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**USE OF GENETIC INFORMATION
ABOUT THE HERD
IN THE DESIGN AND
MANAGEMENT OF DAIRY
FARM SYSTEMS**

**A thesis presented in partial fulfilment
of the requirements for the degree of
Master of Science majoring in Animal Science
at
Massey University
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New Zealand**

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ABSTRACT

The aim of this thesis was to find ways of using the genetic information available about the cows to assist in improving the management of the herd and replacements. In particular models were developed which used Estimated Breeding Values to determine the feed demand of the cow and target liveweights for replacement heifers. The relationships between estimated breeding values (EBV) and cow performance at a range of feeding levels, and the effect of genetic merit on the partitioning of feed to milk or liveweight gain throughout the lactation, were also investigated.

At low levels of feeding, the absolute differences in milk yield between cows corresponded to the absolute differences in breeding values between cows. However, at high levels of feeding the difference in milk yields between genetic groups are greater than the difference in breeding values. This constitutes a form of genotype x environment interaction, which has important practical and economic implications for dairy farms, and for the expected value of genetic improvements.

High genetic merit (HGM) cows partitioned a significantly higher proportion of metabolisable energy intake into milk than low genetic merit (LGM) cows in early (0.68 vs 0.62), peak (0.59 vs 0.57), mid (0.58 vs 0.56) and late lactation (0.53 vs 0.51) (HGM vs LGM respectively). In early lactation, HGM cows utilised more body reserves for milk production (-0.06 vs -0.004, for HGM and LGM, respectively). In addition, HGM and LGM cows appeared to compensate for low intakes in early lactation by reducing the level of MEI partitioned to milk, which probably prevented excessive weight losses. These results with grazing cows confirm published data with cows fed on other rations.

Results from a grazing experiment, with 5 separate farmlets at 5 different stocking rates, were used to provide genetic information and performance per cow of a "calibration" herd corresponding to maximum profitability per farm (max EFS). The genetic and performance information for the calibration herd was then used to predict the performance of other cows or herds based on the difference in EBV for liveweight and milksolids. From these predicted values for liveweight and milksolids the "Genetic Feed Demand" (GFD) of the herd was calculated at max EFS. The GFD can then be used to adapt and improve the Comparative Stocking Rate (CSR) equation by replacing kg liveweight/ha with total GFD. Optimum values for the new CSR of 0.7 to 0.8 are proposed. This simple adjustment using genetic values provides a better estimate of the

feed demand of the herd. From this an appropriate number of cows for the specified feed supply can be determined

Another model was developed to use the liveweight EBV to formulate a set of liveweight targets for individual heifers of any breeds at different ages throughout the first two years of their life. Feeding regimes for the heifers were also proposed. A heifer herd management report was outlined that could be used by farmers and graziers to focus special attention on those individual heifers which were significantly lighter or heavier than their target weights for age.

In conclusion, greater use should be made of genetic information of individual cows and herds when designing and managing dairy farm systems. Genetic values can be used in a number of ways to ensure cows or heifers are fed more appropriately so they achieve levels of performance, which are closer to their pre-determined genetic potential. Genetic information should also be included in tools that are used to model the management of dairy farm systems, as this will improve the accuracy of prediction.

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LIST OF ABBREVIATIONS

Abbreviations

kg	Kilogram
DM	Dry matter
Lwt	Live weight
DIM	Days in milk
MS	Milksolids
ME	Metabolisable energy
MEI	Metabolisable energy intake
MJ	Mega joule
M_m	Metabolisable energy requirements for maintenance
M_l	Metabolisable energy requirements for lactation
M_c	Metabolisable energy requirements for pregnancy
M_g	Metabolisable energy requirements for liveweight gain
M_{g-l}	Metabolisable energy spared from liveweight lost
EP_m	Proportion of energy partitioned to maintenance
EP_l	Proportion of energy partitioned to lactation
EP_g	Proportion of energy partitioned to liveweight change
HGM	High genetic merit
MGM	Medium genetic merit
LGM	Low genetic merit
HF	Holstein-Friesian
J	Jersey
A	Ayrshire
HF/J	Holstein-Friesian/Jersey cross
J/A	Jersey/Ayrshire cross
HF/A	Holstein-Friesian/Ayrshire cross
EBV	Estimated breeding value
PTA	Predicted transmitting ability
BW	Breeding worth
LwtEBV	Liveweight estimated breeding value
GxE	Genotype by environment interaction
PROC	Procedure
SAS	Statistical Analysis System
GFD	Genetic feed demand
EFS	Economic farm surplus
CSR	Comparative stocking rate
max EFS	Maximum economic farm surplus per farm

Statistical terms

*	Significant at $P < 0.05$
**	Significant at $P < 0.01$
***	Significant at $P < 0.001$
SED	Standard error difference
NS	Not significant

Chapter 1

General Introduction and Objectives

This chapter presents a brief overview of the topics that are important in New Zealand dairy production systems and the objectives of this thesis. The system for the production of milk, the effects of stocking rate, and genetic improvement, and the method of dairy cattle genetic evaluation within New Zealand are discussed. More detailed introductions relating to each of the areas studied are given at the start of each chapter.

Introduction to New Zealand dairy systems

New Zealand's dairying system is based on a diet consisting mainly of grazed pasture, grown under temperate climatic conditions. Successful dairy systems in NZ grow large amounts of pasture and efficiently convert the pasture into milk and profit (Kolver, 2001). The system for the production of milk is distinctly seasonal, with the majority of herds calving from July to September (early spring) and herds are generally dried off from May-June (late autumn to early winter), resulting in short lactation lengths of 224-268 days (Livestock Improvement, 2001). An increasing number of herds are now using supplements such as maize silage, and feed by-products. However, these supplements (20 to 50 cents per kg DM) are more expensive than the cost of pasture (10-15 cents per kg DM).

By world standards, New Zealand cows achieve low milk yields of around 310 kg MS/cow (Zwald, *et al.*, 2001; Livestock Improvement, 2001). However, New Zealand Holstein-Friesian cows are capable of achieving yields of in excess of 600 kg MS per lactation when offered total mixed ration diets (Kolver *et al.*, 2002), and about 5% of all commercial herds average more than 400 kg MS/cow (Livestock Improvement, 2001). But, aspects of pasture availability and quality such as its bulkiness and low energy concentration, prevent the attainment of high milk yields per cow in grazing systems (Waghorn, 2002; Burke, *et al.*, 2002).

Every year approximately 20% of the herd is replaced with two year-old heifers generated from females within the herd, or sourced from other herds. The cost of rearing these dairy replacements is a significant expense within the dairy system. It is important that replacements heifers reach their target liveweights to increase the probability that they will all become pregnant at 15 months (Holmes *et al.*, 2002). Their milk yield in

first lactation is also affected by their liveweight and body condition at calving, both of which are determined by their feeding since birth (Penno, 1998)

Interactions between feed supply, and feed demand in pastoral systems

In New Zealand, the stocking rate, which is a general term to describe the number of animals per unit area of land (Penno, 1999), ultimately governs the amount of herbage available per cow on a particular farm throughout the year. Increasing the stocking rate from a low to moderate level leads to increased feed demand per hectare, and increased pasture utilisation (harvesting efficiency), however, there is usually an accompanied reduction in milk yield per cow due to lower pasture intakes per cow. This is compensated for by the greater harvesting efficiency of the pasture and higher pasture intakes/ha, ultimately leading to higher milk production per hectare and profit at higher stocking rates (White, 1987).

Very high stocking rates can result in reduced pasture growth rates, and underfeeding due to intense grazing and pugging. At very high stocking rates, dietary energy is wasted because a large proportion is used to maintain the cows (Holmes *et al.*, 2002). Therefore, the choice of stocking rate should optimise farm profitability by balancing the two major components 1) generous feeding to achieve high levels of efficiency of milk production per cow and 2) underfeeding to ensure high levels of pasture utilisation per hectare (Penno, 1999).

Genetic improvement and its effect on performance and productivity of the dairy system

The genetic improvement of dairy cows has had a significant effect on the whole dairy system. Milk production per cow has increased from 237 kgMS/cow in 1970/71 to 307 kgMS/cow in 2000/01 (Livestock Improvement, 2001), an increase of nearly 1% per year over this period. Whilst improved health, feeding and milking methods can account for some of the increases in production per cow, the effect of genetic improvement has contributed a large proportion of the increase (Holmes *et al.*, 2002). A consequence of

the increase in milk yield per cow is an increase in feed demand per cow over the same period. Increases in pasture growth, supplement use, and improved farm practices have allowed the stocking rate to increase to a small extent despite the simultaneous increases in feed demand per cow.

Many experiments in different countries have proved that high genetic merit (HGM) cows produce significantly more milksolids than cows of lower merit status, as a result of selection for high milk production (Mayne, 1998). However, there are probably no large genetic differences among cows in their ability to digest or metabolise a given feed at a constant level of feeding (Veerkamp, 1998). The higher milk yields of HGM animals are a consequence of their greater ability to partition ME intake to milk output rather than tissue gain, coupled with their higher intakes (Dillon and Buckley 2001; Gordon *et al.*, 1995; Ferris *et al.*, 1998). As a result of this greater partitioning in HGM cows, a number of studies have found that HGM cows achieve larger milk production responses to increases in feeding level than LGM cows – a type of genotype by environment interaction (Fulkerson, *et al.*, 2000; Kennedy, *et al.*, 2002; Ferris *et al.*, 1998).

Genetic Evaluation

The Animal Evaluation Unit of the Livestock Improvement Corporation are responsible for the genetic evaluation of dairy cows in New Zealand. The New Zealand Industry Breeding Objective is: 'identifying animals which are the most efficient converters of feed into profit' (Livestock Improvement, 1996). Six economically important traits are measured; milk yield, fat yield, protein yield, liveweight, survival and fertility. Estimated breeding values (EBV) for each of these traits are estimated for each animal from individual, ancestral and progeny records (Garrick *et al.*, 1996). Each of the EBVs for the animal, are reported relative to values for genetic base cows, and EBVs can be compared across different breeds of cows. The New Zealand genetic base (approximately 30,000 animals) represents the average evaluation of all 1985 born cows, measured for milkfat, protein, milk and 17 traits other than production, the EBVs for these animals are set to the base value of 0 (Livestock Improvement, 1996). The overall merit (or breeding worth) of animals is then calculated by accumulating the

economic effects of all traits in the objective, in other words, the cows strengths, discounted for any weaknesses (Holmes *et al.*, 2002). The Breeding Worth, which is reported relative to the base animals, is an estimate of net income (gross income – costs) per 4.5 t DM eaten.

OBJECTIVES

The general objective of this thesis was to find ways of using the considerable genetic information now available about the cows to assist in improving the management of the herd and replacements. The thesis will illustrate how the genetic values – specifically EBVs - can be used to predict cow performance, to develop optimum target levels of performance and determine the feed demands of the cows and heifers required to achieve these targets.

Chapter 2 investigates if genotype x environment interactions are likely to be important across the range of feeding levels and genetic values which exist within New Zealand herds, and whether the milk production responses to an increase in feeding levels are higher in HGM cows than LGM cows.

In **Chapter 3**, the energy partitioning by Jersey cows of either HGM and LGM was studied to quantify the differences between animals of differing genetic merit for milk production. The effect of the level of feeding (or stocking rate) on the amount of energy partitioned to lactation or liveweight gain in each genetic merit group was also examined.

