Productive and reproductive efficiency of two Holstein Friesian lines of cows which differ genetically for live weight

Daniel Laborde

1998

Productive and reproductive efficiency of two Holstein Friesian lines of cows which differ genetically for live weight

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

of

Master of Applied Science in Animal Science

Massey University

Daniel Laborde

1998

Abstract

Two lines of Holstein Friesian cows which differ genetically for live weight, the Light Line (LL) and the Heavy Line (HL), have been selected at the Dairy Cattle Research Unit (Massey University) since 1989. The aim of the current experiment was to compare the productive and reproductive performance of these two lines during early lactation. Measurements of milk production, liveweight (LW), and pasture intake were made in 1996, while reproductive data were analysed for 1992 to 1997.

In experiment 1a, the milk production of the two lines was compared during the first 12 weeks of the lactation by the weekly measurement of the milk yield and the milk composition of 30 LL cows (average LW= 412 kg) and 27 HL cows (average LW= 445 kg), with the two groups of cows fed and managed identically. Pasture dry matter intake (DMI), calculated as pasture disappearance, was 13 to 15 kg DM a day during these 12 weeks. Although the HL produced slightly more milksolids (MS) than the LL, the difference was not significant (LL= 139 vs HL= 141 kg MS). However, the HL cows > 2 year old produced 7 kg MS more than the LL cows > 2 year old ($P<0.05$). The LW and body condition score (BCS) changes in cows after calving were similar for both lines, but in the heifers the LL lost 17 kg of LW during the first 5 weeks of lactation compared to the HL that maintained their LW ($P<0.05$). Similarly, the BCS of the LL was lower than that of the HL at 40 days postcalving (LL= 4.17 vs HL= 4.43, $P<0.05$) mainly due to the BCS lost by the LL heifers.

In experiment 1b, the DMI and the dry matter digestibility (both estimated using the alkanes technique) of 21 LL cows (406 kg) and 21 HL cows (482 kg), grazing at a pasture allowance of 40 to 45 kg DM/cow/day, was measured in a ten days trial. The grazing behaviour of the two lines was also recorded during 2 days. Although the LL cows ate slightly less DM (LL= 14.3 vs HL= 15.1 kg DM/cow) and had a slightly higher MS conversion efficiency than the HL cows (LL= 120 HL= 110 g MS/kg DM eaten), the differences were not significant. When DMI was regressed on $LW^{0.75}$ and MS yield, the effect of $LW^{0.75}$ only approached significance ($P<0.1$), but the effect of MS was highly significant ($P<0.001$). The two lines had similar DMD (LL= 77.8% vs HL= 78.0%), gross energy conversion efficiency (LL= 44.6% vs HL= 42.3%) and net energy conversion efficiency (LL= 64.8% vs HL= 64.6 %). The bite size of the HL cows (estimated from the grazing time, biting rate and DMI) was heavier than that of the LL cows (LL= 0.46 vs HL= 0.60 g DM/bite, $P<0.01$), but the LL cows compensated for their lighter bite size by increasing the number of bites per minutes (LL= 55 HL= 50 bites/minute, $P<0.05$).

The reproductive performance of the two lines was compared for the period from 1992 to 1997, and the interval Calving-Ovulation was estimated from the concentration of progesterone in milk in 1996 and 1997. The HL cows had shorter calving-ovulation intervals than the LL cows (LL= 32 vs HL= 28 days, $P<0.05$), but the difference in calving-first heat interval was not significant (LL= 43 vs HL= 50 days). Compared to the LL cows >2 year old, the HL cows > 2 year old tended to calve and to conceive later in the calving and mating periods, respectively, because the HL cows had a lower conception rate at first service than the LL cows (LL= 70% vs HL= 58%, $P<0.05$).

The ovaries of 10 cows from each line (LL= 405 vs kg HL= 481 kg) were scanned daily during a complete cycle before the start of mating. Cows from the HL had preovulatory follicles with larger diameter (LL= 12.7 vs HL= 15.7 mm, $P<0.05$) and corpus lutea with larger areas (LL= 690 vs HL= 859 mm^2, $P< 0.05$) than the LL cows. No differences were detected in the diameter of the first and second dominant follicles. On average, the preovulatory follicles of the HL cows achieved their maximum diameter later in the cycle compared to the LL (LL= day 18th vs HL= day 20th).

The results from the current experiment show that although the HL produced slightly more MS than the LL in the longer period, the two lines of cows achieved similar levels of MS yield during early lactation independently of their LW and size. Similarly, although the LL cows had a slightly higher MS conversion efficiency than the HL cows, the differences in energy and MS conversion efficiency between the two lines were not significant. The reproductive data analysed from 1992 to 1997 suggest that the LL cows achieved a better reproductive performance than the HL cows because of their higher conception rate at first service. However, more information is required from other stages of the lactation before any definite conclusion is reached about the feed conversion efficiency of the two lines. Similarly, considering the variation in the reproductive performance of the HL between the years, reproductive data from subsequent seasons must be collected in order to verify, or disprove, the current conclusions.

Acknowledgments.

I am most grateful to my supervisor, Dr C. W. Holmes, for his helpful advice throughout the studies. I really enjoyed his teaching style, common sense, and his approach to the scientific research. He was not only a very good supervisor, but a great person as well.

To my wife Bettina, my main supporter and my principal technician. Thanks for all your love and sorry for all the work.

To my parents, my brother, my sister and the rest of my family for all their support and understanding through faxes and phone calls.

To José Garcia and Nicolás Lopez, we shared discussions and opinions which I hope had made some positive contributions for all of us.

To the staff of the Dairy Cattle Research Unit: Martin Chesterfield, Sandra Dean and Jeff Purchas for their kindness and assistance while carrying out the experiment. I enjoyed working with them.

To : Dr Jeff Wichtel, Professor John Hodgson, Dr Keith Macmillan, Gavin Wilson, Keith Henderson, Dr Scott McDougall and Nigel Perkins who have given their time to discuss ideas, experiments and/or commented on drafts of materials.

To Phil Pearce, and the staff of the Nutrition Laboratory for their help with the analysis of all the samples.

My gratitude to the New Zealand Government for providing the scholarship which made it possible for me to study at Massey University.

On a more personal note I would like to thank : Professor Warren Parker, Nicola Shadbolt, Perry Matthews, Cory Matthew and Ian Brookes. I will remember their lectures. Grant and Barbara Boyden, Keith and Dorothy Dixon, Alistair MacDonald, the staff of the Dairy Farm N° 1, and to many other farmers whom allowed me to work and learn from their farm knowledge. To Tato, Marcela, Amy and Alana, to Vicki D, my mates from the glorious Brown Owl Soccer team and all the other latinoamerican students which made me feel closer to Uruguay.

All these people, in one way or the other, made my studies in New Zealand one of my most wonderful and unforgettable experiences.

TABLE OF CONTENTS.

CHAPTER TWO 34

CHAPTER THREE 43

List of Tables and Figures

Chapter One

INTRODUCTION

The suspected relationship between size of the cows and efficiency of milk production has been the topic of many studies done in the last 50 years (Brody, 1945; Mason,1957; Yerex *et al*, 1988; Holmes *et al*, 1993; Hansen *et al*, 1998). Scientists have approached this subject in two different ways: indirectly, comparing the milk production efficiency between breeds which differ in size (Blake and Custodio, 1986; Gibson, 1986; Oldenbroek, 1988; Ahlborn and Bryant, 1992), or directly, assessing the conversion efficiency of dairy cows from the same breeds, but with different size (Stakelum and Connolly, 1987; Yerex *et al*, 1988; Holmes *et al*, 1993). They attempted to find out the direction in which the size of the dairy cows has to go in order to make the systems more efficient and profitable (Robertson, 1973). However, the conclusions have been controversial (Morris and Wilton, 1976). One constraint was that efficiency ,in economic or biological terms, is not easy to define or to measure (Spedding, 1988; Holmes, 1988; Ostergaard *et al*, 1990). In addition, it is possible that the question about the "ideal" size of the cows does not have only one answer (Robertson, 1973; Holmes, 1973), it could change according to the production system in which the cows are producing (Taylor, 1973; Oldenbroek , 1988).

Milk production in New Zealand is defined as a low input pastoral system (Holmes, 1990; Bryant, 1982). It is based on a high pasture utilisation which is achieved using the appropriate stocking rate under a seasonal system of milk production (Holmes and Macmillan, 1982; Holmes, 1990). A direct consequence of using high stocking rate and maximal pasture utilisation is that each cow of the herd has available a limited amount of the pasture produced in a year, meaning that dry matter intake of the cows is constrained by pasture allowances (Poppi *et al*, 1987; Holmes, 1988). Under this scenario, because of the maintenance costs, size of the cows was identified as a component affecting the final efficiency of the dairy systems in New Zealand (Ahlborn and Dempfle, 1992; Holmes *et al*, 1993). In fact, liveweight of the cows is now given a negative weight in the final selection index of the cows in the new overall objective of increased $ of milk solids produced per tonne of DM eaten (New Animal Evaluation System, LIC, 1996). The objective was to select dairy cows in a more appropriate direction for the New Zealand conditions of production, taking into account that heavier cows have to produce more to be as efficient as a light cow (Holmes *et al*, 1993).

However, because of the existence of genetic correlation, other characteristics may be affected when selecting for or against size of the cows. For instance, some geneticists have expressed some concern about the possible negative effects that selecting against live weight may have on intake capacity and body condition score of the high genetic merit cows. It has also been reported that genetically heavy cows required more service to conceive than light cows (Hansen *et al*, 1998). There are only a few genetic studies designed to evaluate the effect of genetic differences in the LW of cows from the same breed on the efficiency of the dairy systems. In Minnesota, an experiment with 2 lines of Holstein cows which differ genetically for live weight has been running for over 30 years (Hansen *et al*, 1998), but the conditions of production are completely different to those in New Zealand. No experiment has been designed to compare in practice the efficiency of dairy cows within the same breed which differ genetically for live weight under grazing conditions. The Light (LL) and Heavy (HL) genetic lines of Holstein-Friesian cows developed at the Dairy Cattle Research Unit (DCRU, Massey University) is the first attempt to study this subject which has an especial significance for the New Zealand conditions of production. The present experiment was designed to compare the dry matter intake, milk production , feed conversion efficiency, grazing behaviour and reproductive performance during early lactation of the HL and LL lines of cows.

LITERATURE REVIEW

1.1)The concept of Efficiency of a system.

Biological efficiency.

Efficiency is one of the key factors in the success and survival of dairy farms (Holmes, 1996). A general and simple definition of Biological Efficiency (Eff) was given by Spedding (1971):

- **Eff = Production / Resources** (1).

Although very broad , an important concept that arises from the equation is the necessity of clearly identify the resources available and the main biological components included when assessing the efficiency of production systems. Pastoral systems are even more complex than the "pure" production systems (Spedding, 1988; Hodgson, 1990) because in addition to the main processes of feeding, growth, development, reproduction and secreting (Spedding,1971), it is necessary to include the key processes of pasture growth and pasture senescence which explain the biological efficiency of pasture production and utilisation (Holmes, 1990; Hodgson, 1990). All these processes are interrelated in a way that makes difficult to predict the final outcome of any change, and this is why, sometimes, a change which can be considered an improvement in an isolated component does not bring any effect in the final efficiency of the system as a whole (Spedding, 1988).

Economic Efficiency of the production systems.

However, as milk production is an economic activity, it is probably more important to consider efficiency of the systems in economic terms than in biological terms (Holmes, 1996), which can be done including financial costs and returns in the equation 1 (Spedding, 1988). Obviously, as prices of input and output change between countries , the production systems also change according to them, because a system which can be biologically and economically very efficient in one country can be unprofitable in another. In fact, production systems must be adapted to the local costs and returns because although maximum profitability is not always the main goal of farmers, it has to be at least at a level to ensure the business does not go into liquidation (Shadbolt, 1997).

To illustrate this concept, an average milk production system in Pennsylvania is compared to one in New Zealand in Table 1.1. As can be seen, because cows consume much more feed in Pennsylvania than in New Zealand, the former ones achieve much higher milk production per lactation. On the other hand, the New Zealand farmer has to milk more cows per farm and per labour unit to achieve at least the same total surplus as a dairy farmer in Pennsylvania. On a per cow basis, the dairy farms in Pennsylvania are biologically and economically much more productive than dairy farms in New Zealand. At first glance, the low input New Zealand dairy system seems to be very inefficient when none of its economic constraints is taken into account. However, the price per kg MS received by farmers and the cost per kg of grain in each country should be compared before taking any final conclusion. For instance, if the USA system was used with the New Zealand milk price, then the system would lose money. There is no doubt that price of the milk and cost of grain are the main reasons for explaining the logic of using high or low input systems in one case and the other.

This example reinforces the need to identify clearly the resources available in the development of any productive activity when assessing its productivity (Spedding, 1988; Ostergaard *et al*, 1990), and confirms the necessity to describe the main features of the milk production in New Zealand in order to assess its final efficiency. This is the aim of the next paragraphs. No reference will be made to the Dairy Industry components of the system, because it is outside the objectives of this literature review. However, the structure of the industry also explain an important percentage of the success of the New Zealand Dairy industry in the international market.

Table 1.1*Comparison of an average dairy farm in New Zealand and Pennsylvania (USA) in 1989 (adapted from Muller, 1993).*

Parameter	New Zealand	Pennsylvania
Farm Area (ha)	74	109
Herd Size (cows)	157	62
Labour (people)	1.5	2.3
Average Body Weight (kg)	400-450	600
MS production (kg/cow)	254	449
MS production (kg/per farm)	39878	27838
Feed Consumed (kg DM/cow)	4000-4500	7038
Grain Consumed (kg DM/cow)	0	3089
Days in milk	237	305
Price ($/kg Milkfat)	6.00	13.50
Price of grain ($/tone)	350-500	150-200
Total income ($/cow)	1050	3903
Total expenses ($/cow)	423	2543
Surplus ($/cow)	627	1360

1.2) Brief description of the main characteristics of New Zealand milk production systems.

With grass representing between 80-90% of the feed eaten by the cows, dairy production in New Zealand is defined as a pastoral dairy system (Holmes, 1987). There are two main reasons that explain why grass is the basis of dairy production in New Zealand. Firstly, the soil fertility and climate allow to achieve high productions of pasture per hectare and to graze all throughout the year. Secondly, as shown in Table 1.2, although it can be argued about the low or high biological efficiency of the pastoral systems, they were demonstrated to be the alternative of production with the highest sustainable profitability in an scenario where milk price received by farmers depends extremely on the volatile international market prices (Penno and Clark, 1997; Deane, 1993). In a situation where 90% of the milk is exported, the low cost of production is one of the strengths that New Zealand dairy sector has to maintain in order to compete successfully in the international market of milk products (Andersen, 1997).

Table 1.2 ***Summary of the productive and economic response to the use of different types and amounts of supplements in the 8 farmlet trial carried out at the Dairy Research Corporation (adapted from Penno and Clark, 1997)***

Farmlet	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Cows/ha	3.34	3.34	3.34	4.42	4.42	4.42	4.42	4.42
N (kg/ha)	0	200	400	200	400	200	200	200
Supplement(kgDM/cow)								
Silage	0	209	254	101	78	204	1325	612
Grain	0	0	0	0	0	1238	0	484
Balancer	0	0	0	0	0	0	0	338
Silage harvested	0	268	491	0	65	0	0	71
Production								
Milksolid (kg/ha)	1086	1244	1313	1211	1297	1792	1640	1783
Milksolid (kg/cow)	325	373	394	275	294	406	371	404
Days in milk	263	277	286	221	226	281	280	281
EFS ($ /ha)	1842	1989	1861	1575	1598	658	1606	549

As a direct consequence of being a pastoral system, over 90% of the dairy farms in New Zealand are seasonal. Matching maximum cow requirements to maximum pasture growth rates is one of the ways to maximise pasture utilisation and production of milk at low cost (Holmes and Macmillan, 1982). However, as a consequence of the seasonality, dairy farmers in New Zealand do not have the flexibility that other dairy farmers do have in other parts of the world. To maintain the feasibility and profitability of the system, one of the main targets is to have a concentrated calving spread which is based on achieving a short and very efficient mating period (Macmillan *et al*, 1990).

High pasture utilisation is a key factor of the dairy production in New Zealand. Maximum pasture utilisation was showed to be positively associated to increased profitability (Deane, 1993; Howse and Leslie, 1997). As pasture utilisation is in direct relationship to the stocking rate of the farm (Table 1.3), there is also a positive correlation between high profitability and stocking rate (Deane, 1993; Howse and Leslie, 1997). However, high stocking rate means that each cow will have less pasture available each year (Table 1.3), and therefore DMI, and consequently MS production per cow can be compromised in some periods of the season. A good definition of the management of a grazing dairy herd was given by Holmes and Macmillan (1982). They said that it is " The manipulation of the herd feed requirements and amount of feed available, in an effort to optimise the extent to which the requirements of both stock and pasture are satisfied throughout the year". This concept represents a notable difference from those dairy systems where cows are fed according to their requirements, a difference that must be considered when assessing the efficiency of a pastoral dairy system.

Table 1.3. ***Data from 3 years experiment with High Breeding Index Jersey cows managed in similar conditions but at different stocking rate (adapted from Bryant ,1985; cited by Holmes and Parker, 1992)***

Cows /ha	**2.75**	**3.26**	**3.75**	**4.28**
Pasture eaten (approx)				
Tonnes DM/year/cow	3.9	3.7	3.5	3.2
Tonnes DM/year/ha	10.8	11.9	13	13.9
Days in Milk	284	265	260	247
MS produced (kg/cow)	359	328	300	269
MS produced (kg/ha)	991	1069	1128	1152
Efficiency (T DM eaten /ha) / (T DM grown/ha)	0.68	0.77	0.81	0.87

Relatively low MS production per cow and short lactation compared to the international standards are characteristics of the dairy production in New Zealand (Table 1.4). They are a consequence of the seasonality of the dairy production, its reliance on pasture and the relatively high stocking rate. In recent years, the use of extra-feed has been studied as an alternative to have longer lactation and to increase milksolid production per cow and per hectare (Penno *et al*, 1996; Pinares and Holmes 1996; Mac Callum *et al*,1995). Although the economic profitability of these options is extremely dependent on the cost of supplements, on the response obtained in terms of kg MS/kg DM eaten and on the price received per kg MS, some interesting responses to the use of supplement were reported in the last third of the lactation (Penno and Thomson, 1995; Pinares and Holmes 1996). However, it seems that the profitable use of supplements in New Zealand will be mainly confined to their strategic use, and there is no doubt that pasture will continue to provide 80-90% of the diet of the cows.

Trials developed at Massey and Ruakura in the 80´s showed clearly the importance of genetic merit of the cows under grazing conditions in order to improve the efficiency of conversion from feed to milk (Holmes *et al*, 1985; Bryant, 1983). Farmers, scientists and the Livestock Improvement Corporation (LIC) have been developing an important role in the significant improvement of the genetic merit of the New Zealand herd. Over 90% of the dairy farmers use semen from genetically superior sires to artificially breed their cows. The same percentage carry out herd tests every two months (LIC, 1995). Both tools have had a tremendous impact in the genetic improvement. Comparing an average dairy cow in 1955 to one in 1995, it was estimated that 50% of the productive improvement was due to the increase in genetic merit (Holmes, 1995). Furthermore, recent international comparisons showed that, when treated under the same conditions, New Zealand dairy cows have the genetic potential to perform at a similar level to dairy cows from other countries (Peterson, 1988; Graham *et al*, 1991). In 1996, a New Animal Evaluation System was launched in New Zealand. The main focus was on breeding profitable and efficient dairy cows, evaluating them according to their milk fat and protein yield, liveweight and survival (LIC, 1996). Another important feature of the evaluation system is the possibility to compare cows from different breeds which is crucial in New Zealand due to the diversity of breeds and the high percentage of crossbred cows (Table 1.4). The development of selection objectives according to the particular characteristics of their dairy system has been another feature of genetic improvement in New Zealand.

Table 1.4 ***Percentage of cows per breed, and herd test average per breed of the total cows herd tested in New Zealand in 1994 (these data correspond to the total of the cows herd tested in this year, LIC, 1994).***

Breed	%	Days in Milk	Milk (Lt)	Milkfat (kg)	Protein (kg)	Milkfat (%)	Protein (%)
Holstein-Friesian	58	219	3,812	170.1	133.0	4.49	3.50
Jersey	21	224	2,848	167.3	120.2	5.89	4.23
HF x J CrossBred	19	222	3,567	177.7	133.9	5.02	3.77
Ayrshire	2	225	3,552	156.3	127.7	4.41	3.60

The manager plays a crucial role in the efficiency of the systems (Parker, 1996). It is who does the planning, takes decisions and controls the dairy system. Around 70 % of the dairy managers are at the same time owner of the farms. Another 25% are sharemilkers, and most of them own the herd and share risks and profitability with the owner of the land (LIC, 1995). It means that over 90% of the managers have a direct interest in the profitability and performance of the farm. Although it is difficult to estimate the effect of this factor on the final efficiency of the system, there is no doubt that its contribution is high. It probably helps to explain the outstanding increase in the labour efficiency (n° cows milked/ labour unit) occurred in the last 15 years (LIC, 1995) and the excellent reproductive and health performance of the herds compared to other countries (Macmillan, 1997) where the manager receives a salary for his job. However new problems will appear in the near future, and the challenge in New Zealand is not only to find solutions, they have to be based on the premise " to keep it simple".

1.3) Energy conversion efficiency in a dairy cow.

The efficiency of a dairy cow is influenced by multiple factors (Korver, 1988). Ideally, all the inputs and outputs should be included in the measurement of efficiency (Ostergaard *et al*, 1990), and they should be evaluated in the short term (1 lactation as the minimum) or preferentially, over the full productive life of an animal (Spedding, 1988). According to this concept, the most recently developed evaluation systems aim to select the dairy cows including in the selection index many of the factors that contribute to the final biological and financial efficiency (LIC,1996; Veerkamp *et al*, 1995; Visscher *et al*, 1994; Groen *et al*, 1997).

However, probably because of the major effect that total feed has on milk yield and costs in a dairy farm , the definition of milk production efficiency is usually reduced to the concept of feed conversion efficiency (Blake and Custodio, 1984; Holmes, 1988; Groen *et al*, 1997). In general terms, feed conversion efficiency considers some of the milk traits (eg. milk volume, milksolid yield) as the output, and some measure of intake as the input (eg. dry matter, energy, protein). Taking into account the main role of the energy (E), those equations that define feed conversion efficiency in energy terms are those that are most suitable for the different situations.

Johansson (1964) defined Energy Conversion Efficiency (ECE) as:

- Gross E Efficiency = Total E in milk / E Intake. (Johansson, 1964). (2)

However, equation (2) does not take into account the energy associated with the fluctuations in body tissue gain and loss, which have been found as the main explanations for the increased efficiency of the high genetic merit cows (Custodio *et al*, 1983; Holmes, 1988; Mayne and Gordon, 1995). This is why a more appropriate equation for describing ECE of the cows is :

- ECE : $\frac{\text{(Total E in Milk - E in Body Tissue losses or Gain)}}{\text{(E Intake)}}$ (Blake and Custodio, 1984). (3)

The equation (3) indicates that energy efficiency in a per cow basis is the rate of converting dietary nutrients to milk after adjustment for : nutrients supplied by catabolism or nutrients used to recover body tissues (Blake and Custodio, 1984). In other words, according to equation (3), energy efficiency depends on the amount of energy left for milk solid production. The later can be theoretically derived from the sum of dry matter intake times the digestibility coefficient, plus the tissue available for catabolism times the rate of catabolism, minus the energy used for maintenance and pregnancy requirements. It means that energy efficiency will be influenced by diet factors (those that affect DMI and digestibility) and cow factors (mainly genetic merit, physiological state of the cow and LW of the cows).

Cows Factors that affect Energy Conversion Efficiency.

High genetic merit cows (HGM) can be used as a model to study the different factors affecting the ECE of the dairy cows. In fact, it is widely recognised that HGM cows produce more milk , fat and protein than low genetic merit (LGM) dairy cows (Custodio *et al*, 1983; Gibson, 1986; Bryant, 1985; Holmes *et al*, 1985; Fulkerson, *et al* 1997), and that HGM cows are more efficient converters of feed into milk under feedlot conditions (Gibson, 1986) and under grazing conditions (Bryant, 1983; Grainger *et al*, 1981). However, why HGM are more efficient is a live issue.

Looking at equation (3) , in theory, the increase in ECE in a per cow basis could result if cows : were able to increase utilisation of the diet, were able to catabolise and replete more efficiently body tissues (Blake and Custodio, 1984; Bauman *et al*, 1985) or presented less maintenance requirements (Holmes, 1995; Wickhman et al, 1992). However, HGM cows show neither different digestive efficiency (Custodio *et al*, 1983; Grieve *et al*, 1976; Davey *et al*, 1983; Mayne and Gordon, 1995) nor increased ability to metabolise the gross energy (Grainger *et al*, 1985; Trigg and Parr, 1981) compared to LGM cows. It would be expected that HGM cows would utilise energy more efficiently to produce milk (net partial efficiency; k_l) than LGM cows, but again no significant differences were detected for this variable between cows with contrasting genetic merit (Trigg and Parr, 1981). In agreement with above results, although the question was not directly investigated by Moe (1981), he found that 97% of the variation in energy balance between cows was explained by the variation in ME intake, diet and metabolic size. In other words, little of the variation could have been explained by differences in ME utilisation among animals.

Maintenance requirements, when expressed per $kg^{0.75}$, are apparently not affected by genetic merit (Parr and Bryant, 1982; Grainger *et al*, 1985). Van Es (cited by Bauman *et al*, 1985) indicated that the among animal coefficient of variation in maintenance requirements varied between 5 to 10%, once they were adjusted to a common liveweight. It has been reported that maintenance requirement does not only depend on metabolic LW, for instance, they are increased at high milk yield (Taylor *et al*, 1986) which would reduce the ECE of the HGM cows. However, it is accepted that these differences, if they exist, are minor (Taylor *et al*, 1981; AFRC, 1993).

Nutrient partitioning and energy intake are the major reasons for explaining the difference in milk production between HGM and LGM cows (Moe, 1981; Bauman *et al*, 1985), and are important sources of variations in gross energy utilisation during at least some part of the lactation (Veerkamp *et al*, 1994; Veerkamp and Emmans, 1995). HGM cows lose more liveweight during the lactation, and they finished with lower body condition score at drying off compared with LGM cows (Grainger *et al*, 1985; Veerkamp et al, 1994; Fulkerson *et al*, 1997). They are predisposed to mobilise body tissues in order to maintain milk production in these situations where feed intake is a constraint (for physiological or external reasons). For instance, the use of body fat reserves in the first third of the lactation is one adaptation of major importance showed by the dairy cows after hundreds of years of selection. Selection for milk has probably been operating at the level of hormones, receptors and enzymes responsible for the nutrient partitioning and the milk secretion (Blake and Custodio, 1984; Bauman *et al*, 1985). In other words, it seems that the linear increment of apparent energy efficiency showed by HGM dairy cows is by tissue catabolism (Custodio *et al*, 1983).

However, the energy and protein mobilised in this way has to be replaced later, which represents a decrease in the total efficiency of the process (Holmes, 1988). A variation in gross efficiency in part of the lactation might diminish when considered over a whole series of lactation and dry periods (Veerkamp and Emmans, 1995). However, the partial efficiency of depositing energy in body reserves during late lactation and then mobilising them for milk production in early lactation is only marginally less efficient than producing milk directly from feed (Moe, 1971; NRC, 1989; AFRC, 1993). But, in grazing systems, long lactation and good body conditions score at drying off are two targets difficult to achieve at the same time in practice (Pinares and Holmes, 1996), which means that most of the reserves for the next season are deposited in the dry period. In this case, the overall efficiency of the process is reduced significantly.

Although the cause or effect basis of the relationship between dry matter intake and milk production has been discussed for years, it is widely recognised the fact that HGM cows eat more than LGM cows (Gibson, 1986; Holmes, 1988; Veerkamp *et al*, 1994), and that there is substantial genetic variation in intake that explains part of the variation in feed efficiency (Veerkamp and Emman, 1995). Positive genetic correlations (0.56-0.86) were reported between DMI and milk yield during the lactation (Hooven, 1972; Persaud et al, 1991), which indicates that regulation of feed intake is directly coupled to nutrient partitioning and nutrient requirements for milk synthesis. However, it has been reported that the increased DMI showed by the HGM cows satisfied only about 40 to 45% of the increased requirements (Holmes, 1995; Van Arendonk *et al*, 1995; Veerkamp *et al*, 1994). In addition, Gravert (1985) found that the correlation was much lower during the first part of the lactation (0.12), suggesting that selection on milk yield would not automatically increase DMI in early lactation. Both reasons seems to suggest that nutrient partitioning is the main reason for explaining the increased energy conversion efficiency of the HGM cows (Blake and Custodio, 1984; Bauman *et al*, 1985), a fact that brings advantages and disadvantages. Although, in economic terms, the most efficient cows would be those eating the least and producing the most, selecting the cows based only on this criteria would increase the risks of metabolic and reproductive problems which would bring serious consequences in the survival of HGM cows in the future (Van Arendonk et al, 1995)

From this short review it can be perceived that the milk yield-tissue balance-appetite complex is a key determinant of the increased milk production in HGM cows. Holmes (1988) concluded that the increase in Energy Conversion Efficiency in HGM cows is due to the increased yield, little change in liveweight and increased liveweight losses or decreased liveweight gain during lactation, which means genetic variation in partitioning the energy eaten between liveweight gain or milk production. However, the increase in Energy Conversion Efficiency is smaller than the corresponding increase in yield because of the consequent increase in feed intake, and the no evidence of change in digestive or metabolic efficiency (Holmes, 1988).

Milk yield and Energy Conversion Efficiency.

Many authors found high and positive phenotypic and genetic correlations between milk trait yields and gross energy conversion efficiency (Table 1.5). Reviewing the literature, Blake and Custodio (1984) found a range of 0.88 to 0.95, and 0.60 to 0.95 for the genetic and phenotypic correlations, respectively. However, the validity of correlations based on "part-whole relationship", such as milk yield and feed efficiency, was put in doubt by Kennedy (1984) and Holmes (1988). In addition, other authors warned that these high values were inflated because of the experimental procedures (Gravert, 1985; Holmes, 1988; Ostergaard *et al*, 1990) where cows were fed with grain according to milk yield in most of the early experiments where these correlations were calculated (Korver, 1988; Holmes, 1988; Blake and Custodio, 1984). In these situations, the increase in efficiency would reflect the dilution in maintenance costs, and consequently every increase in milk yield would lead to increased food conversion efficiency in animals of a similar size (Korver, 1988; Ostergaard *et al*, 1990).

Feeding cows *ad-libitum*, Grieve (1976) and Custodio *et al* (1983) reported also a high phenotypic correlation (0.75 and 0.84, respectively) between milk yield and energy conversion efficiency. However, the fact that the nutrient contribution from tissue catabolism was not considered was suggested by Blake and Custodio (1984) as an important reasons for the positive and high correlation reported. The higher phenotypic and genetic correlation between milk yield and gross energy efficiency in early than in late lactation seems to back up this suggestion (Persaud *et al*, 1991; Van Elzakken and Van Arendonk, 1993). If the tissue subsidy is taken into account, the correlation between milk yield and energy efficiency has to be lower than the results reported in Table 1.5 (Blake and Custodio, 1984; Gravert, 1985).

Table 1.5. ***Phenotypic and genetic correlation between measures of feed conversion efficiency and milk yield.***

Authors	**Phenotypic Correlation**	**Genetic Correlation**	**Details of the experiment**
Mason *et al* (1957)	0.84	0.91	FCM
Syrstad (1966)	0.95	0.82	FCM for 4 years old
Hooven *et al* (1972)	0.82	0.93	
Lamb *et al* (1977)		0.95	
Custodio *et al* (1983)	0.75-0.58		
Sieber *et al* (1988)	0.63		FCM
Persaud *et al* (1991)	0.61-0.52	0.80-0.85	Milk yield from cows and heifers

Feed Conversion Efficiency.

The possibility to select the dairy cows directly by feed efficiency has been considered several times (Blake and Custodio, 1984; Persaud *et al*, 1991). Feed efficiency has a heritability of 0.25 to 0.35, and has enough additive genetic variation, meaning that although not tested experimentally, genetic progress in feed efficiency could be achieved by direct selection (Blake and Custodio, 1984; Kennedy, 1984; Korver, 1988; Van Arendonk *et al*, 1995). Freeman (1975) pointed out that by selecting for milk yield, efficiency is increased automatically. This indirect selection was estimated to account for 70-95% of the efficiency of direct selection for feed efficiency when selection intensities are equal for the two traits. Persaud *et al* (1991), using the genetic parameters estimated in his trial for the correlation between milk yield and feed efficiency (0.61-0.52), reported that by selecting only for milk yield, the expected correlated responses in efficiency were expected to be 74 and 47% for the 26 and 38 weeks of lactation period, respectively. Based on his results, he suggested that in MOET nucleus schemes, where it is possible to measure feed intake, it was worthwhile to consider direct selection for efficiency.

Taking into account the difficulties of measuring efficiency for a long period in a large number of cows, most workers agreed that the value of selection on feed conversion efficiency in addition to milk yield is limited (Korver, 1988; Ostergaard *et al*, 1990; Holmes, 1988; Kennedy *et al*, 1993). The relative efficiency of selection using measurements of feed intake and feed conversion efficiency during short periods was investigated as an alternative . The general conclusions were that due to the different heritability and correlation values obtained for these two characteristics in different periods of the lactation, at least two short periods of measurement (several weeks apart) were required in order to obtain relatively high efficiency of selection (Hooven *et al*,1972; Van Elzakken and Van Arendonk ,1993; Gibson, 1987) with the measurements taken near mid-lactation (after the peak) giving the best predictions (Gibson, 1987). However, under grazing conditions, direct selection by feed conversion efficiency is impossible at the present time due to economic and technical constraints in the measurement of herbage intake by grazing cows.

Residual Feed Intake (RFI).

Residual feed intake (RFI) has been suggested as an alternative parameter to measure net feed efficiency (Korver, 1988; Van Arendonk *et al*, 1995). It measures the energy intake adjusted for the energy requirements predicted from energy requirement for maintenance (related to $LW^{0.75}$) , for body weight change and for milk production (Van Arendonk *et al*, 1991). Therefore , conversely to gross feed efficiency, selection for residual feed intake is not likely to cause undesired correlated responses in production and body weight (Blake and Custodio, 1984; Veerkamp *et al*, 1995).

However, estimating this parameter, it is important to emphasis three important limitations : the energy requirements are calculated by phenotype partial regression using the equations for partial efficiencies (K_m , K_l and K_f) obtained from the AFRC (1993) that can change for each individual cow, live weight change is not a very exact indicator of changes in body reserves due to the variation in rumen , gut fill and body composition (Veerkamp *et al*, 1995; Van Arendonk *et al*, 1995), and finally, it is necessary to measure feed intake with all the difficulties that it implies (especially under grazing conditions). In fact, a certain amount of the RFI value estimated can be due to the cumulative error in measuring DMI. In addition, the reported "phenotypic heritability for RFI" range from 0.14-0.32 (Kennedy *et al*, 1993; Van Arendonk *et al*; 1991; Veerkamp *et al*, 1995), but the genetic heritability for RFI was reported to be close to zero (Veerkamp *et al*, 1995; Kennedy *et al*, 1993) and some authors did not find evidences of any genetic variation in RFI after correcting for yield, maintenance and LW change (Svendensen *et al*, 1993).

Although more information is required before deciding to include RFI in the selection indexes (Kennedy *et al*, 1993; Veerkamp *et al*, 1995), it was used successfully to compare the feed efficiency between group of cows with high (selected cows) or low (control cows) genetic potential at Langhill (Veerkamp *et al*, 1994). The most efficient cows (lower RFI) were the selected cows, and specially the selected cows fed with a low concentrate diet (Veerkamp *et al*, 1994). These results indicate that this characteristics can be used to compare the feed efficiency of group of cows treated in the same conditions and where the potential sources of errors are the same.

Relationship between milk yield and body size.

