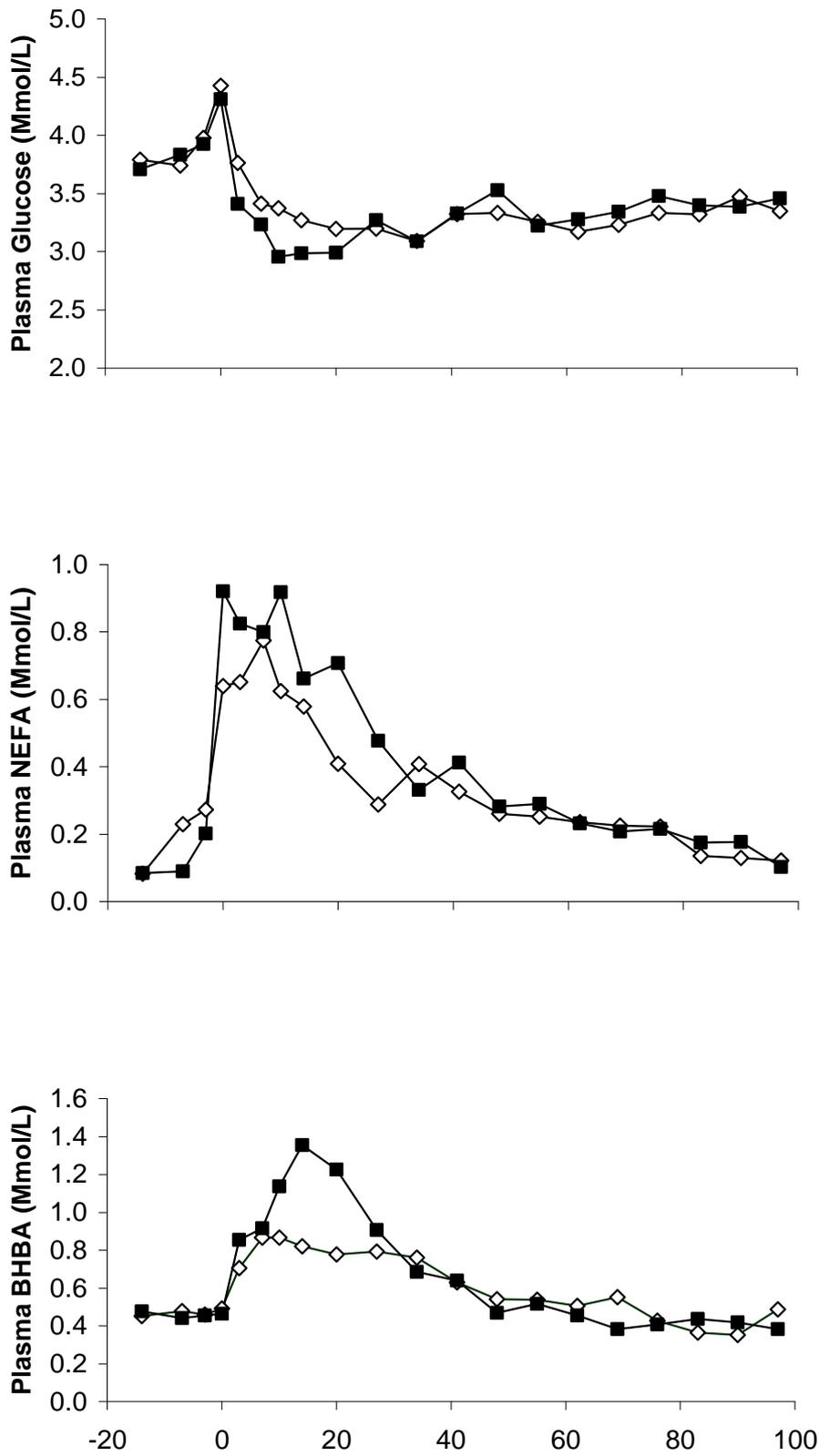
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762   Figure 6.

763   **Figure 6.** Effect of strain of Holstein-Friesian on plasma glucose, non-esterified fatty acid (NEFA) and

764   beta-hydroxybutyrate concentrations (◊ = North American Holstein Friesian; ■ = New Zealand

765   Holstein Friesian). The P-values for the effect of strain on glucose concentration were 0.01 and 0.21 for

766   the transition period (2 wk *pre partum* to d 28 *post partum*) and post transition period (d 29 to d 100

767   *post partum*), respectively. The P-values for the effect of strain on NEFA concentration were 0.29 and

768   0.99 for the transition and post-transition periods, respectively. The P-values for the effect of strain on

769   BHBA concentration were 0.02 and 0.45 for the transition and post-transition periods, respectively.

770   There were no significant strain-by-time interactions observed for glucose, NEFA or BHBA

771   concentrations across the entire experimental period ($P > 0.05$).