In **Chapter 4**, a method was devised where genetic information (specifically the EBVs) can be used to determine the feed demand of the dairy cow at an economically optimum level of performance per cow. This information can then be used to identify the number of cows required for max EFS from a specified feed supply (or in other words to determine the best stocking rate).

Chapter 5 outlines a method whereby EBV for liveweight can be used to determine target liveweights of individual heifers of any breed. Achievement of these targets

should ensure high reproductive performance, and maximise production as 2 year olds, and subsequently as mature animals.

Chapter 6 presents an overview of all the results, and their implications are discussed.

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Chapter 2

Evidence of a genotype by feeding level interaction in grazing Holstein-Friesian dairy cattle at different stocking rates

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ABSTRACT

Lactation yields and estimated breeding values (EBVs) for protein, fat and milk were obtained for individual cows in a farmlet trial carried out at Dexcel in Hamilton, using Holstein-Friesian cows, to test for the existence of a genotype by environment interaction across the range of feeding levels, and EBVs typically found on New Zealand pasture-based dairy farms. At very low levels of feeding, with yields of 267 – 307 kg milksolids per cow (kg MS/cow), regression coefficients of lactation yield on EBVs were not significantly different from the expected value of 1. At high levels of feeding, with yields of 383 – 411 kg MS/cow, most of the regression coefficients for yields of protein, fat and milk on EBVs were significantly greater than 1. The results of this study show that at low levels of feeding the actual differences in production between cows, which differ in EBVs correspond to the actual differences in EBVs, whereas at high levels of feeding the difference in milk yields between genetic groups are greater than the difference in EBVs. This constitutes a form of genotype x environment interaction, in which genotype is measured as breeding values, and has important practical and economic implications for dairy farms, and for the expected value of genetic improvements.

Keywords: genotype; environment; interaction; Holstein-Friesian; pasture-based; breeding values; genetic merit.

INTRODUCTION

Wide ranges of cow genotypes and feeding systems are now being used on New Zealand dairy farms. For example, breeds of cows include Holstein-Friesian (HF) (56%), HF/Jersey (J) cross (21%), J (15%), Ayrshire (1%) and others (7%) which include milking shorthorn, Guernsey and Brown Swiss (Livestock Improvement, 2001). There has also been an increase in the use of overseas genetics, so that by 1998, 38% and 9% of the genetic composition of HF and J cows respectively, was of overseas origin (Harris & Winkelman, 2000). Overseas animals are selected under intensive, high-input feed systems, many of which involve limited access to pasture (Mayne, 1998). This is very different from New Zealand, where animals are selected based on performance in pasture-based systems. A significant number of dairy farmers have changed from traditional low-input systems to high-input systems, resulting in large differences in feed intakes and milk yields per cow across the range of production systems. Therefore, it is important to determine if the phenotypic superiority of high genetic merit (HGM) cows is increased at higher levels of feeding, which would be a form of genotype x environment interaction (GxE).

G x E interactions can take two forms; (1) a scaling effect across environments or (2) a change in the actual ranking of sires or genotypes across environments (Cromie *et al.*, 1998). A number of investigators have found scaling effects across environments. For example, in an Australian study, it was observed that, at low concentrate intakes, the difference in yield between two genetically different groups of cows was only half of what was predicted by the difference in estimated breeding values (EBVs). But, at medium and high intakes of concentrates, the differences in yields closely matched the differences in EBVs (Fulkerson *et al.*, 2000). Similarly, Veerkamp *et al.* (1994) in Scotland, observed that for every 1-kg increase in predicted transmitting ability (PTA) for milksolids (MS), milk yield increased by 18 kg and 47 kg for animals fed low and high levels of concentrates, respectively. These two studies represented significant scaling effects across environments.

An example of re-ranking of genotypes across environments was observed in a trial carried out in New Zealand by Kolver *et al.* (2002). In this trial, New Zealand HF had

slightly higher lactation yields than overseas HF on a fully-fed pasture-based system (465 vs 459 kg MS/cow, respectively). However, on a total mixed ration system the overseas HF had significantly higher lactation yields than New Zealand HF (720 & 602 kg MS/cow, respectively).

In contrast, several Irish studies could not find significant G x E interactions (Buckley *et al.*, 2000; Gordon *et al.*, 1995; O’Connell *et al.*, 2000). However, the authors observed that lack of definite G x E interactions in animal trials may have been due to the small differences between genotypes and/or feeding systems, short trial duration and small numbers of cows.

The objective of the present study was to determine if there are interactions between genotype and feeding level across the range of feeding levels, and EBVs typically found on New Zealand pasture-based dairy farms.

MATERIALS AND METHODS

Lactation yields were obtained for individual cows at Dexcel, in Hamilton (seasons 1999/2000 and 2000/2001) using mixed-age HF cows (Macdonald *et al.*, 2001). Live weights and EBVs for fat, protein, milk and liveweight (Lwt) for individual cows were obtained at the start of the trial. There were 25-33 cows in each of the four feeding level groups, with stocking rates of 2.2 cows/ha (1100 kg Lwt/ha), 2.7 cows/ha (1350 kg Lwt/ha), 3.2 cows/ha (1600 kg Lwt/ha), and 3.7 cows/ha (1850 kg Lwt/ha), respectively. The system was pasture-based, with no imported feed. EBVs for fat, protein, milk and Lwt were 28.8, 26.5, 800 and 52.5 kg, respectively.

STATISTICAL ANALYSIS

The data set was analysed using the PROC MIXED procedure of SAS (2001). For each variable studied, the model included the effects of age, feeding level, experimental year, the interaction between feeding level and experimental year, and the co-variables calving day after the herd’s commencement of calving and the EBV nested in each feeding level and experimental year. The regression coefficients of adjusted phenotypic

observations on EBVs were tested to see if they departed from the theoretical value of 1. Milksolids yields (adjusted for the model effects) were also analysed by regression against milksolids EBVs, to test for significant differences between the highest and lowest feeding levels.

RESULTS

The stocking rates used resulted in different feed intakes in each treatment. The feed intakes for the Holstein-Friesian cows were 5060, 4647, 4373, and 4014 kg DM/cow/year for the high, medium, low and very low feeding levels, respectively based on the differences between pre and post grazing herbage mass throughout the two years of the trial (Macdonald *et al.*, 2001).

Table 2.1: Lactation yields for milk, fat, protein and milksolids of Holstein Friesian cows at four different levels of feeding

Level of feeding (stocking rate)	High (2.2 cows/ha)	Medium (2.7 cows/ha)	Low (3.2 cows/ha)	Very Low (3.7 cows/ha)
Season (1999/2000)				
Milk (kg/cow)	4682 ± 88.2 ^a	4078 ± 86.0 ^b	3647 ± 89.3 ^c	3314 ± 85.0 ^d
Fat (kg/cow)	215 ± 4.1 ^a	188 ± 4.2 ^b	169 ± 4.1 ^c	152 ± 3.9 ^d
Protein (kg/cow)	168 ± 2.9 ^a	144 ± 2.8 ^b	128 ± 2.9 ^c	115 ± 2.8 ^d
Days in Milk	291 ± 2.8 ^a	278 ± 2.7 ^b	244 ± 2.8 ^c	233 ± 2.6 ^d
Milksolids (kg/cow)	383 ± 6.9 ^a	332 ± 6.8 ^b	297 ± 6.8 ^c	267 ± 6.6 ^d
Milksolids EBV (kg)	56 ± 2.3 ^{ab}	59 ± 2.3 ^{ab}	54 ± 2.3 ^a	54 ± 2.2 ^a
Range	33 to 78	37 to 87	22 to 74	30 to 78
Season (2000/2001)				
Milk (kg/cow)	4976 ± 107.2 ^a	4471 ± 99.2 ^b	4071 ± 86.0 ^c	3787 ± 97.0 ^d
Fat (kg/cow)	235 ± 4.8 ^a	206 ± 4.5 ^b	193 ± 5.2 ^b	176 ± 4.5 ^c
Protein (kg/cow)	177 ± 3.7 ^a	157 ± 3.4 ^b	143 ± 3.8 ^c	131 ± 3.4 ^d
Days in Milk	295 ± 2.6 ^a	280 ± 2.4 ^b	271 ± 2.8 ^c	250 ± 2.4 ^d
Milksolids (kg/cow)	411 ± 8.3 ^a	363 ± 7.9 ^b	336 ± 8.9 ^c	307 ± 7.7 ^d
Milksolids EBV (kg)	57 ± 2.2 ^a	58 ± 2.1 ^a	55 ± 2.3 ^a	57 ± 2.0 ^a
Range	33 to 84	37 to 87	31 to 74	38 to 78

Least squares means of lactation yields for fat, protein and milk, and EBV for milksolids at each feeding level are presented in Tables 2.1. As expected, milksolids yields per cow were highest at the high feeding level (383 and 411 kg MS/cow, for the 99/00 and 00/01 seasons, respectively), and were lowest at the very low feeding level (267 and 307kg MS/cow, respectively). The lactation yields at the very low feeding

level are slightly lower than the average production in New Zealand of 310 kg MS per cow (Livestock Improvement, 2001). The differences in milksolids yield per cow between feeding level groups were all significant. The least squares means of milksolids EBVs and the ranges were not different between each feeding-level group.

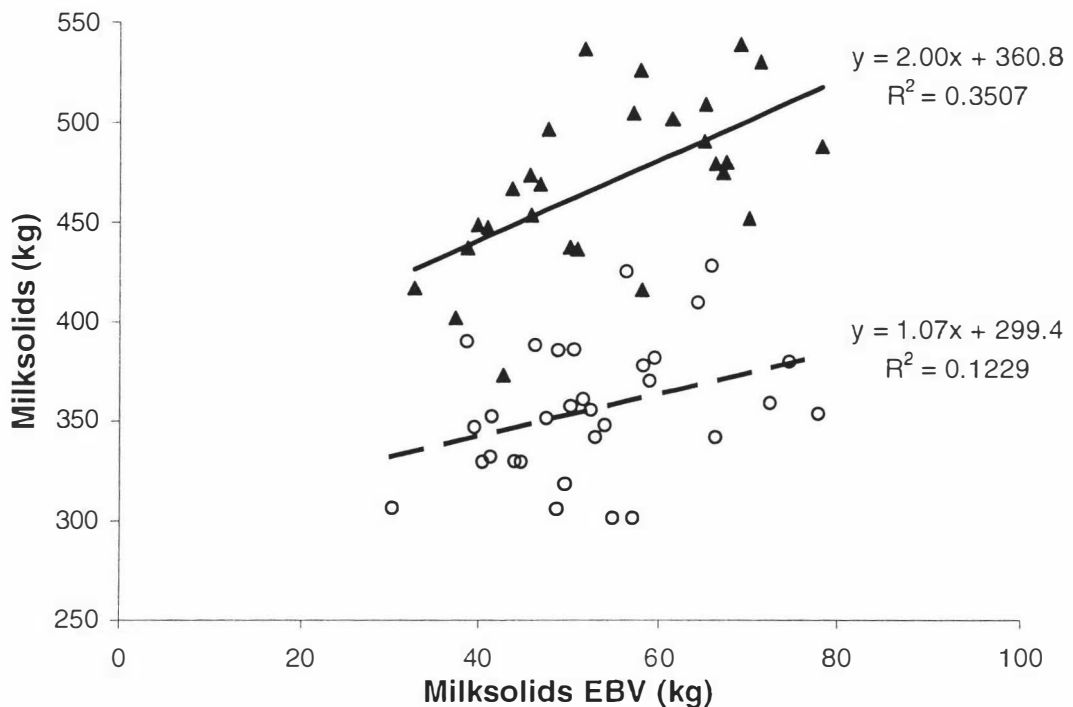
Table 2.2: Regression coefficients of lactation yields for milk, protein, fat and milksolids, on respective estimated breeding values (EBV) at four different levels of feeding

