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A STUDY OF THE INTERACTIONS BETWEEN HOLSTEIN-FRIESIAN GENOTYPES AND FEEDING SYSTEMS, WITH EMPHASIS ON SYSTEM PERFORMANCE AND COW GRAZING ABILITY

A thesis presented in partial fulfilment
of the requirements for the degree of:

Doctor of Philosophy
in Animal Science

Institute of Veterinary, Animal and Biomedical Sciences

Massey University, Palmerston North,

New Zealand

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2006

Dedicated to Sonia, Martín and Dominique

ABSTRACT

Rossi, J.L. 2006. *A study of the interactions between Holstein – Friesian genotypes and feeding systems, with emphasis on system performance and cow grazing ability.* PhD Thesis, Massey University, Palmerston North, New Zealand.

Imported genetic material of the Holstein-Friesian breed from overseas (OS), mainly from North America, has been used in New Zealand (NZ) since the late 1960's. This has diluted the genetic base of the former NZ Friesian genotype selected under intensive seasonal pasture-based systems. As a result, increased concerns have been raised about the negative influence of these overseas genes on the modern NZ Holstein-Friesian, as it is apparent that the OS Holstein-Friesian has a lower capacity to perform on grazed pasture. The objective of the present thesis was to investigate differences in production performance between three Holstein-Friesian genotypes farmed at different feed allowances (FA) on pasture-based systems; in addition, to investigate differences in the grazing process between strains under contrasting managements and sward conditions, and so to identify animal and pasture factors that affect the herbage intake (DMI_H) and performance of the grazing cow. An accurate procedure was also established to estimate DMI_H for cows fed forage and maize supplements, grazing in groups. Two modern high breeding worth (BW) Holstein-Friesian strains from NZ (NZ90) or overseas (OS90) origin and a low BW 1970's NZ Friesian genotype (NZ70) were farmed in two field experiments: (1) a long-term 'system' study that compared the yield performance of these genotypes in a range of systems with different feed allowance (FA) per cow, and a (2) a short-term 'component' study that compared the grazing capacity of the strains under contrasting sward conditions but at a common daily herbage allowance. The differences in productive performance between genotypes increased as the study progressed in the system study, with the largest observed in the last season. The mean milksolids (MS) yield per cow and per hectare were higher in NZ90 (395 kg cow^{-1} and 1,236 kg ha^{-1}) than in the NZ70 (336 kg cow^{-1} and 1,093 kg ha^{-1}) and the OS90 (377 kg cow^{-1} and 1,154 kg ha^{-1}). The higher production of NZ90 cows was supported by their higher mean daily MS yield than the NZ70 (1.45 vs. 1.21 kg MS $cow^{-1}day^{-1}$) and more days in milk than OS90 cows (271 vs. 257 DIM). The lower lactation length of the OS90 strain occurred due to its lower body condition score (BCS) in late lactation, which determined an early dry-off for these cows. The lowest BCS of OS90 at the nadir (irrespective of FA), during lactation and at dry-off indicate these cows mobilised greater amount of body reserves and partitioned most of the energy ingested to yield. Genotype by FA interactions for milk and lactose yields, protein content in the milk and BCS were observed in the second and third seasons of the 'system' study. Milk yield increased as FA increased to a greater extent in OS90 than in the two NZ strains, whereas the content of solids in milk, particularly protein, increased to a greater extent for NZ90 than in both OS90 and NZ70. During lactation DMI_H was higher for NZ90, intermediate in OS90 and lower in NZ70 (14.5, 13.9 and 12.6 kg DM $cow^{-1}day^{-1}$ respectively for NZ90, OS90 and NZ70, as measured with n–alkanes), and declined as lactation progressed, with a smaller difference for the total intake achieved (15.5, 15.2 and 13.1 kg DM $cow^{-1}day^{-1}$ respectively) due to the increased supplement consumption. These results indicate that the OS90 needs more feed with a higher proportion of supplement in the diet to improve productive performance on pasture-based systems; the NZ90 would perform better when cow nutrition is mainly supported by grazing pasture, although further increments in performance could be expected from strategic supplementation, but requiring more feed than NZ70. The DMI_H per unit of live weight (DMI_H/LW) was highest in NZ90 strain in both the 'system' and in the short sward of the 'component' study (31.5 and 31.1 g DM kg^{-1}DM in NZ90 *vs.* 28.9 and 28.6 g DM kg^{-1}DM for OS90 in 'system' and 'component' studies respectively). The higher intake of NZ90 on pasture was sustained by a higher capacity to graze short swards than NZ70 and OS90, and to deal with the herbage of higher bulk density and lower quality present at the base of taller swards. The NZ90 can maintain DMI_H in swards with different structures, indicating higher flexibility to perform under different managements and sward conditions. The size of the jaw is smaller in NZ90 than OS90 (88.4 vs. 92.4 mm) with effects on bite area and bite size, and this flexibility to adapt the size of the bite to swards of different structure may improve bite penetration under constraining sward conditions. The reduced ability of the OS90 to adjust ingestive behaviour to different swards would limit the capacity of this strain to perform on pasture. The fact that OS90 cows increased DMI_H and DMI_H/LW substantially in a leafy and taller sward (up to 21.6 kg cow^{-1} and 40.8 g DM kg^{-1}LW *vs.* 19.2 kg cow^{-1} and 41.0 g DM kg^{-1}LW in NZ90 during early lactation) suggests that yield performance can be improved in these cows even on pasture, by fine-tuning pasture management.