Linzell (1972), in an analysis of 15 different species, found logarithmic regression values for daily milk yield, daily milk energy and mammary gland weight with body weight across breeds and species. This data showed that milk yield and energy were both related to $LW^{0.75}$, and confirmed Brody´s data (1945), that indicated a positive correlation between metabolic live weight and peak daily yield. The same rule can be applied in a within species comparison when the different breeds are managed in the same conditions (Taylor, 1973). He found that daily milk yields ,at or near the peak, were correlated to the metabolic liveweight of the breeds considered in his study. Breed differences in body weight accounted for about two third of the variation in daily yield.

However, the reported applicability of these rules between species and breeds does not guarantee that they will apply also at the within breed level. Table 1.6 and 1.7 summarise some of the results obtained about the phenotypic and genotypic correlations between the traits milk yield and body size of Holstein-Friesian cows. In most of the cases, size was measured mainly as liveweight immediately post-calving. As can be seen, although the range of phenotypic correlation values is large (-0.34 to 0.7), due to differences in management, age of the cows and in corrections factors used in the experiments (Morris and Wilton, 1976), most of the papers reviewed showed a moderate and positive phenotypic correlation between liveweight at calving and milk trait yields during the lactation (Table 1.6 and 1.7). These results indicate that yields of milk and milk solid increase slightly with the increase in liveweight of the cows at calving. This relationship is expected because of the positive effect of body condition score and LW of the cows at calving on milk production (Grainger *et al*, 1982; Rogers *et al*, 1979), the increase in reserve tissues available to increase the rate of catabolism of the heavy cows compared to the light cows (Bauman *et al*, 1985; Blake and Custodio, 1984) and the higher intake capacity of the heavier cows (Holmes, 1974; Stakelum and Connolly, 1987).

The data for genetic correlations between yield of milk traits and liveweight are even more variable than the phenotypic ones. Most of them are low and within a range that goes from slightly positive values to slightly negative ones (Table 1.6 and 1.7). Several authors indicated that the genetic correlation between these two traits changes during the lactation period, being positive in early lactation and negative in mid lactation (Persaud *et al*, 1991; Van Elzakker and Van Arendonk, 1993). These results indicate, as expected, that heavier cows produce more milk in the first weeks of lactation, and that heavier cows after the peak produce less milk. They reflect the difference between cows in the allocation of energy to liveweight gain or production (Bauman *et al*, 1985).

Table 1.6 ***Phenotypic and genetic correlations between liveweight (as a measure of cow size) and milk yield production in Holstein-Friesian cows.***

Authors	Phenotypic	Genetic	Details of measurements
Mason *et al* (1957)	Positive	-0.07	FCM
Syrstad (1966)	-0.03	-0.13	Size measured by heart girth.
Hooven *et al* (1968)	0.44	0.30	FCM
Lin *et al* (1984)	0.72	0.76	
Sieber *et al* (1988)	0.2		BW at 30 days post-calving.
Moore *et al* (1991)	0.11	-0.22	
Persaud *et al* (1991)	-0.20 to -0.35	-0.31 to -0.33	Correlation at 20 and 36 weeks
Van Arendonk *et al* (1991)	0.02	0.04	Whole lactation (305 days).
Lee *et al* (1992)	0.15	-0.01	
Ahlborn and Dempfle (1992)	0.2	0.39	LW estimated using a score scale.
Svendsen *et al* (1994)	0.35 to 0.11	0.7-0.63	Correlation at different stages
Hietanen and Ojala (1995)	0.23	-0.01 to 0.28	Milk yield
Jensen et al (1995)		0.18	
Veerkamp *et al* (1995)		-0.1	Metabolic LW
Van der Waaij *et al* (1997)	0.38	0.32	LW at 21 month

Svendsen *et al* (1994) found that the genetic correlations between body weight and fat corrected milk yield were significantly higher in cows fed with roughage diets (0.7-0.3) than with cows eating high concentrate diets (0.13 to -0.24). Ahlborn and Dempfle (1992) and van der Waaij et al (1997) also reported high genetic correlations between the two variables under grazing conditions. These results suggested that some genes must be affecting variation in milk as well as in body size (Albhorn and Dempfle, 1992) which indicated that selecting in favour of any of the yield traits will results in larger cows with increased growth and maintenance costs. However, they also meant that there was enough flexibility for selecting in favour of milk traits and against body weight without a substantial negative effect on the genetic progress in yield traits (Albhorn and Dempfle, 1992). These results plus the reported negative economic values for body weight (Dempfle, 1986; Van Raden, 1988) were the main reasons to include body weight as weighing negatively in the selection index of the New Animal Evaluation System (LIC, 1996). According to this selection index, the average LW of the dairy cows in New Zealand would be decreased by around 3-4 kg of LW after 20 years of selection (Spelman and Garrick, 1997).

Table 1.7 ***Phenotypic and genetic correlations between liveweight (as a measure of cow size) and milkfat and protein production in Holstein-Friesian cows.***

Authors	**Phenotypic**		**Genetic**	
	Fat Yield	**Protein yield**	**Fat Yield**	**Protein yield**
Lin *et al* (1984)	0.60	0.60	0.84	0.48
Sieber *et al*(1988)	0.24			
Moore *et al* (1991)	0.12	0.14	-0.27	-0.18
Persaud *et al* (1991)*	-0.17 to-0.34	-0.17 to-0.34	-0.31 to -0.22	-0.31 to -0.22
Ahlborn and Dempfle (1992)	0.24	0.18	0.34	0.37
Hietanen and Ojala (1995)	0.19 to 0.31	0.22 to 0.33	-0.06 to 0.02	0.04 to 0.09
Van der Waaij *et al* (1997)	0.16	0.24	0.3	0.34

* The values are for Fat+ Protein at 26 to 38 week lactation period.

Relationship between size and milk production efficiency of dairy cows.

The results presented in the previous section indicated a slightly positive phenotypic relationship between size of the cows and milk yield. They suggested that large and heavy cows had the tendency to produce slightly more milk and milksolid yield than small and light ones. However, are the large cows more efficient producers of milk than the small ones ?

Table 1.8 summarises the results from trials where the phenotypic and genetic correlations between size of the cows and milk production efficiency was assessed. It can be seen that although the range of values is large, the tendency is for a negative correlation between size and feed conversion efficiency . Again, the variability of the values reported probably responded to the peculiar characteristics of each experiment (Morris and Wilton, 1976). Persaud *et al* (1991) suggested that including LW in the selection criteria was likely to increase the accuracy of selection for efficiency to 90% compared to 60% with selection based on yield alone.

The results in Table 1.8 seem to confirm those obtained by Yerex *et al* (1988) in a trial designed specifically to estimate the effect of genetic differences in size on milk production and feed conversion efficiency. After two generations of breeding in favour or against size, on a complete lactation basis, no difference was detected in milk production, but the small cows were 2.3% more efficient than the large ones. The two lines of cows differed in LW by 50.8 kg, in height by 5.6 cm and in length by 6.4 cm.

Table 1.8 ***Summary of the results obtained about phenotypic and genetic correlation between size and feed conversion efficiency in dairy cows.***

Authors	**Phenotypic**	**Genetic**	**Details of measurements**
Mason *et al* (1957)		-0.33	FCM
Hooven *et al* (1968)	-0.04	-0.12	FCM, and age adjusted records
Syrstad (1966)	-0.34	-0.67	FCM
Dickinson (1969)	-0.27		Heifers only
Sieber *et al* (1988)	-0.33		
Van Arendonk *et al* (1991)	- 0.40	-0.93	FCM at 105 days lactation
Persaud *et al* (1991)	-0.50	-0.82	FCM

Holmes *et al* (1993) reported that at a common milk yield, small cows showed a higher feed conversion efficiency than heavy cows (Table 1.9). Those results confirmed theoretical estimations made by Holmes (1973) and Taylor (1973) based on the widely accepted concept that large cows have increased energy maintenance requirements (NRC,1989; SCA,1990; AFRC,1993). Furthermore, the differences in efficiency between large and small cows tended to be greater at low milk production levels, because maintenance requirements represent a greater percentage of the total requirements in these cows (Stakelum and Connolly, 1987). Milk production and maintenance are the most important determinants of the energy requirements of the dairy cows , with energy maintenance representing at least 56% of the energy intake over the period from birth to 4th lactation (Korver, 1988). These results seems to emphasise the importance of cow size in those dairy systems (as in New Zealand) where maintenance requirements represent at least 50% of the annual requirements of a cow (Dempfle, 1986; Wickhman *et al*, 1992)

Table 1.9 ***Values for feed intake and for feed conversion efficiencies for cows of different weights but adjusted to a common value of 78 MJ milk energy produced per day (adapted from Holmes et al, 1993).***

Liveweight (kg)	Feed Intake (kg DM/day)	Feed Conversion Efficiency (kg protein/tonne DM eaten)
350	16.5	49
450	18.5	44
550	20.0	41

1.4) Feed Intake of dairy cows.

The feed intake of cows is a crucial topic in any dairy production system. For instance, it has been suggested that even when pasture allowance is not a limit, low energy intake is the most important limitation to the ability of pasture diets to maximise individual milk yield (Ulyatt and Waghorn, 1993; Tamminga and Van Vuuren, 1995). The results reported by Kolver *et al* (1996) where cows offered a high allowance of pasture produced 13 kg milk less than cows fed with total mixed ration (TMR) seems to confirm this statement, with 60-70% % of the difference explained by the increased DMI and energy density of the TMR compared to the grass diet. On the other hand, the increase in feed intake capacity of the cows is also a priority in those countries where high amounts of supplements is used (Groen *et al*, 1997; Van Arendonk *et al*, 1995). An increase in feed intake capacity would allow them not only to increase production, but to use larger quantities of the cheaper fibrous feed as a response to the continuous reduction in milk price (Muller, 1993; Van Arendonk *et al*, 1995; Tamminga and Van Vuuren, 1995).

Considering that the genetic merit of the cows is increasing at a rate of 1 to 2% per year, the interest for increasing feed intake capacity of the dairy cows is even greater when thinking into the future (Korver, 1988; Oldham, 1995; Veerkamp *et al*; 1994). Although HGM cows under grazing or indoor conditions had increased DMI (Holmes *et al*, 1985; Veerkamp *et al*, 1994; Fulkerson et al; 1997), this increment satisfies only about 40 to 45% of their increased requirements during lactation (Holmes, 1995; Van Arendonk *et al*, 1995; Veerkamp *et al*, 1994). Recent results reported by Veerkamp *et al* (1994) showed that when feed on a high forage diet, high genetic animals were not capable of eating much more than control line animals. Furthermore, the genetic correlation between milk production and energy intake in early lactation was found to be low to moderate (Gravert, 1985; Korver, 1988). All this information indicates that the gap between energy required and the energy taken in the form of feed represents the amount of fat that the cows need to mobilise (Blake and Custodio, 1984; Bauman *et al*, 1985; Veerkamps *et al*, 1994), and in a HGM cow that situation can represent extra metabolic load with potential negative effects on health, reproduction and welfare (Grosshans *et al*, 1996; Macmillan *et al* , 1996; Oldham, 1995).

Under this scenario, the relative merit of the selection for body size achieves even a greater importance. In fact, body size influences the intake capacity (Bines, 1976; Forbes, 1995) and the maintenance requirements of the dairy cows (SCA, 1990). The economic weight of feed intake capacity and LW are in opposing directions, but they are correlated positively (Groen and Korver, 1989) which means that the route to follow in the selection of body size will depend on which one (feed intake capacity or maintenance requirements) would reduce more rapidly (Oldham, 1995; Wickhman *et al*, 1992). The objective of the next section is to review briefly the main factors affecting intake of the dairy cows, making special reference to the effect of the body size on feed intake capacity of the dairy cows and the intake per bite. Finally, the potential consequences of selecting in favour or against LW will be discussed, based on the reported correlations between these two characteristics.

Main factors affecting feed intake of the grazing dairy cows.

Feed intake is a very broad and complex topic due to the multiple variables influencing on it (see reviews by Bines, 1976; Freer, 1981; Forbes, 1996). The complexity is even greater under grazing conditions because, in addition to the animal and plant components, the plant-animal interface is introduced in the equation (Poppi *et al*, 1987; Hodgson; 1990). Laca and Demment (1996) suggested that the mechanisms regulating feed intake are different according to the temporal and spatial scale considered. Over the long time scale, DMI is related to the requirements of the animal (maintenance, production and pregnancy), with the capacity of the ruminant for using energy being the driver of the feed intake (Weston, 1996). On a daily scale, intake is limited by the digestion/passage process, by the gut fill and chemical signals, by the available grazing time and by the rate of intake during active grazing (Ungar, 1996). On an even shorter time scale (minutes or hours), consumption rate is limited by the spatial and morphological properties of the sward (Hodgson, 1985; Black 1990) and by the cropping and mastication capabilities of the animals (Shipley *et al*, 1994; Illius and Gordon, 1989).

The three components of herbage intake.

Daily Herbage Intake was modelled by Allden and Whittaker (1970) as the product between:

Grazing time (GT, minutes/day) X Intake per bite (IB, g DM/bite) X Biting rate (bites/minute).

Sward characteristics have major impact on herbage intake (Allden and Whittaker, 1970; Glassey *et al*, 1980; Hodgson, 1985; Holmes, 1987; Black, 1990; Laca *et al*, 1992). Herbage intake is increased by herbage allowance (Glassey *et al*, 1980; Bryant, 1980; Stockdale *et al*, 1985; Peyraud *et al*, 1996), increased pasture height (Le Du *et al*, 1979; Hodgson, 1985; Laca *et al*, 1992) and increased percentage of leaves or green material in the sward (Chacon and Stobbs, 1976; Forbes, 1988). In general, the relationship between herbage intake and those different characteristics of the sward is curvilinear meaning that each increment in pasture allowance or pasture height results in a successively smaller increment in herbage intake (Poppi *et al*, 1987).

Intake per bite.

From the 3 components of herbage intake, IB is the one affected the most by sward characteristics (Hodgson, 1985; Forbes, 1988; Black and Kenney, 1984; Laca *et al*, 1992), and consequently is the main determinant of herbage intake (Hodgson, 1990). Burlison *et al* (1991) described IB using two equations:

IB = BV (Bite Volume) X Bulk Density of herbage in Grazed Strata.
BV = Bite Depth (BD) X Bite Area (BA) .
where:

- BA is measured as the total area of plant structural units grazed to any extent divided by the number of bites taken (Ungar, 1996).
- BD is defined as a the vertical distance between the sward surface and the cut ends of defoliated leaves and stems (Hodgson *et al*, 1994).

Although the range of bite weights measured by different authors is very wide (Table 1.10), assuming an average grazing time of 520 minutes (Hodgson, 1990) and an average biting rate of 55 bites/minutes (Macgilloway and Mayne, 1996), average bite weights have to be between 0.63 to 0.7 g DM/ bite in order to maximise herbage intake per cow (18-20 kg DM/day). Although most of the values reported in Table 1.10 are above 0.63-0.7 g DM/bite, sward conditions have to be the ideal ones for achieving this bite weight as an average of 24 hours (Holmes, 1987; Hodgson, 1990; Peyraud *et al*, 1996).

Table 1.10 ***Range of bite weights measured by different authors..***

Author	Breed	Bite weight (g DM/bite)
Stobbs (1974)	Jersey	0.31-0.71
Dine (1991)	Friesian	1.7-1.1
Dine (1991)	Jersey	1.5-0.9
Fitzsimons (cited byMcGilloway and Mayne, 1996)	British Friesian	0.42-0.81
McGilloway and Mayne (1996)	British Friesian	0.39-1.19

Effect of Sward Height and Sward density on intake per bite.

Sward height has been reported to be the sward characteristic most closely correlated to bite weight (Black and Kenney, 1984; Burlison *et al*, 1991; Laca *et al*, 1992; McGilloway and Mayne, 1996) mainly because its effect on BD (Laca *et al*, 1992; Dine, 1991; Black and Kenney, 1984). Several researchers reported BD as the component that showed the largest variation in association with the sward characteristics , and as the main determinant of bite weight (Laca *et al*, 1992, Black and Kenney, 1984). Ruminants are able to harvest a constant proportion of the sward height (Wade *et al*, 1989; Burlison *et al*, 1991; Laca *et al*, 1992). Grazing dairy cows were able to remove 34% of sward heights that ranged between 120-385 mm (Wade *et al*, 1989), thus the bite depth increased exponentially with the increase in sward height (Wade *et al*, 1989), and bite weight increased linearly (McGilloway and Mayne, 1996). That explained why cows harvested 0.5-0.8 kg DM/hour in a sward height of 80 mm compared to 3.0-3.5 kg DM/hour in a sward height of 180mm (McGilloway and Mayne, 1996).

Results about the effect of bulk density on bite weight have been less conclusive. Some authors found that density affected bite depth and bite area negatively (Black, 1990; Laca *et al*, 1992). According to them, ruminants grazing at the same herbage mass would have a higher bite weight in a sparse sward than in a dense one (Laca *et al*, 1992). This conclusion would depend on how sparse is the sward, and probably does not apply for tall and very sparse swards. Conversely, McGilloway and Mayne (1996) found that independently from sward height, bite weight and DMI were higher at increased sward density.

Grazing Time and Biting Rate.

Biting rate and grazing time have traditionally been observed as secondary components of the daily herbage intake (Hodgson *et al*, 1994). They are recognised as compensatory mechanisms that ruminants use when energy requirements are increased (Arnold, 1981) or bite weight is reduced because the sward is short (Hodgson, 1990; Chacon and Stobbs, 1976). This compensatory role explains the very broad range of grazing times (420-700 min/day) reported for dairy cows in the literature (McGilloway and Mayne, 1996). For instance, grazing time of HGM cows increased by 12 min/kg milk between 20 to 35 kg of milk (Journet, cited by Demment et al, 1995), and that cows on a sward height of 5 cm grazed for longer than cows on a sward height of 15 to 20 cm (Gibb *et al*, 1996; Pulido and Leaver, 1996). However, cows have to ruminate, and consequently when IB reduction is significant, this compensation will not always be complete, and herbage intake is reduced (Hodgson, 1990).

Recent mechanistic studies about jaw movements generated valuable information about biting rate (Ungar, 1996). It seems that biting rate depends significantly on the time required to form and to process each bite which is directly associated to the bite weight (Ungar, 1996). In tall swards, heavier bite weights are expected and consequently biting rate tends to decrease (Gibb *et al*, 1996). Despite the reduction in biting rate, rate of intake (IB*BR) is increased in tall swards because of the increased bite weight (Gibb *et al*, 1996). Conversely, in short swards, ruminants tend to bite faster, but this increase in biting rate will not completely compensate the diminished intake per bite (Ungar, 1996). Similarly, it is possible that animals with increased requirements can bite faster as a compensatory mechanism. Mayne *et al* (1996) reported increased bite rate of the HGM cows compared to medium genetic merit cows. However, the recorded biting rates ranged between 45-65 bites/minutes (Chacon and Stobb, 1976; Hodgson, 1990), and there are maximum values that can not be overcome, meaning that biting rate also has a limit as a compensation mechanism.

Effect of the size of the ruminant on the intake per bite.

A strong and positive relationship was found when maximum bite size of 12 different species of herbivores was regressed on the average body weight of the species, with maximum bite size scaled with $LW^{0.73}$ (Shipley *et al*, 1994). Considering that body weight is positively related to food intake, this close association is to be expected (Illius and Gordon, 1989). Similar positive relationship was found within the most common domestic species with a general trend characterised by a decrease in grazing time and biting rate, and an increase in bite size, as the size and age of the animals increased (Zoby and Holmes, 1983; Hodgson and Wilkinson, 1967; Brumby, 1959).

It was reported that maximum eating rate of growing cattle fed indoor (r_{max} = KJ metabolizable energy per minute) at given body weight (W kg) can be predicted in normally growing cattle when adult body weight (A kg) is known, by the formula $r_{max} = 31\ u^{0.86}\ A^{0.73}$ where u = W/A (Taylor and Murray, 1987). According to this formula, heavier animals would have a higher eating rate than light and small ones. Although the differences were small, Erlinger *et al* (1990) observed that bite size and grazing time increased with mature LW size (Table 1.11). However, they used the weigh-graze - weight technique to measure DMI, and estimated bite size from biting rate and DMI. All these techniques are not precise, and probably the bite size obtained included the cumulative errors of these measurements.

Table 1.11 ***Three year means for the effect of mature size and rate of maturity on bite size (mg/bite), grazing time (min/day) and biting rate (bite/min) in 16 month-old heifers grazing bermudagrass (adapted from Erlinger et al, 1990).***

	Group 1 (LW :387 kg)	Group 2 (LW: 413 kg)	Group 3 (LW: 468 kg)	Group 4 (LW.589 kg)
Bite size (mg/bite)	528	625	547	637
Grazing Time (min/day)	400	432	452	471
Biting Rate (bites/min)	37	35	38	37

Taylor and Murray (1987) reported a positive relationship between maximum intake rate and incisor breadth of sheep and beef maintained in indoor conditions. The increase in bite weight as the animal increases in size or becomes mature could be explained by the increase of the incisor arcade scaled on body weight (Illius and Gordon, 1989; Taylor and Murray, 1987). Firstly, they regressed incisor breath of 32 grazing ruminants species on their respective species average body weights (Gordon and Illius, 1987) obtaining the following equation:

- Incisor Breadth (mm) = $8.6\ W^{0.36}$

When this predictive formula was tested using independent data, the corresponding predictions were very close to the values measured in sheep and cattle (Ungar, 1996). Secondly, working with cattle grazing at different herbage allowances, Illius and Gordon (1989) found that bite weight was allometrically related to body weight by the following equation :

- Bite Weight = $3.27\ u^{0.46\ (\pm 0.157)}\ A^{0.73}$ (mg OM) (r^2 :51%)

where u represents maturity of weight (current weight/adult weight) and A represents adult or mature weight (kg). However, these results should be accepted cautiously because they were derived from estimated DMI of the animals (using chromium), biting rate and grazing time. Again, all these technique have a reasonably large coefficient of variation (Hodgson, 1982), and so the authors accumulated all errors into their estimates of bite size. Furthermore, the r^2 of the regression indicates that only 50 % of the variation in bite size is explained by variation in body weight. In contrast, Penning *et al* (1991) found that bite size and intake rate per minute were related to mean LW of individual sheep, but width of the dental arcade was related neither to LW nor to any of the ingestive behaviour. It is also possible that larger animals could have larger bite size because :

- heavier animals have greater strength to sever more tillers per bite and they have a shorter chewing time, less jaw movements and consequently reduced processing time per bite (Shipley *et al*, 1994).
- heavier animals can swallow larger particles (Ulyatt *et al*, 1986).

Furthermore, although some animals have larger incisor breadth this does not mean that they will always have larger bite weight. For instance :

- in short swards , large animals would have greater restrictions in bite dimensions (Illius and Gordon, 1989).
- animals may choose to consume smaller bites in order to chew more efficiently.
- some animals can overcome the constraint of mouth size by sweeping up vegetation with the tongue (Hodgson, 1985).
- bite size can be regulated by the trade off between quality and size of the bites (Hodgson, 1985).

Ingestive Capacity as a regulator of feed intake.

There is considerable evidence to suggest that even when bulky forages are given *ad-libitum*, ruminants do not eat to their potential intake (Bines, 1976; Freer, 1981; Kolver *et al*, 1996) because rumen capacity is a major limiting factor with these feeds (Anil *et al*, 1993; Dado and Allen, 1995; Ulyatt and Waghorn, 1993; Faverdin *et al*, 1995). However, there is a considerable debate if it is capacity of the rumen or DM weight in the rumen which limits voluntary feed intake (Mertens, 1994; Illius and Allen, 1994), because even when distension of the rumen limit voluntary intake, there is additional capacity of digesta (Dado and Allen, 1995). At the present, it is more accepted that the DM weight in the rumen is the principal factor controlling intake when forage is offered *ad-libitum* (Tamminga and Van Vuuren, 1995; Ulyatt *et al*, 1986), and that retention time is the most important factor in predicted intake and digestibility (Demment and Van Soest, 1985).

DM present in the rumen depends on the rate at which plant particles are cleared from the rumen (Illius and Allen, 1994; Tamminga and Van Vuuren, 1995; Ulyatt and Waghorn, 1993) which is the sum of size reduction during ruminating and eating (Ulyatt *et al*; 1986), microbial degradation (Wilson *et al*, 1989), increase of the specific gravity of the forage (Tamminga and Van Vuuren, 1995), and passage (Minson, 1990; Ulyatt *et al*, 1986). These 4 steps that prevent feed particles from leaving the rumen are mainly related to characteristics of the forage (Ulyatt *et al*, 1986; Minson, 1990; Tamminga and Van Vuuren, 1995), especially to the percentage of epidermis and vascular structures in the anatomy of the plant (Wilson, 1996). However, it should also exist animal components influencing the passage rate that explains, for instance, the increased flow rate of particles at increased DM intake. Ruminating time in dairy cows decreases at increased DMI (Allen, 1996; Hodgson, 1990), and so to explain the increased clearance rate observed, or it is accepted that the ruminating efficiency is increased or greater ruminal particles pass through the reticulum-omasum orifice (Van Soest, 1994).

The low DM % of the pasture diets has also been pointed out as another reason of the relatively low DMI potential of the grazing cows (Ulyatt and Waghorn, 1993). A dairy cow consuming 15 kg of DM at 18 % of DM, represents a simultaneous intake of 68 kg of waters. Most of the water in pasture is intracellular increasing the bulk capacity of the fresh forage, and restricting DMI for these reason (Anil *et al*, 1993, John and Ulyatt, 1987). Comparing fresh to dried forage, a decrease in VFI by 0,33 kg/DM per each point bellow 18% DM was reported by Verité (1970).

Size of the animal and ingestive capacity.

The gut capacity of mammalian herbivores, which determines the capacity to process food into nutrients, increases linearly with body weight (Demment and Van Soest, 1985; Van Soest, 1994). On the other hand, metabolic rate, as a determinant of the metabolic requirements, increases with weight at a decreasing rate (AFRC, 1993).Consequently, if the metabolic rate and gut size are curvilinearly and linearly related to body weight, respectively, it means that the small animals have higher ratios of metabolic rate to processing capacity than large animals (Van Soest, 1994). In agreement with this results, Purser and Moire (1966) working with ewes with a LW range between 61.8 to 75.5 kg and fed with low quality hay, reported positive correlation between sheep weight and physiological rumen volume, between physiological rumen volume and physical capacity of the rumen, and between ad-lib intakes and physiological rumen volume. In addition all the requirement systems and especially the SCA (1990) and the INRA (Jarrige, 1986) systems predict the potential intake capacity of the ruminants based on their mature live weight.

The retention time of the particles in the rumen has been scaled to body weight to the 0.25 power (Illius and Gordon, 1991) and mathematically modelled by Demment and Van Soest (1985) as :

- Retention Time = $0.589 * D * W^{0.28}$ where D is digestibility and W is body weight.

These formulations state that retention time will be shorter for smaller than larger ruminants when fed the same diet, and so increasing body size should produce higher digestibility because of longer retention times. On the same diet, the digestibility of the roughage is higher in the cow than on the sheep which has been correlated with longer retention time of the particles in the rumino-reticulum (Demment and Van Soest, 1985). All this information indicates that larger ruminants are less constrained by digestive capacity than small ruminants which is a very important concept when the objective is the extraction of energy from cellulose (Van Soest, 1994).

However, there are three main reasons why this statement should be taken with caution. Firstly, the larger body size also increases the total amount of energy required for maintenance and locomotion per unit distance (Demment and Van Soest, 1985). Secondly, most of the studies that showed a positive effect of ingestive capacity on feed intake were done using forage with a digestibility of 50-70% (Conrad *et al*, 1964; Van Soest, 1994) , and probably the results do not apply to temperate grasses with an average digestibility between 65%-85% (Ulyatt, 1981; Wilson *et al*, 1995). It was suggested that capacity limited feed intake of feed with a digestibility below 67% (Conrad *et al*,1964), and the reasons why dairy cows stop eating highly digestible pasture before achieving their maximum potential are not clear (Ulyatt and Waghorn, 1993). Thirdly, most of the relationship between size and different digestive parameters were taken comparing different species of ruminants characterised by contrasting sizes (Demment and Van Soest, 1985; Oldenbroek, 1988). The rules may not be the same when comparing ruminants within the same breed but of different size. For instance, in the developement of their model, Illius and Gordon (1991) scaled the time taken to reduce the size, the retention time and the rate of passage of the particles in the rumen with $LW^{0.27}$. This approach was successfull in interespecific comparison (Illius and Gordon, 1991), but apparently was not successful within species variation in LW (Illius and Allen, 1994). In addition, it has been reported that there can be considerable variation in the physical capacity of the rumen between cows within the same weight (Paloheimo, cited by Purser and Moir, 1966), and that the limitation of body size appears to have its greatest effect on retention in animal with an average LW < 100 kg (Van Soest, 1994). In addition, small rumen volumes tend to contain higher percentages of dry matter (Purser and Moir, 1966), which can explain why models that assume a standard digesta load in the rumen as a fraction of the body weight (measure of the size of a cow) have not been very successful in their predictions of DMI (Mertens, 1994; Illius and Allen, 1994), and why DMI of the small cows as a percentage of LW has been found to be consistently higher than these of the heavy cows (Mackle *et al*, 1996; Oldenbroek, 1988; Donker *et al*, 1983).

All these factors seem to indicate that load capacity is a dynamic variable that changes with physiological state of the animals, production level and type of food (Forbes, 1996). It is possible, that for voluntary intake, quite different exponents are appropriate in different circumstances, depending on whether comparisons were made between animals of different species, animals of different mature size within species or animals within the same specie and the same mature size (Freer, 1981). Besides, the exact level at which the rumen load will limit intake is not known (Weston, 1996), and it is frequently used as a regulator of intake because of the lack of knowledge about the effects of other variables (Illius and Allen, 1994).

Metabolic Control of the feed intake.

Forbes (1995) suggested that : " even though we must incorporate physical factors into any attempt to provide a global explanation of how food intake is controlled, probably we have been overemphasising the importance of physical fill as a limit of the feed intake" For high quality pasture, factors other than rumen NDF will limit voluntary feed intake (Van Soest, 1994; Tamminga and Van Vuuren, 1995). Volatile fatty acids (VFA) have been always suggested as a metabolic signal of satiety in ruminants (Forbes, 1994) acting additively with distension effect (Anil et al, 1993). Acetate infused into the rumen at 2mmol/min depressed intake by 12%, a balloon inflated in the rumen reduced intake by 18%, both together reduced intake by 50% (Forbes, 1996). In addition, the low pH level and high NH_3 levels in blood have been suggested as a cause of low DMI (Forbes, 1995), and both variables are present in cows grazing high quality pastures (Van Vuuren *et al*, 1993; Kolver *et al*, 1996: Carruthers *et al*, 1996). A more accepted concept at the present is that the higher the degradation of the pasture, the higher the accumulation of VFA, the lower the pH level and the higher the osmotic pressure in the rumen (Tamminga and Van Vuuren, 1995). All these factors have been associated to DMI of the cows and their different feed back signals (fill unit, metabolic, etc) will be integrated to prevent DMI (Faverdin *et al*, 1995; Forbes, 1996). The importance of these factors in the long-term control of DM intake is doubtful according to Weston (1996), but they are important in the regulation of the daily meal pattern (Forbes,1995).

State of the animals as the long term factor regulating intake.

Energy requirement is the main factor involved in the regulation of the DMI of the cow (Jarrige *et al*, 1986; Faverdin *et al*, 1995; Weston, 1996). The increase in DMI in response to the increase in milk solid production is a clear illustration. Lactating dairy cows had a greater weight of digesta in the rumen than dry dairy cows, even when feed with medium quality diet that would have limited physically their intake (Faverdin et al, 1995). The high producers can tolerate higher levels of rumen distension because they absorb and utilise VFA faster than low producer cows (Forbes, 1994) which added to the increased rate of passage displayed (Tamminga and Van Vuuren, 1995) explain why they eat more than the low producers.

Cows calving in poor body condition score showed an increased DMI after calving compared to cows in good condition, under grazing and indoor conditions (Grainger *et al*, 1982; Garnsworthy, 1988; Mackle *et al*; 1996). It means that undernutrition which is synonymous with negative energy balance induces a higher motivation to eat. However, in early lactation , dairy cows show a restricted intake in spite of the deep negative energy balance, which is probably explained by the high mobilisation of feed reserves that occurs in this period of the lactation (Bauman *et al*, 1985).

The importance that the energy requirements have as a determinant of feed intake indicates that the Central Nervous system (CNS) receives feed back signals of the energy balance of the cow (Faverdin *et al*, 1995) in addition to the physical and metabolic indicators (Forbes, 1994). However, how all these information is processed is far from being understood : "the complexity of DMI regulation of the ruminants doomed to failure any attempt to predict intake from few parameters characterising the plants and the animals" (Forbes, 1996).

Genetic correlation between size of the cows and feed intake of different selection strategies.

Table 1.12 shows the genetic and phenotypic correlations between body weight of the cows and feed intake from different sources. As expected the genetic correlations were positive, indicating that genetically heavier animals have genetically larger feed intake capacity (Van Arendonk *et al*, 1995), and that intake capacity would be increased by selection in favour of LW (Svendsen *et al*, 1994). In addition, the phenotypic and genetic correlations between roughage intake and body weight were higher in early than in mid and late lactation possibly because roughage intake is limited by intake capacity immediately after calving and more limited by energy requirements later (Svendsen *et al*, 1994). However, although in most of these experiments the cows were fed *ad-libitum*, the phenotypic correlations are significantly lower than the genetic ones which indicates the importance of the environmental factors on the feed intake of the cows. Furthermore, this sort of genetic correlation does not take into account that the heavy cows will logically eat more because their requirements are higher , and not only because of the potential intake capacity. For instance, most of the correlations between LW and residual intake (Total Intake-Intake used in maintenance and production) are very small (Table 1.12), which suggests the importance that the long term energy balance has on the feed intake.

Table 1.12 ***Phenotypic and genetic correlations between LW and intake, and LW and residual intake of the dairy cows .***

	Trait	Genetic	Phenotypic
Van Arendonk (1991)	R intake-LW	0.01	0.00
Persaud *et al* (1991)	Intake-LW at 26 weeks	0.34	0.24
Persaud *et al* (1991)	Intake-LW at 38 weeks	0.46	0.11
Van Arendonk (1991)	Intake-LW	0.65	0.35
Van Arendonk (1991)*	Forage Intake-LW	0.55	0.32
Lee *et al* (1992)	Intake-LW 26 weeks	0.44	0.27
Elzakken *et al* (1993)**	Intake-LW in week 13	0.58-1	0.16-0.20
Elzakken *et al* (1993)	Intake-LW in week 2	0.68-0.70	0.34-0.38
Svendensen *et al* (1994)*	Intake-LW during lactation	0.91-0.76	0.7-0.57
Jensen *et al* (1995)	Intake-LW	0.34	
Veerkamp et al (1995)	R intake-LW	0.06	-0.06
Veerkamp and Brothersone (1997)	Intake-LW	0.27-0.37	

*Forage intake.
** The highest values are for energy intake and the lowest for forage intake.

As was discussed before, selecting to improve feed conversion efficiency does not take into account the buffering capacity of body tissue mobilisation (Blake and Custodio, 1984). High and negative genetic correlations (range from -0.29 to -0.46) were found between yield traits and BCS in early lactation (Peyraud *et al*, 1991; Veerkamp *et al*, 1996), and the correlation between feed intake and yield traits is moderate to low in early lactation(Gravert, 1985; Korver, 1988; Moore *et al*, 1990; Svendsen *et al*, 1994). In addition, high genetic correlation (0.6) between BCS and LW was reported by Veerkamp *et al* (1997). Consequently, selecting only for milk yield traits could increase the gap between the rate of progress in yield and the rate of progress in intake capacity (Van Arendonk *et al*, 1995). Consequently the high genetic merit cows will become thinner (Holmes, 1988; Veerkamp *et al*, 1994; Fulkerson *et al*, 1996) which can have potential negative effects on health and reproduction (Butler and Smith, 1989; Grosshans *et al*, 1996).