Season	1999/2000	2000/2001
High Feeding Level		
Milk yield/Milk EBV	1.86 ± 0.330*	2.01 ± 0.343*
Protein yield/Protein EBV	2.17 ± 0.472*	2.15 ± 0.532*
Fat yield/Fat EBV	1.91 ± 0.589	2.59 ± 0.641*
Milksolids yield/Milksolids EBV	2.00 ± 0.555	2.40 ± 0.616*
Medium Feeding Level		
Milk yield/Milk EBV	1.71 ± 0.454	1.94 ± 0.430*
Protein yield/Protein EBV	1.64 ± 0.524	1.70 ± 0.579
Fat yield/Fat EBV	0.92 ± 0.630	0.97 ± 0.678
Milksolids yield/Milksolids EBV	1.08 ± 0.630	1.08 ± 0.716
Low Feeding Level		
Milk yield/Milk EBV	0.86 ± 0.457	1.49 ± 0.546
Protein yield/Protein EBV	0.59 ± 0.426	1.35 ± 0.633
Fat yield/Fat EBV	0.92 ± 0.524	2.19 ± 0.780
Milksolids yield/Milksolids EBV	0.73 ± 0.485	1.70 ± 0.748
Very Low Feeding Level		
Milk yield/Milk EBV	0.89 ± 0.428	1.78 ± 0.425
Protein yield/Protein EBV	0.77 ± 0.573	1.51 ± 0.596
Fat yield/Fat EBV	1.48 ± 0.495	1.64 ± 0.733
Milksolids yield/Milksolids EBV	1.07 ± 0.578	1.53 ± 0.750

*significantly different to the theoretical value of 1 (P<0.05)

The regression coefficients for the relation between adjusted lactation yields for protein, fat and milk and the respective EBVs for protein, fat and milk, are presented in Table 2.2. At the high feeding level, most of the regression coefficients were significantly greater than 1. At the medium, low and very low feeding levels most of the estimates of the regression coefficient of yields on the respective EBVs, were not significantly different from the expected value of 1.

FIGURE 2.1: Regression of milksolids yield on milksolids estimated breeding value (EBV), at high (—) and very low (- - -) feeding levels of Holstein-Friesian cows for the 1999/2000 season.



The result for the regression of adjusted milksolids yields on milksolids EBVs at the two extreme feeding levels, high and very low, for the 1999/2000 season is presented in Figure 2.1. At the very low feeding level, the regression coefficient of milksolids yields on milksolids EBVs was 1.07, and at the high feeding level, the regression coefficient was 2.00, but is not significantly different from 1. The data for the 2000/2001 season also shows the same relationship with the regression coefficient greater at the highest feeding level (2.40 which is significantly different to 1), than at the lowest feeding level (1.53 which is not significantly different to 1; Table 2.2). The differences between the regression coefficients of each group for each season were not significantly different due to the small number of cows per group, which ranged from 25-33 cows. Overall the results indicate a GxE interaction (or scaling effect) where increases in milk yields caused by increases in feeding level are greater in cows of high genetic merit than in cows of lower genetic merit.

DISCUSSION

The evidence for a GxE interaction reported in the current study with grazing cows can be compared with the results of other trials. In Australia, Fulkerson *et al.* (2000) found that at medium and high intakes of concentrates, the actual differences in milk yields corresponded to the difference predicted from milksolids EBVs, whereas at low feeding levels the difference in yields is only half of what was predicted from EBV differences. Cromie *et al.* (1998), using records from commercial herds in Ireland, observed that bull proofs obtained from systems that used high levels of concentrates, over-predicted genetic merit for cows managed in systems that used lower levels of concentrates, and a similar conclusion was made from the results of an Irish experiment (Kennedy *et al.*, 2002). In Scotland, Veerkamp *et al.* (1994) reported the regression coefficients of milksolids yields on milksolids PTA at low and high concentrate feeding levels of 1.35 and 2.53 (theory = 2), respectively, although the difference was not statistically significant over a 26-week trial period. The results of the present study, along with other published results, show that GxE interactions are present amongst dairy production systems. High feeding levels allow a cow's genetic potential to be fully expressed, whereas at low feeding levels, this ability is compromised (Kennedy *et al.*, 2002).

The results also illustrate that HGM cows achieve greater responses than low genetic merit (LGM) cows when feed intakes per cow are increased. Similar results were found in New Zealand by Grainger *et al.* (1985), who observed that HGM cows achieved greater responses to an increase in feeding level (63 vs 50 g extra milksolids per kg DM of pasture offered for HGM and LGM, respectively). In the current study, feed intakes per cow were increased by managing cows under low stocking rates, however, it is also possible to increase feed intakes per cow through the use of supplements. For example, Fulkerson *et al.* (2000) found that at medium concentrate intakes (0.84 t DM/cow), HGM and LGM cows achieved responses of 105 and 86 g MS per kg of extra concentrate offered, respectively over the course of the lactation. Similarly, Kennedy *et al.* (2002) observed responses of 63 and 72 g MS/kg DM concentrate, for HGM cows changing from low to medium and from low to high levels of concentrates, respectively, whereas the corresponding values for medium genetic merit cows were lower, 50 and 54 g MS/kg DM concentrate. The larger responses to extra feed achieved by HGM cows is

partly due to their ability to partition a higher proportion of their dietary energy intakes towards milk, and less to liveweight gain (see Bryant *et al.*, 2003). These results have important practical implications for dairy farmers, as higher responses to additional feeds would enable the increased and profitable use of a greater range of supplements when these are fed to HGM dairy cows.

The system for the genetic evaluation of dairy cattle adjusts for heterogeneous variance (Harris *et al.*, 1996), and this accounts for the scaling effect described in the current study. Each individual cow record is adjusted to provide an accurate representation of the genetic merit of an animal across a range of production systems within New Zealand. Consequently, animals with high EBVs for milk components will have the same ranking relative to other cows irrespective of the type of system in which they are managed. However, Cromie *et al.* (1998) in Ireland, found evidence of re-ranking of sires for milk and protein yield in herds with very low yields, and it is possible that re-ranking could occur in New Zealand dairy systems with either very low or very high feeding levels (Lopez-Villalobos *et al.*, 1994).

CONCLUSION

The EBVs provide a good indication of the expected performance of cows in average New Zealand herds. At high feeding levels, greater milksolids responses are achieved than is indicated by the differences in EBVs among animals or herds. In addition, higher feeding levels or greater supplement use may be needed to fully exploit the benefits of genetic gain within the herd, although profitability will still depend on the cost of the extra feed and the value of the extra milk.

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Chapter 3

Effect of genetic merit on the estimated partitioning of energy towards milk production or live weight gain by Jersey cows grazing on pasture

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ABSTRACT

High genetic merit cows generally partition more metabolizable energy (ME) to milk and less to liveweight (Lwt) gain than low genetic merit animals throughout the lactation. However, these differences have not been quantified for cows grazing pasture. A comprehensive data set from the 1999/2000 season of the Stratford demonstration farm stocking rate trial was used to estimate ME intakes (MEI) and the amount of ME partitioned into milk, maintenance and Lwt changes of high genetic merit (HGM) (average fat + protein breeding value of 28 kg) and low genetic merit (LGM) Jersey cows (average fat + protein breeding value of 11 kg) from regular measurements of their yields of milk and its components, and their Lwt. Least-square mean yields for HGM and LGM cows were 327 and 289 kg of milksolids per cow respectively. HGM cows partitioned a significantly higher proportion of MEI into milk than LGM cows in early (0.67 vs 0.63; $P < 0.01$), peak (0.59 vs 0.57; $P < 0.05$), mid (0.58 vs 0.56; $P < 0.01$) and late lactation (0.54 vs 0.51; $P < 0.01$) (HGM vs LGM respectively). In early lactation, HGM cows utilised more body reserves for milk production (-0.05 vs -0.01, for HGM and LGM respectively). These results confirm that HGM cows partition more ME to milk throughout lactation than LGM animals for a range of feeding levels on grazed pasture. The greatest difference occurred in early lactation, resulting in increased body tissue loss and a greater negative energy balance in HGM cows.

Keywords: partitioning; genetic merit; energy; pasture-based; energy balance; dairy cows.

INTRODUCTION

HGM dairy cows achieve higher values for gross efficiency than LGM dairy cows, mainly because they achieve higher milk yields, have slightly higher feed intakes and mobilise more body reserves (Fulkerson *et al.*, 2000; Buckley *et al.*, 2000; Ferris *et al.*, 1998a). The higher gross efficiency occurs despite the apparent absence of any difference in partial efficiency of ME use for lactation (Ferris *et al.*, 1998b). Consequently, the higher milk yields of HGM cows are largely attributable to greater partitioning of nutrients into milk, rather than compensatory increases in food intake or metabolic efficiency (Mayne & Gordon, 1995).

Considerable effort has been directed towards modelling the complex biochemical pathways that comprise metabolism at the tissue level. This has improved understanding of the factors that influence milk and tissue responses to changes in energy intake (Kirkland & Gordon, 2001). However, there is a lack of research at the whole animal level on energy partitioning by cows of different genetic merits when grazing on pasture (Saama & Mao, 1993). The aim of the present research is to quantify differences in energy partitioned to milk production and live weight change at each stage of lactation by HGM and LGM dairy cows grazing at different feed levels achieved by different stocking rates.

MATERIALS AND METHODS

The data were derived from a trial using Jersey cows carried out at the Stratford Demonstration farm from July 1998 to May 2001. In this study, the data for only the 1999/2000 season was used, because the data sets for the other two years were incomplete. Cows were allocated to one of four feeding levels (achieved by the use of four stocking rates); high (2.5 cows/ha), medium (3.2 cows/ha), low (3.7 cows/ha) or very low (4.2 cows/ha). Little supplement was fed, and was generally high quality pasture silage conserved on the farmlets. Approximately 40 animals were allocated to each feeding level treatment. Data for the yields of milk, and milk fat and protein concentrations were obtained at two-weekly intervals for each cow during the 1999/2000 season. Individual cow Lwts were measured on seven occasions starting on

the 4th of September 1999 and finishing on the 3rd of April 2000. Pasture samples were collected from paddocks grazed by each treatment group at the time of the two-weekly herd tests, and the megajoule metabolisable energy (MJME) concentration of the consumed pasture was estimated by NIRS analysis (Corson *et al.*, 1999).

