FEED INTAKE CAPACITY AND REPRODUCTIVE PERFORMANCE IN HOLSTEIN-FRIESIAN COWS DIFFERING GENETICALLY FOR BODY WEIGHT

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This thesis is entirely dedicated to my mother Mercedes. To you, I owe more than words can say. Thank you for your endless love.

ABSTRACT

The work outlined in this study was intended to evaluate some differences between cows from two genetic lines of Holstein-Friesian (HF) cows, which have been selected for either heavy or light live weight, but are of similar high genetic merit for milk production. The two aspects studied in this thesis were, feed intake capacity and their reproductive performance because these characteristics can have important effects on efficiency of the cow, and they may be affected by selection for live weight.

In both 1998 and 1999, 16 and 24 pregnant non-lactating high genetic merit Holstein-Friesian cows, which differed genetically in size and weight, were selected from the high (H) and low (L) breeding value for live weight (LW) herd at DCRU Massey University, with eight and 12 animals for each line in 1998 and 1999 respectively. These were fed to appetite on hay (7.52 MJ ME/kg DM in 1998) and on pasture (11.1 MJ MD/kg DM in 1999) in order to measure the maximum voluntary feed intake capacity. The difference between the strains in DMI per cow per day was highly significant ($P<0.01$) in both years. The heavy cows ate 12.52 kg DM of hay and 13.10 kg DM of pasture in 1998 and 1999 respectively, while the light cows consumed 11.11 kg DM of hay and 11.63 kg DM of pasture in 1998 and 1999 respectively. The regression coefficients generated show that for each 100 kg increase in LW, daily dry matter intake per cow increased by 1.43 and 1.81 respectively in 1998, and 1999, a positive correlation between DMI/cow/day and live weight. Overall least squares means values for DMI/cow/day in 1998 and 1999 were 11.81 and 12.36 which indicates that cows in the first year ate 4.4% less hay DM/cow/day than cows on pasture in the second year. Similarly, the overall least squares means values for DMI/cow/day for H and L cows were 12.81 and 11.37, which indicates that H cows ate 11.2% more DM than L cows. The relation between metabolizable energy intake (MEI)/cow per day and LW was also significant ($P<0.01$) and ($P<0.05$) for both years 1998 and 1999 respectively. Least squares means for MEI by line as a treatment and after adjustment by parity number were 94.5 and 144.7 MJ ME/cow per day for the H cows, and 83.9 and 128.4 MJ ME/cow per day for the L cows, in experiment one and two respectively. Regression analysis of the data after conversion into $\log_{10}$, showed that DMI increased in proportion to $LW^{0.66}$ and $LW^{0.65}$ in 1998 and 1998 respectively. These results indicate that lighter cows are not disadvantaged relative to the heavier cows in their capacity to eat feed in excess of their maintenance requirement, which are generally assumed to increase in proportion to $LW^{0.75}$.

The reproductive performance of Holstein-Friesian cows differing genetically for live weight at Massey University was evaluated for the 1998-1999 period. The aim of the study was to evaluate and compare the reproductive performance of the heavy (H) and light (L) cows two year old, three year & older and all age groups. Differences between genetic lines were evaluated for calving intervals: three week calving rate, calving to first service (CFS), planned start of mating to first service (PSMFS), calving to conception (CC), planned start of mating to conception (PSMC), first service to conception (FSC) and calving interval (CI) and percentage of induced cows. In addition, 21 days submission rate (SR), conception rate to first service (CRFS), percentage of cows treated with CIDRs and empty rate were also evaluated. Light cows showed a more concentrated calving pattern than the H cows, and a higher percentage of L cows calved in the first 3 weeks than H cows (72% and 62% respectively). Cows in the H line had a higher proportion of induced calvings. There were no significant differences between H and L cows in CFS, CC, PSMC, FSC and CI. However, the difference in PSMFS between the strains was significant ($P<0.01$): H cows had shorter intervals than L cows (8 days and 13 days respectively). Submission rate at 21days was significantly higher ($P<0.001$) for H cows than L cows (96% and 85% respectively), and H cows had lower CRFS than L cows (50% and 74% respectively; $P<0.05$). Similarly H cows tended to have a higher proportion of empty rates and CIDRs than the L cows. The combination of lower conception rate at the first insemination and the later calving extended the conception and calving pattern for the H cows and at the same time increased the probability of an induced calving. These results indicate that light cows had higher CRFS, achieved a more concentrated calving pattern and fewer needed to be induced to calve than heavier cows.

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CHAPTER I

GENERAL REVIEW

1. GENERAL REVIEW

1.1 New Zealand Pastoral System

New Zealand's intensive grassland systems are almost entirely reliant on grazed pasture. These systems have important constraints on animal production. Most significant is the need for some compromise of individual animal performance to achieve high levels of pasture utilization and still maintain an annual cycle of animal production (Penno *et al.*, 1995). However, to achieve high levels of pasture utilization there must be enough cows to eat all the feed available within the farm system each year.

Penno, (1999) pointed out that stocking rate is a simplification of the relationship between feed demand and feed supply, where the number of cows provides a measure of the annual feed demand and a hectare provides a measure of how much feed is available. Undoubtedly, the number of cows farmed per hectare has a large effect on feed demand, but the cow's size and annual milk production determine the feed requirements of the cow. The amount each cow eats over a season is highly dependent on the amount of feed available, and when it is available relative to the demand for feed by the herd. In order to maximize the efficiency of feed utilization, it requires a higher proportion of the available pasture to be harvested at each grazing (Penno, 1999). The herd will graze harder as cows become increasingly underfed relative to their feed requirements. Thus, achieving high levels of pasture utilization efficiency requires that the feed demand of the herd be slightly in excess of pasture supply. That is, efficiency of pasture utilization increases with increasing levels of under feeding (Penno, 1999).

However, reduced levels of feeding cause reduced milk production and feed conversion efficiency by the cows.

The stocking rate should therefore balance the main objectives of generous feeding to achieve high levels of efficiency of milk production per cow and slight under feeding to achieve high levels of pasture utilization to optimise farm profitability. When stocking rate was increased production per cow decreased (Penno, 1998), which is to be expected as the feeding level of each cow decreased with an increase in stocking rate. An example in dairying systems is where full feeding of cows in early lactation is compromised in order to allow high stocking rates that are capable of converting most spring pasture growth into milk (Bryant, 1981). It is because stocking rate has such a dominant effect on animal demand and pasture use that it is seen as a major factor governing high animal output per hectare from grasslands (Penno, 1999).

The situation on New Zealand dairy farms can be illustrated by comparing average pasture growth rates with estimates of the stock's feed requirements during different months of the year (Sheath *et al.*, 1987). Growth rates can vary widely from year to year depending upon the weather situation, and therefore the seasonal pasture growth does not provide a uniform feed supply throughout the year and it creates the need to fit cattle feed requirements to the pasture growth pattern in order to minimize the waste of pasture and the need for supplementary feeding (Figure 1-1) Thomson and Holmes, (1995).