Taking into account the positive genetic correlation between LW and Feed Intake, between BCS and LW, and the negative correlation between BCS and milk traits in early lactation, some geneticists suggest the dairy cows should be selected in favour of feed intake capacity and live weight with the objective to increase the intake capacity of the cows (Veerkamp, 1995). They say that selecting against size of the cows is the wrong direction to go because BCS would also be reduced along with the intake capacity of the cows. However, maintenance and growing costs will increase under this strategy (Groen and Korver, 1989), and the potential benefits can be lost at the end of the process. In addition, another practical problem is how to estimate intake. As the measure of individual intake and LW is not feasible in their conditions, they are suggesting to predict LW and intake capacity from linear types (Veerkamp and Brotherstone, 1996). The genetic correlation between LW and some traits as stature (0.72) and chest width (0.99) are high, and so good results can be expected. However, the genetic correlations between DMI and these two traits are only moderate (0.20 and 0.32, respectively), which can make difficult to predict the direction of the response. Nevertheless, Veerkamp *et al* (1997) indicated that inclusion of stature, chest width, body depth, angularity and rump width in an index, increased the correlation to 0.65. Conversely, other geneticists suggest that a better understanding of the relationship underlying body weight, milk production and energy intake is required before predicting the consequences of alternative selection strategies (Van Arendonk *et al*, 1995). It is also important to consider that this selection indexes have been thought for countries where, although attemps are being made to reduce the amount of concentrates used, the cows are fully fed during the whole lactation. The current and future scenario surrounding the production system must be considered when assessing the merits of different strategies.

Another approach to increase feed intake and reduce energy deficit in early lactation is to select for increased feed capacity (Van Arendonk *et al*, 1995), and reduced liveweight at the same time (Groen *et al*, 1994). Feed capacity was reported to have a low to moderate heritability that ranged between 0.16-0.44 (Persaud *et al*, 1991; Van Arendonk *et al*, 1991; Veerkamp, 1995), and there is abundant evidence for genetic variability of feed intake capacity (Veerkamp, 1995). Selecting in favour of feed intake and against size, would increase production and intake (Groen and Korver, 1990), and probably this is the right direction to go especially in systems with restricted inputs (Groen and Korver, 1989; Vissher *et al*, 1994; Wickhman *et al*, 1992).

Observed responses in DMI with the increase in size of the cows.

Large size cows show increased intake compared to small cows of the same breed at least when feed ad-libitum (Table 1.13). Most of the data presented in Table 1.13 were obtained by regressing measured DMI on LW and several other variables. However, some of these results should be considered with caution because the authors did not include age , parity (eg: Stakelum and Connolly 1987; Holmes *et al*,1993) nor week of the lactation into the regression. Consequently, the partial regression coefficient for LW would include some of the effects due to age and week of the lactation (Curran and Holmes, 1970). In other cases, such as the regression reported by Curran and Holmes (1970), the r^2 of the equations were relatively low (33%-42%). Nevertheless, the data indicates that the average increase in intake was 1.56 kg of DM for an increase of 100 kg of LW. According to Holmes and Wilson (1987), the extra maintenance requirements caused by an extra 100 kg of LW in the range 400 kg to 600 kg is around 9.5 MJME , or about 0.8 kg DM. In other words, assuming that the energy content of 1 kg DM of pasture is 11 MJ ME, from the increase in intake by 1.5 kg DM/100 kg LW , 0.8 kg of DM will be used for the maintenance of the extra 100 kg of LW. That suggests that increasing the weight of the cow by 100 kg, the net extra intake that would be gained is 0.7 kg of DM (1.5 - 0.8 kg DM).

Table 1.13 ***Results reported in the literature about the increase in DMI (kg DM) of dairy cows by each increase in 100 kg of LW.***

	Coefficient	**Conditions of the trial**
Wallace (1961)*	1.1kg DM/100 kg LW	Grazing
Hutton (1962)*	1.3 kg DM/100 kg LW	Grazing
Holmes and Jones (1964)*	1.34 kg DM/100 kg LW	Grazing
Curran and Holmes (1970)*	2.2-2.4 kg DM/100 kg LW	Grazing and Indoor
Stakelum and Connolly (1987)	1.5 kg DM/100 kg LW	Indoor
Jarrige *et al* (1989)	1.2 kg DM/100 kg LW	Heifers grazing and Indoor
Jarrige *et al* (1989)	0.8 kg DM/100 kg LW	Multiparous grazing and indoor
Holmes *et al* (1993)*	2 kg DM/ 100 kg LW	Grazing and Indoor
Tamminga and Van Vuuren (1995)	1.12 kg DM/100 kg LW	Indoor

* Transformed data.

However, the intake of two lines of cows which differed genetically by size has been compared only in few experiments. The small line of cows (LW= 525 kg) selected at Minnesota ate 0.7 kg DM less than the heavy line (LW= 575 kg) when their feed intake capacity was compared under three different diets (Donker *et al*, 1983). Analysing the results in a similar way as above, in both experiments, the net increase in energy intake was unsignificant when the increment in maintenance requirement of the heavy cows was considered. Interestingly, they also observed that the smaller cows presented a significantly higher DMI/100 kg LW than heavier cows which is in agreement with the results reported by other authors (Mackle *et al*, 1996; Yerex *et al*,1988; Oldenbroek, 1988). Furthermore, similarly to Holmes *et al* (1993), in both experiments, they reported that the differences in DMI were even smaller at higher levels of milk production due to the important effect of milk yield as determinant of feed intake (Stakelum and Connolly, 1987; Donker *et al*, 1983) .

1.5) Main features of the reproduction management in New Zealand dairy farms.

Planned Start of Calving.

In New Zealand, over 90% of the dairy farms are seasonal, and an important decision that dairy farmers must take is the planned start of calving (PSC) (Holmes and Wilson, 1987).It represents the amount of time by which the farmer decides to calve the herd before the peak in spring pasture growth rate, which will affect the percentage of pasture harvested by the cows, the total pasture that would be conserved as silage or hay, the supplement required in early lactation and the average length of the lactation (Bryant and Trigg, 1982; Macmillan and Clayton, 1980). For instance, as the PSC is moved closer to the pasture production peak (late calving date), the probability of underfeeding in early lactation would be reduced. However, a late calving date will imply more pasture conserved at home, less time before pasture quality decrease significantly during the summer, and probably shorter lactation.

It is almost impossible to define an optimum calving date in New Zealand. The average PSC is earlier in the Waikato (15th -25th of July) compared to the South Island (15th-20th of August), a trend that is mostly explained by the different pasture growth rate pattern in the two regions (LIC, 1995). Even in the same regions and with the same pasture growth pattern, several trials indicated that the appropriate PSC will change according to the stocking rate and the supplement used at the farm (McCallum *et al*, 1995; Holmes and Macmillan, 1982). The general concept arising from these results is that an appropriate calving date is the one that does not create a severe feed shortage in early lactation, but that at the same time allows the cows to have the longest lactation.

Calving Pattern.

Depending mostly on the climatic characteristics of the season, on average , cows are milked during 235-240 days (LIC, 1995). Although some farmers are trying to achieve 305 days of lactation length using supplement during autumn, usually the dry off date is not determined directly by the following calving date. It is a decision made keeping one eye on the next milking season and the other in the current body condition score of the cows and the pasture cover in the autumn (Holmes and Wilson, 1987). Most of the herd is dried off at the same time, and so cows that calve late in the season have shorter lactations than the rest of the herd, and generally, their milk production will be lower. Therefore, the achievement of a compact calving pattern in the appropriate moment is probably the main reproductive target for producing milk efficiently in a seasonal dairy farm (Macmillan *et al*, 1990).

This hypothesis was tested using identical twins in 3 trials at Ruakura (Macmillan *et al*, 1984). As was expected , because cows in the group with more concentrated calving date had longer lactation they also had higher levels of production per cow (Table 1.14). However, the average production difference between the groups was established largely in the first half of the lactation before the date from when production began to decline. Interestingly, both groups of cows in each trial declined from essentially the same peak in daily production, which occurred at the same weekly period in November. Although the cows were in different stage of the lactation, the reduction in pasture quality was the main reason for this similar decrease in production between the two group of cows (Macmillan *et al*, 1984).

Table 1.14 ***Effect of calving pattern (concentrate or normal) with the same PSC date in groups of monozygous twins on production difference(a-b) (adapted from Macmillan et al, 1984).***

Trial N°	Difference in Mean calving date (days)	Difference in Lactation length (days)	Difference in Production (kg fat/cow)	Av Peak production (kg /cow/day)
1	8	8	7	0.73
2	12	12	12	0.85
3	16	16	14	0.87

Up to 25% of the cows in a herd may calve during the 6 weeks immediately prior to start of mating (Macmillan *et al*, 1990). Cows calving late in the season will have a short interval between calving and the planned start of mating , which means that they have increased probability to be anoestrus at this moment , and therefore to calve late next season again, to be empty at the end of mating or to be removed from the herd (Harris, 1989). Currently, dairy farmers have the possibility to induce the late calving cows as an aid to reduce calving spread and the ratio of cows culled. Ninety % of dairy farmers are currently inducing in average 10% of the herd (Holmes and Wilson, 1987). However, the future availability of this technique is not clear. It may be banned, taking into account the importance that animal welfare issues are gaining in the international trade market (Macmillan, 1997)

There are different ways to describe the calving pattern of a dairy herd. As the average length of the oestrus cycle in the cows is 21 days, one way is by indicating the percentage of the herd that calves each 21 days after the planned start of calving (PSC). Macmillan *et al* (1990) suggested three intervals to describe the calving spread of a dairy farm. These are :

- The median calving date defined as the interval between PSC and the date when 50% of the herd is calved.
- The period of time between the MCD- to 75% of the herd calved.
- 75%-to- the end of calving .

There are significant variation for the calving pattern between different farms (Macmillan *et al*, 1990), which would be expected to affect the average lactation length, and could explain part of the milk yield differences between herds.

Conception pattern.

The effectiveness of the management in the previous mating period is the main determinant of calving spread (Macmillan *et al*, 1990). As the average gestation length of the New Zealand cows is 282 days (Macmillan, 1974), to maintain an average calving interval of 365 days, and so the feasibility of the system, farmers in New Zealand have 83 days after calving to get their cows in calf. This target depends on the achievement of high submission rates and high pregnancy rates to a single service, both of them are the main factors affecting the conception pattern (Xu and Burton, 1996).

Under a seasonal system of milk production, the intervals between the planned start of mating and the first mating (SMFM), between the planned start of mating and conception (SMCO) , and the % of cows pregnant at 21(P21) and 42 (P42) days of the mating periods were suggested by Grosshans *et al* (1996) as the selection criteria for female fertility and as the indicators to describe the conception pattern of dairy farms. Table 1.15 presents the average values of these 4 indicators in New Zealand, obtained from the analysis of 66294 first and 56923 second lactation of Holstein-Friesian and Jersey cows. An interesting point is the high standard deviation observed in each one of the indicators.

Table 1.15 ***Means and standard deviation for the SMFM, SMCO, P21, P42 and NS (service per conception) in Friesian and Jersey cows in New Zealand (Grosshans et al, 1996).***

	1st lactation				2nd lactation			
	Friesian		Jersey		Friesian		Jersey	
Trait	Average	std	Average	std	Average	std	Average	std
SMFM	18.7	20.2	15.2	16.1	19.4	22.1	14.0	14.9
SMCO	33.3	31.9	29.9	29.8	32.7	31.9	28.0	28.1
PR21	0.46	0.50	0.52	0.49	0.47	0.50	0.54	0.50
PR42	0.73	0.45	0.77	0.42	0.74	0.43	0.79	0.40
NS	1.49	.73	1.51	.74	1.48	.72	1.52	.74

The submission rate after 3 or 4 weeks mating is commonly used to indicate the number of cows detected on heat and inseminated during the first 3 or 4 weeks after the planned start of mating (Macmillan *et al*, 1990). An ideal target to be achieved is 90% of the herd inseminated at least once during the first 3 weeks of AB. The empty rate is used to represent the overall efficiency of AB and natural mating. The average percentage of cows empty after 12 to 16 weeks of mating range between 5-10%, but this figure also has a high standard deviation (Xu and Burton, 1996). Failure to conceive is the second largest cause of removal of cows from New Zealand dairy herds (Harris, 1989).

Multiple factors (eg. AI, management, cows, mineral deficiencies, bull used, infection diseases) can affect the submission rate and the conception rate in a dairy farm (Xu and Burton, 1996; Ferguson, 1991). The main 4 sources of late conception that have been identified in New Zealand: anoestrus, errors in heat detection , fertilisation failure and embryo mortality (Xu and Burton, 1996) will be reviewed briefly in the section that follows.

Postpartum anoestrus.

Following calving, initiation of reproductive function involves a series of physical, endocrine and histological changes that should lead to uterine repair, followed by ovulation and resumption of oestrus cycles , and finally to conception of the cow (Ferguson, 1991). In this context, postpartum anoestrus interval (PPAI) is defined as the period of time following calving before the ovulatory cycles are re-established (McDougall, 1994). However, as oestrus is rarely detected at the first postpartum ovulation, the interval between calving and first detected heat (C-1st H) is probably more useful in practice than the PPAI (McDougall, 1994; Moller, 1970) .

Table 1.16 shows the average PPAI and C-1st H intervals found by researchers in different New Zealand herds. They are longer than those reported overseas (Fonseca *et al*, 1983; Macmillan *et al*, 1996). In fact, with a percentage of anoestrus cows at the planned start of mating which ranges between 10% to 35% for different farms, the postpartum anoestrus is usually indicated as a serious reproductive inefficiency in New Zealand dairy herds (Xu and Burton, 1996; Macmillan, 1995). Anoestrus cows at the start of mating showed a reduced submission rate at 3 weeks post-calving and longer interval SMCO compared to the cycling cows. Consequently, they calved later the following season which may have caused shorter lactations or required induction of calving in these cows (Macmillan, 1995). To identify the anoestrus cows no later than a week before the planned start of mating and to induce their ovarian activity using hormonal treatments has been recommended as the logical strategy to avoid anoestrus cows which will calve late the following season (Macmillan, 1997)

Table 1.16 ***Average post partum anoestrus interval (PPA) and calving-first detected heat interval (C-1st H) reported for 2 years old and mature dairy cows in New Zealand.***

	2 years old		>2 years old	
	PPA (days)	C-1st H (days)	PPA (days)	C-1st H (days)
Burke *et al* (1996)	50.8	62		
McDougall (1995)	40.2	47.1	30.3	35.4
Moller (1970)	50.0		35.0	
Macmillan and Clayton (1980)		65.0		51.0

Factors affecting the duration of post partum anoestrus interval.

Time to first ovulation has consistently been associated with the duration and depth of the normal negative energy balance (NEB) that the dairy cows suffer after calving (Butler and Smith, 1989; Canfield and Butler, 1990; Staples *et al*, 1990; Lucy *et al*, 1992). Energy restrictions influences reproductive functions through depression in gonadotropin hormone release (GnRH) in hypothalamic centers in the brain (Butler and Smith, 1989; Schilo *et al*, 1992). GnRH stimulates release of luteinizing hormone (LH) from the pituitary and high frequency of LH is essential for the follicular development, ovulation, and luteal function in the ovary (Fortune, 1994).

The duration and depth of the NEB depends on the interaction between homeostatic and homeorhetic mechanisms at the cow level (Bauman and Currie, 1980). This interaction is affected principally by the energy intake of the cows (Villa-Godoy *et al*, 1988; Staples *et al*, 1990; Macmillan *et al*, 1996). As a consequence, it is logical that long PPAI have been associated to high stocking rate (McDougall, 1994), high milk production (Macmillan *et al*, 1996; Grosshans *et al*, 1996), low BCS at calving (McGowan, 1981; Grainger *et al*, 1982) and low peri-partum nutrition (Mc Gowan, 1981; McCallum *et al*, 1995). Because first lactating cows present low DMI and increased requirements for growth , they consistently show longer post-partum interval compared to mature cows (McDougall, 1994; Moller, 1970).

Energy balance is commonly defined as the difference between ME eaten (MJ/kg DM eaten) and ME required by the lactating cow (Butler and Smith, 1989). Although, the negative energy balance is an easy concept to understand, it is very difficult to characterise except in calorimetry. High Non Esterified Fatty Acids and low glucose concentrations in blood have been associated to energy balance (Payne, 1987). Staples *et al*(1990) found PPAI was associated positively to NEFA and negatively to glucose in blood. However, under grazing conditions, no significant association was found between PPAI and these two variables (McDougall, 1994). It is possible that postcalving changes in BCS of the cows may a good indicator of the postcalving energy balance of the cows (Butler and Smith, 1989; Ferguson, 1991).

Errors in heat detection.

There are two main concepts associated with heat detection error:

- the efficiency of heat detection (failure to detect a cow that was on heat).
- the accuracy of heat detection (Is the detected cow really on heat ?).

The first errors represents a delay of the insemination of a cow by 21 days, and it will have a major effect on the conception and calving pattern (Xu and Burton, 1996). On the other hand, the second type of error will significantly affect the conception rate and increase the waste of semen (MacGowan, 1981).

The efficiency of oestrus detection can be evaluated from the % of irregular cycles in the cows which return to heat (longer or shorter than 18-24 days). If cycle shorter than 15 days make up more than 15% of the returns, this probably indicates a weakness in oestrus detection. Heat detection is not usually a serious problem in New Zealand compared to other countries (Macmillan *et al*, 1996). The widespread use of the tail-paint technique, the high number of cows on heat at the same time, the fact that most of the milkers are the owner of the herd and probably the seasonality of the heat detection task (a maximum of 6 weeks) are factors contributing to that situation (Macmillan, 1995; Xu and Burton, 1996).

Conception Rate.

The average conception rate in New Zealand dairy farms is around 60%, with some farmers achieving 75% (Xu *et al,* 1995), a rate that is well above the values observed in other countries (Macmillan *et al*, 1996). Conception rate (CR) is an indicator that summarises the overall reproductive performance of the herd and that is influenced by three main physiological processes:

- quality of the oocyte released from the ovary of the cow and its ability to support a normal embryonic development post-fertilisation (Ferguson, 1991).
- fertilisation failure which is mainly related to the availability of capacited sperm to fertilise the ovum before it degenerates, (Vishwanath *et al*, 1996)
- a successful maternal pregnancy recognition (Thatcher *et al*, 1989; Thatcher *et al*, 1995).

Multiple factors ,which vary from the heat detection efficiency , the fertility of the semen, fertility of the cow to the AB technician skills, can affect each of these three stages (Vishwanath *et al*, 1996; Macmillan, 1977; Macmillan and Clayton, 1980; Xu and Burton, 1996). This review is focused only in the main cow factors affecting the conception rate.

Postpartum interval.

In general, it is accepted that the longer the period between calving and first mating, the higher the conception rate expected from a mating (Butler and Smith, 1989; Ferguson, 1996).After calving, the uterus is immense and the ovaries are inactive. Immediately after the delivery the uterus start reducing its size and all the tissues from the pregnancy stage are depleted. This physical involution is followed by processes of regeneration and repair which should be finished by 30 to 35 days postpartum (Fonseca *et al*, 1983), but may be delayed by periparturient diseases as milk fever, retained placenta, dystocia or hypomagnesaemia (Ferguson, 1991; Peters, 1996; Lewis, 1997). As a consequence, these periparturient diseases were found to increase the days open of the dairy cows (Lewis, 1997). Once the ovarian activity begins again, the earlier in postpartum the physical and histological involution is completed, the earlier the breeding may commence. It has been suggested that specific postpartum effects only occurs within the first 40 days (Table 1.17), and no benefit in conception rate would be obtained by delaying first service beyond 40 days postpartum (Ferguson, 1991; Zavy, 1994).

Conception rate was significantly increased by 6 to 7% when at least one pre-mating heat was detected previous to the first mating compared to when none pre-mating heat was detected (Table 1.17). Any additional pre-mating heat (>1) only increases the chance of conception by 2% . Oestrus behaviour is caused by the high level of oestrogen in blood, which is associated with up regulated immune function and phagocytic activity (Lewis, 1997) which can significantly reduce the incidence of clinical and subclinical infection in the uterus (Butler and Smith, 1989; Ferguson, 1991; Macmillan and Clayton, 1980). Furthermore, the second factor is that very often the first oestrus is followed by a short cycle of 8 to 12 days (McDougall, 1994; Fonseca *et al*, 1983), and as a consequence the probability of a successful mating is very poor (Macmillan and Clayton, 1980).

Table 1.17 ***Average conception rate (%) to first service after varied intervals postpartum and after the occurrence or absence of premating heats (adapted from Macmillan and Clayton, 1980).***

	N° premating heat	Interval calving first insemination (days)			Total
		< 30	30-39	> 39	
	0	32	42	59	44
First Insemination	1	39	49	65	51
	>1	40	51	67	53

Energy Balance and Conception rate.

As was discussed before, high producing dairy cows cannot consume enough DM to meet demands of milk production in early lactation (Ulyatt and Whagorn, 1993; McDougall, 1994). Most high producers cows lose BCS after calving and are in negative energy balance (NEB). As can be seen in Table 1.18, BCS losses greater than -0.5 points (around 35 kg in the scale 1-5) reduced significantly conception rate at first service .

Table 1.18 ***The influence of body condition change post- calving on first service conception rate (adapted from Ferguson, 1996).***

	Conception rate(%)		
Body Condition Change(mean)	**Unpublished data**	**Perkins (1985)**	**Britt (1992)**
0.75	56		
0.25	50		62
0	46		
-0.25	43	65	
-0.75	37	53	25
-1	29	17	

Advances in genetic and nutrition have allowed dairy cows to have dramatic increases in milk yield. The effect of this substantial increase in milk yield on fertility of the cows is a controversial topic. Some authors reported a slight decrease in the fertility as the production of the cows is increased (Butler and Smith, 1989; Moore *et al*, 1992; Hoekstra *et al*, 1994; Macmillan *et al*, 1996; Jonsson *et al*, 1997), but others did not detect any negative effect comparing high with average yielding cows (McGowan *et al*, 1996; Van Arendonk *et al*, 1989; Badinga *et al*, 1986; Batra *et al*, 1986). In New Zealand, Grosshan *et al* (1996) reported a moderate antagonistic genetic relationship between milk yield and fertility traits, but the phenotypic correlation was 0. Undoubtedly, high producers are more at risk to suffer deeper and more prolonged NEB compared to low producers which was showed to affect the PPAI and the conception rate (Macmillan *et al*, 1996; Butler and Smith, 1989). As high producing cows normally have a long PPAI, they have fewer heat before the first mating (Butler and Smith, 1989). This was suggested as another possible reason for the observed decrease in fertility of the high genetic merit dairy cows, but a direct effect of NEB on conception rate can not be discarded (Badinga *et al*, 1986; Butler and Smith, 1989; Macmillan *et al*,1996). However, the variation between results reported above suggests that is possible to overcome the negative correlation between fertility and milk production by good farm management. Nevertheless, some of the Scandinavian countries have been including the reproductive performance as a selection criteria of the cows (Hoeckstra *et al*, 1994). Grosshan *et al* (1996) recommended the inclusion of fertility traits in the breeding goal of dairy cows in New Zealand taking into account the potential deterioration of the reproductive performance which is likely to occur with the increase in milk production.

Hormonal and metabolic changes associated with NEB that may influence conception rate have not been clearly identified (Ferguson, 1991). Conception rate was lower in cows with blood glucose concentration < 67 mg/100 ml of plasma (30%) than in cows with glucose > 67 mg/100 ml (62%) . Similarly, cows with albumin concentration in blood > 30 g/l showed a conception rate of 23%, meanwhile those with albumin level up 30 g/l presented a conception rate of 77%. (Wilson *et al*, 1985). Similarly, high serum concentration of free fatty acids and 3-betahydroxibutyrate have been associated to low conception rates and poor reproductive performance in dairy cows (Lean *et al*, 1992, Jonsson *et al*, 1997). High albumin and free fatty acids, and low glucose are characteristics of cows that mobilise reserves.

It has been reported that progesterone production by the corpus luteum of cows which were in NEB is reduced (Villa-Godoy *et al*, 1988; Burke *et al*, 1996). High levels of progesterone in the prior cycle to conception have been associated to increased CR (Fonseca *et al*, 1983; Lucy *et al*, 1992). Energy restriction was also shown to affect the maximum diameters and growth rates of the follicles of beef cows in NEB compared to those from cows in positive energy balance (Mackey *et al*, 1997). NEB also modified the follicular pattern of dairy cows fed on pasture (Burke *et al*, 1996). Furthermore, it was proposed that primordial follicles developed under a metabolic environment characterised by NEB may be less fertile at ovulation, and that the corpora lutea formed after the follicle ovulated would secrete less progesterone (Britt, 1992; Lucy *et al*, 1992). Interestingly, it has been observed that the reduction in progesterone secretion occurred 2 or 3 cycles after the NEB suffered by the cows (Villa Godoy *et al*, 1988; Lucy *et al*, 1992; Burke *et al*, 1995) which is coincident with the breeding period for most of the cows . If these results are confirmed, fertility may be reduced for a period of time 60 to 100 days longer than the negative energy balance (Ferguson, 1996).

Effect of protein on conception rate.

A number of studies have examined the relationship between feeding dairy cows elevated concentration of crude protein (< 19-20%) and conception rate (Ferguson, 1991; Williamson and Fernandez-Baca, 1992). Most, but not all, the studies found that conception rate was decreased when the level of crude protein was elevated in the ration (Ziv, 1994). Lately, it was suggested that the problem occurs when the percentage of rumen degradable protein is high in the diet (Ferguson and Chalupa, 1989), and especially in the cows <3 years (Chalupa and Ferguson, 1989; Williamson and Fernandez Baca, 1992). Feeding excess rumen degradable protein may have resulted in fertilisation failure or early embryonic death which occurred prior to maternal recognition of pregnancy, or a combination of the two factors since most breeding intervals were not extended past 24 days (Zavy, 1994). The reasons for this decrease in conception rate are not known. A possible toxic effect of the urea on the gametes or early embryos was suggested (Ferguson and Chalupa, 1989). Other report suggested changes in the uterus environment (Ziv, 1994), in the release pattern and activity of hormones in the ovary (Williamson and Fernandez-Baca, 1994) or the hypophyseal-pituitary-ovarian axis (Ferguson and Chalupa, 1989).

As a consequence of feeding high levels of degradable protein, ammonia levels increase in the rumen, the excess is rapidly absorbed and it is converted to urea in the liver (Wilson et al, 1995). Poor conception rates were indicated when serum urea nitrogen exceeded 20 mg/dl (Ferguson, 1991) and it was recommended to maintain serum urea nitrogen between 12-17 mg/dl (Ferguson, 1996). However, some results were published where plasma urea nitrogen had concentration in excess of 24 mg/dl and no decline in fertility was observed (Ziv, 1994) .

In New Zealand, cows are mainly fed on pasture during the mating season. Levels of crude protein in spring are between 25-30%, and above 80% of this crude protein is degradable in the rumen (Wilson *et al*, 1995). However, the average conception rate in New Zealand is probably the highest in the world (Macmillan *et al*, 1996) which makes hard to believe that this factor is affecting the conception rate. However, Williamson and Fernandez-Baca (1992) found that conception rate was lower in those farms where the cows were eating grass with high and medium protein level compared to those where the crude protein levels were low. The cows more affected were those in their 4th or later lactation. Furthermore, they found a significant association of blood urea nitrogen and conception (Williamson and Fernandez-Baca, 1992). In conclusion, although it is possible that the level of crude protein can be affecting in some degree conception rate in some farms in New Zealand, the depression of fertility does not appear to be as severe as that reported in other conditions.

Reproduction and size of the cows.

A number of type traits have been gaining importance in the last years because they have been associated with reproduction. For instance, increased loin strength is thought to allow for a better drainage of the reproductive tract after calving and to affect reproduction directly (Morrow, cited by Dadati *et al*, 1986). Van Vleck and Norman (1972) reported that cows with sloping rumps were culled less frequently for reproductive failure and have shorter calving interval than cows with level rump. However, in only a few cases the effect of the size of the cow on the reproductive performance was studied. Dadati *et al* (1986) analysing data collected by the Holstein Association of Canada found that the phenotypic correlations between type traits and calving interval were essentially 0, but the genetic correlations were low to moderate and negative . Particularly in case of size and stature, he reported a genetic correlation of -0.23 and -0.25. Based on the results obtained, he concluded that taller cows with greater size seemed to perform better at breeding, but that direct selection for calving interval would be more effective than to improve reproductive traits by selection for type traits.

Working with collected data from Holstein and Ayrshires heifers in Canada, Batra *et al* (1986) found that most of the reproductive traits considered were positively correlated with weights at calving and at 112 days postpartum, and negatively correlated with weight changes after calving. Only first service conception rate was negatively associated to LW at calving and at 112 days of lactation (-0.28 for Holstein and -0.21 for Ayrshires). Also in Canada, Moore *et al* (1992) reported that the phenotypic and genotypic correlation between days open and LW at calving was close to 0.

Markusfeld and Ezra (1993) divided 648 cows of 8 Israeli Holstein Herds into 4 groups by the 4 combinations of LW and height related to the medians. The average BW of all the cows was 484 kg and they were producing between 9000 and 11000 kg of milk. They found that tall and heavy first lactation cows had a lower pregnancy rate from first AI, independent of milk yield. Their conception rate at first service was 39% compared to 51% of the light cows. Because larger and heavy cows lost more LW after calving, they attributed their lower conception rate to a combination of overcondition and negative energy balance.

Badinga *et al* (1985) suggested a genetic antagonism between body weight and conception rate from an analysis of the records of 2263 Holstein and Jersey cows from a single farm in Florida (characterised by a subtropical climate). They found a genetic correlation of 0.37 between the two variables, but the phenotypic correlation was 0. They attributed the difference in conception rate to the difference in thermoregulatory responses between the heavy and light cows, with the high cows more vulnerable to high environmental temperatures because they have reduced ratios of surface to body weight. They also hypothesised that heavy cows may have a greater incidence of periparturient diseases, but they did not back up their suggestion with any data.

After 30 years of divergent selection for body size in Minnesota, Hansen *et al* (1998) found that the large line of cows during first parity required significantly more number of services to get in-calf (2.08) compared to the small line of cows (1.79). The mean pospartum LW for the large heifers cows was 609 kg and 558 kg for the small heifers cows. Milk production (L: 8492 kg and S: 8535 kg), LW change 1 month after calving (-51 kg vs -50 kg) and calving difficulties did not differ between the lines. In the second and third parity, the least square means for number of services tended to be higher for the large cows, but the differences were not statistically significant. No reason was suggested for the difference in conception rate between the two lines of cows.

Selected large frame Brahman and Angus cows were older at puberty and showed lower conception rate while lactating their first calves compared to small frame cows (Olson, 1994). The reason suggested was that although receiving the same treatment, the small frame cows maintained a better condition score during lactation. He concluded that it was required to feed better lactating first-calf heifers with large frame score than comparable small frame size heifers in order to achieve comparable levels of fertility. However, it would be interesting to know the economic and biological efficiency of the option from the point of view of a commercial producer.

Although the relationship between reproductive performance and size of the dairy cows has not been extensively studied, a tendency seems to exist for the heavy and tall cows to have more reproductive problems. The reasons suggested for this trend have been different and are not conclusive. Perhaps, the potential causes would change according to the characteristics of the production system where the cows are performing.

1.6) Objectives of the study.

As was previously explained, the New Animal Evaluation System in New Zealand places a negative relative economic value on LW in the final Breeding Worth of the dairy cows. The reason for that was to consider in the selection index of the cows the higher feed conversion efficiency of lighter cows at similar levels of MS yield (Holmes *et al,*1993). A moderate and positive genetic correlation between LW and MS production was reported in New Zealand dairy cows (Ahlborn and Dempfle, 1992; Van der Waaij *et al,*1997), but it was suggested that there was enough flexibility for selecting in favour of milk traits and against live weight without a substantial negative effect on the genetic progress in the yield traits (Ahlborn and Dempfle, 1992). Using the current selection index in the New Animal Evaluation System (LIC, 1996), it was predicted that the average LW of the dairy cows in New Zealand would be decreased by around 3-4 kg of LW after 20 years of selection (Spelman and Garrick, 1997). However, some geneticists have expressed some concern about the possible negative effects that selecting against LW may have on intake capacity and body condition score of the high genetic merit dairy cows, especially in early lactation (Van Arendonk *et al*, 1995; Veerkamp *et al*, 1997). They suggested that in order to increase feed intake capacity, a positive value should be placed on LW (Veerkamp, 1995).

In New Zealand, the feasibility of the seasonal system of milk production is based on achieving a high reproductive performance of the herd (Macmillan *et al*, 1984). The correlated effects of selecting for or against any characteristic on the reproductive efficiency of the dairy cows must be considered in this situation. However, the information in the literature about the effects of size on the reproductive performance of the dairy cows is scarce. Recently, Hansen *et al* (1998) reported that a heavy line of cows selected in Minnesota required more services per conception than the light line. Similar genetic antagonism between size and conception rate was reported by Badinga *et al* (1985).

Two genetic lines of Holstein Friesian cows, the Heavy Line (HL) and the Light Line (LL) have been selected at the Dairy Cattle Research Unit (Massey University) since 1989. Both lines of cows are characterised by different size, and similar (but not the same) genetic potential for milk solid production. They have been developed using proven sires with either high or low estimated breeding value (EBV) for liveweight (LW), but with high EBV for milksolid production (MS). The Breeding Worths (BW) and Breeding Indexes of the Heavy and Light Sires used since 1989 are presented in Appendix 1. The objectives of the present study were :

- to compare the productive performance of selected LL and HL Holstein-Friesians cows during early lactation.
- to evaluate the effect of size on the herbage intake of the dairy cows in early lactation .
- to assess the reproductive performance of LL and HL Holstein-Friesian cows for the period from 1992 to 1997.

Chapter Two

MATERIALS AND METHODS

The trial was carried out from the 1st of August to the 10th of November 1996 at the N° 3 Dairy Farm (DCRU, Massey University). During this period, milk production and milk composition of the HL and LL cows were weekly measured during 12 weeks, individual DMI of pasture was compared during 10 days, blood samples were collected in 12 cows per line to measure metabolite concentration and different reproductive indicators were evaluated in both group of cows. Table 2.1 shows the timing of the main activities of the trial. The experiment has been divided into sub-trials in order to help to understand its design more easily .

2.1) Comparison of the milk trait yield, and changes in liveweight and body condition score of the LL and HL cows in early lactation (Experiment 1 a).

Animals and management.

Fifty seven Holstein-Friesian cows, 30 from the LL and 27 from the HL, were used in this experiment. They calved between the 1st of August and the 12th of September of 1996, with the mean calving date on the 15th of August. Age of the animals ranged between 2 years old (HL n= 8, LL n=9) and 7 years old. Average Breeding worth (BW) for the LL and HL were 29 and 20, respectively. The cows were managed with the whole herd, making a total of 120 cows. They were rotationaly grazed on ryegrass-white clover pasture, without receiving any pre-determined pasture allowance during the trial. In August and early September, the cows received Maize Silage as necessary in addition to pasture. Pre-gazing and post-grazing pasture levels were assessed thrice weekly using a rising plate meter to evaluate the feeding level of the herd.

The rising plate meter was calibrated monthly. The regression equations were obtained from the DM weight of 60 pre-grazing and 60 post-grazing sward cuts to ground level, along with the corresponding height recorded with the rising plate meter. Pasture samples were washed to remove soil residues and dried in an oven at 100° C during 48 h to estimate DM weight of the quadrat cuts. Average daily DMI (kg DM/cow) was estimated using the following equation :

$$\text{DMI (KG DM/cow)} = \frac{\{\text{Pregrazing (kg DM/ha)} - \text{Postgrazing (kg DM/ha)}\} * \text{Size of the paddock}}{\text{N° of cows grazing}}$$

It was assumed that the herbage which disappeared during grazing has been eaten by the cows. No correction was made for herbage growth during the grazing period since this was unlikely to be significant because the cows were not grazing for more than 1 day per paddock (Meijs *et al*, 1982).

Measurements and sample collection procedures.

Milk production was measured weekly from calving until week 12 of the lactation using in-line milk meters. Milk composition was analysed from aliquots taken from the morning (06.00 to 08.00 hours) and afternoon (15.30 to 17.00 hours) milking . Concentrations of fat, protein and lactose in milk were measured using a Milkoscan 104 infrared analyser (A/S N. Foss Electric, Denmark). Liveweight (LW) and Body Condition Score (BCS) of the cows were assessed after the morning milking every 15 days. BCS was evaluated by three observers with the three observations averaged.