Calculation of estimated individual energy intakes and the proportions of energy partitioned lactation, maintenance and Lwt change

Energy intakes for each cow in the trial were calculated at intervals of two weeks to coincide with each herd test, using data for Lwt and change in Lwt, milk yield and composition, and energy concentrations of pasture. Individual cow Lwt changes were estimated from the difference in Lwt between consecutive Lwt measurements around the date of the herd test. The metabolisable energy (ME) requirements for lactation (M_l), maintenance (M_m), live weight change (M_g) and metabolisable energy intake (MEI) were calculated as outlined in the Appendix. The requirements for pregnancy were not included as the amounts are negligible (<2 MJME/day) up until about 3-4 months before parturition (refer to equation 7 in the Appendix). The proportions of energy partitioned to lactation (EP_l), maintenance (EP_m), Lwt change (EP_g) were calculated using:

$$EP_l = M_l / MEI$$

$$EP_m = M_m / MEI$$

$$EP_g = M_g / MEI$$

Statistical analysis

Animals were divided into two groups; low genetic merit (LGM) with a milksolids estimated breeding value of <20 kg, and high genetic merit (HGM) with a milksolids estimated breeding value of >20 kg. Four lactation stages were defined; early (<60 days in milk (DIM)), peak (60 to 120 DIM), mid (120 to 180 DIM), and late (180 to 240 DIM). The cows were grazed at four levels of feeding; high, medium, low and very low. Energy partitioned to lactation, maintenance and Lwt change by individual cows in each lactation stage was analysed using the PROC MIXED procedure of SAS (2001). The model included the fixed effects of feeding level, lactation stage, genetic merit, age, and the interactions between genetic merit, lactation stage and feeding level. Repeated

measures for each cow within each feeding level were considered. Using Akaike's information criterion, a compound symmetric structure of the residuals provided the best fit for the data.

RESULTS AND DISCUSSION

Least-square means and standard errors of EBVs, production and Lwt data of the two genetic groups, are shown in Table 3.1. The difference in estimated breeding value for milksolids between the groups was 17.6 kg. This difference is small compared to differences found within and between commercial herds (Livestock Improvement, 2001). HGM animals had significantly ($P < 0.001$) higher daily milksolids (MS) yields than LGM animals throughout lactation, and significantly ($P < 0.05$) higher total MS yields (327 vs 289 kg MS/cow, for HGM and LGM, respectively). However, the actual difference in MS yield (38 kg) was greater than the difference predicted by the estimated breeding values for MS (18 kg). For further discussion see Chapter 2. The differences in Lwt between the two genetic groups were significant in early, mid and late lactation, but not in peak lactation, and the actual differences in Lwt were slightly greater than the difference in estimated breeding values for Lwt between each genetic group.

Table 3.1: Least square means of daily milksolids yields, estimated breeding value (EBV) for milksolids, lactation yield for milksolids, EBV for Lwt, and live weight of high genetic merit (HGM) and low genetic merit (LGM) Jersey cows.

	HGM	LGM	SED	Significance
Daily milksolids production (kg/cow)				
Early lactation	1.59	1.46	0.026	***
Peak lactation	1.48	1.35	0.019	***
Mid lactation	1.48	1.32	0.017	***
Late Lactation	1.11	0.98	0.018	***
Lactation yields				
Milksolids EBV (kg/cow)	28.3	10.8	1.26	***
Milk solids (kg/cow)	327	288	6.8	***
Lactation length (days)	255	253	3.4	NS
Lwt (kg/cow)				
Lwt EBV	-42	-48	2.1	**
Early lactation	384	372	5.9	*
Peak lactation	385	375	5.5	NS
Mid lactation	404	393	5.2	*
Late Lactation	410	396	5.3	**

Estimated MEI and the proportions of energy partitioned to maintenance, lactation and Lwt change in HGM and LGM cows are presented in Table 3.2. HGM cows partitioned a significantly higher proportion of MEI to milk than the LGM cows in early (0.67 vs 0.63), peak (0.59 vs 0.57), mid (0.58 vs 0.56) and late lactation (0.54 vs 0.51) (HGM vs LGM respectively). The proportions of energy partitioned to milk were similar to those reported by Grainger *et al.* (1985), Oldenbroek (1986) and Yan *et al.* (2002). Jersey heifers fed a high-roughage diet partitioned 81, 62 and 54% of MEI to milk for 0-91, 92-182 and 183-273 days of lactation respectively, while the combined Holstein-Friesian and Dutch Red and White heifer groups partitioned 67, 53, and 49% of MEI to milk at the same respective stages of lactation (Oldenbroek, 1986).

Table 3.2: Metabolisable energy intakes (MEI), and proportion of energy partitioned to lactation (EP_l), maintenance (EP_m), and live weight change (EP_g) of HGM and LGM Jersey cows.

	HGM	LGM	SED	Significance
Early lactation				
MEI (MJ/cow/day)	157	151	2.7	*
EP_m	0.38	0.38	0.008	NS
EP_l	0.67	0.63	0.013	**
EP_g	-0.05	-0.01	0.019	*
Peak lactation				
MEI (MJ/cow/day)	166	155	1.9	***
EP_m	0.36	0.38	0.005	**
EP_l	0.59	0.57	0.008	*
EP_g	0.05	0.05	0.011	NS
Mid lactation				
MEI (MJ/cow/day)	166	152	1.8	***
EP_m	0.37	0.40	0.005	***
EP_l	0.58	0.56	0.007	**
EP_g	0.05	0.04	0.009	NS
Late lactation				
MEI (MJ/cow/day)	139	127	1.9	***
EP_m	0.46	0.49	0.008	***
EP_l	0.54	0.51	0.009	**
EP_g	0.00	0.00	0.013	NS

There was a significant ($P < 0.001$) reduction in the proportion of MEI partitioned into milk as the lactation proceeded in both LGM and HGM animals (Table 3.2). This was similar to results of calorimetric studies with cows fed diets consisting of straw, concentrates and lucerne (Kirkland & Gordon, 2000) or cut pasture (Grainger *et al.*, 1985).

The largest significant difference ($P < 0.001$) in EP_1 between the genetic merit groups was measured in early lactation (0.67 and 0.63 for HGM and LGM animals, respectively; Table 3.2). The higher proportion of MEI partitioned to milk at this time was due to greater mobilisation of body tissue (EP_g) in HGM (-0.05) compared to LGM (-0.01) cows. Yan *et al.* (2002) and Snijders *et al.* (2001) also observed that HGM animals mobilised significantly more body fat in early lactation than lower-genetic-merit animals, which had a negative effect on submission and conception rates in the trial reported by Snijders *et al.* (2001). These results emphasise that selection for high milk yields has led to cows which experience a greater negative energy balance (NEB) in early lactation (Knight *et al.*, 1999), a difference which may contribute to the lower fertility now exhibited in New Zealand herds (Holmes, 2001).

In this study, MEI were estimated using Lwt data, milk yields and composition, and energy concentrations of pasture, and were not actual measurements of intake and energy balance by indirect calorimetry. However, Agnew and Yan (2000) have demonstrated that the equations used in this study can be used to accurately predict the ME requirements for maintenance, lactation and Lwt change in grazing dairy cows. In addition, the present estimated values are generally consistent with published measured values (Oldenbroek, 1986; Yan *et al.*, 2002). The present conclusion, that HGM grazing cows partition a greater proportion of dietary energy to milk than LGM cows, is also consistent with results based on measured feed intakes by non-grazing cows (Grainger *et al.*, 1985).

Over the whole lactation, cows at the highest feeding level partitioned a higher proportion of MEI to milk than cows at the lowest feeding level (0.60 vs 0.57, respectively). In early lactation, HGM cows at the highest feeding level partitioned a significantly higher proportion of MEI to milk than HGM cows at the lowest feeding level (0.71 vs 0.62 for high and very low feeding levels, respectively; Table 3.3). Likewise, the difference between the high and very low feeding levels was highly significant ($P < 0.001$) for the LGM cows in early lactation (0.68 vs 0.55, respectively). The same consistent trend was not observed in peak or mid lactation in either HGM or LGM cows.

Table 3.3: The proportion of energy partitioned to lactation (EP_l) at each feeding level of HGM and LGM Jersey cows.

Level of feeding	High	Medium	Low	Very Low
Early lactation				
HGM	0.71 ± 0.017 ^a	0.70 ± 0.015 ^a	0.63 ± 0.023 ^b	0.62 ± 0.019 ^b
LGM	0.68 ± 0.024 ^a	0.67 ± 0.019 ^a	0.62 ± 0.015 ^a	0.55 ± 0.017 ^b
Peak lactation				
HGM	0.59 ± 0.011 ^a	0.62 ± 0.011 ^b	0.58 ± 0.015 ^a	0.58 ± 0.011 ^a
LGM	0.58 ± 0.014 ^{ab}	0.58 ± 0.012 ^{ab}	0.55 ± 0.009 ^b	0.59 ± 0.011 ^a
Mid lactation				
HGM	0.57 ± 0.008 ^a	0.57 ± 0.008 ^{ab}	0.58 ± 0.012 ^{ab}	0.60 ± 0.009 ^b
LGM	0.57 ± 0.011 ^{ab}	0.54 ± 0.009 ^a	0.55 ± 0.007 ^a	0.58 ± 0.009 ^b
Late lactation				
HGM	0.53 ± 0.010 ^a	0.52 ± 0.010 ^a	0.54 ± 0.016 ^{ab}	0.56 ± 0.015 ^b
LGM	0.55 ± 0.014 ^a	0.49 ± 0.012 ^b	0.49 ± 0.010 ^b	0.51 ± 0.013 ^{ab}

^{abc} means within rows with different superscripts significantly different (P<0.05)

In late lactation there was a significant (P<0.05) reduction in the proportion of energy partitioned to milk by LGM cows at medium and low feeding levels (P=0.08 at very low feeding levels) compared to the EP_l for LGM cows at the highest feeding level (Table 3.3). The same relationship was not observed in the HGM cows in late lactation. This data suggests very low feeding levels lead to a reduction in the level of partitioning of MEI into milk during early lactation and late lactation for LGM cows. Cows in early lactation compensated for low intakes by reducing the level of MEI partitioned to milk, which probably prevented excessive weight losses. LGM cows fed at low levels during late lactation partitioned more energy to maintenance of Lwt compared to HGM cows, resulting in lower persistency of milk production.

The cow's ability to partition total dietary energy between maintenance, milk and Lwt change is likely to affect their ability to partition extra dietary energy into milk (the marginal response to extra feed). This has been reported in Chapter 2, which shows an increase in genetic merit has a larger effect on actual milksolids yield at higher levels of feeding compared to lower levels of feeding. This is a form of genotype by environment interaction that has important practical implications for dairy farm systems.

While Jersey dairy cows were used in this trial, different results may have been obtained with Holstein-Friesian cows. For example, Mackle *et al.* (1996) found Jersey heifers partitioned more energy to milk during the lactation than Holstein-Friesian heifers (43%

vs 37%, respectively). Thomson *et al.* (2001) and Oldenbroek (1986) observed that Jersey cows in early lactation utilised a higher proportion of their energy intake for milk production than Holstein-Friesian cows, although this advantage declined as the lactation proceeded.