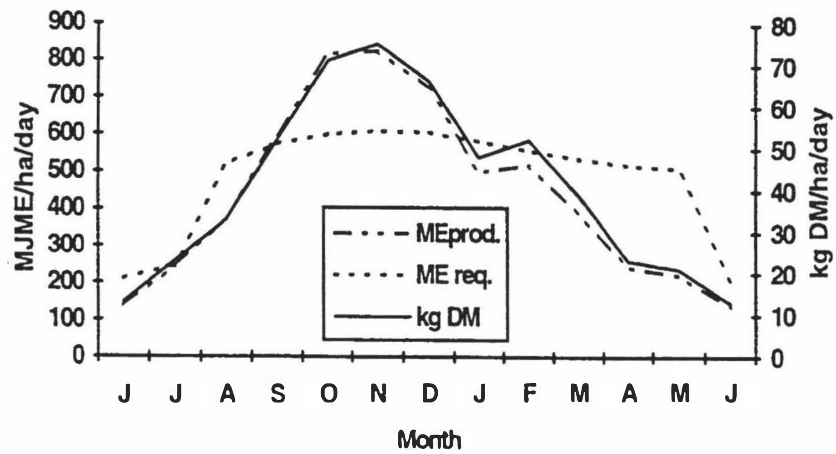

Figure 1-1. Pasture growth and feed requirements throughout the year. Thomson *et al.*, (1995).

1.1.1 Pasture Cover

Average pasture cover is the average of the herbage mass (kg DM/ha) present on each paddock at one time, that is the net result of the difference between rate of pasture growth and pasture consumed. When a forward transfer of pasture "on the paddock" is planned, a high average pasture cover is generated and this is then gradually depleted by careful rationing of pasture. For effective feed planning knowledge of the desired pasture cover at critical times of the year is essential. Regular monitoring of pasture cover is important as it indicates if the plan is on target or if it needs to be modified. Holmes *et al.*, (1993) suggested that an increase in average pasture cover at the start of calving would cause an increase in subsequent milk production, at least in early lactation. Bryant and McDonald (1987), concluded that at stocking rates of 3.5 to 4.2 cows/ha with an average pasture cover of 1200 to 2000 kg DM/ha, an increase of 100 kg DM/ha average pasture cover at the end of July caused an increase of 3 kg milkfat per cow in 4 months, and an increase in milkfat produced per hectare of about 10 kg.

Extra pasture cover at calving can be obtained by several methods including ① grazing-off to reduce feed demand on the farm, ② feeding extra supplements before calving and therefore decreasing pasture consumption, ③ increasing pasture growth through the use of Nitrogen fertilizer and ④ by reducing the area grazed each day, or increasing the rotation length, to reduce the rate of pasture consumption. However, special care must be taken to ensure that excess pasture cover at calving is not accumulated as this can lead to the wastage of pasture in late September due to increased senescence and reduced pasture regrowth (Phillips *et al.,* 1994).

Pasture balance is achieved when the rate of pasture production is equivalent to the rate of pasture consumption. Pasture growth rate is determined by the climate, soil fertility and moisture content, as well as, the plant specie and by grazing management. On the other hand, the rate of pasture consumption by the herd is controlled by the level of pasture feeding per cow, the number of cow per hectare and the use of supplementation (if applicable). In that order, when feed demand exceeds the rate of pasture production, feed deficits occur and the opposite situation occurs during times of surplus. In these cases careful feed planning and prompt implementation of grazing management throughout the year is needed to satisfy cows requirements and to utilise the pasture.

1.2 The Seasonal Calving System

1.2.1 Calving pattern

The planned start of calving (PSC) is commonly used to indicate whether a herd's calving program commences before (early calving) or after in late calving. The interval from the PSC to the mean calving date will indicate the compactness of the calving dates. It will also indicate how many days of lactation have been gained or lost by the average cow in one herd as compared to another herd, or among groups of animals within a herd (e.g. heifers vs. cows) (Macmillan, 1998).

Burke, (1999) Pointed out that the primary rationale for a compact calving is to maximize utilization of the spring pasture flush and cow days in milk (DIM). Therefore, in seasonal systems it is important to achieve a herd's compact calving pattern to match the herd's peak milk production with peak pasture growth (Macmillan, 1984). Equally, the drying off date of the cows is decided on the basis of pasture availability, which usually involves drying off most of the herd at one time (Brightling *et al.*, 1990). Good reproductive performance is required to maintain a tight calving pattern. The number of late calving cows and empty cows must be minimized to achieve low rates of induction and herd wastage (Penno, 1998). Also Hayes (1998) pointed out that the calving pattern of a herd is the result of reproductive performance in the previous season, culling strategies, stock purchases, pregnancy loss and inductions. In addition, **the actual calving pattern will have a major impact on subsequent mating performance because it determines the number of days from calving to the start of mating.** For instance, Figure 1-2 (Hayes, 1998) shows that heifers are commonly mated earlier than the adult herd so these animals can calve earlier than the herd. Despite this, the two year old cows in their first lactation have relatively poor mating performance, which ultimately results in delayed calving (or induction or culling) for the lactation two cows. There are some variations between breeds for calving rates. Friesians have delayed calving relative to crossbreeds and jerseys. Cows that have twin calves tend to have shorter gestations and a bull calf will delay calving (Hayes, 1998).

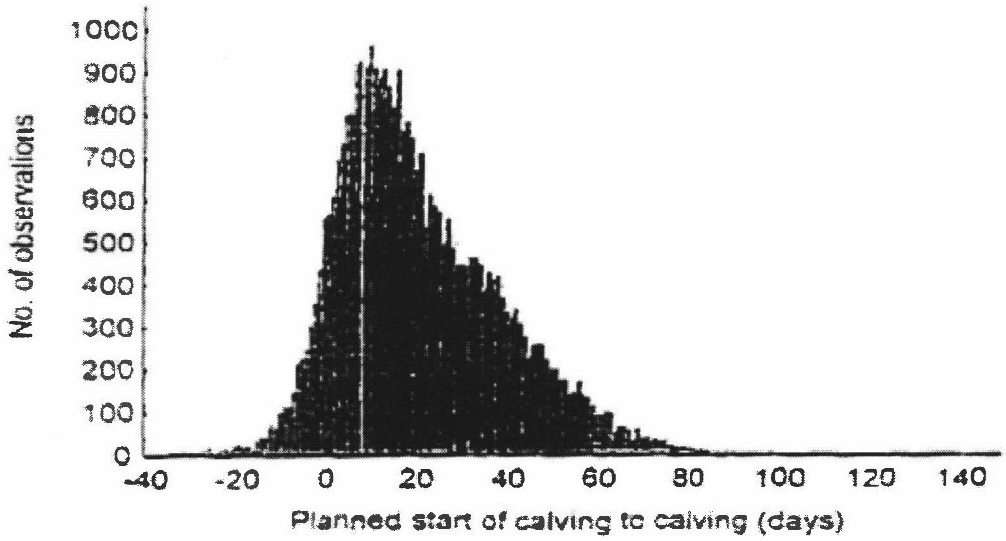

Figure 1-2. The calving pattern for all cows in herds using DairyMAN (Hayes, 1998).