Table 2.1 ***Timing, number of cows used , variables measured and frequency of measurements during the different sub-trials within the experiment about the comparison of the productive and reproductive efficiency of LL and HL cows during early lactation.***

Productive performance				
	Date	**Number of Cows**	**Measurements**	**Frequency**
Trial 1 a	1st August-10th November	LL = 30 HL = 27	Milk production , milk composition. Liveweight and Body Condition Score of cows	Weekly. Fortnightly.
Trial 1 b	1st October-10th October	LL = 21 HL= 21 (included in trial 1 a)	Individual cow dry matter intake (DMI) by alkanes. Energy and milksolid (MS) conversion efficiency	2 estimates each from 5 days.
Trial 1 c	12th Septem-12 October	LL =12 HL =12 (included in trial 1 a)	Blood sample to measure urea, albumin and glucose concentration.	Weekly
Reproductive performance				
Trial 1d	**Date**	**Number of Cows**	**Measurements**	**Frequency**
Date Calving-Date of 1st ovulation Interval (C-Ov)	1st August-25th October	LL=31 HL=25 (same cows as in trial 1 a)	Milk samples to measure progesterone concentration.	Thrice per week
Date Calving-Date of 1st Heat Interval (C-H)	1st August-15th of January	LL=31 HL=25	Heat detection by visual observation	Twice daily
Planned Start of Mating- Date of conception Interval (PSM-Con)	Mating : 1st November-15th January	LL=31 HL=25	AB until the 15th of December and natural mating from this moment until the 15th of January.	Daily
Follicular and Luteal Activity	10th October-5th November	LL =10 HL=10 (a sub selection of the cows used in experiment 1 a)	Scanning of the ovaries.	Daily during one normal cycle.

2.2) Comparison of the dry matter intake, milksolid and energy conversion efficiency of the LL and HL during early lactation (Experiment 1 b)

Animals and management.

From the original 57 cows, 42 (21 from each line) were used in this trial made between the 1st and the 10th of October. Each group of cows consisted in 8 heifers (2 year old) and 13 mature cows from 3 to 6 years old. Average number of days from calving were 44 days and 42 days for the LL and HL, respectively. Average Breeding Worth was 30 for the LL and 20 for the HL. Both groups of cows were rotationaly grazed as one herd on ryegrass-white clover pasture during the experiment, receiving a new strip of pasture each 12 hours. Pre-grazing and post-grazing levels were daily assessed using a rising plate meter . In this experiment the calibration equations for the rising plate meter were previously estimated from the DM weight of 40 pre-grazing and 40 post-grazing quadrat cuts to ground level, along with the corresponding height recorded with the rising plate meter. The technique used was the same as that described in 2.1.1.

Measurements and sample collection procedure for milk, liveweight and body condition scores variables.

Milk yield was measured thrice during the experiment (Day 1, Day 5 and Day 10) using in-line milk meters . Morning and afternoon milk sub-samples from each cow were analysed for milk composition as described in 2.1.2. The average of the three herd tests of each cow was used as the milk production of the cow during the ten days period.

LW and BCS of the cows were measured at the start and at the end of the trial. Measurements were made after the morning milking (between 06.00 to 08.00 hours), with the BCS assessed by three observers. The average of the two BCS and LW measures were used to analyse the results of the experiment.

Measurements of individual cow DMI and digestibility.

Alkanes.

Individual cow DMI and digestibility were measured using the alkanes technique (Doves and Mayes, 1991). On the 22d of September, cows were fitted with slow release alkane capsules (Captec, New Zealand). According to the certificate of testing provided by Captec (NZ) LTD, the capsules contained 7.35 g of n-dotriacontane (C32) and 7.35 g of n-hexatriacortane (C36). The average release rate was 355 mg/day for both alkanes, with an average plunger travel of 2.38 mm/day (CV = 9.17%).

After a period of 8 days (equilibration period) , faecal samples (40 gr) from each cow were taken daily in the morning (06.00 to 08.00 hours) during 10 days (1st -10th October). Faeces were bulked at 4°C for each cow over the 5 days, and then the bulked samples were dried in an oven at 60°C for 10 days and finely ground. The same procedure was used with samples from days 6 to 10.

Pasture sampling.

Pasture samples from each paddock were collected immediately after grazing from 5 exclusion cages distributed at random in the paddock. Pasture from the first 5 days were bulked together and three representative sub-samples were taken to analyse the alkane , chemical and botanical composition. The same procedure was used in the second 5 day period. Pasture samples were freeze-dried and finely ground prior to the analyses. Alkane concentration in pasture and faeces samples were analysed at the Dairy Research Corporation, Hamilton (DRC) using the analytical procedure described by Mayes et *al* (1986) .

Botanical composition was carried out by manual separation of the fresh sub-samples into ryegrass, white clover and other grasses. They were dried separately in an oven at 100° C for 2 days, and their contribution to the sample estimated on a dry matter basis.

Chemical composition and *in -vitro* digestibility were assessed at the Nutrition Lab (Massey University). Organic matter content was measured by ashing the samples in a furnace at 500° C for 16 hours. Acid detergent fibre (ADF) and Neutral detergent fibre (NDF) were analysed using the technique described by Roberstson and Van Soest (1981). *In-vitro* digestibility was predicted through the methodology described by McLeod and Minson (1982). Pectin concentration was determined according to the method described by Blumenkrantz and Asboe (1973). Crude protein percentage was calculated from the nitrogen content of the samples that was measured using a Leco Analyser machine.

Calculations of DMI from alkanes concentrations.

Feed intake was estimated from the concentrations of C33 (natural odd chain) and C32 (dosed even chain) alkanes in the pasture and faeces using the following equation (Dove & Mayes, 1991) :

$$\text{DMI (kg DM/cow/day)} = \frac{Fi / Fj * (Dj)}{(Hi - Fi / Fj * Hj)}$$

where : Dj is the daily release of C32 alkane from the capsule (mg/cow/day).

Hj and Fj are the concentration (mg/kg DM) of C32 in herbage and faeces, respectively.

Hi and Fi are the concentration (mg/kg DM) of C33 in herbage and faeces , respectively.

Calculations of dry matter digestibility (DMD) from alkanes concentrations.

Estimates of DMD were calculated from the ratio of herbage and faecal concentrations of the natural odd-chain alkanes (C31) or (C33):
Digestibility = 1- (Hi / Fi) * Recovery factor

where, Hi and Fi are the respective concentrations (mg/kg DM) of the odd-chain alkanes in herbage and faeces. Assumed recoveries for experiment 2 were 0.83 and 0.86 for C31 and C33, respectively, based on results obtained with cows fed fresh pasture (Stakelum and Dillon, 1990).

Indicators of Efficiency.

The indicators used to compare the productive efficiency of LL and HL cows were:

- Gross Energy Efficiency (GEEff) = (Milk energy output / ME intake) *100.

The total energy in the daily milk yield of each cow (MJ/cow daily) was calculated as :
38.5* Fat + 24.5 * Protein + 15.7 * Lactose
where Fat, Protein and Lactose are the daily yields (kg/day) of each cow .

Metabolisable Energy Cost (MJ ME) for producing 1 kg MS was estimated from :
Net Energy Content (MJ) in milk containing 1 kg MS /K_l . The K_l used was 0.62 (Holmes and Wilson, 1987).

- Milksolid conversion Efficiency (MSEff) (kg MS/kg DMI) = $\frac{\text{kg MS produced}}{\text{kg DM eaten.}}$
- Energy balance (MJ ME) = Energy Intake (DMI * MJ ME/kg DM) - Calculated Energy requirements (MJ ME).
  where Calculated Energy requirements (MJME/day) = 0.6*$LW^{0.75}$ + 64 MJME* kg MS (Holmes and Wilson, 1987).
- Net energy Efficiency (NEEff) : (Milk energy output / ME intake for production) *100.

The ME for production was estimated from the total ME intake (DMI (kg DM/day) * MJ ME/kg DM) minus the maintenance requirement for each cow assumed to be : 0.6* $LW^{0.75}$ (Holmes and Wilson, 1987).

Measurement of grazing behaviour.

Grazing behaviour of the cows was measured on the 5th and 10th days of the DMI trial. Grazing time of the 42 cows was estimated by recording grazing activity every ten minutes during 24 hours. The cows were recorded as grazing or idling, with ruminating activity recorded as idling.

Biting rate was measured in 12 cows per line by counting the number of bites per cow in two minutes (Hogdson, 1982) . Both groups were balanced by age and MS production. Biting rate was recorded by two observers (12 cows each) immediately after the morning milking (between 08.00 and 10.00 hours), between 13.00 at 15.00 hours and immediately after the afternoon milking (between 16.30 and 18.30 hours). Each cow was recorded twice at each time of the day, and the average of the two measures recorded was used in the statistical analysis.

2.3) Measurements and sample collection procedures for metabolites in blood of the LL and HL cows (Experiment 1 c).

During the second month of lactation , samples of blood were taken from 12 cows per line during 4 weeks. The groups were balanced by age, milksolid production and calving date. Blood samples were collected at 0800 h by coccygeal vessel venipuncture. Samples (12 ml) were withdrawn into vacutainers (Nipro Medical, Tokyo, Japan) containing EDTA as anticoagulant and immediately refrigerated at 4° C. One hour later, they were centrifuged at 3000 g and 4° C for 20 minutes. Plasma was stored at -20 °C until processed. Glucose, albumin and urea concentration in plasma were determined at the Animal Physiology Lab (Massey University), as described previously by Cottam *et al (1992)* with intra- and inter-assay coefficients of variation of 1.3 and 3, 1.7 and 2.1, 1.2 and 4.9, for urea, albumin and glucose, respectively.

2.4) Comparison of the reproductive performance of the LL and the HL of cows (Experiment 1 d).

The reproductive performance of the two lines of cows from 1992 to 1997 was assessed . The data was obtained from the detailed records for each cow maintained at the research unit. Table 2.2 shows the number of cows evaluated per year. The intervals calculated for each cow were : Planned Start of calving date to calving date (PSC-Calv), Calving date to first visible heat date (C-H); Planned Start of Mating date to First service date (PSM-1Serv) and Planned Start of mating date to conception date (PSM- Con). The interval Calving-Ovulation (C-Ov) was only compared in 1996-97 and 1997-98 (LL= 66 cows HL=58 cows). Considering the importance of compact calving under a seasonal system of production, the ratio of cows of each line pregnant in the first 21 days of mating and calving in the first 21 days of the calving period were also analysed. In addition, the percentage of cows induced, the percentage of cows pregnant at 1st service, the percentage of empty cows after the mating period and the percentage of cows treated with CIDR were also compared between both lines of cows. Most of these indicators were recommended by Grosshans *et al* (1996) for the evaluation of fertility traits in New Zealand dairy cows.

The reproductive information for the 1996-1997 season was also analysed independently from the 1992-1997 reproductive data because it was only in this season that the BCS, LW ,milk production and ovarian activity of the two lines of cows were closely evaluated.

Table 2.2. ***Number of cows per year(from 1992 to 1997) used to compare the reproductive performance of the LL and HL lines.***

Year	Number of LL cows	Number of HL cows
1992	6	5
1993	10	9
1994	14	19
1995	24	23
1996	32	32
1997	45	44
Total	131	132

Measurements and sample collection procedures for reproductive parameters.

Calving-ovulation interval (C-Ov) in 1996 and 1997.

From ten days post-calving and until the first oestrus post-partum, milk progesterone concentration was determined for 124 cows (LL = 66 cows HL = 58 cows) from milk samples (15ml) taken thrice per week in 1996 and twice per week in 1997. The Milk samples were immediately refrigerated at 5°C until being processed. In 1996, milk samples were processed once a week at AgResearch (Wallaceville) using the enzymeimmunoassay methodology (EIAs) described by Henderson *et al* (1994). In 1997, the samples were processed at the Animal Physiology Lab (Massey University). In both years, the routine was maintained from the 10th of August until the 25th of October when the anoestrus cows were treated with progesterone via a Controlled Internal Drug Release (CIDR, InterAg-New Zealand). Progesterone concentrations in milk higher than 2.5 ng/ml were considered to indicate luteal activity (McDougall, 1994). Ovulation without behavioural oestrus was defined to have occurred 5 days before the day on which progesterone concentration in milk was above 2.5 ng/ml for at least two consecutive samples.

Calving-First Heat Interval (C-H).

Visible heat activity was recorded by the milkers by simple observation assisted by the use of the tail paint method. A cow was considered to be on oestrus when it stood to be mounted by other cow. Ovarian activity of anoestrus cows was checked by manual palpation one week before the planned start of mating (30th October). Those without ovarian activity were treated with a CIDR.

Planned Start of Mating - Conception Interval (PSM-Con).

Mating by artificial insemination (AI) started on the 30th of October and was continued until the 15th of December. Cows on heat were inseminated by a technician from Livestock Improvement Corporation using frozen semen. LL and HL cows were assigned to different predetermined Light or Heavy bulls according to the aims of the long term trial. From the end of the AI period, two bulls were run with the herd until the 15th of January and the natural matings were recorded by the milkers . Cows were pregnancy tested in March by manual palpation. Conception date was estimated from the date of the last service recorded and from the calving date of the following year. When there was no agreement between the last service and the calving date, as the estimated length of pregnancy was the same for the two lines of cows (280 days), conception date was estimated by subtracting 280 days from the calving date of the following year.

Comparison of the follicular and luteal activity between LL and HL cows , during the 1996 season.

The oestrus cycles of 10 cows per line (4 heifers and 6 mature cows in each group) were synchronised on the 1st of October by intravaginal insertion of CIDR (InterAg , Hamilton) for 10 days. A capsule containing 10 mg oestradiol benzoate was inserted with each device. Five ml of prostaglandin (Lutalyse, Upjohn, Auckland) was injected 2 days before the device was removed. Oestrus cows were identified by simple observation with the aid of the tailpainting technique.

The ovaries of the twenty cows were scanned daily from 24 hours after one oestrus until the subsequent oestrus using a Scanner 200 Vet (Pie Medical) with a 5 Mhz linear-array probe. Follicles greater than 5 diameter mm and luteal structures were sketched on a graph prepared for each ovary and recorded on video tape. Diameters of the follicles were measured from the recorded tape from the screen of a TV. Corpus luteal (CL) area was measured from the analysis performed on a Macintosh computer using the public domain NIH Image program (developed at the U.S. National Institutes of Health and available on the Internet at http://rsb.info.nih.gov/nih-image/). Maximum diameter of the Dominant Follicles (DF), the day of the cycle at which DF achieved their maximum diameter, number of follicular waves and area of the CL were the variables selected to compare the follicular and luteal activity between both lines of cows.

2.5) Statistical analysis.

All the results obtained were statistically analysed using SAS (SAS Version 6.11, SAS Institute INC., Cary, NC, USA).

Analysis of the milk yield of the LL and the HL (Experiment 1 a).

The total milksolid (MS) yield (kg/cow), total milk protein (MP) yield (kg/cow), total milkfat (MF) yield (kg/cow) and total milk yield (MY, L/cow) during the first 12 weeks of the lactation were analysed as one way analysis of variance . Line was the treatment effect , and age and calving date were used as covariates. The model was used to analyse the data for heifers and mature cows combined, and for heifers (2 years old) and mature cows (>2 years old)separately.

Multiple regression analysis was performed using total milk yield (MS, MF, MP and MY) in the 12 week period as the dependent variables and LW, age and calving period as the independent variables. The combined data (heifers + mature cows) were regressed first, and the same model was also used to regress separately the information from heifers and mature cows.

Milk yield traits (MS, MF, MP and MY) , milk composition (fat concentration (F%) and protein concentration (P%)), and LW and BCS changes in the first 12 weeks were also analysed using repeated measure statistical analysis. Line was the treatment effect and the weekly herd tests were the time effects. Age and calving period were used as covariates. Again as above, this analysis was made on the combined data, and on the data for heifers and mature cows separately.

Analysis used for the comparion of the DMI, and milksolid and energy conversion efficiency between LL and HL (Experiment 1 b).

One way analysis of variance was used to analyse the individual DMI, dry matter digestibility (DMD) and the different indicators of efficiency. The model included line as a treatment effect and Age as covariates. In the case of DMI analysis, MS (kg/cow) was also included as covariate in the model. Multiple regression analysis were performed using DMI of each cow as the dependent variable and metabolic LW ($LW^{0.75}$) and MS yield (kg/cow/day) as the independent variables.

Repeated measure analysis was used to compare the milk yield traits and milk composition between the two in the three herd tests performed during the ten days trial. The model included line as the treatment effect, the herd test as the time effect, and age as covariates.

Biting rate results were analysed as a split plot design. Line (Heavy or Light), Day (day 1 and 2) and time of the day (morning, noon and afternoon) were the class effects. Each one of their interactions were included in the model and MS (kg/cow/d) was included as a covariate. The effect of Day and Time were tested against the error = Day*Time interaction, and the effect of Line and Line*Time against the error = Line*Time*Day interaction. Grazing time data was assessed using repeated measure analysis. The effect of line was considered as the treatment, day 1 and 2 as the time effect and MS yield (kg/d/cow) used as the covariate.

Analysis of the concentration of blood metabolites and of the reproductive performance between LL and HL (Experiment 1 c and 1d).

Metabolite concentrations (albumin, urea and glucose) were assessed by GLM procedure with the weekly sampling period as a repeated measure. Total MS yield during the first 6 weeks of lactation were included in the model as covariates

The LifeTest procedure (SAS) was used in the analysis of the variables C-Ov, C-H, C-1serv, PSM-Con and PSC-C. These reproductive data were not normally distributed, and some of the cows had censored information (were treated with CIDRs before the PSM, were empty after the mating period or were induced during the calving period). The Lifetest procedure in SAS copes with: data that measure the length of time until the occurrence of one event, data which is not normally distributed, and in addition, it enables to use the information from cows with censored data. The lifetest compares the distribution of events using two tests: the log rank test and the Wilcoxon test. The former places more emphasis on the larger intervals and the latter on short intervals. The covariates age, calving period and year were tested in all the models

The reproductive data were also analysed using ANOVA, but in this case the data were transformed before being statisticaly analysed. Log_{10} transformation was used in case of C-Ov and C-H, and square root transformation in case of PSM-Serv, PSM-Con and PSC-C. Transformed data were compared using the one way analysis of variance. Genetic line was used as treatment effect in every one of the models. Age, calving period and year were used as covariates.

The percentage of cows of each line pregnant in the first 21 days of mating, calved in the first 21 days of the calving period, the ratio of cows induced, the ratio of cows pregnant at 1st service, the ratio of empty cows after the mating period and the percentage of cows treated with CIDR were analysed using chi-square or Fisher´s exact test. The Lifetest procedure was also used to compare the calving pattern and conception pattern of the two lines during the first 21 days of the calving and mating period, respectively. In this case, the data of all these cows with PSM-Co interval and PSC-C interval longer than 21 days were considered as censored data.

Diameters of the follicles and of the corpus luteum (CL) were compared through one way analysis of variance and repeated measure analysis, respectively. The means were adjusted by age and BCS in both cases.

Chapter Three

RESULTS

3.1) Milk production and milk composition of the LL and HL in the first 12 weeks of the lactation (Experiment 1 a).

Apparent DMI (kg DM/cow/day) of cows during the first 12 weeks of lactation.

The weekly average DMI of the cows during the first 12 weeks of lactation are presented in Table 3.1. They were calculated from the DM dissappearance estimated with a calibrated rising plate meter. Details of the calibration equations used in each month are shown in Appendix II.

Table 3.1 *Apparent average DMI (kg DM /cow/day) of the cows during the first 12 weeks of the lactation.*

Week	Pasture DMI (kg /DM/cow/day)	Maize Silage (kg/DM/cow/day)	Total DMI (kg /DM/cow/day)
1	9.8	3.9	13.7
2	8.6	4.7	13.3
3	13.1	-	13.1
4	14.7	-	14.7
5	11.5	4	15.5
6	13.5	2	15.5
7	13.8	-	13.8
8	14.1	-	14.1
9	19.1	-	19.1
10	15.6	-	15.6
11	13.5	-	13.5
12	15.5	-	15.5

Milk production and milk composition of the LL and HL cows during the first 12 weeks of lactation.

The adjusted means for the total MS, MF, MP, and MYproduced by LL and HL cows during the first 12 weeks of lactation are shown in Table 3.2. The two lines of cows did not differ significantly in any of these characteristics when the combined data were analysed. However, when the data for mature cows and heifers were analysed separately, HL mature cows produced more MS than LL mature cows ($P<0.05$) during the 12 weeks period (Table 3.3). The differences in MF and MP yields between the lines approached significance ($P<0.1$). On the other hand, no differences were detected between the two lines for the heifers. Age and calving period were found to have significant effects on MS production in the first 12 weeks. During this time, cows produced 12.4 kg MS ($P<0.001$) more for each increase of one year of age. Similarly, late calving cows produced 3.7 kg MS less for each 10 days period of delay in calving date ($P<0.01$).

Table 3.2 ***Data for the mature cows and heifers combined : adjusted means and standard errors for yield of milksolid (MS, kg/cow), milkfat (MF, kg/cow), milkprotein (MP, kg/cow), and milk (MY, L/cow) of the Light and Heavy cows during the first 12 weeks of the lactation.***

	Light Line (n=30)	Heavy Line (n=27)	Significance of difference
MS 12 weeks (kg/ cow)	138.8 ±2.4	141.1 ±2.6	NS
Fat (kg/cow)	75.8 ±1.4	77.2 ±1.5	NS
Protein (kg/cow)	62.7 ±1.0	64.2 ±1.1	NS
Milk yield (Lt/cow)	1887 ±41.4	1938 ±45.2	NS

NS: not significant * P<0.05 ** P<0.01

Table 3.3 ***Data for mature cows: adjusted means and standard errors for yield of milksolid (MS, kg/cow), milkfat (MF, kg/cow), milkprotein (MP, kg/cow), and milk (MY, L/cow) of the Light and Heavy cows during the first 12 weeks of the lactation.***

	Light Line (n = 21)	Heavy Line (n = 19)	Significance of the difference
MS 12 weeks (kg/ cow)	148 ±2.2	155 ±2.4	*
Fat (kg/cow)	80.5 ±1.5	85.0 ±1.7	NS
Protein (kg/cow)	68.0 ±0.9	70.3 ±1.0	NS
Milk yield (Lt/cow)	2033 ±39	2125 ±44	NS

NS: not significant * P<0.05 ** P<0.01

The analysis of the results using the repeated measure analysis technique agreed with those discussed above. Figure 3.1, 3.2 , 3.3 and 3.4 present the adjusted means of the weekly MS (kg/cow/day), MP (kg/cow/day), MF (kg/cow/day) and MY (L/cow) productions, respectively, of Light and Heavy cows during the first 12 weeks of lactation. The adjusted values of these variables for the combined data, heifers and mature cows are presented in Appendix IV. Heavy cows tended to produce more milksolid than the Light cows ,but for the combined data the repeated measure analysis did not detect significant difference in the MS production between the two lines (Figure 3.1). However, as above, repeated measure analysis indicated that HL mature cows produced more milksolids than LL mature cows (P<0.05). The patterns for MP and MF productions were similar to the total MS production (Figure 3.2 and 3.3). HL cows produced more MF and MP than LL cows, but again the differences were not significant for the combined data . However, HL mature cows produced more MP than mature light cows (P<0.05). On the other hand, the difference in MF production between the mature cows of the two genetic lines approached significance (P<0.1). MY (L/cow/day) was always higher for the HL cows compared to the LL , but again the differences were not significant (Figure 3.4) . As for MS production , HL mature cows produced larger MY than LL cows (P<0.05).

Figure 3.5 and 3.6 present the mean concentration of fat and protein for the two lines, and the adjusted mean values for each week and for each line are presented in Appendix IV. No differences were found in P% or F% between the two lines of cows . Although the differences were not significant, there seems to be a pattern where heavy cows presented higher MP % than light cows in the first 5- 6 weeks, but the opposite occurred for the MP% and MF% in the second half of the period.

Multiple regression analysis was performed to assess the effect of LW, Age and calving period on the yield of the different milk traits during the first 12 weeks of lactation. Only the multiple regression equations for MS yield are shown in the first row of Table 3.4. The regression equations for the other milk traits are showed in Appendix III. As can be seen, MS increased with the increase in LW and age of the cows and with an earlier calving date . The three variables tested were significantly associated to the dependent variables. The same procedure was used to analyse separately the results for the mature cows and heifers (row 2 and 3 of Table 3.4). In this case, the most interesting points were : the effect of LW was not significantly associated to the MS production in any of the two categories and the R^2 of the models were significantly reduced. On the other hand age and calving period maintained their significant effects on MS ($P<0.01$). However, the effect of LW was significantly associated to MP ($P<0.05$) and MY ($P<0.01$) in the case of the heifers data, with total MP produced in the first 12 weeks increased by 0.14 kg by each increase of 1 kg LW of the heifers at calving.

Table 3.4 *Equations obtained from the regression of MS (kg/cow/day) on LW, Age and calving period for the combined data (row 1), mature cows data (row 2) and heifers (row 3).*

(1) MS (kg/cow) =	68.5	+ 0.107 LW *	+ 9.17 Age (years)**	- 3.79 Calving period**	$R^2 = 0.70$
(2) MS (kg/cow) =	90	+ 0.03 LW	+ 5.4 Age (years)**	- 1.99 Calving period**	$R^2 = 0.39$
(3) MS (kg/cow) =	39	+ 0.23 LW		- 7.85 Calving period* *	$R^2 = 0.41$

* P<0.05 ** P<0.01

Changes in LW and BCS in the first 12 weeks of lactation.

Figure 3.7 and 3.8 present the data for the BCS and LW of the two lines during the first 12 weeks of lactation. They are presented separately for heifers and mature cows. The adjusted mean values of these two variables for each one of the categories and lines are presented in the Appendix V.

Heavy and Light cows started the lactation with similar BCS (LL=4.69 vs HL=4.75). However, LW was significantly different between the two groups of cows (LL=412 kg vs HL=445 kg, $P<0.01$), with the difference being larger for mature cows (LL= 431kg vs HL=483 kg, $P<0.01$) than for heifers (LL= 348 kg vs HL=374 kg, $P<0.01$). The differences in LW remained highly significant during the 12 weeks period.

BCS and LW changes followed a similar pattern in both lines, decreasing from calving until week 5 , and increasing after that. The changes in BCS between the two lines of cows was not significantly different between the two lines during early lactation . Nevertheless, the decrease in BCS was larger in the LL cows than in the HL (-0.47 vs -0.29). The BCS of the two lines was different at the 5 week of lactation (LL=4.17 vs HL=4.43, $P<0.05$), a difference that was larger between the heifers (LL=4.1 vs HL=4.6) than between the mature cows (LL=4.2 vs HL=4.4).

Although LL cows lost more LW than HL in the first 5 weeks of lactation (-9.53 vs -3.0 kg), the difference in LW losses was not significant. However, per each 100 kg of LW at calving, LL cows lost significantly more LW than HL cows (-2.41 vs -0.20 kg / 100 kg of LW at calving, $P<0.05$) and the HL heifers almost maintained LW while the LL heifers lost 17 kg of LW during the first 5 weeks of lactation ($P<0.05$). Both genetic lines gained BCS and LW at the same rate between week 5 to week 12 after calving.

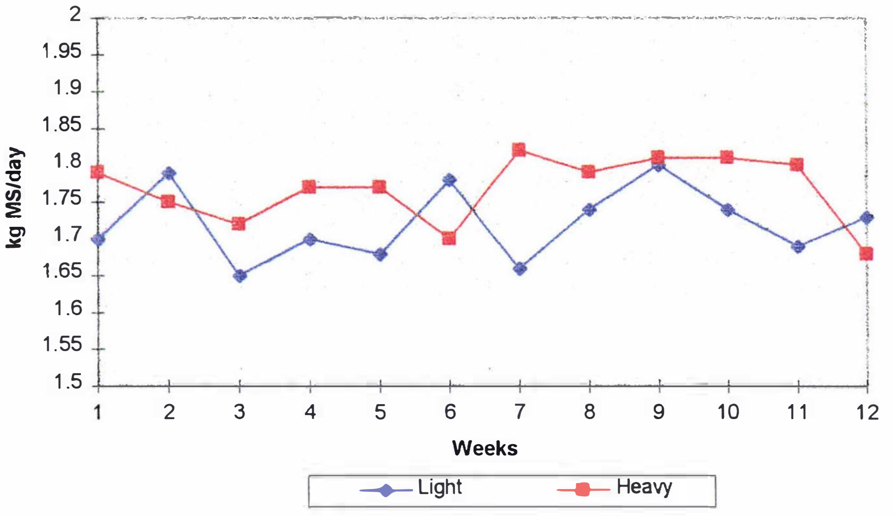

***Figure 3.1** Daily milksolid yield of the HL and the LL cows during the first 12 weeks of the lactation (the differences between the lines were not significant in any of the weeks).*

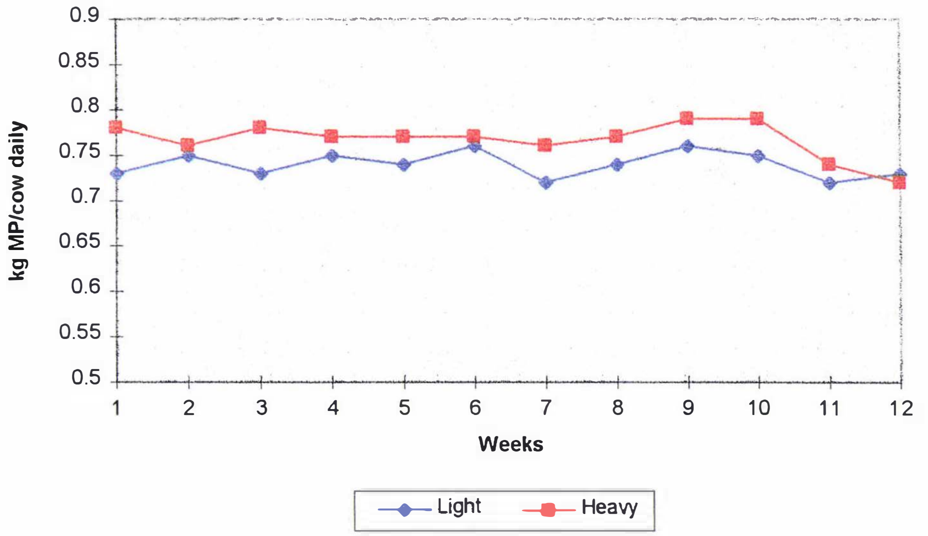

***Figure 3.2** Daily milk protein yield of the LL and the HL cows during the first 12 weeks of the lactation ((the differences between the lines were not significant in any of the weeks).*

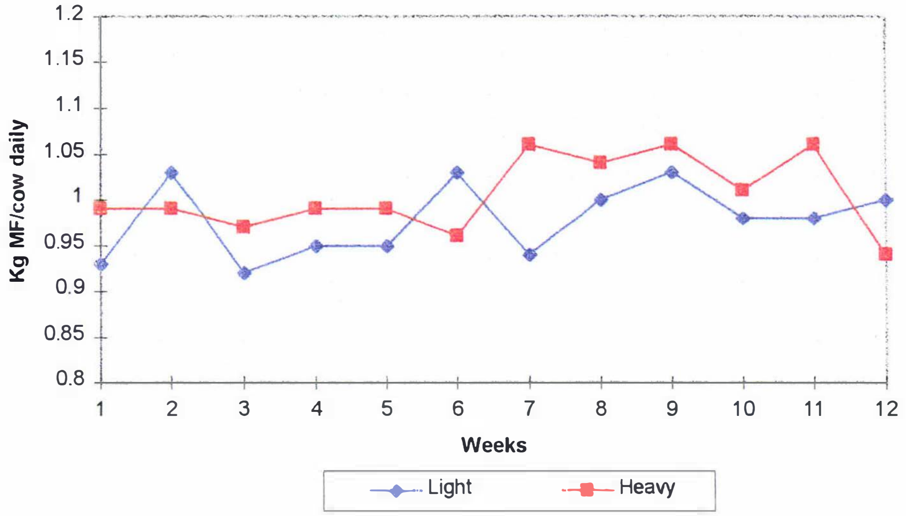

Figure 3.3 Daily milk fat yield of the LL and the HL cows during the first 12 weeks of the lactation ((the differences between the lines were significant in week 7 (LL: 0.94 vs HL: 1.06 kg MF) and in week 11 (LL: 0.98 vs HL: 1.06 kg MF)).

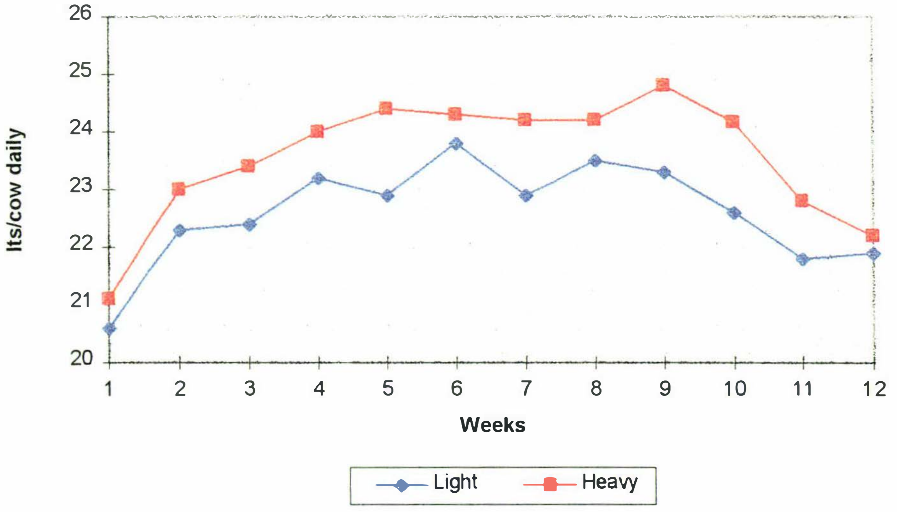

Figure 3.4 Daily milk yield (litre/cow) of the LL and the HL cows during the first 12 weeks of the lactation ((the differences between the lines were significant only in week 10 (LL: 22.6 vs HL: 24.1 litre).

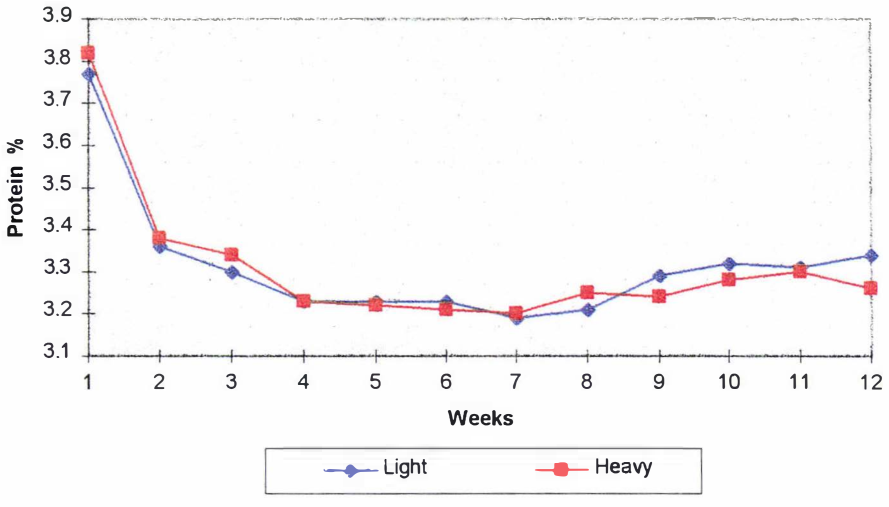

Figure 3.5. Concentration of protein in milk of the LL and the HL cows during the first 12 weeks of the lactation (the differences between the lines were not significant in any of the weeks).

