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A STUDY OF PHYSIOLOGICAL DIFFERENCES BETWEEN
LOW AND HIGH BREEDING INDEX
FRIESIAN HEIFERS

A thesis presented in partial fulfilment of
the requirements for the Degree of Doctor
of Philosophy in Animal Science
at Massey University

GUO-QIANG XING

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ABSTRACT

Friesian heifers from two genetic lines divergently selected for milk production were compared in their metabolic physiology and endocrinology in three experiments. Studies were conducted on the heifers, which were matched for age and bodyweight, in order to identify metabolic differences which might be used as genetic markers for lactational performance.

In the first experiment diurnal variation in plasma metabolite and hormone concentrations and responses to metabolic challenges of glucose, insulin, glucagon, and adrenaline, were measured in 6 high breeding index (HBI) and 6 low breeding index (LBI) heifers aged 6 to 8 months and fed 75% or 125% maintenance energy requirement (MER).

Basal plasma concentrations of creatinine, GH and NEFA were not influenced by selection line. Plasma insulin concentrations after feeding were greater in the LBI than in the HBI heifers. Relative to the concentrations which existed at the time of feeding, the elevation in plasma glucose concentration was greater in the HBI than in the LBI heifers from 7 to 9 hours after feeding. Elevation in plasma urea concentration on feeding was greater in HBI than in LBI heifers. Urea concentrations then declined more rapidly in the selected animals during the postprandial period such that concentrations were lower in HBI than in LBI heifers from 11 till 23 hours after feeding. Responses to metabolic challenge were generally not different between the lines and there were no line x allowance interactions except in the NEFA response to adrenaline where HBI heifers responded more than LBI heifers at 75% MER but not at 125% MER.

When compared with heifers fed 125% MER, those fed 75% MER exhibited: increased plasma creatinine concentrations; a smaller increment in plasma urea concentration after feeding; greater plasma NEFA levels in the post-prandial period; lower insulin concentrations during a 24 hour sampling period; decreased insulin release and glucose removal after glucose administration; greater plasma NEFA concentrations and reduced glucose clearance after insulin injection; enhanced glycogenolytic responses to glucagon and adrenaline;
and increased lipolytic responses to glucagon and adrenaline.

In the second experiment, 8 HBI and 8 LBI Friesian heifers aged 6 months were treated with progesterone by Controlled Internal Drug Release (CIDR) devices and fed 70% MER. Initially, basal plasma metabolite and hormone concentrations were measured in samples collected during a 6 hour intensive sampling period. In the following period, the line x dose interactions of intravenous glucose (0, 75, 150 and 300 mg/kg lw) and insulin (0, 0.1, 1, and 10 ug/kg lw) on metabolic responses were evaluated in a split-plot design carried out over a period of 8 days.

Basal plasma urea and creatinine concentrations were marginally greater (P<0.10) in the LBI heifers than in the HBI heifers but no differences were found between the two lines in plasma concentrations of GH, insulin, glucagon, glucose or NEFA. No significant line differences were found in the number of secretion spikes or the magnitude of the spikes for basal GH or insulin. Glucagon concentrations were measured using a specific double antibody radioimmunoassay developed as part of this programme.

There were marked dose effects of both glucose and insulin challenges on concentrations of insulin, glucose and NEFA. In addition, the HBI heifers released more insulin than the LBI heifers after the glucose challenge in a manner independent of glucose dose. Moreover, volume of plasma glucose distribution (Vd), or the distribution coefficient (\(\Delta\)) was smaller, and glucose disappearance rate greater (in terms of elimination rate constant (k) or the half-life (\(t_{1/2}\)) of the injected glucose), in the HBI than in the LBI heifers.

Insulin challenge resulted in slightly higher plasma insulin concentrations in the HBI heifers than in the LBI heifers. No significant interactions of line x dose in plasma metabolites and hormone concentrations were observed after either glucose or insulin challenges.
The third experiment compared 8 HBI and 8 LBI yearling heifers, fed 140% MER and receiving progesterone treatment, with respect to: diurnal patterns of plasma concentrations of metabolites and hormones; volume of body fluid distribution; ingestive behaviour in terms of rate of eating; responses of lipolysis and glycogenolysis to adrenaline challenge at various times after feeding and fasting; metabolic responses to fasting and refeeding; and pancreatic insulin release and glucose disappearance after glucose challenges administered before and after the withdrawal of progesterone-impregnated CIDRs.