Anoestrus, or non-cycling cows, and poor heat detection are the primary cause of reproductive failure in New Zealand herds (Macmillan, 1995; Penno *et al.*, 1998). To maintain a concentrated calving pattern, non-cycling cows must be accurately identified and treated so that all cows are cycling normally at the planned start of mating. Macmillan (1997), mentioned the main factors contributing to anoestrus: age, breed, body condition score at calving and feeding level after calving. Young cows, particularly first carvers, have higher levels of anoestrus than older cows. Friesians have higher rates of anoestrus than Jerseys. Cows that calve in lighter condition, or are poorly fed after calving, are slower to cycle and have higher levels of anoestrus than better fed cows.

Effects of breed, stocking rate and age on the incidence of anoestrous cows are summarized in Table 1-1 using data from a DRC study at the № 2 Dairy in 1991 (McDougall *et al.*, 1995). The results show that a prolonged anoestrus period is most likely to occur in Friesians rather than Jerseys; in first or second lactations rather than in later ones; and at higher stocking rates with the associated reduced levels of feeding. The animals most at risk are two years old Friesian animals in highly stocked herds where average daily milk yields are depressed through underfeeding.

Table 1-1. Intervals from calving to first ovulation and first detected oestrus in Jersey (J) and Friesian (F) cows of different ages and grazed at two stocking rates (H vs L) (Macmillan, 1997).

	Herd			
	JL	JH	FL	FH
Stocking rate (cows/ha)	3.5	4.5	3.0	4.0
Calving to 1st ovulation (days)	28	31	29	49
Calving to 1st oestrus (days)	31	39	35	52
% ovulation by 50 days	100	89	87	50
% in oestrus by 50 days	100	85	91	38
	Cow age			
	2 yr	3 yr	>3 yr	
Calving to 1st ovulation (days)	40	34	27	
Calving to 1st oestrus (days)	47	38	33	

A second experiment at DRC showed that first lactation Friesians that calved with a low body condition score (4 to 4.5), gained more live weight in the second six weeks of lactation than equivalent Jersey animals (34 kg vs 25 kg; Burke *et al.*, 1995). Additional results from this trial are summarized in Table 1-2. They once again confirm the vulnerability of young Friesian cows to anoestrus, especially when calving at low live weight.

Table 1-2. Intervals from calving to first ovulation and oestrus, and numbers of ovarian follicle waves to first ovulation in Friesian (F) and Jersey (J) heifers with high (H) and low (L) post-calving live weight (Macmillan, 1997).

	JL	JH	FL	FH
Calving live weight (kg)	279	334	354	404
Calving to 1st ovulation (days)	43	46	77	51
Calving to 1st oestrus (days)	60	55	85	62
Nº follicle waves to first ovulation	4.4	4.9	8.3	5.4

This does not mean that the young Jersey cow is not also at risk. Some observations of young Jersey animals indicate that those with significant American genetics, as well as high peak daily yields (> l kg milk fat), reach puberty at higher live weight and have extended periods of anoestrus (Macmillan, 1997).

Low live weight and body condition are related with reduced fertility and higher heifer empty rates, partly because these lighter animals are less likely to have been cycling when bulls are introduced. Macmillan, (1994) found out that the lightest 10% of heifers were five times more likely to be empty, may be because of their younger age, sire effects on growth rate or disease. Also high empty rates among Jersey heifers were recorded in individual herds where animals from more than one herd were grazed together, or where two or three breed types were derived from the same herd. This suggests that herd and breed differences, as well as live weight trends, all contribute to empty rates.

Lower fertility is more commonly seen among multiparous cows rather than primiparous heifers (Macmillan *et al.*, 1996[a]). This difference may vary with the standard of heifer rearing as well as the level of milk production at peak lactation in the cows. For example, in the USA, American Holstein heifers are mated at an average body weight of 350 kg have pregnancy rates to first insemination (percentage of heifers pregnant to the first insemination/heifers inseminated) of over 70% (Smith *et al.*, 1984; Macmillan *et al.*, 1996[a]). Whereas, Friesian heifers reared in New Zealand are mated at about 250 kg have pregnancy rates, which are 10 to 15% lower (Macmillan *et al.*, 1990; Macmillan & Peterson 1993; Macmillan *et al.*, 1996[b]). On the other hand, pregnancy rates to first insemination for cows in New Zealand herds average 60 to 65 % (Macmillan and Day 1982), whereas average rates in American herds are 20% lower (Nebel *et al.*, 1993).

The lower pregnancy rate to first insemination recorded in heifers in New Zealand may reflect effects of under nutrition, especially during the first winter, when they are from 10 to 12 months of age. Well managed Friesian heifers reared solely on pasture can reach puberty before 12 months of age and average 350 kg at the breeding age of 15 months (Penno *et al.*, 1995; Macmillan *et al.*, 1996[b]). Some contemporary animals that had restricted feeding and only averaged 250 kg at 15 months had not reached puberty by this age. Calving patterns, showing a failure of heifers to calve as two year olds and extended calving to conception intervals in two year old lactating heifers and the low body weights of New Zealand heifers at mating and calving, suggest that under nutrition is delaying puberty and affecting the reproductive performance of heifers in some New Zealand herds (Macmillan *et al.*, 1990).

1.2.2 Effects of calving date on milk production

Dates of calving have important effects on farm productivity by determining the timing of the herd's milk supply and the large increase in the daily feed demands of the herd. Since most cows are dried off together on one date, differences between lactation lengths among cows in the same herd are generally produced by each cow's calving date (Macmillan, 1984). Hence, a cow which calves late compared to her herdmates, will have a shorter lactation and a lower total milk yield. These effects are more pronounced during a dry summer, when the whole herd is likely to be dried off early due to a feed shortage (Holmes *et al.*, 1985).