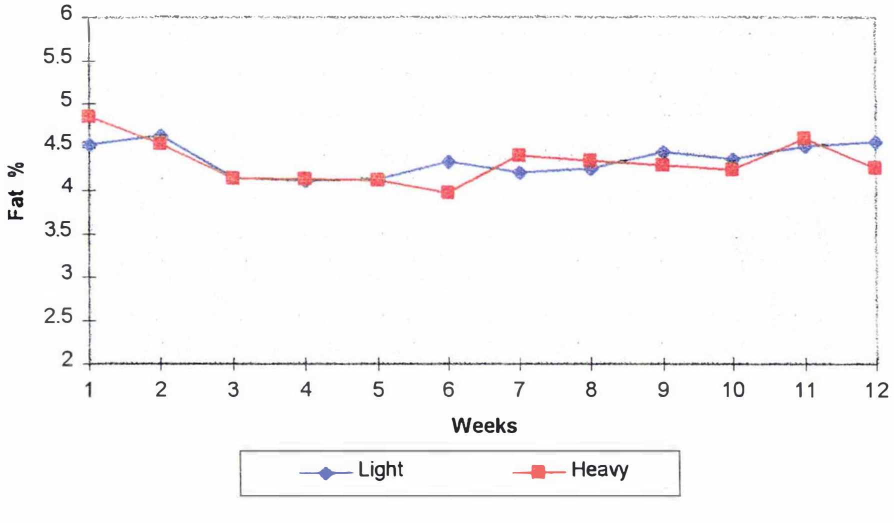

Figure 3.6. Concentration of fat in milk of the LL and the HL cows during the first 12 weeks of the lactation (the differences between the lines were significant only in week 6 (LL= 4.3 HL= 4.0 %).

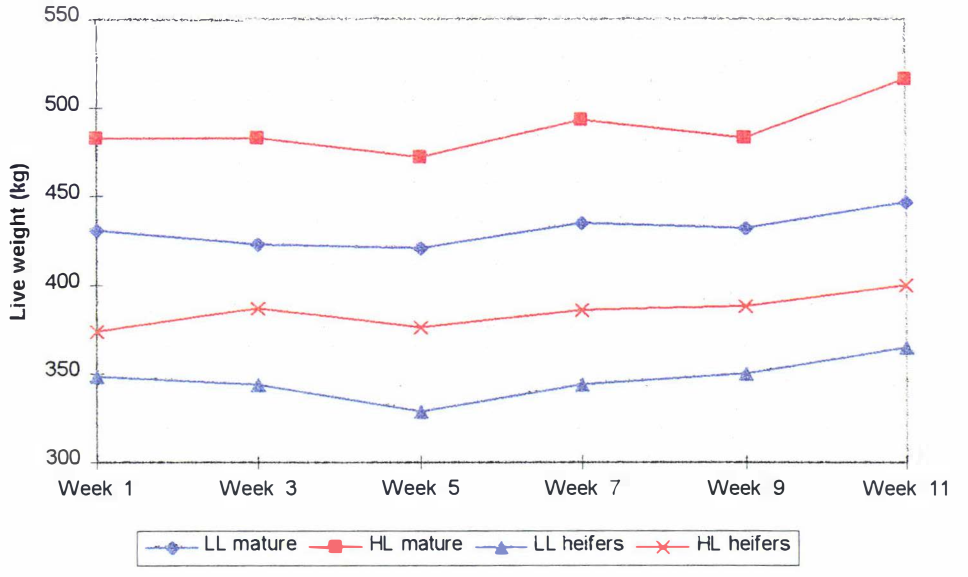

Figure 3.7. Changes in live weight of the LL and HL heifers and mature cows during early lactation.

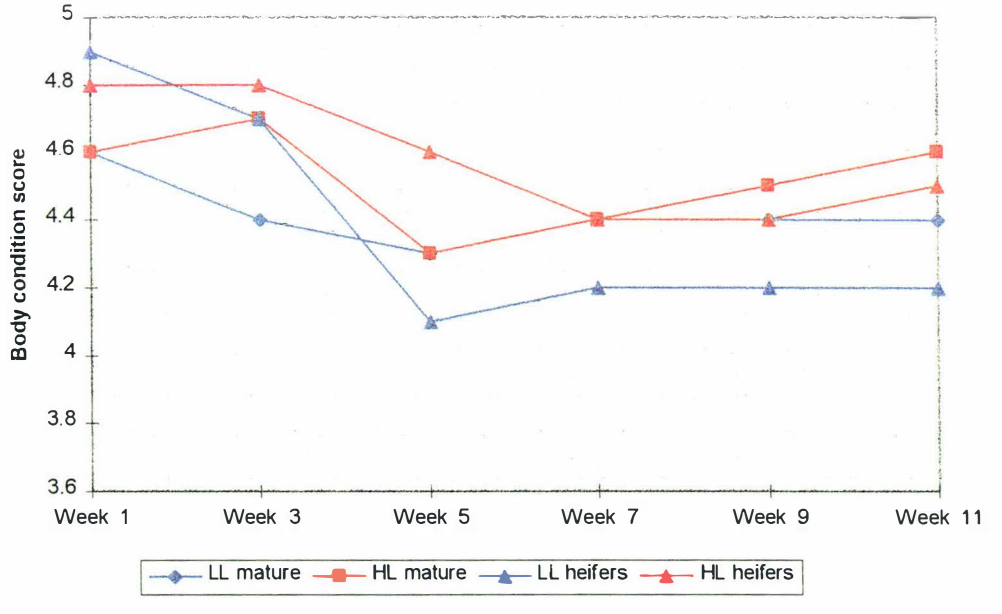

Figure 3.8. Changes in the body condition score of the LL and HL heifers and mature cows during early lactation (the differences were significant in week 5 (LL= 4.17 HL= 4.43).

3.2) Milksolid and energy conversion efficiency for LL and HL cows (Experiment 1 b).

Pregrazing and postgrazing pasture masses in experiment 1b.

Table 3.5 presents the average pregrazing and postgrazing pasture mass (kgDM/ha) , pasture allowance (kg DM/cow/day) and apparent DMI of cows (DM disappearance estimated by using the rising plate meter) during the first and second 5 days of the experiment 1b. The calibration equations used during these ten days were :

Pregrazing pasture mass (kg DM /ha) = 160 x + 147 (R^2 = 0.72).

Postgrazing pasture mass (kg DM/ha) = 161 x + 177 (R^2 = 0.78) where x = reading from meter.

Table 3.5 *Average pregrazing and postgrazing pasture mass (kg DM/ha),daily pasture allowance (kgDM/cow) and estimated daily DMI (kg DM/cow) during the first and second 5 days of the experiment 1 b (± standard deviation).*

	First 5 days	Second 5 days
Pregrazing pasture mass(kg DM/ha)	2505 ±256	3018 ±309
Postgrazing pasture mass(kg DM/ha)	1621 ±132	1812 ±246
Pasture allowance(kg DM/cow)	40 ±7.2	47 ±17
Apparent DMI (kg DM/cow/day)	15.8 ±2.4	19.1 ±1.4

Chemical and botanical composition.

On a DM basis, ryegrass represented 89%, white clover 7.6% and other species 3.6 % of the pasture samples taken for botanical composition. The chemical composition of these samples is shown in Tables 3.6. The energy content of the pasture was estimated to be 11.4 MJ ME/kg of DM (M/D = 0.156 DMD% -0.53; SCA, 1990).

Table 3.6 *Chemical composition of the pasture samples taken during the first and second 5 days of the experiment 1 b (% or g; DM basis).*

	First 5 days	Second 5 days
Dry Matter (%)	18.00	20.00
Organic Material (%)	89.65	88.15
Crude Protein (%)	20.83	20.67
Glucose (g/100g)	9.50	10.36
Dry Matter Digestibility (%)*	77.00	76.43
Organic Matter Digestibility(%)*	77.27	77.40
Ash (%)	10.27	11.96
Neutral Detergent Fibre (%)	42.00	37.46
Acid Detergent Fibre (%)	23.38	21.70
Hemicellulose (%)	18.61	15.77

* Calculated using in vivo standards

Liveweight and milk production of LL and HL cows in experiment 1 b.

The mean adjusted values for LW and milk yield traits of the HL and LL dairy cows in experiment 1b are shown in Table 3.7. The difference in liveweight between the two lines was 76 kg (P<0.01). Light and heavy heifers differed by 23 kg of LW (P<0.01) and mature cows by 105 kg of LW (P<0.01). No significant differences were detected between the lines for LW change, but the average values measured (15 kg of LW in ten days) were impossible to be achieved in practice.

No significant differences were detected between the milk yield traits and milk composition of the two lines of cows in any of the three herd tests made during the 10 days trial. The MS produced per kg $LW^{0.75}$ was also the same for both lines. Consequently, the average of the three herd tests for MS, MP, MF, MY, F% and P% were considered as the estimated production by each cow for the 10 days period.

Table 3.7 *Mean liveweights (kg) and standard deviations, and mean adjusted values and standard errors for daily MY (L/cow), daily MS production (kg MS / cow), daily MP production (kg/cow), daily MF production (kg/cow) and milk composition of the LL and HL cows in experiment 1 b.*

Variable	Light line (n= 21)	Heavy line (n= 21)	Significance of difference
LW (kg)	406 ± 40	482 ± 83	**
MS (kg /c/d)	1.64 ±0.06	1.73 ±0.07	NS
g MS/kg $LW^{0.75}$	19.4 ±0.66	19.0 ±0.68	NS
MY (L)	22.54 ±0.62	23.28 ±0.59	NS
P (kg/cow/d)	0.72 ±0.01	0.75 ±0.01	NS
F (kg/cow/d)	0.95 ±0.02	0.94 ±0.02	NS
MS %	7.42 ±0.16	7.35 ±0.15	NS
Fat %	4.21 ±0.11	4.10 ±0.10	NS
Prot %	3.21 ±0.06	3.25 ±0.06	NS

NS: not significant * P<0.05 ** P<0.01

DMI and digestibility measured by the alkanes technique, energy balance and efficiency of the LL and HL in experiment 1b.

The measured DMI and the adjusted means for DMI, DMD (%), energy balance , MS conversion efficiency, Gross energy efficiency and Net Energy Efficiency of the LL and HL cows during the 10 days of the trial are presented in Table 3.8. Data were available from 21 HL cows , but from only 19 LL cows because faecal alkanes concentration was very low in two of the Light cows, and so their results were discarded. One of them bit the capsule at the time of insertion which probably affected the pattern of alkane release, the other one probably regurgitated the capsule during the trial.

When the DMI of the cows were not adjusted by MS production as a covariante, DMI of the heavy and light cows were significantly different (P<0.05). However, when DMI was adjusted to a common MS yield, although the LL cows ate slightly less than the HL cows, the differences were not statistically significant. As milksolid production had a highly significant effect on DMI (P<0.001), it was considered important to include it as a covariate in order to compare the feed intake capacity of the cows from the two lines. The effect of line on the "corrected" DMI (kg DMI/100 kg LW) was also analysed using the same model as above. Although the light cows presented higher values than heavy cows (3.4 vs 3.2 kg DM/100 kg LW) , the difference was not statistically significant.

Digestibility was similar for both lines. Assuming that the energy requirements of the cows were : 0.6 $*LW^{0.75}$ + kg MS * 64 MJ ME (Holmes and Wilson, 1987), both lines of cows were in an energy balance close to 0. Similarly, no differences in any of the indicators of efficiency were detected between the two lines. However, although not significant, the LL cows showed slightly higher MS conversion efficiency than the HL cows ($P<0.1$).

Table 3.8. ***Measured DMI and adjusted means and standard errors of the DMI (kg DM/day), corrected DMI (kg DM/100 kg LW), DMI/ kg $LW^{0.75}$, DM digestibility, MS conversion Efficiency (kg MS / kg DM eaten), Energy balance, Gross Energy Conversion Efficiency (GEEff) and Net Energy Conversion Efficiency(NEEff) of LL and HL cows during experiment 1b .***

	LL (n=19)	**HL (n=21)**	**Significance of difference**
Measured DMI (kg DM/cow)	13.9 ±0.5	15.5 ±0.4	*
Adjusted DMI (kg DM/cow)	14.3 ±0.5	15.1 ±0.5	NS
DMI as a % of LW (kg DM/100 kg LW)	3.4 ±0.3	3.2 ±0.3	NS
DMI/kg $LW^{0.75}$ (g DM/kg $LW^{0.75}$)	153 ±5.0	151 ±5.0	NS
Digestibility (%)	77.8 ±0.7	78.0 ±0.6	NS
Energy balance (MJ ME)	-3.4 ±5.1	1.6 ±4.8	NS
MS Efficiency (gr MS /kg DM eaten)	120 ±4.0	110 ±4.0	NS
Gross Energy Efficiency (%)	44.6 ±1.3	42.3 ±1.2	NS
Net Energy Efficiency (%)	64.8 ±1.2	64.6 ±1.2	NS

NS: not significant * $P<0.05$ ** $P<0.01$

Multiple regression analysis was performed using DMI (kg/cow/d) of each cow as the dependent variable, and metabolic liveweight ($LW^{0.75}$) and Milksolid production (MS) as independent variables (Figure 3.9). Taking into account the extremely high average LW gain (15 kg) recorded for the cows in the experiment, it was decided not to include LW change in the model.The equation obtained was:

- DMI (kg DM/day) = $-1.75 + 0.063\ LW^{0.75} + 6.1$ kg MS $\qquad R^2 = 0.67$

where :
MS production was significantly associated to DMI ($P<0.001$), but the effect of $LW^{0.75}$ on DMI only approached significance ($P<0.1$).

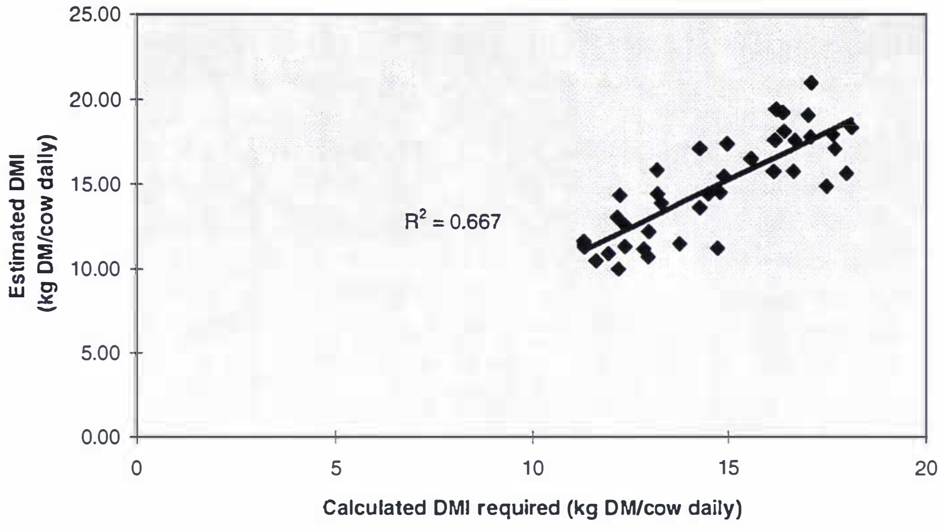

Figure 3. 9. *Regression of the estimated dry matter eaten by each cow (using alkanes) on the calculated DMI required by each cow {DMI (kg DM/cow daily) = ($LW^{0.75}$ * 0.6) + (64 MJ ME * kg of milk solid) divided by 11.4 MJ ME/kg DM}.*

Grazing behaviour of the HL and the LL cows in experiment 1b.

Table 3.9 shows the main results for the grazing behaviour of the LL and HL cows. There were no significant difference in grazing time between the lines on the 2 days recorded. However, biting rate of the LL was consistently faster than that of the HL (Table 3.9). Although cows had faster biting rate after the morning milking, the effect of moment of the day was not significant . Interestingly, the model used indicated that for each increase of 0.1 kg MS produced per day, biting rate was increased by 0.6 bites per minute (P<0.001).

Table 3.9 *Mean and standard errors of the grazing time(minutes /day) and biting rate (bites/ minute) of light and heavy cows in experiment 1b.*

	N° cows	Light cows	Heavy cows	Level of significance
Day 1 (Total Grazing Time in minutes)	42	536 ±9.8	527 ±9.3	NS
Day 2 (Total Grazing Time in minutes)	42	507 ±8.7	503 ±8.3	NS
Morning biting rate (bites/ minute)	24	58 ±2.1	53 ±2.2	*
Noon biting rate (bites/ minute)	24	51 ±2.1	42 ±2.2	*
Evening biting rate (bites/ minute)	24	54 ±2.2	50 ±2.2	*
Mean 24 hs Biting rate (bites/ minute)	24	55 ±0.9	50 ±0.8	*

NS: not significant * P<0.05 ** P<0.01

3.3) Concentration of metabolites in blood of the HL and LL cows.

The adjusted mean values for concentration of glucose, albumin and urea for each of the four weekly samples are presented in Tables 3.10, 3.11 and 3.12.

Glucose concentrations were consistently higher in the HL cows than in the LL ones (Table 3.10). However, the differences were not significant in any of the weeks. In addition,there were no differences in the concentration between the 4 weeks. A negative association was found between glucose concentration in blood and MS production during the first 6 weeks of lactation (P<0.01). BCS at calving and BCS at 40 days were also found to be positively associated to glucose concentration in blood (P<0.05).

Table 3.10. ***Mean glucose concentration (mmol/Lt) in blood of Light and Heavy cows in the second month of lactation (± standard errors).***

	Week 1	Week 2	Week 3	Week 4
Light cows	3.23 ±0.10	3.28 ±0.05	3.22 ±0.04	3.60 ±0.07
Heavy cows	3.31 ±0.11	3.36 ±0.05	3.31 ±0.05	3.62 ±0.07
Signif level	NS	NS	NS	NS

NS: not significant * P<0.05 ** P<0.01

Urea and albumin plasma concentrations were not significantly different between the LL and HLcows (Table 3.11 and Table 3.12) in any of the sampling periods analysed. Again, no significant differences were found between weeks. None of the covariates used in the model was significant.

Table 3.11 ***Adjusted mean of albumin concentration (g/L) in blood of LL and HL cows in the second month of lactation (± the standard errors).***

	Week 1	Week 2	Week 3	Week 4
Light cows	38.70 ±0.5	39.79 ±0.5	37.85 ±0.5	40.88 ±0.4
Heavy cows	38.08 ±0.5	40.03 ±0.5	37.20 ±0.5	41.01 ±0.4
Signif level	NS	NS	NS	NS

NS: not significant * P<0.05 ** P<0.01

Table 3.12 ***Adjusted mean of urea concentration (mmol/L) in blood of LL and HL cows in the second month of lactation (± standard errors).***

	Week 1	Week 2	Week 3	Week 4
Light cows	6.38 ±0.3	5.59 ±0.2	5.83 ±0.2	6.72 ±0.2
Heavy cows	6.87 ±0.3	6.01 ±0.2	6.19 ±0.2	7.00 ±0.3
Signif level	NS	NS	NS	NS

NS: not significant * P<0.05 ** P<0.01

3.4) Comparison of the reproductive performance of the LL and HL cows.

Reproductive performance of the HL and LL cows from 1992 to 1997.

Calving Ovulation Interval (C-Ov) in 1996 and 1997.

The estimated means of the C-Ov intervals for each line are shown in Table 3.13. They were significantly different according to the Wilcoxon Test (P<0.05). These results suggest that the HL had more cows with shorter intervals than the LL. The values obtained differed significantly between the years, and between heifers and mature cows. The mean interval C-Ov was significantly shorter in 1997 than in 1996 (1997=24 days (±1.7), 1996=36 days (±3.6), P<0.05), and shorter for mature cows compared to heifers (mature cows=25 days (±1.38) vs heifers=36 days (±4.4), P<0.05).

Table 3.13 ***Calving-ovulation interval (C-Ov), calving-first heat interval (C-H), planned start of mating-first service interval (PSM-1Serv), planned start of mating-conception interval (PSM-Con) and planned start of calving-calving interval (PSC-C) of the LL and the HL of cows (± the standard errors).***

Interval	**N° of cows**	**LL**	**HL**	**Level of significance**
C-Ov (days)	124	31 ±2.5	28 ±3.2	*
C-H (days)	260	43 ±2.0	50 ±6.0	NS
PSM-1Serv(days)	234	11 ±1.0	12 ±1.0	NS
PSM-Con (days)	234	21 ±1.8	25 ±2.0	NS
PSC-C (days)	260	22 ±1.6	25 ±1.7	NS

NS: not significant * P<0.05 ** P<0.01

A second analysis was performed using ANOVA, with data transformed to logarithms($_{10}$). The transformed means of the C-Ov intervals differed significantly (LL=26.3 days vs HL:=21.8 days, P<0.05). Again the effect of year and age were significant. In conclusion, although the results are not exactly the same between ANOVA and Lifetest, they indicate that the HL of cows tended to ovulate earlier than the LL of cows.

Calving -First Heat Interval (C-H) from 1992 to 1997.

There was no difference in the C-H interval (Table 3.13) nor in the % of cows treated with CIDR (8% vs 8%) between the two lines. When the C-H interval was analysed separately for heifers and mature cows from the two lines, although the difference was not statistically significant, the HL mature cows had a tendency to present longer C-H intervals than the mature cows of the LL (LL=38.1 days vs HL=50.8 days, P<0.1), while the heifers from the two lines had similar C-H intervals (LL heifers=53 days ± 3.9 vs HL heifers=51 days ± 4.5). The GLM procedure used for the analysis of the transformed data also indicated no significant effect of line (LL=36.8 days vs HL=38.63 days) on the C-H interval. The effects of year and calving period were not significant, but heifers (2 year old cows) showed longer C-H intervals than mature cows (heifers=52.24 days ± 3.0 vs mature=49.60 days ± 6.3).

Planned Start of Mating- First Service Interval (PSM-1Serv), Planned Start of Mating-Conception Interval (PSM-Con) and Planned Start of Calving- Calving interval (PSC-Calv) from 1992 to 1997.

No significant differences were detected in the PSM-1Serv interval between the lines for the combined data (Table 3.13), or for the heifers and mature cows separately. It was the same for heifers and mature cows, independently of the effect of line. To assess the same data using ANOVA, the data was transformed (square root transformation), and the effect of line was not significant (LL=9.67 days ± 0.69, HL=9.48 days ± 0.69).

The length of pregnancy was the same for the two lines of cows (LL=280 days ± 0.7 vs HL=280 days ± 0.7). Consequently, the calving pattern must be a mirror image of the previous mating season. Neither the Log-Rank Test nor the Wilcoxon Test detected differences in the distribution of the PSM-Con interval between the two lines (Table 3.13). However, the difference between the heifers of the two lines approached significance (LL heifers=18.4 days ±2.9 vs HL heifers=26.3 ± 3.53, P<0.1). In agreement with the lifetest procedure, ANOVA also showed no difference between the lines in the PSM-Con interval (LL=17.7 days ±1.60 vs HL=19.8 days ±1.63). Only the effect of age and year approached significance when used as covariates (P<0.1 in both cases). At the end of the mating period, no difference was detected between the lines in the percentage of empty cows from 1992-1996 (LL=7% vs HL=5.7%).

In relation to the PSC-C interval, the lifetest procedure did not detect differences between the calving pattern of the two lines (Table 3.13). The heifers (2 year old) of the two lines presented the same PSC-C interval (LL heifers=15.6 days ± 2.3 vs HL heifers=15.0 days ± 2.1). However, the difference in the three year old approached significance (LL cows=23.7 ± 3.23 vs HL=31.8 ± 3.3, P<0.1), and the HL cows >3 year old also tended to show longer PSC-C intervals than the LL cows >3 year old (LL=25.16 ± 2.0 vs HL=30.45 ± 2.1, P<0.1) Similarly, the ANOVA did not detect any difference between the two lines (LL=19 days vs HL=22 days). Independently of the effect of line, the heifers showed a shorter interval compared to the mature cows (heifers=15.27days ± 1.5 vs mature cows=27.85days ± 1.4, P<0.001). Although the calving pattern for the two lines was similar, the percentage of HL cows induced was significantly higher than that of LL cows (HL=9.1% vs LL=1.5%, P<0.05).

Most of the information analysed indicated that the distribution of the PSM-Con and the PSC-C were the same for both lines. However, a compact calving is critical under the New Zealand conditions of production. Therefore the conception pattern and the calving pattern were analysed by dividing the mating and the calving periods into intervals of 21 days. This comparison was carried out using the chi-square procedure to compare the percentage of cows of each line which conceived (Table 3.14) and which calved (Table 3.16) in each 21day period . The lifetest procedure was used with the same objective, but in this case, the data of all these cows with a PSM-Co interval and a PSC-C interval longer than 21 days were considered as censored data.

The percentage of cows which conceived in the first 21 days of mating tended to be higher for the LL than for the HL cows (Table 3.14). Although the difference only approached to significance (P<0.1), it was especially large in the first calving cows (P<0.1). The results of the lifetest procedure were the same as the chi-square analysis: more cows of the LL than from the HL conceived in the first 21 days (P<0.05).

Table 3.14 ***Percentage of first calving cows, mature cows and total animals (combined data) from the Heavy Line (HH) and Light Line (LL) which conceived during the first 21 days of mating.***

	N° cows	LL (n= 115)	HL (n=115)	Level of Significance
% of first calving cows	**77**	76	56	†
% of mature cows (> 2 year old)	**153**	69	62	NS
% of cows (combined data)	**230**	71	60	†

NS: not significant, † P<0.1 * P<0.05 ** P<0.01

The results shown in Table 3.14 agree with those presented in Table 3.15. The conception rate at first service is significantly higher for the LL cows than for the HL cows, a difference that is larger in the first calving cows. In the mature cows (>2 year old), although the difference was not significant, the proportion of HL cows requiring more than one service to conceive also tended to be higher than for the LL cows.

Table 3.15 ***Conception rate at first service of the first calving cows, mature cows and total animals (combined data) from the HL and LL.***

	N° of cows	LL (%) (n= 115)	HL (%) (n=115)	Level of Significance
First calving cows %	**86**	74	58	†
Mature cows (> 2 year old)	**172**	69	57	†
Combined data	**258**	70	58	*

NS: not significant, † P<0.1 * P<0.05 ** P<0.01.

In agreement with the results discussed above, more LL cows than HL cows tended to calve in the first 21 days of the calving period (Table 3.16). The difference between lines was larger in the 3 year old cows, but there was no difference in the first calving heifers (Table 3.16). The Lifetest procedure performed by censoring the data of those cows with a PSC-C interval longer than 21 days also indicated that more cows from the LL line calved in the first 21 days period of calving than from the HL line (P<0.05).

Table 3.16 ***Percentage of first calving cows, 3 year old cows and total animals (combined data) from the HL and LL that calved during the first 21 days of the calving period.***

	N° cows	LL (n=131)	HL (n=133)	Level of Significance
% of first calving cows calved in the 1st 21 days	**89**	80	75	NS
% of 3 year old cows calved in the 1st 21days	**175**	58	42	†
% of cows calved in the 1st 21 days (combined data)	**260**	66	53	†

NS: not significant, † P<0.1 * P<0.05 ** P<0.01.

Although the results seems to suggest that the LL cows achieved a slightly better overall reproductive performance than the HL cows along the years, this conclusion should be taken with caution because the reproductive results changed significantly from year to year, especially for the HL (Table 3.17).

Table 3.17 ***Percentage of cows (combined data) from each line which calved in the first 21 days of calving period, conceived during the first 21 days of mating period and conception rate at first service in 1994, 1995, 1996 and 1997.***

	Line	1994 (n=33)	1995 (n=47)	1996 (n=89)	1997 (n=89)
% Cows calving in the 1st 21 days	LL	50	83*	71*	56
	HL	56	56*	47*	53
% Cows conceiving in the 1st 21 days	LL	71†	83*	67	76
	HL	58†	52*	56	72
% Cows pregnant at 1st service	LL	79†	74*	62	77
	HL	63†	43*	53	73

† P< 0.1 * P< 0.05.

Comparison of the reproductive performance between the two lines of cows in the 1996-1997 season.

The C-Ov, C-H, PSM-1Serv and the PSM-Con intervals for the two lines of cows in the 1996/97 season are presented in Table 3.18. The trends observed are similar to those reported for 1992 to 1997 which included the data of the 1996/97 season. They are presented separately because of the additional data derived from the measurements of milk production, LW and BCS changes, metabolites concentrations in blood and from the scanning of the ovaries.

The HL cows tended to ovulate earlier than the LL cows. However, the C-H interval was the same for both lines. From the covariates used, BCS at calving, BCS at the 5th week of lactation and milksolids yield during the first 6 weeks of lactation were negatively associated to the C-Ov interval. The only covariate associated with the C-H interval was the BCS at the 5th week of lactation.

The information about the calculated energy balance (Energy eaten- Calculated Energy Required) of the cows from experiment 1b was used in conjunction with the reproductive data of the same cows. Independently of the effect of line, those cows with an energy balance lower than -10 MJME had C-Ov (46.5±8.1 vs 24.0±1.7 days) and C-H intervals (61.8±7.6 vs 39.9±3.02 days) significantly longer than the cows with an energy balance above -10 MJME (P<0.05).

There were no significant differences between the two lines for PSM-1Serv and PSM-Con intervals, and of the covariates used, only BCS at the 5th week of lactation approached significance.

Table 3.18 ***Calving-ovulation interval (C-Ov), calving-first heat interval (C-H), planned start of mating-first service interval (PSM-1Serv) and planned start of mating-conception interval (PSM-Con) of the LL and the HL of cows during 1996/97.***

	LL (n= 30)	HL (n= 25)	Level of significance
C-0v (days)	40 ±5.2	25 ±1.9	NS
C-H (days)	52 ±4.5	53 ±6.3	NS
PSM-1Serv (days)	11 ±1.4	10 ±1.4	NS
PSM-Con (days)	14 ±1.3	11 ±1.4	NS

Comparison of the follicular and luteal activity of the HL and LL cows.

From the 20 cows synchronised, one of the light heifers was discarded from the trial because it developed a cystic follicle in the right ovary. As a consequence, the results presented correspond to the scanning of 9 Light and 10 Heavy cows. Table 3.19 summarises average LW, BCS, MS production and days post-partum of the cows used in the trial. From the 19 cows, one showed 2 follicular waves and another 4 waves during their cycles, with the rest presenting 3 follicular waves.

Table 3.19 *Average LW, BCS, MS production and days post-calving of the LL and HL cows used in the scanning trial.*

	Light Cows (2 heifers and 7 mature cows)	Heavy cows (3 heifers and 7 mature cows)
Average LW (kg)	405	481
Average BCS	4.47	4.68
Average MS (kg MS/d/ cow)	1.83	1.80
Days post-calving (days)	54	58

Table 3.20 shows the main results of the variables measured. The mean diameter of the ovulatory follicles were larger in the Heavy than in the Light cows, but no differences in the diameter were found in case of the first and second Dominant Follicles (Figure 3.10). Furthermore, light cows showed shorter cycle lengths than heavy cows, but considering the number of cows used in the trial, this result should be taken with caution.

Table 3.20 *Mean values for the adjusted diameters of dominant follicles and day of the cycle at which they achieved maximum diameters forHL and LL cows (± standard errors) .*

	Light cows (n =10)	Heavy cows (n= 9)	
Diameter of the 1st Dominant Follicle (mm)	12.2 ±0.4	12.6 ±0.4	NS
Average Day of the cycle (days)	6.93	6.46	NS
Diameter of the 2nd Dominant Follicle (mm)	14.5 ±1.1	14.7 ±1.0	NS
Average Day of the cycle (days)	11.61	11.7	NS
Diameter of the Ovulatory Follicle (mm)	12.7 ±0.9	15.7 ±0.9	*
Average Day of the cycle (days)	18.0	20.6	*
Cycle Length (days)	19.7	21.4	*

NS not significantly different * P<0.05 ** P<0.01

Table 3.21 presents the results for the area of the CL measured in synchronised HL and LL cows. According to the repeated measure analysis, the difference in the average area of the CL between the two lines approached significance (P< 0.1). However, the average areas of the CL were statistically different between the two lines in the days 9 (P<0.01), 10 (P<0.05) and 11 (P<0.05) of the cycle. These days are coincident with the maximum development of the luteal tissues (Table 3.21 and Figure 3.11).

Table 3.21 *Mean values for the area of the Corpus Luteum for HL and LL cows on different days of the oestrus cycle.*

Day	**5**	**7**	**9**	**10**	**11**	**13**	**15**
Light (mm^2)	364 ±31	492 ±46	575 ±41	652 ±58	690 ±60	683 ±54	628 ±64
Heavy (mm^2)	422 ±30	610 ±44	726 ±39	839 ±56	859 ±57	807 ±51	699 ±61
Signif Level	NS	NS	**	*	*	NS	NS

NS: not significant * P<0.05 ** P<0.01

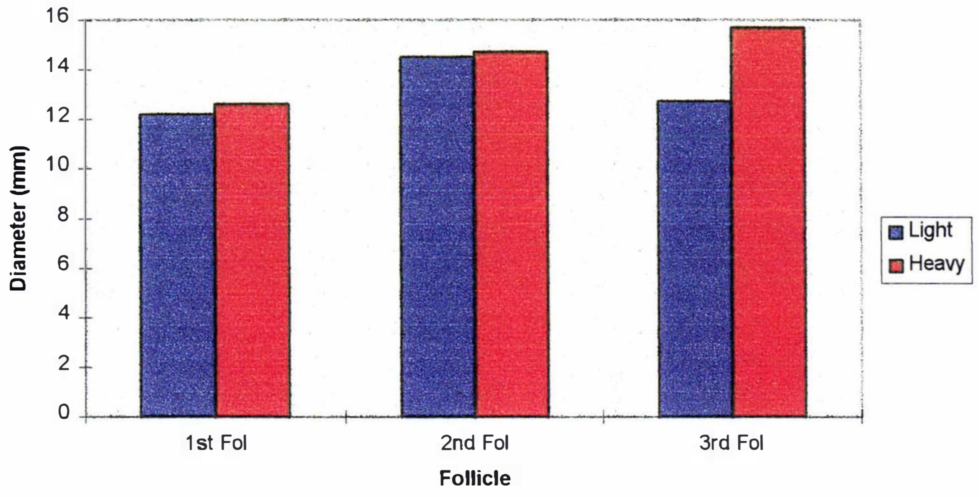

Figure 3.10 Comparison of the mean diameter of the first, second and third dominant follicle of the HL and LL cows scanned during a complete cycle.

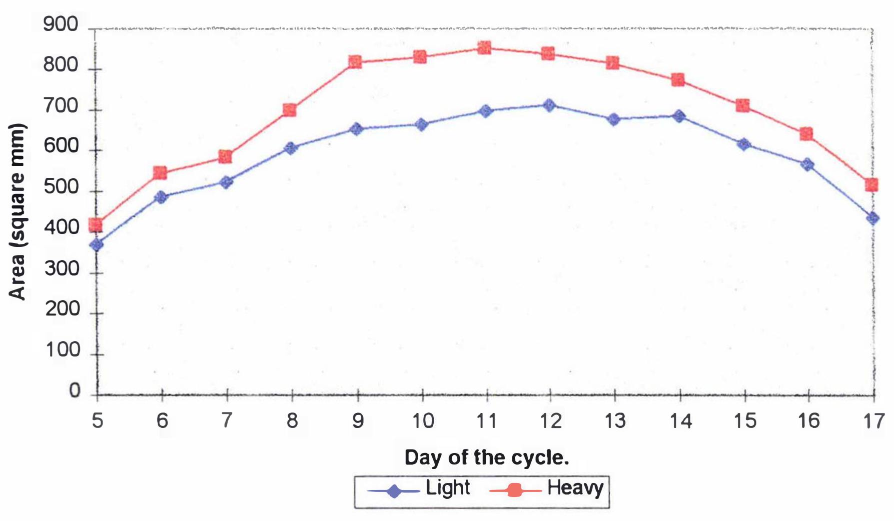

Figure 3.11 Comparison of the area of the corpus luteum (mm²) in the HL and LL cows scanned during a complete cycle.

Chapter Four

Discussion of results.

4.1)Results of the experiment 1 a.

Milk yield traits and milk composition of the HL and LL cows during the first 12 weeks of lactation.