Diurnal plasma concentrations of glucose, were greater, but plasma urea and creatinine levels were lower, in HBI than in LBI heifers. Plasma glucagon levels at the onset of feeding/refeeding were only briefly greater in HBI heifers than in LBI heifers. The volumes of urea distribution, plasma distribution (as measured by Evans blue (T1824) distribution), and the extracellular fluid distribution (as measured by thiocyanate (NaSCN) distribution) were similar between the HBI and LBI heifers. In general, rate of eating was similar between the lines over the experiments except it was greater in the LBI than in the HBI heifers on the first day of measurement. In addition, the eating rate fell substantially in the LBI but not in HBI heifers 28 hours after the withdrawal of progesterone-CIDRs.

Lipolytic response to adrenaline was minimal 7 hours after feeding, and maximal after 72 hours of fasting, whereas the reverse was true for glycogenolytic responses. There were significant line x time of challenge interactions in pre-challenge plasma NEFA concentrations, HBI heifers fasted for 72 hours exhibiting greater elevation in plasma NEFA concentration. Time of challenge relative to feeding/fasting did not, however, influence the magnitude of selection line effects on lipolytic or glycogenolytic responses.

Basal plasma insulin concentration and pancreatic insulin release after glucose challenges were greater in HBI than the LBI heifers, irrespective of the presence or absence of progesterone-impregnated CIDRs. Although basal plasma glucose concentration was greater in the HBI than in the LBI heifers, glucose disappearance was similar between
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These results demonstrated that genetic variation exists in nitrogen, lipid, glucose and insulin metabolism between the HBI and the LBI heifers. Appropriate experimental conditions such as different feeding regimens, use of metabolic challenges and control of oestrous activity, alone or in combination, were useful means of maximising these genetic differences. While these metabolic characteristics have the potential to become markers for dairy merit, their genetic relationships with milk production should be confirmed in further studies and these traits should also be evaluated in progeny tested bulls before their wide use in dairy cattle breeding.
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AI  Artificial insemination  
A_{kp}  Alkaline phosphatase  
AMI  Amylases  
ANOVA  analyses of variance  
BHBA  β-hydroxybutyrate  
C_0  Concentration at time=0 (after challenge)  
CCK  Cholecystokinin  
CIDR  Progesterone-impregnated controlled internal drug releaser  
CNS  Central nervous system  
cpm  Counts per minute  
C.V.  Coefficient of variation  
DM  Dry matter  
DNAFP  DNA Finger Print  
GH  Growth hormone  
GHRH  Growth hormone releasing hormone  
GIP  Gastric inhibitory peptide  
GnRH  Gonadotrophin releasing hormone  
GPY  Guinea pig gamma globulin  
h^2  Heritability  
IGF(s)  Insulin-like growth factor(s)  
HBI  High breeding index  
k  Fractional removal rate of injected metabolite  
LH  Luteinizing hormone  
LBI  Low breeding index  
LWT  Live weight  
MANOVA  Repeated-measures analyses (multivariate analyses of variance)  
MER  Maintenance energy requirement  
MHC  Major histocompatibility complex  
MJ  Megajoules  
NaSCN  Sodium thiocyanate  
NEFA  Non-esterified fatty acids  
ng  Nanogram  
PCV  Packed (red) cell volume  
PL  Placental lactogen  
Prl  Prolactin  
Pg  Picogram  
r  Repeatability  
RFLP  Restriction fragment length polymorphism  
r_g  Genetic correlation  
RIA  Radioimmunoassay  
S.D.  Standard deviation  
S.E.  Standard error of the mean  
SGOT  Serum glutamic oxaloacetic transaminas  
t_{1/2}  Half-life  
T1824  Evans blue dye  
T_3  Triiodothyronine  
T_4  Thyroxine  
Tf  Transferrin  
TRH  Thyrotropin-releasing hormone  
Hg  Microgram  
Vd  Volume of fluid distribution  
VIP  Vasoinhibitory peptide  
VMH  Ventromedial hypothalamus  
\( \Delta \)  Fluid distribution coefficient
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<td>Significance of selection line, dose of glucose injected and line x dose effects on parameters describing glucose disappearance curves from the plasma following glucose injections of 0, 75, 150 and 300mg/kg lw t in 8 HBI and 8 LBI heifers</td>
</tr>
<tr>
<td>Table 4.4</td>
<td>Means and standard errors for various insulin parameters describing the insulin disappearance curves after insulin injection of 1 μg/kg lw t in 8 HBI and 8 LBI heifers</td>
</tr>
<tr>
<td>Table 5.1</td>
<td>Kinetics of distribution and disappearance of urea, T1824 and NaSCN in 8 HBI and 8 LBI heifers following injections of urea (60 mg/kg lw t), T1824 (1 mg/kg lw t), and NaSCN (20 mg/kg lw t)</td>
</tr>
<tr>
<td>Table 5.2</td>
<td>Glucose kinetics measured at 2 hours before and 46 hours after CIDR withdrawal in HBI and LBI heifers that received glucose challenges (150 mg/kg lw t)</td>
</tr>
</tbody>
</table>