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Chapter 4

Utilisation of genetic information to determine the level of performance and the feed demand of the cow which corresponds to the farm's optimum economic performance

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ABSTRACT

Finding the correct balance between a herds' feed demand and feed supply is vitally important in pastoral-based systems, to ensure high levels of performance and profitability. The stocking rate expression "cows per hectare" has become outdated because not all cows' are equal, for instance, cows' of different liveweight, and/or genetic merit have different feed demands. In addition, the amount of feed grown per hectare varies, and additional feed may be provided from other sources. The recent introduction of comparative stocking rate (CSR) more adequately describes the balance between demand and supply as it includes all sources of feed supplied, and it takes into account the liveweight of the cow. But, the CSR expression does not take into account the greater feed requirements of cows with high genetic merit for milk yield. A new method is being developed, which uses the cow's estimated breeding values to estimate per cow performance at the level of feeding which corresponds to maximum \$EFS per farm (max EFS). The method has been "calibrated" against experimental results from a pasture-only farmlet study for which \$EFS was calculated. The calculated cow performance and liveweight are used to determine the "Genetic Feed Demand" (or GFD), which can then be used to adapt and improve the CSR equation by replacing kg Lwt with total GFD. New optimum CSR values are 0.7 to 0.8. The method is a significant improvement because it uses genetic data for both cow liveweight and milk production to determine the feed demand of the cow, and it will remain valid into the future, because it will accommodate future genetic changes for milksolid yield and liveweight. Further development and validation will be undertaken in ongoing studies.

INTRODUCTION

An essential facet of the New Zealand dairying farming system is the need to find the right balance between feed supply, which is mainly pasture, and a herds' feed demand. The farm's "stocking rate" has been used to describe this annual feed balance on farms in New Zealand and its importance has been recognised since the 1950's. Stocking rate is usually expressed as the number of cows grazed per hectare. The number of cows provides a measure of the annual feed demand and, on a pastoral farm, a hectare provides a measure of how much feed is available (Penno, 1999).

The main effects of stocking rate are illustrated by the results of a pasture-based farmlet trial using Holstein-Friesian cows (Macdonald *et al.*, 2001) (Table 4.1).

Table 4.1: Results from an experiment with five separate dairy "farmlets", with Holstein Friesian cows at 5 different stocking rates, with no heifers grazed-on and with no "imported" supplements fed (Macdonald *et al.*, 2001)

	Holstein Friesian cows per hectare				
	2.2	2.7	3.2	3.7	4.3
Comparative stocking rate (kg Lwt/t DM total offered)	62	76	90	103	120
Silage conserved (t DM/ha)	1.5	1.4	0.9	0.4	0.1
Proportion of farm area topped in the year	2.1	1.0	0.4	0.1	0.0
Pasture eaten: t DM per cow	5.06	4.65	4.24	4.01	3.71
t DM per hectare	11.1	12.5	13.6	14.9	16.0
Calculated feed reqd. for maintenance of cows (t DM/ha)	4.7	5.7	6.7	7.7	8.7
Performance of cows: kg MS/hectare	967	1043	1105	1145	1168
kg MS/cow	435	380	353	309	274
Days in milk	296	278	260	238	222
Liveweight (kg/cow)	489	475	472	467	448
Efficiencies					
<u>Pasture Harvesting:</u> Pasture utilisation (%)	63	70	72	81	81
<u>Feed conversion:</u> kg MS produced / t DM eaten	86	82	83	77	74
Economic farm surplus (EFS) (\$/ha)*	2884	2960	3054	2940	2751

*\$4.50 kg MS

At lower stocking rates, the cows are fed generously, are heavier and can be milked for longer lactations due to more available pasture per cow, consequently they achieve higher yields of milk per cow. However, milk yield per hectare is lower than at the higher stocking rates due to a reduced pasture utilisation. At the higher stocking rates, more pasture is eaten per hectare. The quantity of pasture (and silage) available to each cow is reduced, and as a result they are thinner and must be dried off earlier. They produce less milk per cow and are probably less fertile with longer anoestrous intervals and lower submission rates.

Cows/ha has been used as an expression of stocking rate for many years. However, the expression (cows/ha) has a number of deficiencies because it does not account for differences between herds in cow size, milk yield, the number of young stock grazed, or the amount of feed supplied per hectare. For example, a large, high yielding cow needs more feed and can eat more feed than a small, low yielding cow. The farm may graze only the milking herd, or it may graze heifers and other stock, which need additional feed. Also, farms vary in the amount of feed they grow per hectare, and additional feeds may be brought in (Holmes, *et al.*, 2002).

Recently, a new expression has been proposed called the comparative stocking rate or CSR, which is expressed as kg liveweight (Lwt)/t total DM offered. For research farmlets with no imported feeds and no heifers grazed, profitability per hectare was maximised at around 80-90 kg Lwt/t DM, and yields per cow were maximised at 60-70 kg Lwt/t DM (MacDonald *et al.*, 2001; Penno 1999). The CSR expression is a step forward as it takes into account cow size and feed supply. However, it fails to include level of milk production per cow, which is a major component leading to variation in feed requirement per cow. The ideal expression would include a measure of the genetic merit of the cow, which would make allowance for the greater feed requirements of genetically superior animals.

Ultimately, the cows' feed demand is determined by her Lwt, and her yields of milk and solids, and the cows' genetic abilities for these characteristics are described by her estimated breeding values (EBV) for Lwt, milk yield, fat yield and protein yield plus effects of crossbreeding (hybrid vigour). This paper will describe how these EBV's can

be used to predict cow performance at the feeding level (or stocking rate), which results in the highest level of economic farm surplus (max EFS) for pasture-only systems. The predicted performance (milk yields and Lwt) will then be used to determine the cow's "Genetic Feed Demand" (GFD) at max EFS, and determine the number of cows which can be milked for a specified feed supply.

METHODS

The results of the study by Macdonald et al. (2001) (Table 4.1) and the results of studies presented in Table 4.2 can be used to define stocking rates and corresponding levels of performance per cow that optimise profitability in pasture-based systems. The milksolids yields at which EFS is maximised have been highlighted and these range from 334 to 362 kg MS/cow for Jersey, Holstein-Friesian and mixed breed herds with average EBVs. This compares to the 353 kg MS/cow achieved by Holstein-Friesian cows at the most profitable stocking rate in the study by Macdonald *et al.* (2001) (Table 4.1).

Table 4.2: Description of a number of farmlet and commercial studies where \$EFS/ha has been measured.

System description	Cows/ha	BW	Breed	kg MS/cow	kg MS/ha	EFS/ha (\$)	Reference
Control	3.3			311	1040	2207	Macdonald, 1998
200 kg N/ha	3.3	NS	HF	362	1208	2496	
200 kg N/ha	4.4			269	1190	2140	
Pasture-based	2.5			376	956	1521	G. Pitman, unpublished, 2002
	3.2	93	J	345	1092	1838	
	3.7			285	1056	1627	
	4.2			259	1073	1528	
Commercial systems							
Top 10% EFS	3.1	61	Mixed	344	1060	2869	C.Glassey, pers comm.
Average	2.5	60		323	817	1717	
Commercial systems							
Top 25% EFS	3.3	NS	Mixed	334	1100	2278	Howse and Leslie, 1997
Average	3.0			302	915	1702	

Use of a calibration herd in the formulation of the model

The system of genetic evaluation in New Zealand produces estimated breeding values after correcting the phenotypic records for heterogeneous variances. The expected performance of cows can be estimated as the sum of the average productive

performance of the contemporary group (cows of the same age, herd, and season) plus estimated breeding values, and (in the case of crossbred cows) plus the heterosis effect. For example, at moderate feeding levels, a straight-bred cow with EBV of +20 kg protein would be expected to produce 20 kg more protein per lactation than herd contemporaries with an average EBV of 0 kg protein. Likewise, a cow with a Lwt EBV of +40 kg is expected to be 40 kg heavier than her contemporaries with 0 kg EBV for Lwt (Harris *et al.* 1996).

Hybrid vigour needs to be estimated based on the proportion of crossbred animals in the herd, as the effect of hybrid vigour is not included in EBVs. The values presented in Table 4.3 are the maximum levels of hybrid vigour for each breed cross (Lopez-Villalobos, 1998). However, it is highly unlikely these maximum levels of hybrid vigour will occur across the herd due to back-crossing, and other departures from the first cross.

Table 4.3: Maximum hybrid vigour for straight cross animals

	HF/J	HF/A	J/A
Milksolids	4.3%	2.1%	5.0%
Lwt	1.7%	0.1%	2.3%

For this study, the lactation yields and EBVs were obtained for the group of cows that achieved the highest levels of \$EFS (3.2 cows/ha) in the farmlet trial by Macdonald *et al.*, (2001) (Table 4.1), and these are used as calibration values (or the contemporary group). By using the yields and EBV of the calibration herd from the study by Macdonald *et al.* (2001), the performance per cow for other herds at max EFS can be predicted using the relationship between EBV and performance as described above.

The calibration cows' were Holstein-Friesian, managed under a pasture-based system at a medium to high level of feeding. They had an average age of 4.6 years, which is similar to the average age of cows in New Zealand dairy herds (Livestock Improvement, 2001), and achieved milksolid yields which were within the range of 334 to 362 kg MS/cow, which corresponds to maximum EFS/ha in other studies (Table 4.2).

A brief description of yields and EBV for the calibration herd is given below:

	Actual performance of calibration herd at max EFS/ha	EBV of calibration herd
Milk (kg)	4275	+747.9
Milkfat (kg)	201	+27.5
Protein (kg)	152	+25.8
Lwt (kg)	472	+50.1

VALIDATION

The lactation yields and EBVs of the max EFS herd (3.2 cows/ha) at Stratford were also obtained (G. Pitman, unpublished, 2002; refer to Table 4.2 and Chapter 3 for details of the study) to compare and validate the use of the calibration herd values (Table 4.4). The actual Lwt of the cows at Stratford was 375 kg, very similar to the predicted Lwt of 376 kg. The predicted milksolids production (321 kg MS) is 7% lower than the actual yield (345 kg MS) at max EFS. These differences are expected because temporary environmental effects are not included in the prediction of expected performance. However, the predicted milksolids yield is very similar to the yields per cow (324 kg MS) that resulted in the max EFS in the previous year (1998/99). In addition, the predicted range of expected yields for typical cows within New Zealand herds (refer to Table 4.8) is also within the range of yields at max EFS as illustrated in Table 4.2. Further testing is needed to check the validity of these results for a wider range of farms and systems

Table 4.4: Milksolids yields and Lwt predicted for the Stratford herd based on the differences in EBVs between the calibration herd and those at the Stratford

	EBV			Performance per cow		
	Calibration herd	Stratford	Difference	Actual Calibration Herd	Predicted Stratford	Actual Stratford
Milk (kg)	747.9	-189	937	4275	3338	
Fat (kg)	27.5	16.6	10.9	201	190	
Protein (kg)	25.8	3.9	21.9	152	131	
Milksolids (kg)	53.3	20.5	32.8	353	321	345
Lwt (kg)	50.1	-45.7	95.8	472	376	375

Calculation of Genetic Feed Demand per cow

The predicted performance i.e. Lwt and milk yields, at max EFS can then be used to determine the GFD of the herd. The equations used to calculate the feed requirements (or GFD) are outlined in the Appendix. An average energy concentration of feed of 11 MJME/kg DM has been assumed.

VALIDATION

The method for the calculation of feed requirements, can be compared with the results of a similar study by Garrick (1996). The feed requirements of a dairy cow with a Lwt of 450 kg, achieving yields for milk, fat, and protein of 4600, 223, and 170 kg, respectively, was estimated at 4.7 t DM (Garrick, 1996). In the present study, the GFD of a cow with the same Lwt, and yields of milk is 4.8 t DM. The calculated GFD of the calibration herd (4.35 t DM/cow) is similar to the measured value (4.24 t DM/cow), which was calculated from the differences between pre and post-grazing herbage mass (Macdonald *et al.*, 2001). Further testing is needed to check the validity of these results.