A series of trials carried out by Macmillan, (1984) comparing pairs in different groups of identical twins: one group with concentrated and the other with normal calving pattern (Trials 1-3), both groups with the same PS date. In contrast, in trial four, both groups had a concentrated pattern (35 days total spread), which differed by 30 days in their mean calving date (July vs August). As pointed out by García *et al.*, (1999) the very concentrated calving periods in trial four, avoided the confusion between calving date and calving pattern. It shows that earlier calved cows produced 22 kg of milk fat more than the later group, because of longer lactation length (37 days) (Table 1-3). While later calving cows produced higher yields in November, because they were better fed in early lactation, this extra milk was not enough to overcome the deficit in days at the start. Therefore, it would appear that a compact calving pattern is desirable. However, care must be taken to ensure that the concentrated calving spread and the increased feed demand does not cause a feed deficit and underfeeding in early lactation. Underfeeding in early lactation can cause the early calvers to have reduced daily milk yields and to produce less in total than cows which calved later, despite the early calving cows having longer lactations (Holmes, 1985). However, this resultant pasture deficit could be overcome by the feeding of supplements.

Table 1-3. Effects of calving pattern with the same PS date (Trials 1 to 3) or same calving pattern with varied PS date (trial 4) in groups of monozygous twins on production differences (Macmillan, 1984).

Trial Nº	Comparison (a) vs (b)	Mean calving date (days)	Lactation length (days) (y)	Production kg m.fat/cow (x)	Av. Peak production kg/cow/day	Ration x, y
1	C vs N	5	8	7	0.73	0.87
2	C vs N	12	12	12	0.85	1.00
3	C vs N	16	16	14	0.87	0.87
4	C July vs N Aug	37	37	22	0.84	0.60

C = concentrated calving pattern N = normal calving pattern

The relationships between calving date, the amount of feed on the farm, and the use of supplements are important. In a trial where no supplements were fed, so that the early calved cows were underfed in early lactation, Bryant (1982) found that later calving dates (14 August) resulted in slightly more milkfat yield per ha (+2.9%) than early calving dates (21 July), particularly at a high stocking rate (4.32 cows ha^{-1}). Similar results arise in a survey of 554 farms in the Waitoa region conducted by Paul (1982), who compared daily milkfat yield at peak of lactation with the total lactation yield for cows that calved between I July (early) and 20 August (late). Although no differences were found in the total milk fat production per cow, calving later was associated with higher daily milk fat yields at the peak of lactation, reflecting higher feeding levels in early lactation for the later calving cows.

If an adequate level of feeding (pasture or supplements) can be provided to the cows in early lactation, an additional advantage of a relatively earlier mean calving date is that the majority of the milk will be produced during spring and early summer (Garcia *et al.*, 1999). A factor, which is important in New Zealand areas where the variability between years of pasture production increases specially during summer and early autumn (Thomson, 1998).

1.2.3 Feeding and Reproduction

McKay (1997) found a tight calving pattern was the common component of successful farming systems and the problem of non-cycling cows was prevented by good management such as achievement of body condition score at calving close to or better than five, and well fed cows from calving through to mating. Undoubtedly, a successful mating program becomes the basis of the desirable calving pattern and the initial point should be to achieve high submission rates. Key factors to prevent low submission rates are (Burke, 1999):

- ❖ Minimize the number of cows with prolonged anoestrus periods.
- ❖ Decrease late calving cows (those calving within 40 days from planned start of mating).
- ❖ Increase heat detection procedures.

1.2.3.1 Prolonged post-calving anoestrus

Besides the physiological anoestrus, a problem arises when it is prolonged and extended. Anoestrus cows may be truly anovulatory (have not yet started ovulating after calving) or ovulating but not expressing a detectable oestrus (Burke, 1999).

Macmillan (1997), quantified the level of anoestrus in the High/Low stocked Friesian and Jersey trial (see Table 1-1). During this trial 28% of the first calving Friesians in the high stocked treatment herds had not been detected in oestrus by the start of mating. However, all the first calving Jersey heifers were cycling by the planned start of mating.

1.2.3.2 Late calving cows

Commonly the late calvers, aged cows, heifers, diseased or induced cows are included in this group. Both the proportion of a herd that is affected and the level of effect are important. For example, there is no point identifying a large group of inadequate cows as a cause of reproductive problems if the overall performance is above target for the group (Hayes, 1998). Therefore, it is important to focus on the large groups that have a major effect on performance, which are the first lactation cows and non-cycling cows.

To achieve a 21 day submission rate (the percentage of the herd mated in 3 weeks) of 94% in the milking herd, cows must have been calved at least 60 days before the start of mating (Hayes, 1997; Hayes 1998; Burke, 1999). This submission rate will drop to below 80% for cows calved only 40 days, and to 50% for cows calved only 20 days. A late calving is a consequence of a late conception date during the previous mating, most likely because the cow was not submitted for insemination early during the AB period (Hayes, 1997). Unfortunately many of these cows are not induced early enough, because the decision to induce is made after cows are identified as late calving cows during the calving period (Hayes, 1998). Despite this, any improvement in the number of days from calving to mating should have some beneficial effects, but direct effects of the induction process further complicate this. For example, induced cows had a reduced chance of conception to first service and for the entire mating program when compared to non-induced contemporaries that calved at the same time (Table 1-4). Induction of calving has also been shown to have a direct negative effect on milk production (Figure 1-3). Induced calving will have benefits, provided that the herd's calving pattern is sufficiently modified to balance the negative effects of the induction process. Late inductions may not adequately achieve this objective (Hayes, 1998).

Table 1-4. Reproductive performance for induced and normally calved contemporaries (Hayes 1996; cited by Hayes 1998).

	Induced calving	Normal calving	Probability
21 day submission rate (%)	87.5 ± 1.7	89.0 ± 1.6	NS
Conception to first service (%)	54.4 ± 3.3.	59.5 ± 3.3	P = 0.03
Pregnancy rate (%)	91.4 ± 2.1	93.6 ± 1.7	P < 0.0001

1.2.3.3 Poor oestrus detection efficiency

Daily submission rates of 4-5% of the herd are required to achieve a submission rate of 94% to AB at 21 days after the planned start of mating (Table 1-5) (Hayes, 1998). High submission rates to AB requires cycling cows that are expressing oestrus and skilled oestrus detection procedures, while treating anoestrus cows early will enhance the 21-day submission rate (Burke, 1999).

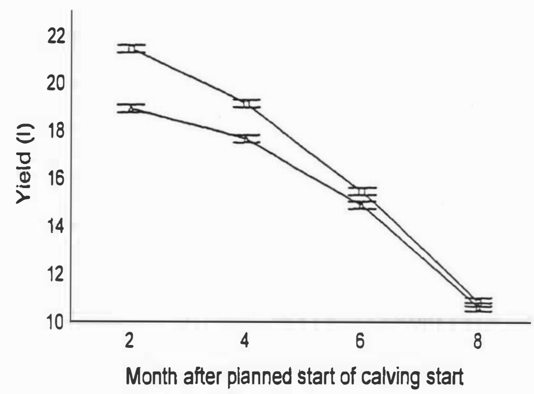

Figure 1-3. Mean daily milk yield (liters) for cows induced to calve (Δ) and cows that calved normally (□) (Hayes, 1998).