The analysis of the combined data (heifers + mature cows) indicated that, although the HL cows produced slightly more milk yield traits than the LL cows, the production of the two lines during the first 12 weeks of lactation did not differ statistically for any of the milk traits considered. However the HL mature cows produced significantly more MS (kg/cow) and MY (lt/cow) than the LL mature cows, but this difference could not be detected for the heifers. These results conflict with those obtained with the regression analysis. In fact, heifers from the two lines produced similar milk yield traits, but the multiple regression analysis indicated that for each increase in 1 kg of LW at calving total milk protein production during the first 12 weeks increased by 0.14 kg. On the other hand, although the HL mature cows produced more MS and MY than the LL mature cows, the multiple regression equation of the milk yield traits of this group of cows indicated that the effect of LW was not significant. The inconsistent effect of LW on milksolid yield suggests that high milk yield can be achieved independently of the LW of the cows.

In the trial developed at Massey, the two lines of cows (HL and LL) have been selected to maximise differences in LW and minimise differences in MS yield as a result of genetic selection. Consequently, as the two lines were treated the same and had similar BCS at calving, any difference in milk yield between the lines should appear if a positive genetic correlation exists between size and milk yield traits exists. The conflicting data obtained in the current experiment is coincident with the broad range of genetic correlations reported in the literature between size and milk yield. According to different authors, the correlation was : high and positive (Lin *et al*, 1984; Ahlborn and Dempfle, 1992; Van der Waaij *et al*, 1997); low and positive (Jensen *et al*, 1995), close to 0 (Van Arendonk *et al*, 1991; Mason *et al*, 1957), low and negative (Syrstad *et al*, 1966; Moore *et al*, 1991; Lee *et al*, 1992; Veerkamp *et al*, 1995) or moderate and negative (Persaud *et al*, 1991). In New Zealand, a high genetic correlation between LW and MS production has been recently reported (Ahlborn and Dempfle, 1992; Van der Waaij *et al*, 1997), and it was suggested that this "might signify population - specific pleiotropism with some genes affecting variation in milk as well as in body size" (Ahlborn and Dempfle, 1992). However, in Minnesota, in an experiment with similar characteristics to those of the current trial, the heavy and light lines of cows produced the same amount of fat corrected milk in all the nutritional treatments compared (Donker *et al*, 1983). In a more recent update of this trial, the similar milk production between the two lines, and the differences in LW, were confirmed after 30 years of selection (Hansen *et al*, 1998).

Although the two lines of cows (HL and LL) developed at the DCRU differs genetically in size, the existence of phenotypic correlations between size and milk yield may explain some of the conflicting results of the current experiment. Bearing in mind that this experiment was confined to the early lactation of the cows, most of the reports in the literature indicated a moderate positive phenotypic correlation between LW of the cows after calving and milk yield traits during the whole lactation which agrees with the results obtained in the current experiment (Mason *et al*, 1957; Lin *et al*, 1984; Sieber *et al*, 1988; Hietanen and Ojala, 1995). Ahlborn and Dempfle (1992) and Van der Waaij et *al* (1997) reported a low to moderate phenotypic correlation between LW of Holstein Friesian primiparous cows and milk yield in New Zealand. However, part of this positive phenotypic correlation between LW and MS production may be related to the different condition score of the cows at calving. For instance, Stakelum and Connolly (1987) found no difference in milk yield between Heavy and Light cows with a difference in LW of 54 kg but similar BCS. In agreement with the current results, grazing heifers which calved at the same body condition score but with different skeletal size (due to nutritional differences) did not show significant differences in milksolid yield (Stewart and Taylor, 1996; Mackle *et al*, 1996).

The milk fat % and milk protein % did not differ significantly between the two lines during early lactation, although the LL cows had a slightly higher fat % . Similar trends were indicated by Donker *et al* (1983). In their analysis of the data from grazing primiparous cows, Ahlborn and Dempfle (1992) reported a very low phenotypic correlations between body size, and fat % and protein % (-0.03 and 0.04, respectively). These results agreed with those reported by other researchers (Mason *et al*, 1957; Sieber *et al*, 1988; Hietanen and Ojala, 1995). They suggest that selecting by size would not have any effect on milk composition.

LW and BCS changes of the HL and LL cows during the first 12 weeks of lactation.

Because of the breeding objectives in the current experiment, the two lines of cows differed on average by 52 kg (mature cows) and 26 kg (heifers) at calving. The trend observed confirmed earlier indications that differences in body weight of the genetic lines increased with parity (Garcia Muñiz *et al*, 1996). Similar differences in LW were reported in Minnessota after 3 generations of divergent selection by size (Yerex *et al*, 1988). Despite the differences in LW, the two lines of cows started the lactation with similar BCS (LL=4.69 vs HL=4.75). Although 1 unit of BCS may not represent the same amount of body tissue weight for the HL cows as for the LL cows , the LL cows lost slightly more condition than the HL cows during the first 5 weeks of the lactation (-0.47 vs -0.29), a difference that was not statistically significant. However, the difference in BCS was significant after 5 weeks of lactation (LL=4.17 vs HL=4.43, $P<0.05$), a difference that was larger for the heifers (LL=4.07 vs HL=4.58, $P<0.1$) than for the mature cows of the two lines (LL=4.21 vs HL=4.37). In their trial, Stakelum and Connolly (1987) indicated that although there was no difference in the condition score of the heavy and light cows at the beginning of the experiment, the smaller cows had a slightly lower score during subsequent periods.

Although the postcalving LW change is not a very reliable indicator of changes in body composition because of the possible misleading effects of gut fill (Wallace, 1961; Van Arendonk *et al*, 1995), some trends can be perceived when LW change is analysed in conjunction with changes in BCS. The changes in LW were similar to the corresponding changes in BCS discussed above. However, the pattern of LW change was different for heifers and mature cows. The mature cows of the two lines lost the same LW during the first 5 weeks of lactation (-8.5 vs -8.8 kg), but the HL heifers maintained their LW while the LL heifers lost -17.6 kg of LW in early lactation ($P<0.05$). Earlier reports indicated that, independently of the level of nutrition after calving, heavy cows at calving tend to lose LW during early lactation. Conversely, light and low BCS cows at calving maintain or gain LW because they partition more energy into liveweight gain (Rogers *et al*, 1979; Grainger *et al*, 1982; Stewart and Taylor, 1996; Penno, 1997). However, in the current trial, because of the particular breeding objectives, the two lines of cows had different LW, but similar BCS and similar genetic potential for MS yield. Therefore, it is expected that the partition of nutrients, and BCS and LW changes would be the same for both lines. This suggestion is confirmed by the similar concentrations of albumin, glucose and urea found in plasma for the two lines of cows during the second month of lactation. However, this situation was probably different for the heifers. According to the results presented by Garcia Muñiz *et al* (1996), HL heifers achieved liveweight maturity later than LL heifers. Therefore, it is possible that the heifers from the HL and the LL were at different stages of maturity at calving. Consequently, HL heifers partitioned more energy to tissue deposition for growth instead of milk production which may explain the different pattern in LW change and the similar milk yield observed for the heifers of the two lines in early lactation.

The relationship between the production of milk traits and LW and BCS changes of the LL and HL cows during the first 12 weeks of lactation.

Results obtained with cows fed total mixed ration diets (Garnsworthy, 1988) and pasture diets (Rogers *et al*, 1979; Grainger *et al*, 1982; Penno, 1997) indicated that cows with higher LW and BCS at calving produced more milk, protein and milk fat than lighter and thinner cows. Mackle *et al* (1996) found that heavier heifers at calving achieved higher milk yield, but not higher MS yield compared to light heifers. However, although not always reported, in most of these trials there was a positive association between LW and BCS of the cows at calving, with heavier cows having better BCS and so more body reserves to mobilise (Grainger *et al*, 1982; Mackle *et al*, 1996). A consistent trend reported in those experiments was that the heavier animals lost more LW than light cows during early lactation. The light cows ate more, but they partitioned more feed energy into LW gain (Garnsworthy, 1988; Grainger *et al*, 1982). The higher production achieved by the heavier cows at calving was explained by the utilisation of more body reserves for milk production. In addition, Veerkamp *et al* (1995) indicated a high phenotypic and genetic correlation between LW and BCS, and between DMI and BCS which suggests that the heavy cows have genetically more reserves to mobilise and bigger ingestive capacity, and consequently producing more milk than the light cows.

However, in the experiment at Massey, the two lines did not differ in BCS at calving and the tendency was for the LL to lose more LW and BCS after calving than the HL cows. In other words the higher yield of milk traits showed by the HL mature cows compared to the LL cows during early lactation was not explained by differences between the lines in their changes in LW and BCS after calving. Furthermore, the phenotypic correlation found between BCS and LW at calving was very small (0.12) which was to be expected because the cows had been selected for heavy or light weights and the variables BCS and LW should be independent. In addition, as will be discussed more extensively below, no difference was detected in the ingestive capacity of the two lines of cows when measured for a 10 day period in early lactation.

In conclusion, it can be said that under the conditions of this experiment, for the mature cows the HL produced slightly more MS during early lactation than the LL , but this difference did not exist between the heifers. The difference found between the mature cows could not be explained by differences in LW and BCS changes. In fact, although not significant, the LL cows showed a tendency to lose more LW and BCS than the HL cows. Considering the results from the multiple regression analysis, the effect of LW on milk yield traits was inconclusive which suggests that milk yield and size are not closely correlated.

4.2) Discussion of Experiment 1b.

Pregrazing and postgrazing pasture mass during experiment 1b.

A calibrated rising plate meter was used daily to measure the pregrazing and postgrazing pasture masses during the 10 days experiment. The DM disappeared was estimated from the difference between pregrazing and postgrazing pasture mass and the size of the paddock, and it was assumed to give a measure of the DMI eaten by the cows . The advantages and disadvantages of the technique has been discussed elsewhere (Earle and MacGowan, 1979; L'Huillier and Thomson, 1988; Stockdale, 1984). In the present experiment, in order to increase the accuracy of the technique, the same person measured the 200 samples per paddock and calibrated the rising plate meter. The values for r^2 of the calibration equations for pregrazing (0.72) and postgrazing (0.78) are lower than those reported by Stockdale (1984) and Earle and Mc Gowan (1979), but they are acceptable in relation to the objective of using this technique in the trial : to estimate the feeding level of the cows during the ten days period.

Based on the estimated pregrazing and post-grazing pasture masses , and the pasture allowances, it is suggested that the intake of the cows was not constrained by the sward characteristics during the 10 days period (Bryant *et al*, 1980; Glassey *et al*, 1980; Peyraud et al, 1996). This suggestion is confirmed by the average DMI of the cows estimated from the DM dissappearance. The average DMI figure obtained by this method for the first five days was similar to that measured using alkanes , but the average for the second 5 days was well above the average DMI estimated from the alkanes concentration in feces and herbage.

Liveweight and milk production of the HL and LL cows in early lactation in the experiment 1 b.

The average difference in LW between the two lines in experiment 1b was higher (76 kg) than that of the cows used in experiment 1a (42 kg). The reason was that from the total number of cows used in experiment 1a, LW and milk production were the two main criteria used to select the cows for the experiment 1b. Consequently, the mature cows differed by 105 kg LW and the heifers by 23 kg, with some overlapping of the phenotypic LW for the two lines. The same situation has been reported in the trial at Minnesota (Hansen *et al*,1998). The change in LW for the two lines of cows in the ten days period was 15 kg, a value which is improbably high, confirming the reported difficulties encountered in measuring this variable in short experiments (Van Arendonk *et al*, 1995; Korver, 1988).

As in the results obtained during the first 12 weeks of the lactation, although the HL cows produced slightly more MS (1.73 vs 1.64 kg MS) and MY (23.3 vs 22.5 lt) than the LL cows, the differences were not significant. MS production per kg of $LW^{0.75}$ was the same for two lines of cows (LL=194 vs HL=190 g/kg $LW^{0.75}$). In the multiple regression analysis, LW was not a significant factor in explaining the variation in milk production between the cows.

DMI (alkanes) and Grazing behaviour of the HL and LL cows in early lactation.

The pasture DMI measured by the alkane technique during the ten days period (LL=14.35 vs HL= 15.16 kg DM/day) were similar to the values reported by other authors working at similar pasture allowances (Glassey *et al*, 1980; Bryant *et al*; 1980; Peyraud *et al*, 1996). Furthermore, they are also similar to the theoretical DMI required for the average cow of the two lines calculated from their actual milk yield and LW (Holmes and Wilson, 1987) (Table 4.1).

Table 4.1 ***Comparison between the calculated theoretical DMI requirements of the average LL and HL cow and the mean DMI measured using the alkane technique.***

	LL cows	HL cows
Maintenance requirements (MJ ME) (0.6 x $LW^{0.75}$)*	54.3	61.7
Requirements for production (MJ ME) (kg MS x 64 MJ ME**)	105.0	110.7
Total requirements (MJ ME)	159.3	172.4
Theoretical DMI requirements (kg DM) ***	14.0	15.1
DMI measured using the alkanes	14.4	15.2
Difference	+ 0.4	+ 0.1

* Holmes and Wilson (1987).
** Average ME energy required to produce 1 kg MS (estimated from the results in this experiment).
*** (Total MJ ME req / 11.4 MJ ME /kg DM) MJ ME/kg was estimated from the chemical composition of the pasture samples (SCA, 1990).

The light cows ate slightly less than the heavy cows, but the 0.8 kg DM of difference was not statistically significant. At least 24 cows from each line would have been required to detect this difference as significant ($p<0.05$). However, the difference between the two lines in this experiment is in the range of those reported by other authors (Table 4.2). Stakelum and Connolly (1987) also found a difference in DMI of 0.4 to 0.6 kg DM between heavy and light cows differing by 54 kg of LW, maintained indoors and fed with cut grass . Donker *et al* (1983) reported that the DMI of the heavy line (575 kg) and light line (525 kg) of cows selected in Minnesota differed by 0.7 kg DM.

Table 4.2 *Results reported about the increase in DMI (kg DM) of dairy cows for each increase of 100 kg of LW (values estimated from the regression coefficient for LW of the equations presented by the authors).*

	DMI increase/100 kg LW	Conditions of the trial
Wallace (1961)*	1.10 kg DM	Grazing
Hutton (1962)*	1.30 kg DM	Grazing
Holmes and Jones (1964)*	1.34 kg DM	Grazing
Curran and Holmes (1970)*	2.30 kg DM	Grazing and Indoor
Brown *et al* (1977)	1.20 kg DM	Total mixed rations
Stakelum and Connolly (1987)	1.50 kg DM	Indoor
Jarrige *et al* (1989)	1.20 kg DM	Heifers grazing and Indoor
Jarrige *et al* (1989)	0.80 kg DM	Old cows grazing and indoor
Holmes *et al* (1993)*	2.00 kg DM	Grazing and Indoor
Tamminga and Van Vuuren (1995)	1.12 kg DM	Indoor

* Transformed data.

Although the difference was not significant, as a percentage of LW, the LL ate slightly more than the HL (LL= 3.4 and HL= 3.2 kg DM/100 kg of LW). Similar trend has been reported by other authors (Donker *et al*, 1983; Stakelum and Connolly, 1987; Mackle *et al*, 1996; Oldenbroek, 1988). The LL cows ate 1.42 compared to 1.25 kg NDF/100 kg LW eaten by the HL cows, which are higher (especially for the LL) than the average figure of 1.2 kg NDF/100 kg LW suggested as the maximum NDF that a cow could eat (Mertens, 1994). In addition, the cows were in early lactation in this experiment (average 42 days after calving), and maximum DMI under grazing conditions may be achieved at 90 to 100 days after calving (Wallace, 1961; Jarrige *et al*, 1986; Mackle *et al*, 1996). Therefore, even higher intakes could be expected at slightly later stage of the lactation.

In the current experiment (row 1 in Table 4.3), when DMI was regressed on $LW^{0.75}$ and MS production, the coefficient of regression for LW was 0.063 (approached significance, $p<0.1$) and the coefficient for MS production was 6.1 ($p<0.001$). The inclusion of age in the regression did not change the r^2 value or the coefficient of regression of $LW^{0.75}$. Interestingly, using the LW and MS information from experiment 1b with the equations presented in Table 4.3 (row 2 and 3), the predicted DMI were not significantly different from those predicted from the equation obtained from the current trial. That similarity indicates the close association between the three predictive equations for the range of LW and productions considered in this experiment. However, it is important to emphasis that although the predictive results were the same, the effect of LW was significant at the 1% in the equation published by Wallace (1961), and the coefficient reported for Kg MS (after transformation) was smaller than that in the current experiment.These differences in the results suggest that, as a driver of DMI, MS production was much more important in the current trial than in Wallace´s experiment which can be related to the higher production and genetic merit of a cow in 1996 than in 1961.

Table 4.3. ***Equations from the regression of DMI on $LW^{0.75}$ and milksolid production in the current experiment (row 1), published by Wallace (1961) (row 2) and published by Holmes and Wilson (1987) (row 3).***

1) Current experiment	$DMI(kg/d) = -1.75 + (0.063\ LW^{0.75}) + (6.1 * kg\ MS)$
2) Wallace (1961)*	$DMI\ (kg/d) = (0.08\ LW^{0.73}) + (3.42 * kg\ MS)$
3) Holmes and Wilson (1987) **	$DMI\ (kg/D) = \frac{(0.06\ LW^{0.75} + 64\ MJ\ ME * kg\ MS)}{11.4\ MJ\ ME/kg\ DM}$

* The original equation was transformed from organic matter to dry matter, and from milkfat corrected milk to MS.

* *The original equation was transformed using the data from the current experiment.

The average difference in maintenance between the lines was 7.4 MJ ME (Table 4.1) which corresponded to 0.65 kg DM (7.4 MJ ME / 11.4 MJ ME/kg DM). The difference in DMI measured was 0.8 kg DM which suggest that most of the increased DMI showed by the heavy cows would have been used to satisfy their increased maintenance requirements. This suggestion was confirmed by the fact that the difference between the two lines of cows for the ratio $DMI/LW^{0.75}$ (kg DM/kg of $LW^{0.75}$) was not significant. This data suggests that, compared to the HL cows, the DMI of the LL cows was not constrained by their size under the conditions of the current experiment. That is in contradiction to the suggestions made about the important effect of size of the cows on absolute DMI, especially in early lactation (Svendsen *et al*, 1994). In agreement with these results, several authors indicated that fill capacity was not an important constraint of the DMI for the dairy cows when fed high quality pasture (Weston, 1996; Forbes, 1995; Ulyatt and Waghorn, 1993). Conrad *et al* (1964) reported that fill capacity limited forage intake when forage digestibility was below 67%. The digestibility of the pasture in the current experiment was 77% , well above the limit suggested by Conrad *et al* (1964). MS yield was the variable which significantly affected DMI of the cows in the present experiment, which is in agreement with the suggestion that the energy deficit is the main driver of intake (Weston, 1996; Faverdin et al, 1995).

The values measured for grazing time and biting rate are similar to those reported in the literature under similar sward characteristics (Macgilloway and Mayne, 1996; Gibb *et al*, 1996; Pulido and Leaver, 1996; Hodgson, 1990). No difference was detected in the grazing time between the lines, but the LL cows had a faster biting rate than the HL cows. Similar results were obtained by Garcia Muñiz *et al* (unpublished data) in another experiment with a similar group of cows from the two lines. The data about DMI, grazing time and biting rate were used to estimate bite size of each cow, although the limitations of these estimations are recognised (Hodgson, 1982). The HL cows had mean bite weights significantly heavier than those of the LL cows (LL=0.46 ± 0.03 g vs HL= 0.60 ± 0.03 g, $P<0.001$), values which are in the range of those reported in the literature (Stobbs, 1974; McGilloway and Mayne, 1996; Gibb *et al*, 1996). In the same analysis, a significant effect of MS yield on bite size was also detected, with the bite size increasing by 0.02 grs by each increase in 0.1 kg of MS. In agreement with the present results, large Holstein heifers were reported to show increased bite size compared to small Holstein heifers (Erlinger *et al*, 1990) and the increased bite size of animals in energy deficit was indicated by Newman *et al* (1994) and Chilibroste *et al* (1997). Looking at the results from the present experiment it is logical to think that the faster biting rate shown by the LL cows was a compensatory strategy to overcome their lighter bite weight compared to the HL cows (Hodgson and Wilkinson, 1967).Furthermore, biting rate was increased by 0.55 bites per minute by each increase of 0.1 kg MS produced. The increase in biting rate has been also suggested as a compensatory mechanism developed by animals in energy deficit (Chacon and Stobb, 1976; Mayne *et al*, 1996).

Digestibility of pasture DM by the HL and LL cows in early lactation in the experiment 1 b.

Diet digestibility was estimated for each cow from dietary and faecal concentrations of the n-alkanes C31 and C 33 (Stakelum and Dillon, 1990). However, recoveries of alkanes were not measured in this experiment, and so it was necessary to use assumed values. The recovery of alkanes is greater when cows are fed fresh pasture as opposed to silage or concentrate, and consequently, the higher range of recovery rate cited in the literature were assumed, 0.83 for alkane C31 and 0.86 for alkane C33 (Stakelum and Dillon, 1990). Both alkanes gave similar results of digestibility. At the same time both were similar to the digestibility measured *in vitro* (average digestibility from alkanes: 77.5% vs digestibility *in vitro*: 77%) .

There was no difference in the digestibility of the diet between the two lines (0.78). Based on studies where the digestibility of fibrous diets was compared between ruminants species of different size, it was suggested that because of the increased ruminal capacity of the heavy ruminants, they showed longer retention time and consequently, they achieved greater digestibility of the diets (Demment and Van Soest, 1985; Van Soest; 1994). However, these principles did not apply in the present study for varied reasons. Firstly, in this experiment the animals compared are from the same species. Secondly, it is possible that the difference in size between the two lines was not big enough to cause a detectable difference in digestibility. Thirdly, the herbage grazed by the cows had a digestibility of 77% which is very high for a "fibrous" diet.

Efficiency of the LL and HL cows in early lactation.

In the current experiment, the gross feed conversion efficiency (kg MS/kg DM) of the LL cows was slightly higher than that of the HL cows, but the difference only approached to significance (0.120 vs 0.114 kg MS/kg DM, P<0.1). The values were similar to those reported by other authors (Table 4.4).

Table 4.4 Gross feed conversion efficiency (kg MS/kg DM) of dairy cows reported in the literature by different authors.

Authors	Efficiency (kg MS/kg DM)	Feed	Stage of Lactation
L´Huillier *et al* (1988)	0.10	Grazing cows	Short trial in mid lactation
Persaud *et al* (1991)	0.11	Total mixed ration	Whole lactation
Holmes *et al* (1993)	0.10	Grazing cows	Short trial in mid lactation
Veerkamp *et al* (1994)	0.12-0.11	Total mixed ration	Whole lactation
Peyraud *et al* (1996)	0.10	Grazing cows	Short trial in mid lactation
Mackle *et al* (1996)	0.116-0.114	Grazing cows	Whole lactation

The gross energy efficiency (MJ ME in milk/MJ ME eaten) was not significantly different between the lines (LL=44.5 vs HL=42.3). These values are similar to the 43.6 to 43.9 reported by Veerkamp *et al* (1994) comparing a group of high genetic merit Holstein-Friesian cows with a control group, but are higher than those reported by Mackle *et al* (1996) during the whole lactation of grazing heifers (36.2 to 37.1).

Holmes *et al* (1993), and Stakelum and Connolly (1987) compared the feed conversion efficiency of Holstein-Friesian cows with different size. They concluded that at similar levels of milk production, the small cows were more efficient than the large cows because the lower maintenance requirements of the former. However, a comparison of the feed conversion efficiency of two lines of cows which differ genetically in liveweight may not be the same as the comparison between two group of cows that differ phenotypically in LW. Selecting in favour or against one variable is expected to affect others by the existence of genetic correlation (Groen *et al*, 1997; Van Arendonk *et al*, 1995). Most of the reports in the literature suggest that the phenotypic and genetic correlations between size and feed conversion efficiency are moderate to high and negative (Mason *et al*, 1957; Syrstad, 1966; Van Arendonk *et al*, 1991; Persaud *et al*, 1991). There was only one long term trial in which the gross feed conversion efficiency over the whole lactation of two lines of cows differing genetically for LW was compared (Yerex *et al*, 1988; Donker *et al*, 1983). The cows bred for small size (525 kg) were 2.8% more efficient than cows bred for large size (575 kg). The maximum difference achieved in gross energy efficiency was at the third month of lactation (small=0.53 vs large=0.48), but there was no difference during the first two months of lactation. In the current experiment, the cows were in early lactation, and the LL cows were slightly more efficient than the heavy cows, but the difference was not significant. Larger number of cows would have been required to detect a difference in this variable between the two lines of cows in early lactation because the difference is relatively small.

A limitation of the gross feed conversion efficiency is that it does not take into account the energy involved in the mobilisation or deposition of body tissues (Blake and Custodio, 1984). However, measurements of liveweight changes and composition of LW changes in short term experiments (> 30 days) are very inaccurate (Stakelum and Connolly, 1987; Van Arendonk *et al*, 1995), and may be even worse when comparing two lines of cows with different size. In the experiment 1 b, although the LW gains recorded were impossible to be achieved in real terms (1 kg LW/day), no difference in LW gain was detected between the lines. The estimates of the energy balance of the two lines of cows were more credible. In fact, based on the average MS production, LW and DMI of each cow, no difference was detected in the calculated daily energy balances of the two lines (LL=-3.40 MJ ME vs HL=1.65 MJME). The values were almost 0 suggesting that the cows were close to maintenance of constant LW and BCS during the experiment 1 b.

As was expected, the net energy efficiency (Milk energy output/ME intake available for milk production* 100) did not differ between the lines (LL=64.8 vs HL=64.5). These values were in the range of those reported in the literature (Table 4.5). Part of the differences in the values reported in this table are because : the equations used to derive maintenance requirements were not the same between experiments (Moe and Tyrrell, 1975), the maintenance requirements were not really the same under the different conditions of the experiments (Taylor *et al*, 1981; Holmes *et al*, 1993) and the diets were also different between experiments (Moe and Tyrrell, 1975). The fact that no difference was detected between the lines agree with the suggestion made by Moe and Tyrrell (1975): "there is little evidence that net energetic efficiency varies with milk yield, stage of lactation or breed of animal when the composition of the milk and the diet is the same". In the current experiment, the diet and milk composition of the lines was not different.

Table 4.5 Net Energy conversion efficiency (MJ in milk/(MJ ME eaten-MJ ME required for maintenance)* 100) of dairy cows reported in the literature by different authors.

Authors	Net Energy Efficiency	Feed	Stage of lactation
Custodio *et al* (1983)	65%	Total mixed ration	Early lactation
Oldenbroek (1988)	61%	Roughage diets	Whole lactation
Graham *et al* (1991)	59%-58%	Total mixed rations	Whole lactation

4.3) Discussion of the results about the reproductive performance of the two lines of cows.

Calving Ovulation Interval (C-Ov) and Calving First Heat Interval (C-H).

The LL cows tended to present longer C-Ov intervals than the HL cows. Independently of the line, the C-Ov interval was longer for the heifers (2 years old cows) than for the mature cows (> 2 years old), and the effect of year was also significant with the C-Ov interval being shorter in 1997 than in 1996. The mean C-Ov intervals reported by other authors in New Zealand are shown in Table 4.6. The C-Ov interval in the current trial were similar to those reported by McDougall (1994) for Holstein friesian cows at low stocking rate. Although the level of nutrition of the cows in the current experiment was relatively high, the C-Ov intervals were longer that those reported in the literature for dairy cows fed total mixed rations according to requirements (Fonseca *et al*, 1983). The extended C-Ov interval showed by the 2 years old cows compared to the mature cows supports the reports from other authors under grazing conditions (Table 4.6)

Table 4.6 Average post partum anoestrus interval (PPA) and calving-first detected heat interval (C-1st H) reported for 2 years old and mature dairy cows in New Zealand.

	2 years old		>2 years old	
	PPA (days)	C-1st H (days)	PPA (days)	C-1st H (days)
Moller (1970)	50.0		35.0	
Macmillan and Clayton (1980)		65.0		51.0
McDougall (1994)	40.2	47.1	30.3	35.4
Burke *et al* (1996)	50.8	62		

The two lines of cows did not differ in their C-H intervals or in the number of cows treated with CIDRs. Although the C-Ov intervals of the mature HL cows was shorter than those of the LL cows, their C-H intervals tended to be longer than those of the LL mature cows, and similar to those observed for the 2 years old cows of the two lines. Independently of the line, the heifers showed a longer C-H interval than the mature cows. The mean C-H intervals observed in the different years are in the range of those reported for grazing cows in New Zealand (Table 4.6) and for cows feed total mixed ration ad-libitum (Fonseca *et al*, 1983; Staples *et al*, 1990; McGowan *et al*, 1996). The longer C-H interval of the 2 year old cows compared to older cows has also been observed in previous trials (Table 4.6), but the differences reported were larger than those found in the current experiment. The main reason for that short difference was the relatively long C-H interval presented by the HL mature cows in this experiment.

The different pattern of the C-Ov and the C-H intervals between the lines may have been caused by the fact that only 30% of the HL cows were detected in oestrus at first ovulation, compared to 40% of the LL line. The ratio of first ovulations accompanied by oestrus in this experiment are similar to those reported by McDougall (1994) and Lamming and Bulman (1976) . No data was found about the effect of size on the oestrus behaviour of cows from the same breed, but between breeds, Jerseys were more likely to be detected in oestrus at the first ovulation than Friesians (McDougall, 1994; Fonseca *et al*, 1983).

In 1996 and 1997, the C-Ov interval was inversely related to BCS at calving and BCS at 40 days post-calving (P<0.01). Weekly milk yield was only available for 1996, and a negative relationship was detected between this interval and milksolids yield during the first 6 weeks of lactation (P<0.05). Similarly, the C-H interval was negatively associated to BCS at 40 days post-calving. Extended C-Ov and C-H intervals have been related to BCS at calving (McDougall, 1994; Macmillan *et al*, 1984; Grainger *et al*, 1982), nutrition level post-calving (Butler and Smith, 1989; Grainger *et al*, 1982; McDougall, 1994; McCallum *et al*, 1995) and milksolid yield (Macmillan *et al*, 1996; Grosshans *et al*, 1996; Fulkerson *et al*, 1997). In the current experiment, although the two lines of cows started the lactation with the same BCS and no significant difference was detected in BCS changes after calving , the LL presented a lower BCS at 40 days of lactation compared to the HL (P<0.05). Similarly, as a percentage of the LW, the LW losses of the LL cows were significantly larger than those of the HL cows.

The energy balance (EB) of cows is defined as the Energy required for production and maintenance minus the Energy Intake. The C-Ov and C-H intervals of these cows in an EB lower than - 10 MJME at the 5 week of lactation were longer than those cows in a positive or slightly negative EB. The interval C-Ov has consistently been associated with the duration and depth of the normal negative energy balance (NEB) that the dairy cows experienced after calving (Canfield and Butler, 1990; Staples *et al*, 1990; Lucy *et al*, 1992) which depends on the interaction between homeostatic and homeorhetic mechanisms at the cow level (Bauman and Currie, 1980). This interaction is affected principally by the energy intake and the energy required by the cows (Villa -Godoy *et al*, 1988; Staples *et al*, 1990; Macmillan *et al*, 1996). Extended C-Ov periods have been reported to be associated with reduced feed intakes, reduced production and increased loss of LW (Staples *et al*, 1990; Lucy *et al*, 1992). Based on the DMIs and milksolids yields measured in experiment 1b, 47 % of the LL cows were in a energy balance lower than - 10 MJME compared to 22% of the HL cows. This different pattern observed for the two lines in LW and BCS changes, and in the energy balance after calving can explain the slightly longer C-Ov interval showed by the LL cows compared to the HL cows.

No difference was detected between the lines in the plasma concentration of glucose, urea and albumin during the second month of lactation. That suggests that the cows sampled (12 per line) had similar energy balance. Because of the association between energy balance and glucose concentration in blood (Payne, 1987), this metabolite was reported to be negatively associated to the C-H and C-Ov interval (McDougall, 1994; Canfield and Butler, 1990). However, as in case of this experiment, this relationship has not been found consistently (Staples *et al*, 1990). Considering the fine control of metabolites in blood, a large number of animals is probably required in order to find any association between energy balance, metabolites in blood and reproductive performance.

Planned Start of Mating-First Service Interval, Planned Start of Mating-Conception Interval and Planned Start of calving- Calving Interval.

The PSM-1serv and PSM-Con intervals were the same between the two lines, but the HL cows tended to show longer PSM-Con intervals than the LL cows. This tendency shown by the HL is reflected in the lower percentage of HL cows which conceived in the first 21 days of mating compared to LL cows. The length of the PSM-1serv and PSM-Con intervals are significantly shorter than those reported by Grosshans *et al* (1996), but similar to those reported by Macmillan *et al* (1995) and Xu *et al* (1995). However, Grosshans *et al* (1996) analysed the reproductive performance of 48534 Friesian cows, and in this trial, as in case of the other two experiments cited above, the number of observations involved were limited . A great variation in the PSM-1ser and PSM-Con interval between the farms was indicated by the results reported by Macmillan *et al* (1990). For the two years old cows, the difference in PSC-Con interval between the two lines approached significance ($P<0.06$), and explained the significant effect of age on the analysis of this interval. In fact, the 2 years old cows showed a longer PSM-Con interval than the older cows. Conversely to these results, Grosshans *et al* (1996) did not find a major effect of age on the PSM-Con intervals, and the higher fertility of the younger cows has been reported elsewhere (Ziv, 1994; Xu and Burton, 1996).

Because the length of pregnancy was the same between the lines, the slightly different mating pattern between them was also reflected in the calving pattern. Although the PSC-C interval was similar for the two genetic lines, more LL cows calved in the first 21 days of calving, and fewer LL cows were induced. The differences were especially marked between the 3 years old cows of the two lines. The advantage of a compact calving in a seasonal system of milk production was indicated by earlier results at Ruakura (Macmillan *et al*, 1984). According to the data from the current experiment, late calving cows produced 3.7 kg MS less in the first 12 weeks of lactation for each 10 days of delay in calving date. However, the effect of the more concentrated calving pattern of the LL cows on the overall milksolid yield of a farm system can not be concluded from this experiment that was confined to the first 12 weeks of lactation . The slightly higher daily milksolids production showed by the HL cows could fully compensate for the extra days in milk by the LL cows.

Although the percentage of empty cows at the end of mating was the same for the two lines of cows, the LL of cows showed a higher conception rate (CR) at first service than the HL of cows. That explained the tendency of the HL cows to conceive later in the season. The different conception rate was more marked in 1994 and 1995, and between the 3 years old cows of the two lines. The average CR in New Zealand is around 60%, with some farmers achieving 75% (Xu *et al*, 1995). Although the CR of the two lines are in the range of these values, the average ratio of the LL cows was consistently higher than that for the HL . In agreement with these results, after 30 years of divergent selection for body size in Minnesota, Hansen *et al* (1998) found that the large line of cows after their first parity required a significantly larger number services to conceive (2.08) compared to the small line cows (1.79). In the second and third parity, although the conception rate of the small line of cows selected was higher than that of the large line, the differences were not significant. A genetic antagonism between body size and conception rate was also suggested by Badinga *et al* (1985), and Markusfeld and Ezra (1993). Batra *et al* (1986) found also a negative genetic correlation (-0.28) between LW of the cows at 112 days of lactation and conception rate at first service. However, negative genetic correlation were reported in Canada between calving interval, and size (-0.23) and stature (-0.25) (Dadati *et al*, 1986), and the phenotypic correlations between reproductive parameters, and stature and size were reported to be close to 0 (Dadati *et al*, 1986; Moore *et al*, 1992).

The reasons for the antagonism between size and conception rate were unclear. The heavy cows had a greater incidence of periparturient diseases (Badinga *et al*, 1985) which significantly affect the conception rate of the cows (Peters, 1996; Lewis, 1997). However, the incidence of periparturient diseases was similar for the two lines of cows developed at Massey (Garcia Muñiz *et al*, 1998). In general, conception rate at first heat is increased by a longer period between calving and first mating (Butler and Smith, 1989; Ferguson, 1996). Other authors suggested that the specific postpartum effect on conception rate only occurs within the first 40 days (Ferguson, 1991; Zavy, 1994). In the present analysis of the data, the mean Calving-First service interval was similar for the two lines and longer than 40 days (LL=83 days vs HL=80 days). Macmillan and Clayton (1980) showed the importance of the occurrence of one previous oestrus before the first mating, with only a minor effect from any additional pre-mating heat(>1). In the current experiment, the percentage of cows in anoestrus at the PSM was the same between the lines which means that the same number of LL cows and HL cows had at least one detected heat prior to the PSM. Furthermore, the average non return rates achieved by the HL and LL bulls used through artificial insemination throughout New Zealand were the same for both lines (69%). Particularly for 1994 and 1995, the non return rate were also similar for the H and L bulls used (1994: LL=71% HL=70%, 1995: LL=68.5% HL=70%).