Keywords: Pasture-based dairy systems, Holstein-Friesian, genotype environment interactions, grazing ability, grazing behaviour, pasture management.

ACKNOWLEDGEMENTS

I came to New Zealand for a PhD in Animal Science thanks to the generous support from the New Zealand Government's aid and development agency (NZAID); in addition, to the support received from my home university, Faculty of Agronomy, University of Buenos Aires.

I considered myself fortunate due to the opportunity I had of being a Massey University student working at Dexcel, a unique experience and a great possibility to learn for a foreign student interested in New Zealand dairy industry. I am particularly grateful to Colin Holmes, my chief supervisor, for giving me the opportunity to get involved in the 'Strain Trial' and to study under his supervision. I largely thank him for his support, encouragement and patience during this time. His fast replies and annotated drafts returns helped me to focus on the main results from my work.

I was also fortunate to have John Hodgson and Cory Matthew as co-supervisors, as their precise advice was also fundamental. I appreciated every time they visited me in Hamilton and their involvement in the 'component' trial; the opportunity to discuss with John some aspects of the pasture-animal interface, his very much valued suggestions, comments and help during the writing up of my thesis. It is clear to me today that if I had paid more attention to my supervisor's suggestions from the start, life would have been easier for me as a student in New Zealand.

By the time I arrived at Hamilton in late March 2002 the 'Strain Trial' had already started at the old Dexcel No 2 dairy. Although I was involved in the trial since my arrival, it took me time to settle. Soon after arrival John Milburn was appointed farm manager and this made my time at the 'No 2' a lot easier. John is not only an excellent manager, he became a good friend and I really enjoyed sharing time with him and the rest of the staff at the farm. Hopefully they also found enjoyable having me around, requiring their frequent help.

I acknowledge and appreciate Bruce Thorrold, Kevin Macdonald and Eric Kolver contributions as my Dexcel's co-supervisors. Bruce and Kevin introduced me to the daily management of the trial and got me involved in the weekly planning, supported by the 'religious' Monday farm walks and calibration cuts that we shared also with John Milburn and Chris Glassey. I learned a lot from these Monday's meetings and I appreciate enormously being part of such a team. I thank particularly Kevin Macdonald, support and numerous contributions to my work, for teaching me practical aspects of farm management during the hours we spent at the farm, for his entertaining talks and stories, and for sharing his friendship with me and my family.

Apart from the samples collected from each cow and paddock in the experiment, the additional data measured from the pastures, the repeated observations of grazing behaviour, and some hours at the laboratory, the understanding of the methodologies used to obtain accurate intake estimates from our data kept me awake for long hours. The help provided by Deanne Waugh, Glenise Ferguson and Jim Lancaster preparing samples or in the field, and Steve Edwards and Keryn Rollerson at the laboratory was huge. Jim Lancaster was also responsible for the vast recording of trial's data.