The proportion of normal length return intervals (18-24 d) to double length return intervals (39-45 d) can be a useful indicator of oestrus detection efficiency or heat detection rate (HDR) (Hayes, 1998). For example, National HDR is 92% while the target requires an HDR of 96%. HDR can be calculated by:

$$\text{HDR} = \frac{(\%\text{normal returns} - \%\text{double returns})}{\%\text{normal returns} \times 100}$$

Table 1-5. Calving and mating performance during 1995 from records on the LIC national and DairyMAN database (Extracted from: Hayes, 1997; Burke, 1999).

Parameter (%)	National database	DairyMAN	Targets
Calving			
Induced calving	5.9	7.8	0
28 d calving rate	60.8	68.4	75
56 d calving rate	88.9	93.7	97
Calved <40 d before PSM	17.8	11.3	8
Mean days PSC to actual calving	31.8	26.8	-
Mating			
21 d submission rate	76.3	86.0	94
28 d submission rate	81.6	91.3	100
Short cycles 2-17 d	18.7	13.2	<5
Normal cycles 18-24 d	61.0	63.6	>80
Double cycles 39-45 d	4.8	5.8	<3
Non-return (49 d, 1st service)	69.4	64.5	71
28 d pregnancy rate	60.9	63.5	79
56 d pregnancy rate	81.8	85.0	96
Empty rate	9.3	7.1	3

1.3 Seasonal Mating and Calving

As mentioned before, the major factor influencing a herd's calving pattern is the preceding season's conception pattern. This in turn must be based on the date for the start of the artificial breeding program (SAB), the average interval from SAB to first insemination and the percentage weekly distribution of these first inseminations.

Since the length of the cow's oestrous cycle is 21 days, the percentage inseminated in the first 3 weeks of the breeding program is an important indicator of breeding management. It is defined as herd's submission rate (SR) (Macmillan, 1998). Since insemination precedes conception and the latter outcome cannot even be estimated for at least 3 weeks after insemination, a herd's conception pattern is obtained too late for any effective corrective measures to be applied. Then the importance of management emphasis in the breeding program of seasonal dairy herds must be on achieving a high 3 weeks SR.

The pattern of submissions is a function of the reproductive cycle of individual cows within a herd and the management strategies at the start of mating. Submission rates during the first 3 weeks of mating are not the same for each week (Figure 1-4) (Hayes, 1998). There are significantly more cows mated on day 1 because this includes cows in oestrus during the previous day (or even longer if tail paint is the only indicator of oestrus). Cows with an oestrous interval of greater than 21 days may not be submitted until the fourth week of mating.

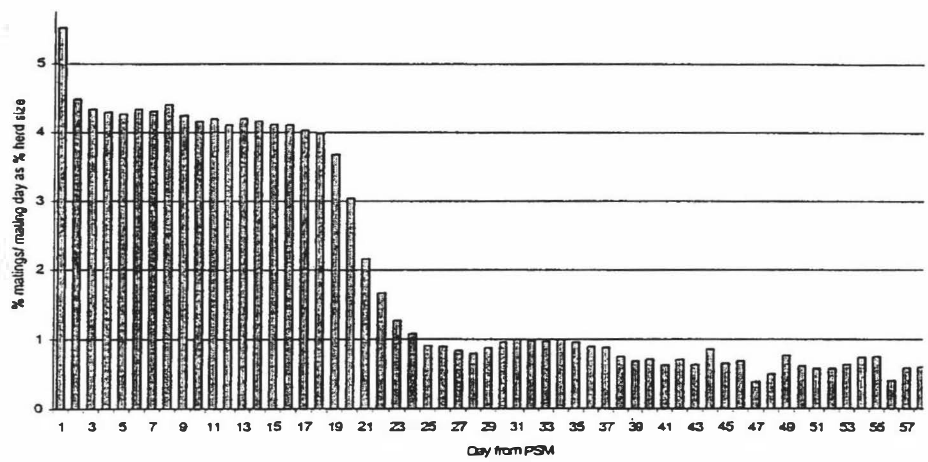

Figure 1-4. Submission rates for New Zealand dairy herds (97/98 season) LIC (Hayes, 1998).

Conversely, some cows having their first cycle just before the start of mating will have a short return interval and will therefore be mated in the 10 days (Hayes, 1998). Also the small peak between day 29 and 37 of mating that is probably due to the use of controlled intravaginal drug release (CIDR™) device (Macmillan and Peterson, 1993) for progesterone delivery at the end of the first round of artificial breeding (AB) (McDonald *et al.*, 1998).

Therefore, failure to detect oestrus has been identified as the major factor causing delays in the intervals from calving to first service and to conception (Lamming *et al.*, 1998). Experiments in which groups of cattle have been observed continuously have shown that most show behavioral oestrus. This suggests that the problem is mainly one of management, with the tendency of cows to come into oestrus most often during the night.

Leaving non-cycling cows untreated resulted in a 21 day submission rate of only 65% and a 21 day in-calf rate of 36%. Treating with CIDR's increased the submission rate to 94% and the 21 day in-calf rate to 53%. Milking once a day gave similar results to leaving the non-cycling cows untreated (Penno, 1998).

Non-cycling cows must be accurately identified at least one week before mating. Cows should be tail-painted 4-5 weeks before the planned start of mating then checked one week before the planned start of mating (Macmillan 1979; Penno, 1998). Cows with undisturbed paint should be put up for veterinary inspection and given a CIDR treatment for anoestrus. Natural mating should continue for 12-15 weeks after the planned start of mating to minimize empty rates and provide the option of induction of particularly valuable late calving cows. Tail-paint should be used at all times as a cheap and .effective aid to heat detection. Grazing management must ensure the herd is well fed by the planned start of mating.

Mean while, conception rates in New Zealand dairy farms have being reported to be about 60%, with some farmers achieving up to 75% (Xu *et al.*, 1995). Conception rate is an indicator that summarizes the overall reproductive performance of the herd and that is influenced by physiological processes (Macmillan *et al.*, 1996[b]):

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

1.3.1 Importance of drying-off dates and body condition score

The known facts are that cows when dry require less feed than when milking, the amount of feed required to achieve gain in condition is higher than that required to maintain condition and, at a given level of feeding, liveweight gain will be higher for dry than for milking cows (Bryant, 1982). Any change in drying-off date can have major effects on a herd's feed requirements for any particular date in spring or autumn in addition to the effect of the herd's stocking rate. If a herd is dried off too late, the body condition of the cows and the amount of pasture on the farm are both likely to have decreased excessively. Thus, although the prolonged lactation will have resulted in an increased milk production in the current season (Holmes & Macmillan, 1982). It may also have resulted in reduced body condition and pasture cover at the end of lactation, which will penalize production in the next lactation.