PRACTICAL APPLICATION AND DISCUSSION

Presented in Figure 4.1, is a simple step-by-step calculation sheet that can be used to calculate the milksolids yields, cow Lwt, and Genetic Feed Demand at max EFS.

- The herd EBVs (entered in *Step One*) are used to determine the optimum yields per cow in *Step Two* and the expected Lwt of the herd in *Step Three* (calculated values are shown in Tables 4.5 and 4.6).
- The GFD (4050 kg DM) of cow with 0 kg EBV for all traits (BW=\$0) and the accompanied increase in GFD for every 1 kg increase in EBV of each trait is shown in Table 4.7. These values are used in *Step Four* to calculate the additional feed required by the herd compared to the base animal with 0 kg EBVs.
- In *Step Five* the total additional feed requirements are then added onto the value of 4050 kg DM, to determine the GFD of the herd.

Figure 4.1: Prototype worksheet to calculate Genetic Feed Demand and the number of cows for a specified feed supply, to achieve the max EFS¹.

Step One: Entering estimated breeding values (EBV) of the herd					
Milk EBV (kg)	-189	(A)			
Fat EBV (kg)	16.6	(B)			
Protein EBV (kg)	3.9	(C)			
Liveweight EBV (kg)	-45.7	(D)			
Milksolids EBV = B+C	20.5	(E)			
<i>EBV can be obtained from a Trait Evaluation Report</i>					
Step Two: Calculate milksolids yield					
Base Cow Production (refer to Table 4.5)	300		kg MS/cow		
add Milksolids EBV (E)	20.5				
	321		kg MS/cow (F)		
<i>add effect of hybrid vigour (refer to Table 4.3)</i>					
F multiplied by hybrid vigour estimate for milksolids	0.0		kg MS/cow (G)		
Milksolids yield	321		kg MS/cow		
Step Three: Calculate cow liveweight					
Base cow liveweight (refer to Table 4.6)	422				
add liveweight EBV	-45.7		kg		
	376		kg (H)		
<i>add effect of hybrid Vigour (refer to Table 4.3)</i>					
H multiplied by hybrid vigour estimate for liveweight	0		kg (I)		
Estimated average herd liveweight	376		kg		
Actual LWT (if measured)	0		kg		
Liveweight deviation* = Actual LWT minus Est. LWT	0		kg (J)		
<i>*(0 kg if actual LWT not measured)</i>					
Step Four: Calculate additional feed requirements			<i>refer to Table 4.7</i>		
Milk EBV (A)	-189	multiplied by	0.15	-28	kg DM
Fat EBV (B)	16.6	multiplied by	5.72	95	kg DM
Protein EBV (C)	3.9	multiplied by	3.18	12	kg DM
Liveweight EBV (D)	-45.7	multiplied by	4.31	-197	kg DM
Adjustments					
(J) + (I)	0.0	multiplied by	4.31	0	kg DM
Milksolids hybrid vigour (G)	0.0	multiplied by	4.71	0	kg DM
Additional feed requirements				-118	kg DM (K)
Step Five: Calculate Genetic Feed Demand (GFD)					
Base cow feed demand				4050	
Additional feed required of herd (K)				-118	kg DM
Genetic Feed Demand (GFD)				3932	kg DM/cow
Step Six: Calculate new CSR					
Number of cows milked				300	cows
Total GFD = GFD x Number of cows milked				1,180	t DM
Total Feed Supply				1,600	t DM²
New CSR = Total GFD/Total Feed Supply				0.74	

¹calculated values are for the Jersey herd at Stratford (see Table 4.4 for further details)

²100 ha growing 16 t DM/ha.

Table 4.5: Predicted milksolids yield based on EBV for milksolids at max EFS (+1 kg EBV = +1 kg MS)

EBV for milksolids (kg)	Predicted milksolids (kg MS/cow)
0	300
20	320
40	340
53*	353
60	360
80	380
100	400
120	420
140	440

*calibration herd values in **bold****Table 4.6:** Predicted Lwt based on EBV for Lwt at max EFS (+1 kg EBV = +1 kg Lwt)

EBV for Lwt (kg)	Predicted Lwt (kg/cow)
-60	362
-40	382
-20	402
0	422
20	442
40	462
50*	472
60	482
80	502
100	522
120	542

*calibration herd values in **bold****Table 4.7:** The Genetic Feed Demand for max EFS for a base cow (EBV = 0 kg for all traits, and the increase in GFD caused by an increase of one unit in yield or Lwt)

	Additional feed required compared to base (kg DM/cow)
Base cow (GFD = 4050 kg DM)	
+ 1 kg milk	0.15
+ 1 kg milkfat	5.72
+ 1 kg protein	3.18
+ 1 kg milksolids	4.71
+ 1 kg Lwt	4.31

The calculated genetic values can then be used to adapt and improve CSR (see below) to include the effects of the genetic merit of the cow (*Step Six*).

The New Improved CSR = $\frac{\text{GFD/cow} \times \text{Number of cows}}{\text{Total t DM offered}}$

The calculated GFD/cow (the amount which must be EATEN by the herd) for max EFS, is multiplied by the number of cows on the farm to obtain the total GFD value. The calculated total GFD value is divided by the total t DM offered (determined using the method proposed for the CSR calculation; Speight, 2002).

The new equation is a simple modification of the CSR proposed by Penno (1999). The base line (total t DM offered) is unchanged, but the top line (GFD/cow x number of cows or total GFD) is improved as it includes the effects of genetic merit for yields of milksolids and Lwt (instead of actual Lwt only). The calculated value of 0.74 in Figure 4.1 is within the optimum range of 0.7 to 0.8 for the new CSR (essentially a measure of the feed utilisation of the farm). The new CSR for the calibration herd was 0.72, and the range 0.7 to 0.8 included herds at slightly lower and higher stocking rates, but which produced similar EFS/ha (see Table 4.1)

In the study by Macdonald *et al.* (1998) feed utilisation ranged from 0.70 in the Control farmlet with 3.3 cows/ha to greater than 0.80 in the farmlets that used supplementary feeds. Increasing the proportion of supplements in the diet increased the level of feed utilisation, as these feeds were consumed with lower levels of wastage. These two studies demonstrate that even in controlled conditions, feed utilisation varies greatly. However, high stocking rates will generally increase the level of pasture utilisation, but will also cause decreases in the amount of feed eaten per cow and performance per cow, and can cause decreases in EFS/ha (Table 4.1)

If the calculated CSR is lower than 0.7, this suggests that, for cows with this particular GFD, either the number of cows is too low or the total feed supply is too high. The actual performance of the herd (per cow) would be expected to be higher than the levels which correspond to max EFS/ha. In this case, more cows could be farmed on the specified feed supply.

On the other hand, if the calculated CSR is higher than 0.8 this suggests that for cows with this particular GFD, either the number of cows is too high or the total feed supply is too low. The actual performance of the herd (per cow) would be expected to be lower than the level which corresponds to max EFS. In this case, fewer cows could be farmed or extra feed could be added.

People who are excellent managers of pasture and supplements (eg. minimise the wastage of pasture, or supplements when feeding to the cows) may be able to achieve utilisations of close to 0.8, while simultaneously meeting the herds GFD for max EFS. Whereas, managers who are not so skilful, would only be able to achieve utilisations of close to 0.8 by restricting the herds feeding levels to below the GFD/cow (lower levels of performance) and so reducing EFS/ha below the maximum value. Therefore, excellent managers may target new CSRs of 0.8, average managers 0.75 and managers with less confidence in their ability to feed cows and utilise feeds could target 0.7.

- **Examples**

The milksolids yields, Lwt, and GFD for 1998-born cows from the four major breed groups have been calculated as an example in Table 4.8. This information shows that average Holstein-Friesian (HF) cows' have the highest GFD, due to these animals being heavier and producing the highest milksolids yields of all the breeds. Jersey cattle have the lowest GFD, as they achieve the lowest milksolids yields and have the lowest Lwt. HF/J, and Ayrshire's (A) have intermediate values for GFD.

Table 4.8: The average estimated breeding values (EBV) for animals from the four major breed groups born in 1998 (Livestock Improvement, 2001) and their predicted yields per cow, Lwt and GFD corresponding to the max EFS.

	EBV (kg)				Predicted values/cow for max EFS			Stocking rate (cows/ha) ²
	Milk	Milkfat	Protein	Lwt	Milksolids (kg)	Lwt (kg)	GFD (t DM)	
HF	+901	+26.4	+28.5	+55.6	355	478	4.7	2.6
J	-98	+17.2	+6.1	-43.8	323	378	4.0	3.0
HF/J	+400	+23.4	+17.6	+6.1	347 ¹	432	4.4	2.7
A	+469	+9.8	+15.4	+8.9	325	431	4.3	2.8

¹assuming hybrid vigour of 6 and 3.5 kg for milksolids and Lwt, respectively.

²assuming a feed supply of 16 t DM/ha and a new CSR value of 0.75.

Using these calculated GFD values for the different breeds, the required number of cows for the specified feed supply can be calculated (Table 4.8) using the New Improved CSR equation. This information shows that fewer HF cows need to be milked than HF/J, A, or J cows to achieve max EFS. In addition, cow Lwt should not be used as the major factor to determine the required number of cows (as with the original CSR), as this will result in the underfeeding of cows with higher genetic potential for milk production.

Limitations

- The model uses a narrow calibration base provided by the one HF calibration herd. Also, because the calibration herd was managed in a pasture-only system, the GFD cannot yet be used confidently for predictions on farms which use supplementary feeds intensively and achieve higher yields per cow. These issues will be addressed in the near future.
- If cows are going to be managed in systems which differ from the farm system where breeding values were estimated, then expected performance has to account for scale effects (a type of genotype by environment interaction; refer to chapter 2). Consequently, it may have been possible to inflate the EBVs to reflect the feeding level, however, a conservative approach has been taken until further evidence of scaling effects is found within New Zealand production systems. In addition, within this paper the predicted yields per cow are only slightly above the average of the national herd. Therefore, in herds with milksolids yields close to the national average, use of EBV to predict performance as described in this paper is reasonably accurate.
- The calculation of optimum EFS by Macdonald et al. (2001) assumed costs and prices in 2001, and it is possible/probable that changes in these could affect the level of performance, and the GFD which corresponds to max EFS.

Advantages of GFD and the new CSR equation

- GFD significantly improves the CSR, so that it includes all aspects of the genetic merit of the cow.

- The GFD takes into account the higher feed requirements of heavier animals (similar to CSR), but it also provides a method by which to calculate the herd's genetic Lwt from the herds EBV for Lwt.
- GFD also accounts for the higher feed requirements of cows with higher genetic merit for milk yield. It illustrates that as the genetic merit of cows' increase there will need to be an accompanied increase in feed intakes to ensure cows' can achieve the level of performance corresponding to max EFS.
- GFD will remain useful as the genetic merit of herds and individual cows increase.
- The GFD can be used to determine the required number of cows for the farms' total feed supply.
- The method provides genetic-based targets for milksolids yield per cow, which corresponds to achievement of max EFS. These will be valuable aids for important management decisions.