The larger and heavy cows lost more LW after calving (Markusfeld and Ezra, 1986), and the energy balance of the cows was reported to affect the conception rate (Ferguson, 1996; Britt, 1992). Similar results were reported for Brahma and Angus cows selected by small and large frame (Olson, 1994). However, in the current experiment for the 1996 season, the two lines of cows started the lactation with similar BCS, and the two lines of cows had the same BCS at mating, and similar BCS and LW changes after calving. The effect of BCS at mating, BCS change between calving and mating, and LW change between calving and mating was not associated to the PSM-Con interval. But at the same time, the difference in conception rate were not marked in 1996, and no data about LW and BCS is available for the 1994 and 1995 seasons when the differences in fertility were larger.

The ovulatory follicles of the HL cows had a diameter 3 mm larger and ovulated later during the cycle than those of the LL cows scanned. The former also showed larger area of CL on days 9, 10 and 11, which are the days of maximum development of luteal tissue (Grygar *et al*, 1997). Holstein cows (USA) presented longer oestrus cycles, heavier CL, but lower progesterone in serum than Friesian cows (New Zealand) (Bilby, personal communication)and, as in the current experiment, both group of cows differed significantly for LW which may explain some of the differences detected in the follicular waves, CL weights and characteristics of the cycle. The conception rate of the cows was reported to be affected by the follicular pattern and follicular diameter (Burke *et al*, 1996; Mackey *et al*; 1997) and the production of progesterone from the corpus luteum (Fonseca *et al*, 1983; Villa Godoy *et al*, 1988; Lucy *et al*, 1992). However, in case of the present experiment, the significance of the differences detected in the size of the follicular and luteal structures are unclear, and to use them for explaining the difference in conception rate between the lines is very speculative.

Finally, although the reproductive data analysed from 1992-1997 seem to suggest that the LL cows achieved a slightly better reproductive performance than the HL cows , this conclusion should be taken with caution because the reproductive results change significantly from year to year . Therefore, more information is required from subsequent years before any definite conclusion is reached about the reproductive performance of the two lines of cows.

Chapter Five

Conclusions.

The two groups of cows (LL= 30 HL= 27) had similar MS, MF, MP and MY during the first 12 weeks of the lactation, but the HL >2 year old cows produced 7 kg MS and 93 litres more than the LL > 2year old cows during this period. However, multiple regression analysis indicated that the effect of LW was not significantly associated to the MS yield achieved by the cows > 2 years old, but had a significant effect on the MP yield of the heifers. In fact, total MP of the heifers during the first 12 weeks of the lactation was increased by 0.18 kg by each increase in 1 kg of LW at calving. The results suggest that high milksolid yields in early lactation are achievable independently of differences in size of the cows.

Although the two lines of cows had similar BCS at calving and similar LW and BCS changes after calving, the LL heifers lost more LW and BCS in the first 5 weeks of the lactation than the HL heifers. Consequently the BCS at 40 days postcalving of the LL was lower than that of the HL. The different pattern in LW and BCS losses between the heifers of the two lines may have occurred because the HL heifers matured later than the LL heifers. Therefore, the HL heifers partitioned more nutrients to LW gain than the LL heifers in early lactation which directed more nutrients to MS production.

Although the LL cows had a slightly lower DMI and a slightly higher MS conversion efficiency than the HL cows during early lactation, these differences between the lines were not significant. The DMI/kg $LW^{0.75}$, DMD, energy conversion efficiency and calculated net conversion efficiency were similar for the two lines. Both lines of cows had also similar grazing time, but the biting rate of the LL cows was faster than that of the HL. The average bite size of the HL cows, estimated from the variables DMI, grazing time and biting rate, was heavier than that of the LL. It is suggested that the faster biting rate by the LL cows was an attempt to compensate for their lighter bite weight. MS production was the only variable significantly associated to DMI in the multiple regression analysis performed. The effect of $LW^{0.75}$ approached significance. The results obtained in this experiment indicated that the two lines of cows did not differ in any of the parameters selected to compare the gross conversion efficiency between the two lines. It is also suggested that the herbage intake of LL cows was not adversely affected by the size or LW of the cows, because the LL cows had slightly higher values for DMI/kg LW.

The HL cows had shorter C-Ov intervals than the LL cows, but the C-H interval was similar for the two lines because more first ovulation were accompanied by heat in the LL than in the HL. Although the proportion of empty cows at the end of the mating period was similar for the two lines, the HL cows tended to conceive later during the mating period which extended the calving pattern of the HL cows. The cause for that prolonged calving and mating pattern was the lower conception rate at first service observed in the HL compared to the LL. However, the possible reasons for the poorer fertility of the HL are unclear. The two lines differed in the area of the CL and in the follicle diameter of the ovulatory follicle, but these differences may not be related to the difference in conception rate. Calving difficulties, percentage of cows in anoestrus at the PSM and the interval conception-first service were similar for the two lines. Similarly, no difference was detected throughout New Zealand in the fertility of the heavy and light bulls used to breed the two lines of cows at the DCRU.

Finally, although the two lines of cows had similar gross conversion efficiency during early lactation, it is suggested that ,before any definite conclusion is reached about the conversion efficiency of the two lines, it is necessary to compare them at different stages of the lactation, and probably in a system trial. Similarly, although the LL had a better reproductive performance than the HL for the period from 1992 to 1997, considerable variation was observed between years, so that more information should be obtained from the subsequent years in order to validate the current results.

Appendices.

Appendix 1.

The values for the Breeding Worth of the Heavy and Light Sires used during the project .

Table 1. Name, BW and estimated breeding values for payment, protein, fat, milk, LW and survival of the Heavy sires used in Massey high-low liveweight trial.

AB Code	Name	Year	BW	Pay BV	Prot	Fat	Milk	LW	Surv
63220	Charnwood Prefect Dynamo	1989	-9/91	25	18	29	1073	77	1
85211	Crocketts Rascal	1989	24/91	65	25	30	839	95	0
63366	Woodbine Valiant Elmer	1990	45/99	99	43	31	1498	121	0
63464	Hanoverhill Romeo	1990	-13/99	31	13	12	455	106	0
87247	Jamieson Tyrant	1991	16/93	52	20	34	674	83	-3
87287	Snowline Linkhorne	1991	16/96	59	28	30	1136	98	-1
86297	Snowline CP Premier	1992	21/96	47	16	27	503	61	0
88225	Fullertons Ward	1992	65/99	96	38	37	1253	76	0
88294	Waitekohe Starbuck Neogen	1992	33/94	70	27	35	1009	84	3
87243	Hiwinui B K Skyman.	1993	51/99	83	33	23	1007	80	0
89237	Halls Armstrong	1993	48/91	81	28	33	759	81	-1
89290	Tokaroa T P Boxer	1993	45/91	86	35	28	1208	92	3
88225	Fullertons Ward	1992	65/99	96	38	37	1253	76	0
90264	Hills Baldwin	1994	58/91	93	32	32	882	78	2
90274	SR Dawson Belvedere	1994	77/91	103	34	35	869	63	2
91208	Athol Baron	1995	74/93	109	40	41	1184	80	0
91288	Bagworth BrightEagle	1995	61/83	85	28	41	835	52	2
91293	Bucklin Bear Canute	1995	56/90	94	39	39	1391	90	1
92201	Etazon US Dalton	1996	71/80	110	44.7	32	1437	85.2	-0.8
92288	Snowline Professional	1996	52/87	84	38.6	27	1425	77.4	1.4
92243	Summerhays As Hawk-ET	1996	51/87	98	29.9	33	615	108	0.3
93227	Peticote US Eaton-ET	1997	80/90	105	47	38	1706	90	0.6
93309	Wilson Elixir	1997	89/87	109	45	31	1484	77	0.6
93304	Hallville Everest	1997	96/88	114	47	39	1609	76	1

Appendix 2.

Calibration equations used in August, September and October of 1996 with the rising plate meter to predict the pregrazing and postgrazing herbage masses.

Month	Pregrazing equations		Postgrazing equations	
August	y = 133.17 x + 653	R^2 =69	y = 171.8 x + 430	R^2 = 77
September	y = 122.6 x + 875	R^2 =62	y = 140.5 x + 662	R^2 = 65
October	y = 143.6 x + 318	R^2 =71	y = 161.0 x + 177	R^2 = 76

y = kg DM/ha x= reading of the rising plate meter.

Appendix 3.

Equations obtained in Experiment (1 a) from the regression of MS (kg/cow/day), MF (kg/cow/day) , MP (kg/cow/day) and MY Lt/cow/day) on LW, Age and calving period.

1) Heifers + cows: combined data.

MS (kg/cow) =	68.54 +	0.107 LW	+ 9.17 Age (years)	- 3.79 Calving period	R^2 = 0.70
Milk protein (kg/cow) =	26.16 +	0.059 LW	+ 4.1 Age (years)	- 0.25 Calving period	R^2 = 0.73
Milkfat (kg/cow) =	42.36 +	0.05 LW	+ 5.02 Age (years)	- 2.48 Calving period	R^2 = 0.63
Milk yield (Lt/cow) =	957 +	1.48 LW	+ 105 Age (years)	- 28.5 Calving period	R^2 = 0.53

b) Mature cows only.

MS (kg/cow) =	90	+ 0.03 LW	+ 5.4 Age (years)	- 1.99 Calving period	R^2 = 0.39
Milk protein (kg/cow) =	36.35	+ 0.021 LW	+ 2.3 Age (years)	- 0.48 Calving period	R^2 = 0.47
Milkfat (kg/cow) =	53.6	+ 0.015 LW	+ 3.0 Age (years)	- 1.5 Calving period	R^2 = 0.28
Milk yield (Lt/cow) =	1456	+ 0.032 LW	+ 39.7 Age (years)	- 0.98 Calving period	R^2 = 0.12

3) Heifers only.

MS (kg/cow) =	39	+ 0.23 LW	- 7.85 Calving period	R^2 = 0.41
Milk protein (kg/cow) =	5.47	+ 0.14 LW	- 3.24 Calving period	R^2 = 0.42
Milkfat (kg/cow) =	34	+ 0.09 LW	- 4.61 Calving period	R^2 = 0.37
Milk yield (Lt/cow) =	-601	+ 5.82 LW	- 103.4 Calving period	R^2 = 0.52

Table 2. Name, BW and estimated breeding values for payment, protein, fat, milk, LW and survival of the Light sires used in Massey high-low liveweight trial.

AB Code	Name	Year	BW	Pay BV	Prot	Fat	Milk	LW	Surv
84260	Martin Park	1989	44/99	46	11	26	196	8	1
85274	Ross´s Lord Russell	1989	46/90	53	16	10	311	13	2
81252	Maniapoto AB Kitchener	1990	34/99	52	18	30	650	38	3
82236	Judds Merrill	1990	37/99	38	13	21	340	1	-3
87201	Athol SS Viceroy	1991	24/93	42	20	20	786	44	-1
87268	McHardys Turban	1991	17/99	27	9	21	330	20	0
87284	Savages Trigg	1992	24/99	45	24	11	983	49	1
88241	Jamieson Wonder	1992	38/99	43	17	30	678	14	0
88269	Olds Winfield	1992	33/99	43	21	21	882	25	0
89208	Bartons Apostole	1993	46/92	57	20	27	644	28	2
89248	SR Karls Aranui	1993	65/92	84	27	31	721	46	3
89287	Waitekohe Pres Nonparei	1993	40/92	53	23	31	1012	32	4
89202	Athol A B Mike	1994	62/90	75	29	37	1021	33	1
89208	Bartons Apostle	1994	46/92	57	20	27	644	28	2
90281	Kingsmill P A Walesa	1994	79/92	101	35	38	1036	48	3
91217	Mitchells Cortez	1995	30/90	42	22	33	1110	30	2
90281	Kingsmill P A Walesa	1995	79/92	101	35	38	1036	48	3
92279	Okau Secret Jacko	1996	66/90	90	38	37	1403	55	0
90258	Mchardys Birch	1996	72/91	88	27	37	611	47	3.8
91236	Jellymans Chester	1996	89/73	88	29	32	735	35	0.5
91258	Mere-Awa Vulcan Dikee	1996	56/89	78	28	39	919	47	1
9362	Rolfes Elliot	1997	110/91	111	41	37	1212	35	1.3
93279	Ancells Elros	1997	98/89	103	40	34	1271	42	1.3
93263	Smiths Elation	1997	93/87	103	41	37	1361	57	1.6

Appendix 4.

Daily adjusted means for MS yield (kg MS/cow/day) of the Light and Heavy Holstein Friesian cows during the first 12 weeks of lactation, 1996.

	MATURE COWS AND HEIFERS. (n =57)			MATURE COWS. (n = 40)			HEIFERS (n=17)		
	Light	Heavy	Signif	Light	Heavy	Signif	Light	Heavy	Signif
Week 1	1.70	1.79	NS	1.80	2.00	NS	1.36	1.32	NS
Week 2	1.79	1.75	NS	1.86	1.91	NS	1.55	1.52	NS
Week 3	1.65	1.72	NS	**1.74**	**1.88**	*	1.41	1.36	NS
Week 4	1.70	1.77	NS	1.78	1.92	NS	1.46	1.42	NS
Week 5	1.68	1.77	NS	1.82	1.88	NS	1.39	1.57	NS
Week 6	1.78	1.70	NS	1.94	1.83	NS	1.38	1.46	NS
Week 7	1.66	1.82	NS	**1.7**	**2.02**	**	1.40	1.37	NS
Week 8	1.74	1.79	NS	1.89	1.97	NS	1.33	1.46	NS
Week 9	1.80	1.81	NS	1.93	1.98	NS	1.43	1.52	NS
Week 10	1.74	1.81	NS	1.86	1.97	NS	1.42	1.49	NS
Week 11	1.69	1.80	NS	**1.80**	**2.00**	**	1.37	1.39	NS
Week 12	1.73	1.68	NS	1.87	1.84	NS	1.33	1.39	NS

NS : not significant * P<0.05 ** P<0.01

Daily adjusted means for MP yield (kg /cow/day) of the Light and Heavy Holstein Friesian cows during the first 12 weeks of lactation, 1996.

	MATURE COWS AND HEIFERS. (n =57)			MATURE COWS. (n = 40)			HEIFERS (n=17)		
	Light	Heavy	Signif	Light	Heavy	Signif	Light	Heavy	Signif
Week 1	0.73	0.78	NS	0.84	0.90	NS	0.57	0.57	NS
Week 2	0.75	0.76	NS	0.82	0.84	NS	0.57	0.61	NS
Week 3	0.73	0.78	NS	0.79	0.86	NS	0.57	0.633	NS
Week 4	0.75	0.77	NS	0.80	0.83	NS	0.60	0.65	NS
Week 5	0.74	0.77	NS	0.80	0.84	NS	**0.58**	**0.68**	*
Week 6	0.76	0.77	NS	0.83	0.84	NS	**0.59**	**0.67**	**
Week 7	0.72	0.76	NS	**0.77**	**0.83**	*	0.58	0.62	NS
Week 8	0.74	0.77	NS	0.81	0.84	NS	0.57	0.63	NS
Week 9	0.76	0.79	NS	0.82	0.87	NS	**0.59**	**0.65**	**
Week 10	0.75	0.79	NS	0.80	0.86	*	0.60	0.64	NS
Week 11	0.72	0.74	NS	0.76	0.82	NS	0.58	0.611	NS
Week 12	0.73	0.72	NS	0.78	0.79	NS	0.57	0.61	NS

NS : not significant * P<0.05 ** P<0.01

Daily Adjusted means for MF production (kg /cow) of the Light and Heavy Holstein Friesian cows during the first 12 weeks of lactation, 1996 .

	MATURE COWS AND HEIFERS. (n =57)			**MATURE COWS. (n = 40)**			**HEIFERS (n=17)**		
	Light	Heavy	Signif	Light	Heavy	Signif	Light	Heavy	Signif
Week 1	0.93	0.99	NS	0.99	1.10	NS	0.80	0.74	NS
Week 2	1.03	0.99	NS	1.03	1.08	NS	0.98	0.84	NS
Week 3	0.92	0.97	NS	0.95	1.02	NS	**0.83**	**0.72**	**
Week 4	0.95	0.99	NS	0.98	1.09	NS	0.85	0.77	NS
Week 5	0.95	0.99	NS	1.01	1.05	NS	0.80	0.89	NS
Week 6	1.03	0.96	NS	1.11	1.01	*	0.79	0.79	NS
Week 7	0.94	1.06	*	0.99	1.19	**	0.82	0.75	NS
Week 8	1.00	1.04	NS	1.08	1.14	NS	0.76	0.83	NS
Week 9	1.03	1.06	NS	1.09	1.14	NS	0.83	0.87	NS
Week 10	0.98	1.01	NS	1.05	1.11	NS	0.81	0.84	NS
Week 11	0.98	1.06	*	1.03	1.19	**	0.78	0.78	NS
Week 12	1.00	0.94	NS	1.12	1.06	NS	0.76	0.77	NS

NS : not significant * $P<0.05$ ** $P<0.01$

Daily adjusted means for milk yield (Lt /cow/day) of the Light and Heavy Holstein Friesian cows during the first 12 weeks of lactation, 1996.

	MATURE COWS AND HEIFERS. (n =57)			**MATURE COWS. (n = 40)**			**HEIFERS (n=17)**		
	Light	Heavy	Signif	Light	Heavy	Signif	Light	Heavy	Signif
Week 1	20.6	21.1	NS	22.3	23.8	NS	15.5	15.0	NS
Week 2	22.3	23.0	NS	23.9	25.4	NS	17.5	18.4	NS
Week 3	22.4	23.4	NS	24.0	25.8	NS	17.6	19.2	NS
Week 4	23.2	24.0	NS	24.6	26.2	NS	18.8	20.3	NS
Week 5	22.9	24.4	NS	24.8	26.1	NS	**18.4**	**21.4**	**
Week 6	23.8	24.3	NS	25.4	26.2	NS	**18.7**	**21.4**	*
Week 7	22.9	24.2	NS	**24.2**	**26.6**	*	18.4	19.9	NS
Week 8	23.5	24.2	NS	25.0	26.7	NS	18.6	19.9	NS
Week 9	23.3	24.8	NS	24.8	27.5	NS	18.2	20.3	NS
Week 10	22.6	24.1	*	**23.9**	**26.1**	**	18.4	20.4	NS
Week 11	21.8	22.8	NS	**22.9**	**25.0**	*	17.9	19.1	NS
Week 12	21.9	22.2	NS	24.2	25.0	NS	17.4	19.4	NS

NS : not significant * $P<0.05$ ** $P<0.01$

Daily adjusted mean for MP% of the LL and HL cows during the first 12 weeks of lactation, 1996.

	MATURE COWS AND HEIFERS. (n =57)			**MATURE COWS. (n = 40)**			**HEIFERS (n=17)**		
	Light	Heavy	Signif	Light	Heavy	Signif	Light	Heavy	Signif
Week 1	3.8	3.8	NS	3.8	3.8	NS	3.7	3.9	NS
Week 2	3.4	3.4	NS	3.4	3.4	NS	3.3	3.3	NS
Week 3	3.3	3.3	NS	3.3	3.3	NS	3.3	3.3	NS
Week 4	3.2	3.2	NS	3.2	3.2	NS	3.2	3.2	NS
Week 5	3.2	3.2	NS	3.3	3.2	NS	3.2	3.2	NS
Week 6	3.2	3.2	NS	3.3	3.2	NS	3.2	3.2	NS
Week 7	3.2	3.2	NS	3.2	3.2	NS	3.2	3.1	NS
Week 8	3.2	3.2	NS	3.3	3.3	NS	3.0	3.2	NS
Week 9	3.3	3.2	NS	3.3	3.2	NS	3.3	3.2	NS
Week 10	3.3	3.3	NS	3.3	3.3	NS	3.3	3.2	NS
Week 11	3.3	3.3	NS	3.3	3.3	NS	3.3	3.2	NS
Week 12	3.3	3.3	NS	3.4	3.3	NS	3.3	3.2	NS

NS : not significant * P<0.05 ** P<0.01

Daily adjusted mean for MF% of the LL and HL cows during the first 12 weeks of lactation, 1996.

	MATURE COWS AND HEIFERS. (n =57)			**MATURE COWS. (n = 40)**			**HEIFERS (n=17)**		
	Light	Heavy	Signif	Light	Heavy	Signif	Light	Heavy	Signif
Week 1	4.5	4.8	NS	**4.3**	**4.8**	*	5.1	5.0	NS
Week 2	4.6	4.5	NS	4.3	4.4	NS	5.6	4.6	NS
Week 3	4.1	4.1	NS	4.0	4.1	NS	4.8	3.7	**NS**
Week 4	4.1	4.1	NS	4.0	4.1	NS	**4.5**	**3.8**	**
Week 5	4.1	4.1	NS	4.0	4.0	NS	4.4	4.2	NS
Week 6	**4.3**	**4.0**	*	**4.4**	**3.9**	**	**4.2**	**3.7**	*
Week 7	4.2	4.4	NS	4.1	4.5	NS	4.5	3.8	NS
Week 8	4.2	4.3	NS	4.3	4.3	NS	4.1	4.2	NS
Week 9	4.4	4.3	NS	4.4	4.2	NS	4.5	4.3	NS
Week 10	4.4	4.2	NS	4.4	4.3	NS	4.4	4.2	NS
Week 11	4.5	4.6	NS	4.6	4.8	NS	4.4	4.1	NS
Week 12	4.6	4.3	NS	4.6	4.3	NS	**4.4**	**4.0**	*

NS: not significant *P<0.05 ** P<0.01.

Appendix 5.

Adjusted means for body condition score of the LL and HL cows during the first 12 weeks of lactation, 1996.

	MATURE COWS AND HEIFERS. (n =57)			MATURE COWS. (n = 40)			HEIFERS (n=17)		
	Light	**Heavy**	**Signif**	**Light**	**Heavy**	**Signif**	**Light**	**Heavy**	**Signif**
Week 1	4.69	4.71	NS	4.6	4.6	NS	4.9	4.8	NS
Week 3	4.51	4.6	NS	4.4	4.7	NS	4.7	4.8	NS
Week 5	4.21	4.4	*	4.3	4.3	NS	4.1	4.6	*
Week 7	4.33	4.4	NS	4.4	4.4	NS	4.2	4.4	NS
Week 9	4.39	4.5	NS	4.4	4.5	NS	4.2	4.4	NS
Week 11	4.40	4.6	NS	4.4	4.6	NS	4.2	4.5	NS

NS: not significant * P<0.05 ** P<0.01

Adjusted means for liveweight of the LL and HL cows during the first 12 weeks of lactation, 1996.

	MATURE COWS AND HEIFERS. (n =57)			MATURE COWS. (n = 40)			HEIFERS (n=17)		
	Light	**Heavy**	**Signif**	**Light**	**Heavy**	**Signif**	**Light**	**Heavy**	**Signif**
Week 1	412	445	**	431	483	**	349	374	**
Week 3	404	449	**	423	483	**	344	387	**
Week 5	399	439	**	421	472	**	329	376	**
Week 7	414	456	**	435	493	**	344	386	**
Week 9	412	452	**	432	483	**	350	388	**
Week 11	429	477	**	447	516	**	365	400	**

NS: not significant * P<0.05 ** P<0.01

References.

AFRC. (1993). Energy and proteins requirements of ruminants. CAB International, Wallingford, UK. 155 pages.

Ahlborn, G. and Bryant,A.M.(1992). Production, economic performance and optimum stocking rates of Holstein-Friesian and Jersey cows. *Proceedings of the New Zealand Society of Animal Production.* 52:7-9.

Ahlborn, G. and Dempfle, L.(1992). Genetic parameters for milk production and body size in New Zealand Holstein-Friesian and Jersey. *Livestock Production Science.* 31: 205-219.

Anil, M.H., Mbanya, J. and Forbes, J.M.(1993). Response in the voluntary intake of hay or silage by lactating cows to intarruminal infusions of sodium acetate, sodium propionate or rumen distension. *British Journal of Nutrition.*69:699-712.

Allden W.G.and Whittaker I.A.McD.(1970). The determinants of herbage intake by grazing sheep: The interrelationship of factors influencing herbage intake and availability. *Australian Journal of Agricultural Research.* 21:755-766.

Allen, M.S.(1996). Physical constraints on voluntary intake of forages by ruminants. *Journal of Animal Science.* 74: 3063-3075.

Arnold, G.W.(1981). Grazing behaviour. In: World Animal Science 1. Grazing Animals pp 79-104. Ed: F.H.W.Morley. Elsevier Scientific Publishing, New York.

Badinga, L., Collier, R.J.and Thatcher, W.W. (1985). Interrelationships of milk yield, body weight, and reproductive performance. *Journal of Dairy Science.* 68: 1828-1831.

Batra,T.R., Lee,A.J. and McAllister, A.J.(1986). Relationships of reproduction traits, body weight and milk yield in cattle. *Canadian Journal of Animal Science.*66:53-65.

Bauman, D.E. and Currie, W.B.(1980). Partitioning of nutrients during pregnancy and lactation: a review of mechanisms involving homeostasis and homeorhesis. *Journal of Dairy Science.*63:1514.

Bauman, D.E., McCutcheon, S.N., Steinhour, W.D., Eppard, P.J. and Sechen, S.J.(1985). Sources of variation and prospects for improvement of productive efficiency in the dairy cow. *Journal of Animal Science.* 60: 583-592.

Bines, J.A.(1976). Regulation of food intake in dairy cows in relation to milk production. *Livestock Production Science.*3:115.

Black, J.L. and Kenney, P.A. (1984). Factors affecting diet selection by sheep. II) Height and density of pasture. *Australian Journal of Agricultural Research.* 35:565-578.

Black, J.L. (1990) Nutrition of the grazing ruminant. *Proceedings of the New Zealand Society of Animal Production.* 50:20-25.

Blake, R.W. and Custodio, A.A.(1984). Feed efficiency. A composite trait of dairy cattle. *Journal of Dairy Science.* 67:2075-2083.

Blake, R.W., Custodio, A.A. and Howard, W.H.(1986). Comparative Feed Efficiency of Holstein and Jersey cows. *Journal of Dairy Science.* 69: 1302-1308.

Blumenkrantz, N. and Asboe-Hansen, G.(1973). New method for quantitative determination of Uronic Acids. *An. Biochem.* 54: 484-489.

Brumby, P.J.(1959). The grazing behaviour of dairy cattle in relation to milk production, live weight and pasture intake. *New Zealand Journal of Agricultural Research.* 2:797-807.

Burlison, A.J., Hodgson, J. and Illius A.W. (1991). Sward canopy structure and the bite dimensions and bite weight of grazing sheep. *Grass and Forage Science.*46: 29-38.

Butler, W.R. and Smith, R.W. 1989. Interrelationships between energy balance and postpartum reproductive function in dairy cattle. *Journal of Dairy Science.*72: 767-783.

Britt, J.H.(1992). Nutrition, weight loss affect reproduction, embryonic death. *Feedstuffs* pp 12:13-17.

Brody, S.(1945). Bioenergetics and Growth. Hafner, New York, N.Y., 1023 pp.

Bryant, A. M. (1980). Effect on herbage allowance on dairy cow performance. *Proceedings of the New Zealand Society of Animal Production* 42:82.

Bryant,A.M. and Trigg,T.E.(1982). The nutrition of the grazing dairy cow in early lactation. p 185-205. In : Dairy production from pasture. Edited by: K.L. Macmillan and V.K. Taufa. New Zealand Society of Animal Production.

Bryant, A.M. (1983). The effect of breeding index on the performance of non-lactating Jersey cattle. *Proceedings of the New Zealand Society of Animal Production.* 43:63-66.

Bryant,A.M., Cook,M.A.S. and Macdonald, K.A.(1985) Comparative dairy production of Jersey and Friesians. *Proceedings of the New Zealand Society of Animal Production.* 45:7-11.

Burke, C.R., McDougall, S. and Macmillan, K.L.(1995). Effects of breed and calving liveweight on postpartum ovarian activity in pasture fed dairy heifers. *Proceedings of the New Zealand Society of Animal Production.* 55:77-78.

Burke, C.R., Verkerk, G.A. and Macmillan, K.L.(1996). Hormonal induction of oestrus during the early postpartum period and the subsequent effects of nutrition on ovarian activity in dairy heifers. *New Zealand Society of Animal Production.* 56: 230-232.

Canfield, R.W. and Butler, W.R.(1990). Energy balance and pulsatile LH secretion in early postpartum dairy cattle. *Domestic Animal Endocrinology 7: 323-330.*

Carruthers,V.R., Neil, P.G. and Dalley, D.E.(1996). Microbial protein synthesis and milk production in cows offered pasture diets differing in non-structural carbohydrate content. *Proceedings of the New Zealand Society of Animal Production.* 56: 255-259.

Chacon, E. and Stobbs, T.H.(1976) Influence of progressive defoliation of a grass sward on the eating behaviour of cattle. *Australian Journal of Agricultural Research.* 27: 709-727.

Chilibroste, P., Aguilar, C. and Garcia, F.(1997). Nutritional evaluation of diets. Simulation model of digestion and passage of nutrients through the rumen-reticulum. *Animal Feed Science Technology.* 68: 259-275.

Combellas, J.and Hodgson, J. (1979). Herbage intake and milk production by grazing dairy cows. 1) The effect of variation in herbage mass and daily herbage allowance in a short term trial. *Grass and Forage Science.*34:209-214.

Conrad, H.R., Pratt, A.D. and Hibbs, J.W.(1964). Regulation of feed intake in dairy cows.1.Change in importance of physical and physiological factors with increased digestibility. *Journal of Dairy Science.*47:54-62.

Cottam,Y.H., Blair H.T., Gallaher, B.W., Purchas, R.W., Breier, B.H., Mc Cutcheon, S.N. and Gluckman, P.D.(1992). Body growth, carcass composition, and endocrine changes in lambs chronically treated with recombinantly derived insulin-like growth factor-1. *Endocrinology.* 130: 2924-2930.

Curran, M.K. and Holmes, W.(1970). Prediction of the voluntary intake of food by dairy cows. 2 . Lactating grazing cows. *Animal Production.* 12: 213-224.

Custodio, A.A., Blake, R.W., Daham, P.F., Cartwright, T.C. and Coppock, C.E.(1983). Relationships between measures of feed efficiency and transmitting ability for milk of Holstein cows. *Journal of Dairy Science.*66: 1937-1946.

Dadati, E., Kennedy, B.W., and Burnside, E.B. (1986). Relationships between conformation and calving interval in Holstein cows. *Journal of Dairy Science.*69: 3112-3119.

Dado, R.G. and Allen, M.S.(1995). Intake limitations, feeding behavior, and rumen functions of cows challenged with rumen fill from dietary fiber or inert bulk. *Journal of Dairy Science.* 78: 118.

Davey,A.W.F., Grainger,C. and Holmes,C.W.(1983). Nutritional and physiological studies of differences between Friesian cows of high and low genetic merit. *Proceedings of the New Zealand Society of Animal Production.*41:49-43.

Deane,T.H.(1993). The relationship between milkfat production per hectare and economic farm surplus on New Zealand dairy farms. *Proceedings of the New Zealand Society of Animal Production.*53:50-53.

Demment, W.M. and Van Soest, P.J.(1985). A nutritional explanation for body size patterns of ruminants and nonruminants herbivores. *The American Naturalist.*125:641-672.

Demment, M. W., Peyraud, J.L. and Laca, E.A. (1995). Herbage intake at grazing: a modelling approach. In: M. Journet, E.Grenet, M-H. Farce, M.Theriez, C. Demarquilly (Eds). Recent Developments in the Nutrition of Herbivores. Proceedings of the IV[th] International Symposium on the Nutrition of Herbivores. 121-141. INRA Editions, Paris.

Dempfle, L.(1986). Increasing the efficiency of the dairy cow with regard to body size. *Research Bulletin n° 4* . Livestock Improvement Corporation, Hamilton, New Zealand.

Donker, J.D., Marx, G.D. and Young, C.W.(1983). Feed intake and milk production from three rates of concentrate for cows bred to differ in size. *Journal of Dairy Science*.66: 1337-1348.

Dove, H.and Mayes,R.W.(1991). The use of plant wax alkanes as marker substances in studies of the nutrition of herbivores: A review. *Australian Journal of Agricultural Research.* 42: 913-952.

Earle, D.F.(1976). A guide to scoring dairy cow condition. *J. Agric., Victoria.* 74: 228.

Earle, D.F. and McGowan, A.A.(1979). Evaluation and calibration of an automated rising plate meter for estimating dry matter yield of pasture. *Australian Journal of Experimental Agriculture and Animal Husbandry*.19:337-343.

Erlinger, L.L., Tolleson, D.R. and Brown, C.J.(1990). Comparison of bite size, biting rate and grazing time of beef heifers from herds distinguished by mature size and rate of maturity. *Journal of Animal Science*. 68:3578-3587.

Faverdin, P., Baumont, R. and Ingvartsen, K.L.(1995). Control and prediction of feed intake in ruminants. In: M. Journet, E.Grenet, M-H. Farce, M.Theriez, C. Demarquilly (Eds) Recent Developments in the Nutrition of Herbivores. Proceedings of the IVth International Symposium on the Nutrition of Herbivores. 95-121. INRA Editions, Paris.

Ferguson, J.D. and Chalupa, W.(1989). Impact of protein nutrition on reproduction in dairy cows. *Journal of Dairy Science*.72:746-766.

Ferguson, J.D.(1991). Nutrition and reproduction in dairy cows. *The Veterinary Clinic of North America*. July 1991. pp 483.

Ferguson, J.D.(1996). Diet, production and reproduction in dairy cows. *Animal Feed Science and Technology*. 59:173-184.

Fonseca, F.A., Britt, J.H. and Rakes,A.H.(1983). Reproductive traits of Holsteins and Jerseys. Effect of age, milk yield and clinical abnormalities on involution of cervix and uterus, ovulation, oestrus cycles, detection of oestrus, conception rate and days open. *Journal of Dairy Science*.66:1128-1147.

Forbes, T. D. A. (1988). Researching the plant-animal interface: The investigation of ingestive behaviour in grazing animals. *Journal of Animal Science*. 66: 2369-2379.

Forbes J.M (1995). In: Voluntary feed intake and diet selection in farm animals. CAB International. 532 pages.

Forbes, J.M.(1995). Voluntary intake: a limiting factor to production in high yielding dairy cows? In: *Breeding and Feeding the high genetic merit cow.* Eds:Lawrence T.J, Gordon, F.J. and Carson, A. British Society of Animal Production Occasional Publication. N° 19, pp 13-19.

Forbes, J.M.(1996) Integration of regulatory signals controlling forage intake in ruminants. *Journal of Animal Science*.74:3029-3035.

Fortune, J.E.(1994). Ovarian Follicular Growth and Development in Mammals. *Biology of Reproduction*.50:225-232.

Freeman, A.E.(1975). Genetic variation in nutrition of dairy cattle. In: The effect of genetic variation on nutrition of Animals. National Academy of Science, Washington, DC.pp.19-46.

Freer, M.(1981). The control of intake by grazing animals. In: World Animal Science 1. Grazing Animals. Ed: F.H.W.Morley. Elsevier Scientific Publishing, New York. Page105-120.

Fulkerson, B., Hough, G., Davison,T.and Goddard, M.(1997). The interaction between genetic merit and level of feeding of Friesian dairy cows. *Report from the New South Wales (NSW) Agriculture Dairy Research Group*(1996/1997).

Garcia-Muñiz, J,G., Holmes, C.W. and Wickham, B.W.(1997). Growth and onset of puberty in two genetically different lines of Holstein-Friesian heifers selected for either heavy or light body weight. *Proceedings of the New Zealand Society of Animal Production.* 57:46-48.

Garcia-Muñiz, J,G., Holmes, C.W., Garrick, D.J., Lopez-Villalobos, N.and Spelman, R.J. (1998). Calving difficulty in two genetic lines of Holstein-Friesian cows differing in mature liveweight. *Proceedings of the 6th World Congress on Genetics Applied to Livestock Production. Volume* 20: 39-42.