When a decision about calving date or drying off date is being made, the two factors, which must be considered, are: the daily feed requirements of the herd and the daily pasture growth rate. For instance calving date for a particular season is decided in the spring of the previous year, whereas the drying off date can be decided at any time during lactation (Macmillan, 1985[a]; Macmillan, 1985[b]). For example, for cows fed on restricted amounts of pasture during three weeks in late lactation, these cows ate 7.5 kg DM/day, produced 0.35 kg MF/day and lost 0.36 kg body weight/day. Thus during this time they would have eaten 158 kg DM, produced 7.4 kg MF/day and lost 7.6 kg of live weight. However, if they had been dried off at the beginning of this three-week period, they could have been fed at a lower level and yet not lost weight. They could therefore have produced no MF, lost no weight and consumed only 120 kg DM (Holmes & Macmillan, 1982; Macmillan, 1985[a]).

Important management decisions must be made in autumn in order to achieve target BCS at calving. In terms of energetic, the main factors are body condition, feed on hand and feed to be grown or supplied as supplements over winter. Along with production levels, the balance of these factors will determine the drying off date for individuals (Macdonald, 1997).

Macdonald, (1997) pointed out the tough decision of drying-off dates, either to carry on milking to make money now, or to dry-off now to set up for a better start to next season. One alternative might be to add more feed into the system to sustain longer lactations without compromising target CS at calving. As a rule, cows can add 0.5 CS units per month over the dry period if adequately fed. When using BCS as the criteria for drying off, the following calculation is applied to determine how long the dry period should be in order to calve at BCS 5 or more (Macdonald, 1997):

$$\text{Required dry period (months)} = \frac{\text{(BCS at calving} \quad - \quad \text{BCS at drying off)}}{\text{0.5 CS units gain per month}}$$

Is widely recognized that BCS has significant effect on both early lactation milk yields and time from calving to first cycle (McGrath, 1999). Bryant (1980), showed that cows which were dried off five weeks early produced 10 kg less milk fat; gained 26 kg more live weight and grazed less intensely than cows dried off later. The immediate decrease in milk production must be weighed against the probable future advantages due to savings in live weight and feed. For example heifers dried off four weeks early produced 320 kg milk less in their first lactation, but 270 l milk more in their second lactation than heifers dried off four weeks later (Gordon, 1993; Holmes 1987).

Also, the relationship between body condition score at calving and per cow performance has been clearly established. Where cows are well fed after calving, production per cow in the first 20 weeks of lactation increases by about 8.5 kg milkfat for each unit increase in condition score over the range from 3 to 6. If cows are underfed in early lactation the response drops to about 6.5 kg milkfat/cow (Grainger *et al.*, 1982; Deane, 1993). Data comparing the performance of cows in condition score 4 versus condition score 5 at calving is shown in Table 1-6.

Table 1-6. The effect of condition score at calving on per cow performance (Extracted from Holmes and Wilson, 1987; Deane, 1993).

			Condition score at calving		Difference score
			5	4	5 v 4
Milkfat production (kg/cow):					
	weeks	0 to 5	28.7	25.2	3.5
		6 to 20	79.9	74.9	5.0
		0 to 20	108.6	100.1	8.5
Condition score:					
	weeks	0	5.0	4.0	1.0
		5	4.8	4.2	1.0
		20	4.9	4.7	0.2

The cows in condition score 5 at calving lost condition in early lactation as they mobilized body fat for milk production. The cows in condition score 4 did not have this body fat and in early lactation, partitioning some energy away from milk production into liveweight gain (Deane, 1993).

Table 1-7 describes how this decision rule at the DRC Nº 2 Dairy Farm sets minimum BCS for drying-off. Also, other criteria considered for drying off decisions are daily milk yield and days to next calving. Cows producing less than five litres for two consecutive weeks are dried off to maintain milk quality and udder health. Cows who maintain sufficient body condition will be milked until 50 days prior to their due calving date (McGrath, 1999).

Table 1-7. Minimum drying off condition score for individual cows (Macdonald *et al.*, 1997).

	Minimum condition score	
Dry off time	Cows	Heifers
Early March	2.5	3.0
Start April	3.5	4.0
End April	4.0	4.5
Mid May	All	All

1.3.2 Post-calving strategies for reducing anoestrus

There are no unique recipes for achieving the systems targets. However, one study involving small numbers of Friesian cows found that feeding 1.4 kg/cow/day of concentrates during the three weeks before mating improved conception rates without affecting submission rates, but the effect of concentrates on resumption of oestrus cycling was not reported (Wilson *et al*, 1989; Burke, 1999). When pasture fed cows were supplemented with 5 kg/cow/day of pasture silage during the first month of lactation, feed intake and milk yields were increased and body tissue loss was reduced, but reproductive performance not improved. Correctly managing feed supply in early lactation is extremely important to subsequent reproductive season. A guideline plan is shown in Table 1-8, it reflects best practice breeding management under present conditions in New Zealand. However, it may need to be modified to meet individual farm targets.

Table 1-8. Guideline plan, which reflects best practice management (Burke, 1999).

Checklist	Days to PSM	Notes
Calving starts (heifers)	-89	Calve heifers in BCS 5.5
Calving starts (cows)	-82	Calve cows in BCS 5
Start recording pre-mating heats	-35	Apply tail paint and refresh regularly. Change tail paint color as cows comes into oestrus.
Treat non-cycling cows (early treatment option)	-7	Vets check non-cycling cows that have been calved 28 days or more. CIDR treatment for those without a palpable CL.
	-1	Remove DICRs, apply fresh tail paint
Planned start of mating (PSM)	0	Inject non-cyclers with 1 mg ODB
	1	Inseminate cows in heat
Follow up check (late treatment option)	22	Vets check cows, which have not yet been IA, especially late calvers.
Pregnancy diagnosis	63	Identify cows pregnant to first 28 days of mating.
Final pregnancy diagnosis	140	From 35 days after removal of bulls. Evaluate management options of empty cows
Drying-off		Cow condition, feed budget
Winter management		Cow condition, mineral status

The most effective oestrus detection procedure is to observe cows standing while being mounted from the rear by one or more herdmates. The herd should be checked at least three times daily while they are in the paddock and able to express normal behavior. Also important is using aids to detect oestrus likely oestrus markers applied to the base of the tail to provide physical evidence that a cow has been ridden by herdmates. The most used technique is the tail painting (Macmillan *et al.*, 1980; Burke, 1999; Burton *et al.*, 1999).

