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

1989

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;

andincreased 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 lwt) and insulin (0, 0.1, 1, and 10 ug/kg lwt) 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 (Δ) 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

the two lines following glucose challenge in this experiment. There was a significant line x progesterone presence/withdrawal interaction in the pre-challenge plasma glucose concentrations. Plasma glucose concentrations were greater in the HBI than in the LBI heifers 46 hours after the removal of progesterone CIDRs but not prior to removal of the CIDRs.

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.

ACKNOWLEDGEMENTS

I want to express my sincere gratitude to my supervisors, Dr. Duncan D.S. Mackenzie and Dr. Stuart N. McCutcheon, for their enthusiasm, critical guidance, wise counsel and stimulation throughout this study. Their contribution to this project has been immeasurable. To me this has been an invaluable educational experience through which I have had the opportunity to share their broad knowledge and scientific philosophy.

I want to give my special thanks to Professor R.D. Anderson without whose permission, and assistance with Departmental facilities, my pursuit of this study would not have been possible.

I gratefully acknowledge the assistance given to me by the following:-

Mrs. Janice. A. Rumbal, Miss Margaret F. Scott, Miss Yvette H. Cottam and Mr. W. Barry Parlane for their excellent technical assistance. Miss Margaret F. Scott also proof-read several chapters of this thesis.

The staff of the Dairy Cattle Research Unit, Massey University, for willing assistance in management of the heifers.

My fellow postgraduate students in the Animal Science Department: Mark Carter, Carolyn Clark, Maria Dattena, Jose Solis-Ferreya, Sabine Muller, Coby Hoogendoorn, Tessa Matthew, Anne McClelland, Seok-Hong Min, Peter Morgan, Sam Peterson, Christine Roberts, Bruce Southey, Beverley Thompson, Sean Beer, Peter Walsh, Zhenzhong Xu, and visiting fellows Gao Hu, Carla Kroonsberg, Andries Mesken, Leon Pijls, Machteld Van Maanen and Peter Van Dinther for helping in blood sampling and conducting challenges during various stages of this study. Raymundo Rangel for his assistance in administration of the progesterone-CIDRs to the heifers.

Dr. K. M. Moriarty for advice on raising glucagon antisera, and the staff of the Small Animal Production Unit, especially Mr. J.E. Ormsby, for assistance in immunizing the guinea pigs.

Dr R. M. Greenway and Ms G.M. Borrie for urea and creatinine assays.

The staff of Massey library for excellent service.

The staff at the Computer Center, Massey University, for excellent service and assistance, especially Dr.Hugo Varela-Alvarez and Dr. Ted Drawneek for valuable advice on fitting non-linear models.

Dr. Ian L. Gordon and Dr. Dorian Garrick for valuable advice on statistical analysis of the data.

My fellow postgraduate students and the members of the Animal Science Department for moral support and providing a friendly academic atmosphere.

My fellow overseas students at the Massey campus, both from China and other parts of the world, for their moral support and friendship.

The growth hormone used in GH RIA was kindly supplied by Dr. S. Raiti, National Hormone and Pituitary Program, NIDDKD, NIH, USA.

Professor George Shouksmith, Dr. John Zhan-Peong Liang and Mr. Tony True for the arrangement of part-time work in the Department of Psychology, which provided my principal support for the first three years of this study.

Financial assistance, in part, from the following sources is gratefully acknowledged:

The Helen E. Akers Postgraduate Scholarship (1986/87) and a Graduate Scholarship from the Faculty of Agricultural and Horticultural Sciences; Massey University Scholarship (1988); and a scholarship from the Livestock Improvement Corporation of the New Zealand Dairy

Board (1989).

The New Zealand Dairy Board is gratefully acknowledged for its financial support of this project.

Finally, my parents, my brothers and sister for their love, encouragement, and support.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

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
GP_γ	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 histocompatability 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 transamines
$t_{1/2}$	Half-life
T1824	Evans blue dye
T_3	Triiodothyronine
T_4	Thyroxine
Tf	Transferrin
TRH	Thyrotropin-releasing hormone
µg	Microgram
Vd	Volume of fluid distribution
VIP	Vasoinhibitory peptide.
VMH	Ventromedial hypothalamus
Δ	Fluid distribution coefficient

LIST OF FIGURES

LIST OF TABLES