Garnsworthy, P.C.(1988). The effect of energy reserves at calving on performance of dairy cows. In: Nutrition and Lactation in the dairy cow. Ed: Garnsworthy, P.C. Butterworths, London.

Gibb, M.J., Huckle, C.A., Nuthall, R. and Penning, P.D. (1996). Can grazed pasture meet the needs of the high genetic merit dairy cow ?. In: *Grass and Forage for cattle of high genetic merit. British Grassland Society*. Published by: The Bristish Grassland Society N° 1 Earley Gate University of Reading, Reading, Berkshire, RG6 6AT.

Gibson, J.P.(1986). Efficiency and performance of genetically high and low milk producing British Friesian and Jersey cattle. *Animal Production*.42:161-182.
Gibson, J.P.(1987). Part-lactation predictors of complete lactation milk-energy yield, food intake and food conversion efficiency. *Livestock Production Science*.17:323-335.
Glassey C., Davey A.W.F.and Holmes C.W (1980) Allowance and milk production. *Proceedings of the New Zealand Society of Animal Production.* 40: 59
Gordon, I.J. and Illius A.W (1987). Incisor arcade structure and diet selection in ruminants. *Functional Ecology.* 2:15-22.
Graham,N.J., Burnside,E.B., Gibson, J.P., Rapitta, A.E. and McBride, B.W.(1991). Comparison of daughters of Canadian and New Zealand Holstein Sires for first lactation efficiency of production in relation to body size and condition. *Canadian Journal of Animal Science*.71:293-300.
Grainger,C., Wilhelms,G.D., and McGowan,A.A.(1982). Effect of body condition at calving and level of feeding in early lactation on milk production of dairy cows. *Australian Journal of. Experimental Agriculture and Animal Husbandry*.22:9-17.
Grainger, C., Holmes, C.W.and Moore, Y.F.(1985). Performance of Friesian cows with high or low breeding index. *Animal Production.* 40:389-400.
Gravert, H.O.(1985). Genetic factors controlling feed efficiency in dairy cows. *Livestock Production Science*.13:87-99.
Grieve, D.G., Macleod, G.K., Batra, T.R., Burnside, E.D.and Stone, J.B.(1976). Relationship of food intake and ration digestibility to estimate transmitting ability, body weight, and efficiency in first lactation. *Journal of Dairy Science.* 59:1312-1318.
Groen, A.F., Steine, T., Colleau, J.J., Pedersen, J., Pribyl, J.and Reinsch, N.(1997). Economic values in dairy cattle breeding, with special reference to functional traits. Report of an EAAP-working group. *Livestock Production Science.* 49:1-21.
Groen, A.F., Arendonk, J.A.M., Steverink, M.H.A. and Berentsen, P.B.M.(1994). The economic value of body weight in dairy cattle: influences of farm intensity and environmental legislation . Forty-fifth annual meeting of the European Association of Animal Production, Edinburgh.
Grosshans, T., Xu, Z.Z. and Burton, L.J.(1996). Genetic parameters for fertility traits in seasonal dairy cattle. *Proceedings of New Zealand Society of Animal Production.* 56: 38-41.
Grygar, I., Kudlac,E., Dolezel, R. and Nedbalkova, J.(1997). Volume of luteal tissue and concentration of serum progesterone in cows bearing homogeneous corpus luteum or corpus luteum with cavity. *Animal Reproduction Science.* 49:77-82.
Hansen, L.B., Cole, J.B. and Marx, G.D.(1998). Body size of lactating dairy cows: results of divergent selection for over 30 years. *Proceedings of the 6th World Congress on Genetic Applied to Livestock Production. Volume*.20: 35-38.
Harris, B.L.(1989). New Zealand dairy cows removal reasons and survival rate. *New Zealand Journal of Agricultural Research.* 32:355-358.
Hietanen, H. and Ojala,M.(1995). Factors affecting body weight and its association with milk productions traits in Finish Ayrshire and Friesian Cows. *Acta Agricultural Scandinava* 45:17-25.
Hodgson, J. and Wilkinson, J.M.(1967). The relationship between live-weight and herbage intake in grazing cattle. *Animal Production*.9: 365-376.
Hodgson, J (1982). Ingestive behaviour.p.113-118. In J.D. Leaver (ed.). Herbage intake Handbook. British Grassland Society., Hurley, Berks.
Hodgson, J. (1985).The control of herbage intake in the grazing ruminant. *Proceeding of the Nutrition Society.* 44: 339-346.
Hodgson J. (1990). Grazing management. Science into practice. Longman handbooks in Agriculture.
Hodgson, J., Clark, D.A. and Mitchell, R.J. (1994). Foraging behavior in grazing animals and its impact on plant communities. page 796. In: Forage quality, evaluation, and utilisation. Editor: George C. Fahey, Jr.

Hoekstra, J., van der Lugt, A.W., van der Werf, J.H.J.and Ouweltjes, W.(1994). Genetic and phenotypic parameters for milk production and fertility traits in upgraded dairy cattle. *Livestock Production Science*.40:225-232.

Holmes,C.W. and McMillan,K.L.(1982). Nutritional Management of the dairy herd grazing on pasture. pp 244 In: Dairy production from pasture. New Zealand Society of Animal Production. Edited by K.L. Macmillan and V.K. Taufa.

Holmes, C.W, Brookes I.M., Ngarmsak, S and Davey, A.W.(1985). Effect of level of feeding at different times of the year on milk production by Friesian cows of high or low genetic merit. *Proceedings of the New Zealand Society of Animal Production*. 40:135-138.

Holmes, C.W. and Wilson, G.F (1987) Milk production from pasture. Butterworths, New Zealand.

Holmes, C.W.(1988). Genetic merit and efficiency of milk production by the dairy cow. page 195-215 In: Nutrition and Lactation in the dairy cow. Editor: P.C.Garnsworthy.

Holmes, C.W., Wilson, G.F., Kuperus, W., Buvaneshwa.S. and Wickham, B. (1993). Liveweight, feed intake and feed conversion efficiency of lactating dairy cows. *Proceedings of the New Zealand Society of Animal Production* 53: 95-99.

Holmes C. W. (1987) Pasture for dairy cows.page 133.In: Livestock feeding on pasture. New Zealand Society of Animal Production. Occasional Publication N° 10.

Holmes, C.W.(1990). Principles and practices of profitable dairy farming. *Proceedings Ruakura Farmers Conference*.41: 60-67.

Holmes,C.W. and Parker,W.(1992).Stocking rate and its effects on dairy farm productivity. *Dairyfarming Annual*.44: 25-36.

Holmes, C.W.(1995). Genotype X environment interactions in dairy cattle: a New Zealand perspective. In: Breeding and Feeding the high genetic merit cow. Eds:Lawrence T.J, Gordon, F.J. and Carson, A. British Society of Animal Production Occasional Publication. N° 19, pp 51-58.

Holmes, C.W.(1996). Efficiency: The key to profitable survival. *Dairyfarming Annual*. 48: 28-36.

Holmes, W. and Jones, J.G.W.(1964). The efficiency of utilisation of fresh grass. *Proceedings of the Nutrition Society*. 23: 88-99.

Holmes, W.(1973). Size of animal in relation to productivity. Nutritional aspects. *Proceedings of the British Society of Animal Production*. 2 (new series):27-34.

Hooven, N.W., Miller,R.H. and Plowman, R.D.(1968). Genetic and environmental relationships among efficiency, yield, consumption and weight of Holstein cows. *Journal of Dairy Science*.51:1409-1419.

Hooven, N.W., Miller, R.H. and Smith, J.W.(1972). Relationships among whole- and part-lactation gross feed efficiency , feed consumption and milk yield. *Journal of Dairy Science*.55:1848-1855.

Howse, S. and Leslie, M.(1997). Can dairy farmers make money by spending money ? *Proceedings of Ruakura Conference*. 48:10-19.

Hutton, J.B.(1962). The maintenance requirements of New Zealand dairy cattle. *Proceedings of the New Zealand Society of Animal Production*. 22:12-34.

Illius, A.W. and Gordon, I.J (1987). The allometry of food intake in grazing ruminants. *Journal Animal Ecology*.56:989-999.

Illius, A. W. (1989). Allometry of food intake and grazing behaviour with body size in cattle. *Journal Agricultural Science. Cambridge*.113: 259-266.

Illius, A. W. and Gordon, I.J.(1991). Prediction of intake and digestion in ruminants by a model of ruminants kinetics integrating animal size and plant characteristics. *Journal Agricultural Science. Cambridge*.116: 145-157.

Illius, A.W. and Allen, M.S.(1994). Assessing forage quality using integrated models of intake and digestion by ruminants. pp 869. In: Forage quality, evaluation, and utilisation. Editor: George C. Fahey, Jr.

Illius, A.W. and Jessop, N.S.(1996). Metabolic constraints on voluntary intake in ruminants. *Journal Animal Science*.74: 3052-3062.

Jarrige, R., Demarquilly,C., Hoden, A. and Petit, M.(1986). The INRA fill unit system for predicting the voluntary intake of forage based diets in ruminants: a review. *Journal of Animal Science*.63:1737-1758.

Jarrige, R.(1989). Feedings standards for ruminants. pp 15-21. In: Ruminant Nutrition. Recommended Allowances and Feed Tables. R.Jarrige (ed).

Johanson, I.(1964). Genetic aspects of dairy cattle breeding. University of Illinois Press, Urbana. 259 pages.

John, A. and Ulyatt, M.J.(1987). Importance of dry matter content to voluntary intake of fresh grass forages. *Proceedings of the New Zealand Society of Animal Production.* 47:13-16.

Jonsson, N., Fulkerson, B., Mayer, D. and Bryant, D.(1997) The relationship between genetic merit or production, level of concentrate supplementation, fertility and biochemical measures of energy balance in dairy cows. *Report from the New South Wales (NSW) Agriculture Dairy Research Group*(1996/1997).

Kennedy,B.W.(1984). Breeding for feed efficiency: swine and dairy cattle. *Canadian Journal of Animal Science.*64:505-512.

Kennedy, B.W., van der Werf, J.H.J. and Meuwissen,T.H.E.(1993). Genetic and statistical properties of residual feed intake. *Journal of Animal Science.* 71:3239-3250.

Kolver, E. and Muller, L.D.(1996) Intake of pasture by high producing dairy cows. *Journal Dairy Science.* 79(1):234 (Supplement 1).

Korver,S.(1988). Genetic aspects of feed intake and feed efficiency in dairy cattle: a review. *Livestock Production Science.*20:1-13.

Laca, E.A., Ungar, E.D. and Demment, M.W. (1992) Effects of sward height and bulk density on bite dimensions of cattle grazing homogeneous swards. *Grass and Forage Science.* 47:91-102.

Laca, E. A. and Demment, M.(1996). Foraging strategies of grazing animals. In: J. Hodgson and A.W. Illius (eds). The ecology and management of grazed ecosystems. Cab International.

Lamb, R.C., Walters, J.L., Andersson, M.J., Plowman,R.D., Mickelsen, C.H. and Miller, R.H.(1977). Effects of sire and intercation of sire with ration on efficiency of feed utilisation by Holsteins. *Journal of Dairy Science.*60: 1755-1767.

Lamming, G.E. and Bulman, D.C.(1976). The use of milk progesterone radioimmunoassay in the diagnosis and treatment of subfertility in dairy cows. *British Veterinary Journal.*132:506-517.

Lean,I.J.,Troutt,H.F., Bruss, M.L. and Baldwin,R.L.(1992). Bovine somatotropin. *The Veterinary Clinics of North America.*8:147-163.

Lee, A.J., Boichard, D.A. and Lin, C.Y.(1992). Genetics of growth, feed intake and milk yield in Holstein Cattle. *Journal of Dairy Science.* 75:3145-3154.

Lewis, G.S.(1997). Uterine health and disorders. *Journal of Dairy Science.* 80: 984-994.

L'Huillier, P.J., Parr, C.R., and Bryant, A.M.(1988). Comparative performance and energy metabolism of Jerseys and Friesians in early-mid lactation. *Proceedings of the New Zealand Society of Animal Production.*48:231-235.

L'Huillier, P.J.and Thomson, N.A.(1988). Estimation of herbage mass in ryegrass/white clover dairy pastures. *Proceedings of the New Zealand Grassland Association.* 49: 117-122.

Lin, C.Y., MacAllister, A.J., and Lee, A.J.(1984). Multitrait estimation of relationships of first lactation yields to body weight changes in Holstein heifers. *Journal of Dairy Science.* 68:2954-2963.

Linzell, J.L.(1972). Milk yield, energy loss in milk, and mamary gland weight in different species. *Dairy Science Abstract.*34:351-360.

Livestock Improvement Corporation (1995). *Dairy Statistics.*

Livestock Improvement Corporation (1996). Animal Evaluation Technical Manual.

Lucy, M.C., Savio, J.D., Badinga, L., De La Sota. and Thatcher, W.W.(1992). Factors that affect ovarian follicular dynamics in cattle. *Journal of Animal Science.*70:3615-3626.

Macgilloway, D.A. and Mayne, C.S.(1996). The importance of grass availability for the high genetic merit cow. In: Recent Advances in Animal Nutrition.pp 135-169. Ed: P.C. Garnsworthy and D.J.A. Cole.

Mackey,D.R., Sreenan, J.M., Roche, J.F. and Diskin, M.G.(1997). The effect of acute changes in energy intake on follicle wave turnover in beef heifers. *Irish Journal of Agricultural and Food Research.*36:95.

Mackle, T.R., Parr, C.R., Stakelum, G.K., Bryant, A.M. and Macmillan, K.L.(1996). Feed conversion efficiency, daily pasture intake, and milk production of primiparous Friesian and Jersey cows calved at two different liveweights. *New Zealand Journal of Agricultural Research*. 39:357-370.

Macmillan, K.L.(1974). The application of artificial breeding as a reproductive technique in cattle. *Proceedings of the New Zealand Society of Animal Production*. 34:158-166.

Macmillan, K.L. and Curnow, R.J.(1977). Tail painting- a simple form of oestrus detection in New Zealand dairy herds. *New Zealand Journal of Experimental Agriculture*. 5:357-361.

Macmillan, K.L.(1979). Factors influencing conception rates to artificial breeding in New Zealand dairy herds: a review. *Proceedings of the New Zealand Society of Animal Production* 35: 129-137.

Macmillan, K.L.and Clayton, D.G.(1980). Factors influencing the interval to post-partum oestrus, conception date and empty rate in an intensively managed dairy herd. *Proceedings of the New Zealand Society of Animal Production* 40: 236-239.

Macmillan, K.L, Taufa,V.K. and Pearce, M.G.(1984). Calving patterns and their effects on herd production. *Proceedings of the Ruakura Frarmers Conference*. p 25.

Macmillan,K.L., Henry,R.I., Taufa,V.K. and Phillips,P.(1990). Calving pattern in seasonal dairy herds. *New Zealand Veterinary Journal*.38:151-155.

Macmillan, K.L., Day, A. M. and Taufa, V.K.(1995). Comparative reproductive performance of cycling and anoestrous cows in five New Zealand Dairy Herds. *New Zealand Veterinary Journal*. 43:115-120.

Macmillan, K.L. and Lean, I.J. (1996). Relationships involving milk yield, energy balance, blood metabolites and fertility in high yielding dairy cows. *Australian Journal of Veterinary*. 43:121-124.

Macmillan, K.L.(1997).. Current threats and opportunities in dairy production. *Proceedings of the Ruakura Farmers Conference* 49: 40-43.

Markusfeld, O. and Ezra, E.(1993). Body measurements, metritis and postpartum performance of first lactation cows. *Journal of Dairy Science*. 76: 3771-3777.

Mason, I.L., Robertson, A. and Gjelstad, B.(1957). The genetic connexion between body size, milk production and efficiency in dairy cattle. *Journal of Dairy Research*.24:135-143.

Mayes, R.W., Lamb, C.S. and Colgrove, P.M.(1986). The use of dosed and herbage n-alkanes as markers for the determination of herbage intake. *Journal of Agricultural Sciences, Cambridge*.107: 161-170.

Mayne, C.S. and Gordon, F.J.(1995). Implications of genotype x nutrition interactions for efficiency of milk production systems. In: Breeding and Feeding the High Genetic Merit cow. British Society of Animal Science. Occasional Publication N° 19. Edinburgh pp 67-77.

Mayne,C.S.(1996). Can grazed grass provide ?. High vs Medium Genetic Merit cows. In: *Grass and Forage for cattle of high genetic merit. British Grassland Society*. Published by: The Bristish Grassland Society N° 1 Earley Gate University of Reading, Reading, Berkshire, RG6 6AT.

McCallum, D., Thomson, N. and Clough, J.(1995). Use of concentrate feed to maintain the feed supply at high stocking rate: Demonstration Farm at Waimate West. *Dairyfarming Annual. Massey University*. 47:15-19.

McDougall,S.(1994). Postpartum anoestrum in the pasture grazed New Zealand Dairy cow. PHD Thesis (Massey University).

McGowan, A.A.(1981). Effect of nutrition and mating management on calving patterns. *Proceedings of the New Zealand Society of Animal Production*.41: 34-38.

McGowan, M.R. and Veerkamp, R.F.(1996). Effects of genotype and feeding system on the reproductive performance of dairy cattle. *Livestock Production Science*.46:33-40.

McLeod, M.N. and Minson, D.J.(1982). Accuracy of predicting digestibility by the cellulase technique: the effect of pretreatment of forages samples with neutral detergent of acid pepsin. *Animal Feed Science and Technology*. 7: 83-92.

Mertens, D.R.(1987). Predicting intake and digestibility using mathematical models of ruminal function. *Journal of Animal Science*. 64:1548-1558.

Mertens, D.R. (1994). Regulation of forage intake. Prediction of intake as an element of forage quality. In: Forage Quality, Evaluation and Utilization. Edited by: G.C.Fahey. Page 450.

Minson, J.D.(1990). In : Forage in ruminant nutrition. Academic Press, Inc.

Minson, D.J. and Wilson, J.R. (1994). Prediction of intake as an element of forage quality. In: Forage Quality, Evaluation and Utilization. Edited by: G.C.Fahey. Page 553.

Moe, P.W. and Tyrrell, H.F.(1975). Efficiency of conversion of digested energy to milk. *Journal of Dairy Science*.58:602.

Moe, P.W. (1981). Energy metabolism of dairy cattle. *Journal of Dairy Science*. 64:1120-1139.

Moller, K.(1970). Uterine involution and ovarian activity after calving. *New Zealand Veterinary Journal*. 18: 141-145.

Moore, R.K., Kennedy, B.W., Schaeffer, L.R. and Moxley, J.E.(1991). Relationships between age and body weight at calving and production in first lactation Ayrshires and Holsteins. *Journal of Dairy Science*. 74:269- 278.

Moore, R.K., Kennedy, B.W. and Moxley, E.(1992). Relationships between age and body weight at calving, feed intake, production, days open and selection indexes in Ayrshires and Holsteins. *Journal of Dairy Science*. 73:938-947.

Morris, C.A. and Wilton, J.W.(1976). Influence of body size on the biological efficiency of cows: a review. *Canadian Journal of Animal Science*. 56:613-647.

Muller, L.(1993). Limitations of pastures for high production by dairy cows- a US perspective. In: Improving the quality and intake of pasture based diets for lactating dairy cows. N.J. Edwards and W.J. Parker (ed). Occasional Publication N° 1. Department of Agricultural and Horticultural Systems Management, Massey University, New Zealand.

Newman, J.A., Parsons, A.J. and Pennings, P.D.(1994). A note on the behavior strategies used by grazing animals to alter their intake rates. *Grass Forage Science*. 49: 502-505.

Oldenbroek, J.K.(1988). The performance of Jersey cows and cows of larger dairy breeds on two complete diets with different roughage contents. *Livestock Production Science*.18:1-7

Oldham, J.D (1995). Genotype, Nutrition and Behaviour interactions in Ruminants. In: Recent Advances in Animal Nutrition.1995. Page 122. Editors: P.C. Garnsworthy and D.J.A. Cole.

Olson, T.A.(1994). The effect of cow size on reproduction. page 243-249. In: Factors affecting the calf crop. C.R.C Press, Boca-Raton, Florida. Ed: MJ Field and R.S. Sand.

Ostergaard, V., Korver, S., Solbu, H., Andersen, B., Oldham, J. and Wiktorsson, H.(1990). Main report-E.A.A.P working group on: efficiency in the dairy cow. *Livestock Production Science*. 24:287-304.

Parker, W.J.(1996). How to analyse your inputs and costs. *Dairy Farming Annual* 48:48-56.

Payne, J.M. and Payne, S.(1987). The metabolic profile test. Edited by Oxford.

Penning, P.D., Rook, A.J.and Orr, R.J.(1991). Patterns of ingestive behaviour of sheep continuously stocked on monocultures of ryegrass or white clover. *Applied Animal Behaviour Science*. 31:237-250.

Penno, J.W., Thomson, N.A. and Bryant, A.M.(1995). Summer milk- supplementary feeding. *Proceedings of Ruakura Farmers Conference*, p17-23.

Penno, J.W.; Bryant, A.M. and Macdonald, K.A.(1996). Effect of high rates nitrogen fertiliser and cereal concentrate supplements on pasture production and yield milksolids from dairy farm systems. *Proceedings of the New Zealand Society of Animal Production* .56:236-238.

Persaud, P., Simm,G. and Hill, W.G.(1991). Genetic and phenotypic parameters for yield, food intake and efficiency of dairy cows feed ad-lib. *Animal Production*. 52:435-444.

Peters, A.R.(1996). Herd management for reproductive efficiency. *Animal Reproduction Science*.42:455-464.

Peterson, R.(1988) Comparison of Canadian and New Zealand sires in New Zealand for production, weight and conformation traits. LIC report. 12 pages.

Peyraud, J.L., E.A.Cameron., M.H.Wade. and G.E. Lemaire.(1996). The effect of daily herbage allowance, herbage mass and animal factors upon herbage intake by grazing dairy cows. *Annales de Zootechnie*. 45:201-217.

Pinares,C. and Holmes, C.(1996). Effects of feeding silage and extending lactation on the pastoral dairy systems. *Proceedings of the New Zealand Society of Animal Production*. 56: 238-240.

Poppi D.P., Hughes T. P. and L'Huillier P. J. (1987). Intake of pasture by grazing ruminants. In: Livestock feeding on pasture. page 55. *New Zealand Society of Animal Production. Occasional Publication N° 10.*

Pulido, R. and Leaver, J.D.(1996). Set stocking versus strip grazing for dairy cows. Effect of initial milk yield, sward height and concentrate level on herbage intake and grazing behaviour. In: *Grass and Forage for cattle of high genetic merit. British Grassland Society*. Published by: The Bristish Grassland Society N° 1 Earley Gate University of Reading, Reading, Berkshire, RG6 6AT.

Purser, D.B.and Moir, R.J.(1966). Rumen volume as a factor involved in individual sheep differences. *Journal of Animal Science*. 25: 509-515.

Robertson, A.(1973). Body size and efficiency. *Proceedings of the British Society of Animal Production*. 2 (new series):9-14.

Robertson, J.B.and Van Soest, P.J.(1981). " The detergent System of Analysis and its application to human foods, in the analysis of dietary fibre in Food". Vol.3. Chapter 8, ED. W.P.T. James and O.Theander. Marcel Dekker, Inc.: New York.

Rogers, G.L., Grainger, C. and Earle, D.F.(1979). Effect of nutrition of dairy cows in late pregnancy on milk production. *Australian Journal of Experimental Agriculture and Animal Husbandry*. 19: 7-12.

Schillo, D.(1992). Effect of dietary energy on control of luteinizing hormone secretion in cattle and sheep. *Journal of Animal Science*. 75:1271-1278.

Shipley, L.A., Gross, J.E., Spalinger, D.E., Hobbs, N.T. and Wunder, B.A.(1994). The scaling of intake rate in mammalian herbivores. *American Naturalist*.143:1055-1082.

Sieber, M., Freeman, A.E. and Kelley, D.H.(1988). Relationships between body measurements, body weight and productivity in Holstein dairy cows. *Journal of Dairy Science*.71:3437-3445.

Spedding, C.R.W.(1971). Grassland ecology. Oxford University Press. 221p.

Speeding, C.R.W.(1988). An introduction to agricultural systems. Elsevier Applied Science. 185 pages.

Spelman, R.J. and Garrick, D.J.(1997). Effect of live weight and differing economic values on responses to selection for milk fat, protein, volume, and live weight. *Journal of Dairy Science*. 80:2557-2562.

Shadbolt, N (1997). Key performance indicators. *Dairyfarming annual* 49:107-112.

Stakelum, G. and Connolly, J.(1987). Effect of body size and milk yield on intake of fresh herbage by lactating dairy cows indoors. *Irish Journal of Agricultural Research*.26:9-22.

Stakelum, G. and Dillon, P.(1990). Dosed and herbage alkanes as feed intake predictors with dairy cows: The effect of feeding level and frequency of perennial ryegrass. *Proceedings VII European Grazing Workshop*. October, 1990.

Standing Committee on Agriculture (1990). Feeding Standards for Australian Livestock: Ruminants. CSIRO Australia, Melbourne.

Staples, C.R., Thatcher, W.W. and Clark, J.H.(1990). Relationship between ovarian activity and energy status during the early postpartum period of high producing dairy cows. *Journal of Dairy Science* 73: 938-947.

Stewart, J.A. and Taylor, J.W.(1996). Larger size, or higher body condition, for increased first lactation milk production in dairy heifers. *Proceedings of the Australian Society of Animal Production*. 18:376-379.

Stobbs, T.H.(1973). The effect of plant structure on the intake of of tropical pastures. 2) Differences in sward structure, nutritive value and bite size of animals grazing Setaria anceps and Chloris Gayana at various stages of growth. *Australian Journal of Agricultural Research*. 24: 821-824.

Stobbs, T.H.(1974). Rate of biting by Jersey cows as influenced by the yield and maturity of pasture swards. *Tropical Grasslands*. 8: 81-86.

Stockdale, C.R.(1984). Evaluations of techniques for estimating the yield of irrigated pastures intensively grazed by dairy cows. 2. The rising plate meter. *Australian Journal of Experimental Agriculture and Animal Husbandry*. 24: 305-311.

Stockdale, C.R. (1985) Influence of some sward characteristics on the consumption of irrigated pastures grazed by lactating dairy cattle. *Grass and Forage Science*.40: 31-39.

Syrstad, O.(1966). Studies on dairy herd records.IV. Estimates of phenotypic and genetic parameters. *Acta Agricultural Scandinava*. 16:79-96.

Svendsen, M., Skipenes, P. and Mao, I.L.(1993). Genetic parameters in the feed conversion complex of primiparous cows in the first two trimesters. *Journal of Animal Science*. 71:1721-1729.

Svendsen, M., Skipenes, P. and Mao, I.L.(1994). Genetic correlation in the feed conversion complex of primiparous cows at a recommended and a reduced plane of nutrition. *Journal of Animal Science.* 72:1441-1449.

Tamminga, S. and Van Vuuren, M.(1995). Physiological limits of fibrous feed intake and conversion in dairy cows. In: A.F.Groen and J. Van Bruchem (Eds)., Optimal utilisation of local feed resources. Perspectives of dairy cattle production systems in the Netherlands. Wageningen Pers, Wageningen, pp 19-33.

Taylor, St.C.S.(1973). Genetic differences in milk production in relation to mature body weight. *Proceedings of the British Society of Animal Production.* 2 (new series):15-25.

Taylor, St.C.S., Turner, H.G. and Young, G.B.(1981). Genetic control of equilibrium maintenance efficiency in cattle. *Animal Production.*33:179-194.

Taylor, St.C.S., Murray. J.I. and Illius, A.W.(1987). Relative growth of incisor arcade breadth and eating rate in cattle and sheep. *Animal Production.* 45: 453-458.

Thatcher,W.W., Macmillan, K.L., Hansen,P.J. and Drost, M.(1989). Concepts for the regulation of corpus luteum function by the conceptus and ovarian follicles to improve fertility. *Theriogenology.*31:149.

Thatcher, W.W., Staples, C.R., Oldick, B. and Schmitt, E.P.(1994). Embryo health and mortality in sheep and cattle. *Journal of Animal Science.*72(Suppl 3):16-30.

Trigg, T.E. and Parr, C.W.(1981). Aspects of energy metabolism of Jersey cows differing in breeding index. *Proceedings of the New Zealand Society of Animal Production.* 41: 44-47.

Ulyatt, M.J.(1981). The feeding value of temperate pastures. In: World Animal Science 1. Grazing Animals. Ed: F.H.W.Morley. Elsevier Scientific Publishing, New York.page 125-139.

Ulyatt, M.J., Dellow, D.W., and Reid, C.S.W. (1986). Contribution of chewing during eating and rumination to the clearance of digesta from the ruminoreticulum. In: Control of digestion and metabolism in ruminants. edited by : L.P.Milligan.

Ulyatt, M.J.and Waghorn, G.C.(1993). Limitations to high levels of dairy production from New Zealand pastures. pp 11-32. In: Improving the quality and intake of pasture based diets for lactating dairy cows. N.J. Edwards and W.J. Parker (ed). Occasional Publication N° 1. Department of Agricultural and Horticultural Systems Management, Massey University, New Zealand.

Ungar, E.D.(1996). Ingestive behaviour. Pages 185-218. In: J. Hodgson and A.W.Illius (eds). The ecology and management of grazing systems. Commonwealth Agriculture Bureau International, Wallingford, UK.

Van Arendonk, J.A.M., Hovenier, R. and De Boer, W.(1989). Phenotypic and genetic association between fertility and production in dairy cows. *Livestock Production Science.*21:1-12.

Van Arendonk, J.A.M., Nieuwhof, G.J., Vos, H. and Korver, S.(1991). Genetic aspects of feed intake and efficiency in lactating dairy heifers. *Livestock Production Science.* 29:263-275.

Van der Waaij, E.H., Galesloot, P.J.B. and Garrick, D.J.(1997). Some relationships between weights of growing heifers and their subsequent lactation performances. *New Zealand Journal of Agricultural Research.*40: 87-92.

Van Elzakker, P.J.M.van. and Arendonk, J.A.M.van (1993). Feed intake, body weight and milk production: genetic analysis of different measurements in lactating dairy heifers. *Livestock Production Science.*37:37-51.

Van Arendonk, J.A.M., Groen, A.F., Van der Werf, J.H.J. and Veerkamp, R.F.(1995). Genetic aspects of feed intake and efficiency in lactating dairy cows. In: A.F.Groen and J. Van Bruchem (Eds). Optimal utilisation of local feed resources. Perspectives of dairy cattle production systems in the Netherlands. Wageningen Pers, Wageningen, pp 34-44.

VanRaden, P.(1988). Economic value of body size in Holsteins. *Journal of Dairy Science.71*(Suppl.1):238.

Van Soest, P.J.(1994). Nutritional Ecology of the ruminant. Published by Cornell University Press. 476 pages.

Van Vleck, L.D. and Norman, L.C. (1972). Association of type traits with reasons for disposal. *Journal of Dairy Science.*55:1698.

Verité,R. and Journet, M.(1970). Influence de la teneur en eau et de la deshydratation de l'herbage sur se valeur alimentaire pour la vache laitiere. *Annales de Zootechnie.*19: 255-268.

Veerkamp, R.F., Simm,G., and Oldham, J.D.(1994). Effects of interaction between genotype and feeding system on milk production, feed intake, efficiency and body tissue mobilisation in dairy cows. *Livestock Production Science.*39:229-241.

Veerkamp, R.E.; Simm, G. and Oldham, J.D.(1995). Genotype by environment interaction: experience from Langhill. In: Breeding and Feeding the high genetic merit cow. Eds:Lawrence T.J, Gordon, F.J. and Carson, A. British Society of Animal Production Occasional Publication. N° 19, pp 43-50.

Veerkamp,R.F. and Emmans, G.C.(1995). Sources of genetic variation in energetic efficiency of dairy cows: a review. *Livestock Production Science.* 44:87-97.

Veerkamp, R.F., Emmans, G.C., Cromie, A.R. and Simm, G.(1995). Variance components for residual feed intake in dairy cows. *Livestock Production Science.* 41:111-120.

Veerkamp, R.F.(1996). Live weight and feed intake in dairy cattle breeding goal. Proceedings of the international workshop on functional traits in cattle, Gembloux, Belgium. Interbull bulletin n° 12, pp173-178.

Veerkamp, R.F. and Brotherstone, S.(1997). Genetic correlation between linear type traits, food intake, live weight and condition score in Holstein Friesian Dairy cattle. *Animal Science.*64:385-392.

Villa-Godoy,A., Hughes,T.L., Emery,R.S., Chapin,L.T.and Fogwell, R.L.(1988). Association between energy balance and luteal function in lactating Holstein cows. *Journal of Dairy Science.* 71: 1063-1072.

Vishwanath,R., Xu,Z. and Macmillan, K.L (1996). Prospects for overcoming the physiological limits of dairy cow fertility. *Proceedings of the New Zealand Society of Animal Production.* 56:355-358.

Visscher, P.M., Bowman,P.J., and Goddard, M.E.(1994). Breeding objectives for pasture based dairy production systems. *Livestock Production Science.* 40: 123-137.

Wade M.H., Peyraud J.L., Lemaire G. and Comeron E.A (1989). The dynamic of daily area and depth of grazing and herbage intake of cows in a five day paddock system. In: Proc XVI International Grassland Congress. Nice. p 1111-1112.

Wallace, L.R.(1961). The nutritional requirements of dairy cattle. *Proceedings of the New Zealand Society of Animal Production.* 21: 64-78.

Weston, R.H.(1996). Some aspects of constraint to forage consumption by ruminants. *Australian Journal of Agricultural Research.* 47:175-197.

Wickham, B., Ahlborn-Brier, G., and Harding, K.(1992). Size and efficiency in Holstein Friesian animals. *World Holstein Friesian Conference, Hungary.*

Williamson, N.B. and Fernandez-Baca, E.(1992). The role of dietary protein and energy in dairy herd fertility. *Proceedings of the First International Conference for the Society of Dairy Cattle Veterinarians of the New Zealand Veterinary Association.* page 39.

Wilson, J.R., D.E. Akin., M. N. McLeod. and D.J. Minson.(1989). Particle size reduction of the leaves of a tropical and temperate grass by cattle. Relation of anatomical structure to the process of leaf breakdown through chewing and digestion. *Grass Forage Science.* 44:65-75.

Wilson, J.R. and Kennedy, P.M.(1996). Plant and Animal constraints to voluntary feed intake associated with fibre characteristics and particle breakdown and passage in ruminants. *Australian Journal of Agricultural Res*earch.47:199-225.

Wilson,G.F., MacKenzie., DDS. and Holmes, C.(1985). Blood metabolites and infertility in dairy cows. *Proceedings of the New Zealand Society of Animal Production.* 45:17-20.

Wilson, G.F., Moller,S., Parker, W.J. and Hodgson, J.(1995). Seasonal differences in pasture composition and nutritional implications. *Dairyfarming Annual.*47:46-56.

Woodward, S.J.R.(1997). Formula for predicting animals'daily intake of pasture and grazing time from bite weight and composition. *Livestock Production Sc*ience. 52:1-10.

Xu, Z.Z.; Burton, J.R.; Burton, L.J.and Macmillan, K.L.(1995). Reproductive performance of synchronised lactating dairy cows. *Proceedings of the New Zealand Society of Animal production.*55: 222-224.

Xu, Z.Z. and Burton, L.J. 1996. Reproductive efficiency in lactating dairy cows. *Proceedings of the New Zealand Society of Animal Production.* 56:34-37.

Yerex, R.P., Young, J.D. and Marx, G.(1988). Effects of selection for body size on feed efficiency and size of Holstein cows. *Journal of Dairy Science.* 71:1355-1360.

Zavy, M.T.(1994). Embryonic mortality in cattle. In: Embryo Mortality in Domestic Species, M.T.Zavy and R.D.Geisert (Eds), Boca Raton, CRC Press.pp.99-140.

Zoby, J.L.F. and Holmes, W. (1983). The influence of size of animal and stocking rate on the herbage intake and grazing behavior of cattle. *Journal of Agricultural Science.*100: 139-148.