1.4 Grazing management

A grazing management system is defined as an integrated combination of animal, plant, soil and other environmental components, and the grazing methods by which the system is managed to achieve specific results or goals of a producer (Clark and Kanneganti, 1998). Dairy cattle performance under grazing is positively related to consumption of high quality forage. The essential points to achieve a highly productive and efficient system are: provision of an appropriate amount of quality feed (as pasture and supplements), to meet most of the animal requirements and achieve high feed utilization and conversion efficiency through high genetic merit cows with an adequate stocking rate and calving pattern (Bryant, 1984).

High breeding worth (BW[1]) cows will be able to convert feed more efficiently into milk with the same digestive and energetic efficiency, partitioning more energy towards milk and less into body fat (Penno and Kolver, 2000). Therefore, increasing the consumption of high quality forage is critical for profitable dairy production because grazed forage is the cheapest source of nutrients. However, very large and high producing dairy cows fed forages alone probably will not reach their genetic potential for milk production, because of lower energetic content in forages and lower intake from grazed forage (Kolver. 1998). This suggests that partial substitution of grazed forage with supplementation should be needed for high genetic merit cows in order to meet their high producing yields (Clark and Kanneganti, 1998). Unfortunately, the cost of concentrate supplements are high relative to milk prices in New Zealand.

[1] BW: economic index to evaluate the animals' genetic value. It consider traits such as: milk fat, protein, milk yield, live weight, survival (LIC, 2000)

Grazing management should be seen as one part of the system's management and it can be simply summarized as "where and when to move the grazing animals" (Sheath *et al.*, 1996). However, changes in grazing management can influence the condition and performance of the animal, plant and physical resources of the system. Therefore, the most obvious effect of grazing management is on the nutrition and subsequent performance of grazing animals (Smetham, 1994).

Because of the interrelationship between stocking rate and individual animal performance, it is important that high system efficiency is not over-emphasized when product quality is important or where year to year variation in forage supply is considerable (Sheath *et al.*, 1996). Flexibility in stock policy and feed demand can be achieved by adjustments to the commencement and duration of lactation of breeding animals. Appropriate stock policies that better align feed demand with forage supply are the hallmark of profitable animal production in low input systems (Bryant and MacDonald, 1987).

1.4.1 Pasture supply management

Grazing management should aim to keep pasture cover in the optimum range for net pasture production. This range is between 2000 to 3000 kg DM/ha for rotationally grazed dairy pastures in New Zealand. However, Matthews (1994) indicated that in ryegrass/white clover dairy pastures this range is between 1200-1400 kg DM/ha as post-grazing and 2500-3000 kg DM/ha as pre-grazing. As pasture approaches the lower end of this optimum, pasture quality is likely to increase but continued severe grazing will push pasture into a zone of lower productivity due to reduced growth rate because of insufficient leaf area and photosynthesis (Clark and Kanneganti, 1998). On the other hand, at the upper limit, pasture productivity can be high but will be restricted due to increasing rates of senescence and decay, and quality will be also decreased. Between these two positions, net pasture production is relatively insensitive to changes in herbage mass or management. Matthews (1994), also pointed out that the potential range over which residual pasture yield can fluctuate without restricting net herbage production or cow performance is probably only 400 kg DM/ha. Between 1700-2100 kg DM/ha in the winter and early spring and 2000-2400 kg DM/ha in late spring-summer period.

In New Zealand where little supplementation occurs, one of the main premises in a seasonal dairy system based on pastures is to have an average pasture cover of 2000-2400 kg DM/ha at calving to ensure an adequate level of feeding in early lactation when feed demand by the herd is very high. This period normally occurs in late winter (Clark *et al.*, 1998; Sheath *et al.*, 1996). The recommendation of Clark and Kanneganti (1998) is to have at least 1400 kg DM/ha average post-grazing residual on farm when pasture surpluses begin to accumulate. The presence of higher amounts imply that a higher stocking rate could have been carried and will make the late spring control of pasture more difficult if conservation is not practiced. On the other hand, lower amounts would mean cow and pasture performance in the first two months of lactation would have been compromised to such an extend that production would not recover during the current lactation. It also means that cow condition will have fallen and that anoestrus may be a problem. To achieve those targets required informed decisions on drying-off date, culling proportion, purchase of supplementary feed, grazing-off and nitrogen fertilizer use (Sheath *et al.*, 1996).

Clark and Kanneganti (1998) pointed out that, from the time when pasture surpluses begin to accumulate until mid-summer the primary aim of grazing management should be to increase intake per cow.

1.4.1.1 Supplementary feeds and the substitution rate

It is obvious from the preceding discussion that supplements of feeds can have important effects in pastoral systems. An important issue is the substitution rate, which refers specifically to the reduction in pasture intake (kg DM/cow/day) that occurs for each kg DM of supplements consumed (Kellaway *et al.*, 1993). Most estimates of substitution assess it relative to unsupplemented pasture intake. Substitution should be calculated as the change in pasture intake for each additional increment in supplement feeding. High substitution can reduce the response for extra feed and profitability because pasture is the cheapest source of nutrients, and is not used effectively.

The substitution rate is generally very low (0 to 0.2) for cows at very low level of feeding, but is high for cows at higher levels (0.4 to 0.8) and can reach 1 at very generous levels of feeding (Grainger *et al.*, 1989), when the cow's total feed intake capacity is saturated (Figure 1-5).

The substitution rate is roughly proportional to the ratio of the level of feeding to her maximum potential level of intake (Table 1-9) (Grainger *et al.*, 1989).

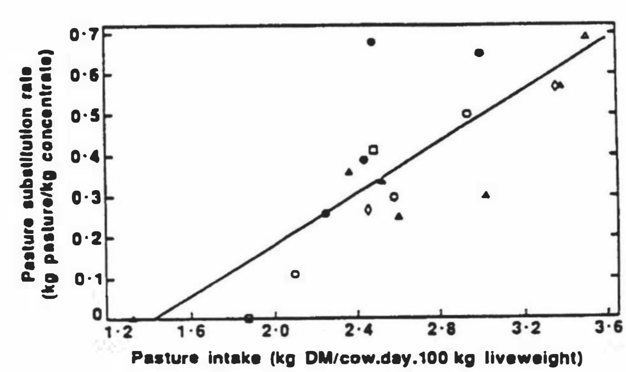

Figure 1-5. Demonstration of substitution rate for grazing cows at different levels of pasture intake (Grainger *et al.*, 1989).

Table 1-9. Estimated values for substitution rate, for cows at different relative levels of feeding (Extracted from Grainger *et al.*, 1989).