After the 'Strain Trial' was finished, I moved to AgResearch, Ruakura, where I was responsible for a 'component' trial at the No 1 dairy during the spring of 2004. As usual, Kevin Macdonald's help and support were invaluable; in addition, the support provided by Barbara Dow for the statistical data analysis from the two field experiments was acknowledged and appreciated.

Jenny Jago, Errol Thom, Garry Waghorn, John Roche and others within Dexcel provided me with useful suggestions. Also external people gave me very valuable advice or help, like Hugh Dove with the n–alkane procedure, Yani Garcia for his comments on the use of the $\delta^{13}C$ method or Bill Wales with the use of a set of grazing recorders (actually he lent me the instruments, which were used repeatedly in the 'Strain Trial'), Gerald Cosgrove who lent me additional recorders for the 'component' trial. Also my son Martín helped me with the management of the cows at Ruakura during most weekends. Therefore, without all these efforts, this thesis would not be finished yet. I hope that the information provided here will help others to move forward with the understanding and design of improved intensive pasture-based systems and the identification of the best cows to suit them.

Thanks to Ruth Hodgson, Dorothy Holmes and Robyn Macdonald for their kindness and friendship, which were very much appreciated and will be always remembered. To the Russ, Beacon, Dodd, and Peresson families for being part of our lives while living in New Zealand; to Pierre Beukes a very good friend and tennis player who I have the pleasure to have beaten several times on the tennis court (obviously the only few I will remember), also to Jim Lancaster and Garry Waghorn for their daily jokes, easy smile and late talks, I will not easily forget; and to a large number of nice people I have the great fortune to met.

As the main reason to come to study to New Zealand was motivated by my interest in pasture-based dairy systems, I came to learn as much as I could, committed to succeed in my doctoral ambition. My family left behind work, school and friends to follow me on my personal quest to fulfil my wish. We all succeeded despite the time it took to make new friends, to understand the 'foreign' jokes, to speak the English language and to love

the place and accept the differences. However, this would not have been possible without the support of the friend we made; hopefully I am not leaving anybody without acknowledging. Thinking back to the great time we spent in New Zealand and remembering the good things that happened to us during this time, we feel as never have left, like a part of our souls is still here.

Finally my greatest thanks should go to my family, as without their support my PhD would never have been completed. And although my wife Sonia and Martín helped me at the farm, my daughter Dominique was sure to bake banana cakes for me at home, so it was their ongoing and unconditional love and support which allowed me to overcame times when it would have been easier to give things up. This PhD belongs to all of us, as we all gained it by sharing any minute on the road together. This New Zealand 'experience' has undoubtedly made us wiser and will affect our lives forever.

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LIST OF TERMINOLOGY AND ABBREVIATIONS