CONCLUSIONS

Overall the GFD and new CSR calculation is a significant advancement over the traditional cows/ha, or kg Lwt/tDM offered. In the future, as genetic merit for yield of milksolids increases, the genetic target for yield and the GFD per cow for each breed will also increase (even though Lwt will probably not increase significantly). In order to accommodate these increases:

- The number of cows must be reduced, or;
- The total feed supply must be increased, or;
- The feed utilisation efficiency must be increased above the 0.7 to 0.8 (less likely).

GFD and the new CSR will stimulate greater thought by farmers and consultants, and helps to provide greater understanding of the major factors that determine feed requirements of the cow. It also emphasises the importance of utilising as much feed as possible to maximise production. It provides a relatively simple method using available genetic information about the cows, which farmers can use to determine the number of cows for their dairy system. Further validation tests and developments will result in methods that are simpler and more robust.

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Chapter 5

**Use of breeding values to improve the management
of dairy heifers, by calculation of individual live
weight targets of each heifer**

ABSTRACT

Replacement heifers which make up approximately 20% of the herd, need to reach specific target weights to ensure they calve as two year olds, and subsequently achieve high milk yields and good fertility. Currently, different liveweight (Lwt) targets are recommended for different breeds such as Holstein Friesians and Jerseys. However, these do not allow for genetic differences in Lwt between heifers within a breed. This is especially important with the increased use of overseas Holstein Friesian strains, which have a higher mature Lwt potential than New Zealand-bred animals. A method has been formulated whereby the estimated breeding value for Lwt (LwtEBV) of any breed of heifer is used to calculate a mature Lwt potential of the animal, from which a re-parameterised von Bertalanffy growth curve function is used to calculate target Lwts from 0-24 months of age needed to reach the mature Lwt. For example, target Lwts at mating are 353, 329, 299 and 264 kg, for heifers with LwtEBVs of 100 (typical Overseas Holstein Friesian), 60 (New Zealand Holstein Friesian), 10 (Friesian Jersey cross) and -40 (Jersey), respectively. The estimated mature Lwt of these animals are 578, 538, 496 and 438 kg, respectively. Feed requirements have also been calculated. The system uses genetic information about Lwt of individual heifers (LwtEBV) to provide an accurate representation of the mature Lwt potential of the animal. It will allow farmers to compare the Lwt of their heifers with targets at specific stages of their development, and to identify individuals which are below (or above) their targets, so that they can be managed appropriately.

INTRODUCTION

In New Zealand's pastoral dairy system, approximately 20% of the herd is replaced annually with two year-old heifers, and rearing these dairy replacements is an important cost within the dairy operation. The feed intake/growth of these animals affects their subsequent ability to achieve to their genetic potential milk yields, survive in the herd, and to calve at 24 months of age and thereafter at 12 month intervals (Bryant and McRobbie, 1991).

Correct feeding management throughout the heifers development encourages mammary gland development, and ensures high Lwts at calving (Heinrichs, 1993). There is a positive relationship between Lwt at first parturition and milk yield in first lactation (Keown and Everett, 1986). In New Zealand this relationship ranges from 0.36 to 0.43 kilogram of extra milksolids (kgMS) for every additional kilogram of Lwt at two years of age (Penno *et al.*, 1997b; van der Waaij *et al.*, 1997; Bryant and McRobbie, 1991).

Lwt is also a key determinant of the onset of puberty, because a heifer reaches puberty when she attains a certain proportion of her mature Lwt (McNaughton *et al.*, 2002). For example, puberty was reached when high and low live weight selection line heifers were 48% and 47% of mature weight, or 241 kg and 221 kg, respectively (Garcia-Muniz, 1998). Similar results of 47% (258 kg), 43% (271 kg) and 43% (237 kg) of mature weight were observed in the trial by McNaughton *et al.* (2002), using high genetic merit New Zealand, overseas and low genetic merit New Zealand Holstein Friesian strains, respectively. Failure to reach puberty before the start of the mating period can have a significant effect on pregnancy rates in seasonally-calving herds in New Zealand, and low Lwt at the commencement of mating is a main factor affecting the failure of heifers to conceive (Macmillan, 1994).

A number of investigators have described target weights for heifers for a New Zealand system (Penno *et al.*, 1997; Bryant and McRobbie, 1991). Target weights at mating (15 months) and calving (24 months) of 60% and 90% of the estimated mature weight, respectively, were suggested by Troccon (1993). However, the individual heifer's mature weight cannot be estimated unless her genetic background is known. For

instance, New Zealand-bred Holstein Friesian (NZHF) cows have lower mature Lwts than cows with a high proportion of overseas genetics (OSHF); therefore target weights should be lower for the NZ-strain animals, than for the overseas strain animals (McNaughton *et al.*, 2002).

In the trials carried out by McNaughton *et al.* (2002) and by Garcia-Muniz (1998) puberty was reached when the animals – all Holstein Friesian - ranged from 221 to 271 kg of Lwt. These results indicate that even within the same breed of cattle, different Lwt targets are needed to account for genetic variation in Lwt between animals (Hoffman, 1997). This is especially important in New Zealand, due to the increased use of genetically heavier OSHF strain sires on NZHF, crossbreed, and Jersey dairy cows. A model has been developed that uses the genetic value for Lwt for a heifer to calculate her target Lwt at important stages of her growth.

METHODS

A theoretical model was developed to simulate the Lwt and feed requirements of heifers with different LwtEBV over the first two years of development

The mature Lwt (W) of an animal is calculated relative to a theoretical base animal. The base animal is the average Lwt (529 kg) of 6-8 year old Holstein-Friesian cows in 2000/2001 (Livestock Improvement Corporation, 2001). The average LwtEBV of these animals was estimated at 50.6 kg (Bill Montgomerie personal communication):

$$W = 529.3 + (\text{LwtEBV} - 50.6)$$

where: LwtEBV = Lwt breeding value of heifer

An estimated value of 1.7 % has been added onto the mature weight of the Holstein-Friesian/Jersey cross heifer to account for the effect of heterosis (Lopez-Villalobos, 1998).

The Lwt (W_t) at age t (in months) was calculated using the re-parameterised von Bertalanffy equation as given by Baaker and Koops (1977):

$$W_t = W \{ 1 - [1 - (W_o/W)^{1/3}] e^{-kt} \}^3$$

where: W = mature Lwt (derived from breeding values), W_o (Birth Weight) = $(W^{0.73} - 28.89)/2.064$ (Roy, 1980), k (constant related to rate of maturing) and e = base of the natural logarithm.

The weight of the foetal components (W_f) was calculated using the formulae:

$$W_f = \log^{2.932 - (\exp(-0.00406t) * 3.347)}$$

where t = days since conception.

The value (W_f) is then multiplied by a factor: $W_o/40$ kg calf (AFRC, 1993).

The metabolisable energy requirements of heifers are calculated for periods of 1-month until first parturition using the formulae proposed by AFRC (1993). Feed requirements (kgDM/heifer/day) are calculated assuming an energy concentration of the feed of 11MJME/kgDM.

RESULTS AND DISCUSSION

Presented in Table 5.1 are Lwt targets and in Table 5.2 feed requirements for average Overseas Holstein Friesian, New Zealand Holstein Friesian, Friesian Jersey cross and Jersey heifers. The Lwt targets for 100 and 10 kg LwtEBV heifers are very similar to those recommended by Troccon (1993) for heifers with estimated mature weights of 500 and 600 kg, respectively (Table 5.1). However, use of the described method allows the mature weights to be calculated from the LwtEBV, whereas the targets described by Troccon (1993), required an estimation of the expected mature Lwt based on appearance or breed.

The calculated targets are also similar to those recommended by Penno *et al.* (1997) and McNaughton *et al.* (2002). (McNaughton *et al.*, 2002) recommended mating Lwt targets of 340 kg Lwt, and 300 kg Lwt for animals with a high proportion of overseas Holstein Friesian (OSHF) genetics (84 LwtEBV) and New Zealand- type Holstein Friesian animals (48 LwtEBV), respectively. The values calculated by the model for their BV's

are 339 and 317 kg for OSHF and NZHF animals, respectively. (Garcia-Muniz, 1998) found 96% of the H (LwtEBV 78) and 99% of the L (LwtEBV 42) selection line animals had reached puberty, when they had reached 57% (283 kg) and 58% (273 kg) of their mature Lwt at mating, respectively. The target Lwt at mating of the animals represented in the model (Table 5.1), are 60% of the mature Lwt, hence, at these Lwt targets all animals should have reached puberty by mating.

Table 5.1: Lwt targets for different breeding value heifers at important management stages.

Breed ¹	OS HF	NZ HF	FxJ	J
LwtEBV (kg)	100	60	10	-40
9 months (Sent away to graze)	230	214	197	174
15 months (Mating)	353 (360) ²	329	299 (300)	264
21 months (Home from grazing)	461	429	395	349
24 months (pre-partum)	537 (540)	500	460 (450)	406
Mature Weight	578 (600)	538	496 (500)	438

¹ OS HF = Overseas Holstein Friesian, NZ HF = New Zealand Holstein Friesian, FxJ = Friesian Jersey cross, and J = Jersey

² Numbers in brackets as recommended by Troccon (1993)

The required pre-puberty growth rate of heifers at the two extremes, 100 (OSHF) and -40 LwtEBV (Jersey) are 0.70-0.80 and 0.45-0.55 kg/day, respectively. It has been reported that excessive pre-puberty (90-300 kg) growth rates of 0.4 and 0.7 kg/day for Jersey and Holstein-Friesian, respectively, can have negative effects on subsequent milk production (Sejrsen and Purup, 1997; Carson, *et al.*, 2002). However, in New Zealand, pre-puberty growth rates of 0.8 and 0.65 kg/day in Holstein Friesian and Jersey heifers, respectively, did not result in a significant negative effect on subsequent milk production (Penno *et al.*, 1997; Penno, 1997). Similarly, Holstein Friesian pre-pubertal growth rates of 0.66 to 0.95 kg/day did not result in a reduction in first lactation milk yield in Ireland (Carson *et al.*, 2000). Therefore, it is unlikely the pre-puberty growth rates needed to reach the Lwt targets are going to have a negative effect on milk production. Also, the recommended target of 537 kg at 2 years of age for OSHF heifers are roughly the same as the 540 kg target as recommended by Carson *et al.* (2002) in Ireland.

Table 5.2: Feed requirements (kgDM/day) for different breeding value heifers at important management stages.

Breed	OS HF	NZ HF	FxJ	J
LwtEBV (kg)	100	60	10	-40
9 months (Sent away to graze)	5.9*	5.4	4.9	4.2
15 months (Mating)	6.9	6.4	5.8	5.1
21 months (Home from grazing)	7.6	7.1	6.5	5.8
24 months (pre-partum)	10.6	9.9	9.2	8.2

*assuming a feed energy concentration of 11 MJME/kgDM

The data in Table 5.2 can be used to match the level of feeding to the LwtEBV of the animals reared, and ensure they reach Lwt targets. It is obviously not correct, for example, to assume that all black and white heifers (which could be OSHF, NZHF and or crossbreds) have the same mature Lwt and hence the same target weights. Failure to recognise this could result in the severe underfeeding or even overfeeding of heifers, and as a result Lwts that maximise production will not be reached.

Table 5.3: Proposed management report for heifers, with heifers ranked according to their deviations from their individual target weights.