Abbreviations

ADF	acid detergent fibre
AFRC	Agricultural and Food Research Council
am	ante meridian
B	bite
BCS	body condition score
B_D	bulk density
BR	bite rate
BV	breeding value
BW	breeding worth
BZ	bite size
$C_{27}...C_{35}$	odd natural *alkanes*, different carbon chain
C^3	winter grasses, C^3 photosynthetic pathway
C_{32}	dosed of pellets with C_{32}–*alkanes*
C^4	summer grasses, C^4 photosynthetic pathway
CIDR®	controlled internal drug-releasing device
C_O	concentrate feed
CP	crude protein
Cr_2O_3	chromic oxide
CRC	contolled release capsule
CSR	comparative stocking rate
DH	herbage in-vitro digestibility
DHA	daily herbage allowance
DHA/LW	daily herbage allowance per LW unit
DIM	days in milk
DM	dry matter
DMD	dry matter digestibility
DMI	daily dry matter intake
DMI_H	daily herbage DMI
DMI_H/LW	daily herbage DMI per LW unit
DMI_{MZ}	daily maize silage or maize grain DMI
DMI_{PS}	daily pasture silage DMI
DMI_S	daily supplement DMI
DMI_T	daily total DMI
DMI_T/LW	daily total dry matter intake per LW unit
DMI_V	daily dry matter intake visual
D_Oj	dosed n-alkane j
DS	supplement in-vitro digestibility
DTA	daily total allowance
E	eating supplement
e	error term
En_{BAL}	energy balance
En_M	energy required for maintenance
En_O	energy in milk
E_T	eating time
F	faeces
FA	feed allowance
FA1...4	feed allowance level from 1 (lowest) to 4 (highest)
FC	milk fat concentration
F*i...ii...j*	*i...ii...j-alkanes* concentration in faeces
FO	faecal output
FO_H	herbage faecal output
FO_S	supplement faecal output
FO_T	total faecal output
G	grazing
GE	genotype of Holstein-Friesian
G_E	gross energy
GLU	concentration of glucose in blood samples
G_T	grazing time
G_T/R_T	grazing to ruminating ratio
H	herbage
HAR	herbage accumulation rate
HERD	cows allocated to experimental mobs
H_F	proportion of herbage in faeces
H_I	highest feed allowance (equal to FA4)
H*i...ii...j*	*i...ii...j-alkanes* concentration in herbage
HM	herbage mass
HM_{POST}	post-grazing herbage mass
HM_{PRE}	pre-grazing herbage mass
H_R	height reduction
i..ii	content of C_{31} & C_{33} odd natural *alkanes*
IA	artificial insemination
IR	intake rate
j	content of C_{32} dosed *n-alkane*
J_Z	jaw size
k_l	efficiency of energy utilisation for milk
k_m	efficiency of energy utilisation for maintenance
LC	milk lactose concentration
LIC	Livestock Improvement Corporation
L_O	lowest feed allowance (equal to FA1)
LW	liveweight
$LW^{0.75}$	metabolic LW
LW_E	empty LW
M	measurement period
M_E	dietary metabolisable energy
ME	metabolisable energy
MJ ME	megajoule of ME
MJ	megajoule
MS	milksolids
NDF	neutral detergent fibre
NE_m	net energy maintenance
NIRS	Near Infrared Reflectance Spectroscopy
NPO	nominal pasture offered
NSO	nominal supplement offered
NTF_O	nominal total feed offered
NZ	New Zealand
NZ70	NZ Holstein-Friesian dairy cow of the 1970's
NZ90	NZ Holstein-Friesian dairy cow of the 1990's
OF	oesophageal fistulated animals
OM	organic matter
OMD	organic matter digestibility
OS	overseas
OS90	OS Holstein-Friesian dairy cow of the 1990's
P	parity
PADI	Paspalum dilatatum poir.
PC	milk protein concentration
P_E	experimental period
pm	post meridian
P_O	pasture offered
PR_{EXP}	pre-experimental period
PU	pasture utilisation
q_m	dietary ME/G_E
R	ruminating
ratio	Relation C_{31}/C_{33} in H or F
Rel H/F	ratio C_{31}/C_{33} in H to the same ratio in F
R*i...ii...j*	Recovery of *i...ii...j-alkanes* in faeces
RPM	Rising Plate Meter
RT	ruminating time
SAS	Statistical Analysis System®
SC	sward condition
SC	sward condition
S_F	proportion of supplement in faeces
SH	sward surface height
SHORT	short sward
SH_{POST}	post-grazing sward surface height
SH_{PRE}	pre-grazing sward surface height
S*i...j*	content of n-alkane in the supplement
SR	stocking rate
TALL	tall sward
TMR	total mixed ration
TS_O	total supplement offered
vs.	versus
Y	age of the cow (in years)
$\delta^{13}C$	ratio of the natural ^{12}C and ^{13}C isotopes in the herbage or feed
$\delta^{13}C_F$	ratio ^{12}C and ^{13}C in faeces
$\delta^{13}C_S$	ratio ^{12}C and ^{13}C in supplement

LIST OF SYMBOLS

Weights, volumes, measures and statistical terms

P	probability
*	significant at $P<0.05$
**	significant at $P<0.01$
***	significant at $P<0.001$
°C	degree centigrade
CORR	correlation
g	gram
kg	kilogram
km	kilometre
L	litre
m	meter
m^2	square meter
mg	milligram
n	number of observations
ha	hectare
MJ	megajoule
mm	millimetre
t	tonne
h	hour
min	minute
MIXED	mixed
PROC	procedure
r	coefficient of correlation
r^2	coefficient of determination
REG	regression
RMSE	root mean square error
SD	standard deviation
SE	standard error of the mean
SED	standard error of the difference (maximum indicated)
CV	coefficient of variation