Heifer Number	Age (Months-Days)	LwtEBV (kg)	Target Lwt (kg)	Actual Lwt (kg)	Difference (kg)	Difference (%)
1	14m 25d	16	298	240	-58*	-19%
2	14m 17d	29	302	265	-37	-12%
3	15m 5d	56	328	305	-23	-7%
4	14m 29d	-25	275	270	-5	-2%
5	14m 20d	98	345	360	+15	+4%
6	15m 15d	6	302	330	+28	+9%
7	15m 6d	49	324	370	+52	+16%

A proposed management report for heifers at 15 months of age is presented in Table 5.3, in which the heifers are ranked according to their deviation from individual target weights. The target Lwt - calculated for age at weighing - is compared with the actual Lwt, and the differences in kg Lwt and as a percentage of the target are recorded. Heifers within 5% of targets are probably at the appropriate Lwt. Heifers that are more than 10% below their target need additional feeding to ensure they reach subsequent Lwt targets. Similarly, if animals are more than 10% above their target, management

should ensure they do not have excessive Lwt gain before puberty, which could have detrimental effects on milk production.

CONCLUSION

The method proposed for calculating heifer Lwt targets will facilitate the improved management of dairy heifers. Heifers will have an improved chance of getting in calf early as yearlings, and enable them to produce to their capabilities over a long productive lifetime when they enter the herd. Ultimately, leading to improved profitability and greater farmer satisfaction from milking well-grown heifers.

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CHAPTER 6:

General Discussion

The present study has highlighted a number of key points about the use of genetic data for management of dairy cows and replacements. Milk production systems are dynamic; feeding HGM cows will depend upon accurate knowledge of the animals' nutrient requirements for differing functions, and feeding systems should be developed with the genetic values for potential yields and liveweight of the cow in mind. Clearly, HGM cows need to be offered higher allowances to allow them to consume the higher feed intakes necessary for them to express their potential for milk production.

Each aspect of the research has been discussed in detail in the respective chapters 2 to 5. The aim of this general discussion is to summarise and integrate the main points arising from the research.

Partitioning and genotype x environment interactions

The results of studies outlined in this thesis, and studies by Fulkerson *et al.* (2000), Kennedy *et al.* (2002) indicate that scaling effects (a type of G x E interaction) are common within the range of dairy systems and cow genotypes present within New Zealand and worldwide. HGM cows exhibit greater marginal responses in milk yield per unit of additional feed offered because they partition more of the extra feed consumed to milk. Consequently, there is a higher economic breakeven cost of supplementation for animals as GM increases (Ferris *et al.*, 1998). Clearly, the ability of cows to express their milk production potential at low levels of feeding is limited by the lack of dietary energy, and the value of a unit increase in genetic merit in a low concentrate, pasture-based system will be smaller than the value of the same increase in genetic merit in a high concentrate system (Kennedy *et al.*, 2002).

As cows of higher milk yield potential, and hence higher nutrient requirements, become more numerous, the greatest challenge to dairy producers will be to develop management systems, particularly in nutrition, that allow cows to fully express their genetic potential (Funk, 1993). However, what is optimum for the cow nutritionally and what is optimum for whole farm profit may be quite different. Maximum profit per farm will probably be achieved at levels of performance per cow which are 10 to 20% below

their genetic potential if fully fed on pasture (Macdonald *et al.*, 2001; Kolver *et al.*, 2002).

Higher levels of partitioning to milk in HGM cows cause increased milk yields, but result in the depletion of body tissue which can compromise reproductive performance (Ferris *et al.*, 1998). Although the depletion of body tissue reserves may be acceptable in the short term, a much longer-term approach must be adopted when considering the nutrition of the HGM dairy cow. It is likely that improved feeding of these HGM animals will help to ensure they get in-calf at regular intervals, which is essential for pasture-based systems.

Optimum performance and feed demand per cow

Use of cows per hectare as a measure of the balance between feed demand and supply (or stocking rate) is inadequate (Penno, 1999). There is a need to determine directly the feed demand of the cow from genetic values, which can be used to predict a level of performance that optimises profitability. The CSR equation can be adapted to better represent the feed demand of the herd. This is achieved by replacing *kg Lwt* with the *total GFD* of the herd. Optimum values for the new CSR are 0.7 to 0.8. The GFD also illustrates that management changes such as lower stocking rate or increased feed supply (eg. more nitrogen fertiliser or imported supplementary feeds) will be needed to meet the increase demands of the HGM cow (Holmes *et al.*, 2002).

Heifer replacement liveweight targets

Too often heifers enter the herd in poor condition and at low liveweights. This study has devised a set of liveweight targets that are based on the EBVs for liveweight of the individual heifer. These, if achieved, should allow replacements heifers of any breed to fully express their reproductive and milk production potentials. Proper feeding and regular weighing of young stock - to enable comparisons of actual liveweight with pre-determined genetic targets - will help to ensure that they conceive at about 15 months and again at 27 months, and produce to high levels when they enter the herd.

General Discussion

To date, genetic information has not been widely used for management purposes on commercial dairy farms. The present study has highlighted the fact that genetic values such as EBVs can be valuable for farmers in the practical management and design of their dairy farm systems. With the increased use of the computers, and web-based tools there is increased interest in using computer models to aid decision making for every day farming situations. Models such as UDDER and CAMDairy can forecast the effect of changes to feeding regimes and thus prevent management mistakes from occurring (Uribe, *et al.*, 1996). Integration of financial aspects can help to estimate the profitability of these changes. Further development of these tools to include the effects of genetics and GxE interactions will enhance their scope and improve the accuracy of prediction. Understanding the phenotypic and genetic variation among cows in their ability to partition nutrients between tissue and milk, will enable this information to be used as a predictive tool to determine the likely milksolids response to supplementation (Saama and Mao, 1993).

Accurate information from commercial farms can be valuable as these systems are run in “real” conditions. Collaborations between research organisation, such as the use of data from The Stratford Demonstration Farm and Dexcel in Hamilton in this thesis, will need to become commonplace as research funding becomes more stringently monitored. As more information becomes available on quantitative trait loci (QTL) and genetic markers, these findings should be incorporated into the design of farm systems, and their effect assessed.

CONCLUSIONS

- HGM dairy cows partition a higher proportion of feed to lactation throughout the lactation, and they appear to adjust the level of partitioning depending on their nutrient intake.
- GxE interactions are present within the range of New Zealand dairy systems, and these interactions could have significant implications in the design of genetic

evaluation. Specific genotypes may need to be tailor-made for the type of system in which they are managed.

- Genetic information can be used to help determine the feed demand/cow to maximise \$EFS per farm. This information can then be used to determine the stocking rate required to achieve the max EFS from a specified supply of feed. Genetic information is also useful because it helps farmers to determine the genetic potential of cows within the confines of their systems.
- Management of heifer replacements can be improved through more adequate monitoring techniques and heifers can be treated individually rather than simply dependent on breed or colour. Ensuring all heifers reach their pre-determined target weights will ensure each animal has the best chance to perform to a high level when it enters the herd.
- The genetic-based models developed in this thesis have been developed with the farmer mind, and it is hoped that the adoption and improvement of these models can aid in the management and design of commercial dairy farm systems.

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Appendix

Calculation of feed requirements

Calculation of feed requirements

The efficiency of energy use for maintenance (K_m) = $0.35q_m + 0.503$, the efficiency of energy use for lactation (K_l) = $0.35q_m + 0.420$, the efficiency for growth of the conceptus (K_c) = 0.133 , the efficiency of energy use for growth in lactating ruminants (K_g) = $K_l * 0.95$, , and the efficiency of the use of mobilised body reserves for lactation (K_i) = 0.84 , q_m = ME/Gross Energy (GE) of feed. An average energy concentration of feed of 11 MJME/kg DM has been assumed.

A generalised equation for the **total metabolisable energy requirements or intake** (MEI) of dairy cattle as proposed by (AFRC 1993).

$$\text{MEI (MJME/day)} = C_L \{ M_m + M_l + M_c + M_g \} \quad (1)$$

where C_L = correction factor, M_m , M_l , M_c , and M_g , represent energy requirements for maintenance, lactation, pregnancy, live weight gain, respectively, as defined below:

Maintenance component (M_m) has been calculated using:

$$M_m = (F_m + A_c)/k_m \quad (2)$$

Where F_m = Fasting Metabolism and A_c = Activity allowance

Agnew & Yan (2000), in reviewing 42 recent studies, found the equations of NRC (2000) and AFRC (1993) underestimated the fasting metabolism (F_m) of high genetic merit cows by 20-30%. From the summary of these studies, a value for F_m requirements of $0.40 \text{ Lwt}^{0.75}$ has been adopted, which is 25% higher than the value proposed by AFRC (1993). In addition, an activity allowance (A_c) of 0.016 Lwt has been used, assuming a cow walking 3km daily and grazing pasture (Lopez-Villalobos, 1998).

Lactation component (E_l)

Energy value of milk (EV_l) is calculated using:

$$EV_l = 0.0376F\% + 0.0209P\% + 0.976 \quad (3)$$

where: $F\%$ is fat concentration and $P\%$ is protein concentration, g/kg.

The energy required for lactation, M_l , is then calculated from:

$$M_l = (\text{MJ/day}) = Y (EV_l)/k_l \quad (4)$$

where Y is the yield of milk in kg/day

The pregnancy component (M_c)

The total energy retention at time t (E_t , MJ), in the gravid foetus in cattle, assuming a 40 kg calf birthweight is:

$$\text{Log}_{10}(E_t) = 151.665 - 151.64e^{-0.0000576t} \quad (5)$$

where t is days from conception

The daily energy retention (E_c) can then be calculated from:

$$E_c = 0.025W_c(E_t \times 0.0201e^{-0.0000576t}) \quad (6)$$

where E_t in MJ is calculated as in equation (5), and W_c = calf birthweight = $(Lwt^{0.73} - 28.89)/2.064$ (Roy, 1980)

The energy requirements for pregnancy (M_c) are then calculated using:

$$M_c = E_c/k_c \quad (7)$$

The energy retained in the body per kg of bodyweight gain (M_g) is calculated using:

$$M_g = E_g/k_g \quad (8)$$

Where $E_g = 19 \text{ MJ/kg Lwt}$ (AFRC, 1993)

The dietary energy spared per kg of bodyweight lost (M_{g-l}) by lactating animals is calculated using:

$$M_{g-l} = E_{g-l}/k_l \quad (9)$$

Where $E_{g-l} = E_g/k_l$

At high levels of feeding increased rumen outflow leads to an overestimation of the ME available when a constant ME concentration is assumed. A correction factor (C_L) has been added to account for increased rumen outflow, as recommended by AFRC (1993):

$$C_L = 1 + 0.018(L - 1) \quad (10)$$

where L is calculated energy intake in multiples of maintenance

Assumptions in Chapter 4

- For dry animals in equation (2), a fasting metabolism (F_m) value of $0.36 \text{ Lwt}^{0.75}$ has been adopted (Agnew and Yan, 2000).
- A cow loses and gains one condition score throughout the year. One condition score is equivalent to 40 kg in a mature Holstein-Friesian of 530 kg Lwt (Holmes *et al.*, 2002; Livestock Improvement, 2001). Hence, Lwt equivalent of one condition score in other animals = $40 \times (\text{Lwt}/530)$. M_g in equation (1) is replaced with $(M_g - M_{g-1})$ to calculate the energy requirements for one condition score change throughout the year.
- Lactation length assumed to be 260 days.

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