Actual level of feeding (without supplement) / maximum potential level of feed intake	Expected substitution rate (decrease in pasture intake (kg DM) per kg DM supplement eaten)
Below 0.4	0
0.5	0.2
0.7	0.5
0.9	0.8
1 (ad libitum)	1

In Figure 1-5, intake has been expressed as total metabolizable energy consumption calculated as a percentage of live weight, before additional supplements have been provided. The main point to note is that the correlation between substitution and intake are not very strong, which is attributed to the consumption of those supplements (Meijs, 1986). It is obvious there are many factors, other than intake, that are likely to have some impact. It is appropriate, therefore, to consider the various factors that might influence the levels of substitution recorded under various circumstances in some detail. For instance, the value of the substitution rate can also be affected by the composition of the feeds, in particular by the composition of the supplement given. For example, for grazing cows, the SR were: 0.45 for high starch concentrates and 0.21 for high fibre concentrates (Meijs, 1986). However, in well balanced pastoral systems, substitution is used deliberately to substitute supplement instead of pasture in order to present a feed deficit and to maintain pasture cover and feeding levels.

1.4.1.2 Amount of pasture

Pasture allowance has a major influence on pasture intake, with the relationship generally being positive up to a daily pasture allowance of about 4 kg DM/100 kg of live weight. Much of this effect is due to the increase in the relative ease with which cows can harvest the herbage as the allowance increases. Pasture allowance has also been found to be one of the major factors influencing the level of substitution that occurs when supplements are fed. Not only does pasture intake increase as pasture allowance increases, the reduction in pasture intake due to supplementation also increases (Table 1-10) (Stockdale *et al.*, 1997).

This reduction in herbage intake resulting from supplementation is mainly manifested through a reduction in grazing time, with little effect on rate of biting or bite size. The range in reduced grazing time has been reported as three to more than 20 min/kg concentrate, depending on sward conditions (Sarker and Holmes 1974; Cowan *et al.*, 1977; Jennings and Holmes 1984). With forage supplements, similar effects on grazing time and levels of substitution were shown for hay, but with silage supplements, greater effects have been recorded.

Table 1-10. Effects of pasture allowance (kg DM/cow/day) on levels of substitution (kg DM reduction in pasture intake/kg DM of supplement eaten) for grazing cows (Stockdale *et al.*, 1997).

Pasture allowance	Pasture intake	Supplement intake	Level of substitution
16	10.9	0.1	-
16	9.3	4.0	0.41
29	14.9	0.1	-
29	11.7	4.1	0.80

1.4.1.3 Pasture mass

Leaver (1986) suggested that a reduction in herbage mass will lead to a reduced level of substitution of concentrates for herbage.

Similarly, the substitution of forages for herbage also depends on sward conditions. Phillips and Leaver (1985) reported levels of substitution of 1.29 kg herbage DM/kg silage DM at a herbage height of 9.6 cm in early summer, and of 0.68 kg herbage DM/kg silage DM at a herbage height of 7.2 cm in late summer. When Stockdale (1996) offered Friesian cows 20 kg DM/cow/day of white clover herbage, and supplemented this with maize silage, he found a clear, positive relationship between level of substitution and herbage mass over the range of about 3-7t DM/ha (Table 1-11 and Figure 1-6).

Table 1-11. Effects of pasture mass (t DM/ha) on levels of substitution (kg DM reduction in pasture intake/kg DM of supplement eaten) for grazing cows (Stockdale *et al.*, 1997).

Pasture mass	Pasture intake	Supplement intake	Level of substitution
3.8	13.2	0	-
3.8	11.6	3.9	0.41
5.0	13.6	0	-
5.0	10.8	3.9	0.72

It suggests that taller pastures are trampled and fouled to a greater degree than are short pastures, thereby rendering them less palatable. A primary aim of feeding supplements is to maintain pasture utilization, while maximizing total DM intake. Nevertheless, pasture utilization can be maintained by offering a reduced pasture allowance in combination with supplements. If this does not occur, supplements will become increasingly uneconomic as herbage mass increases. It is likely that the best use of supplements will occur when pastures are short.

1.4.2 Partitioning between milk yield and liveweight gain

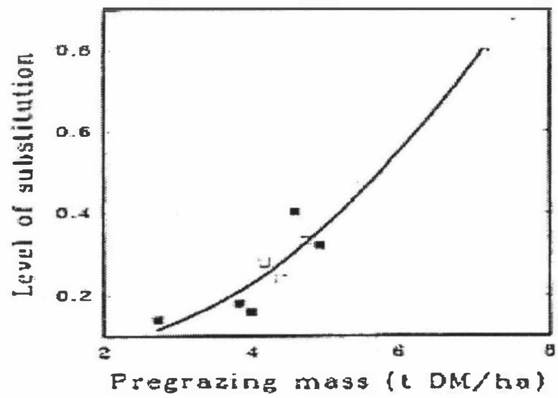

Figure 1-6. Relationship between level o substitution and pre-grazing herbage mas for cows offered 20 kg DM/c/d white clove and 3.4-5.0 kg DM/c/d of maize silag (Stockdale *et al.*, 1997).

Despite the substitution effect, extra feed eaten from another source generally causes an increase in the total quantify of nutrients and energy absorbed from the digestive tract. However not all the extra energy will then be absorbed by the udder and converted into milk, some will be used elsewhere for gain in body weight (assuming that maintenance and pregnancy costs have already been satisfied by the basic ration) (Kellaway *et al.*, 1993).

1.4.2.1 Body condition score (BCS)

Two aspects of BCS affect milk response. One is the cow's condition score at the start of supplementary feeding and the second is the way in which the supplement changes body condition over time. In addition, BCS affects the cows' fertility, as shown in an earlier section. The change in body condition over time interacts with stage of lactation to determine whether changes in partitioning allow extra body condition to be expressed as increased milk production (Kellaway *et al.*, 1993). Farmers need to know the optimal condition score at which to calve the animal and the best way of achieving this condition score.

Body condition score at calving for cows should be at least 5 while some advisors even suggest higher BCS. However it is not an overall average target, it is a target for each individual cow that is to be milked and bred in spring. Because achieving an average BCS of 5 is pointless if large proportions of the animals are below BCS 4.7 (Burke, 1999). First calving Friesians are especially susceptible to body condition at calving. For example, even those that calve in very good condition will take an average of 51 days to ovulate for the first time and 62 days to express oestrus for the first time (Burke *et al.*, 1995; Burke *et al.*, 1996; Burke, 1999). Each of these intervals can be extended by 24 days in those heifers calving below BCS 5, regardless of being offered generous pasture allowances during early lactation.

Cows in high condition at calving had lower DM intakes in early lactation. This was a linear relationship, resulting in a decrease in DM intake of 0.8 kg/day for each unit increase in condition score (Figure 1-7) (Garnsworthy, 1988).

Therefore if, the energy concentration in pastures are around 11.5 MJ ME/ kg DM, the optimal strategy is to calve animals in condition score 5 allow them to mobilize some body tissue to support milk production. But BCS at calving should not be more than 6, because DM intake is further depressed, reproductive performance is decreased and there is increased incidence of metabolic disease. While, below condition score 5, cows give lower milk production due to the partition of energy towards body condition (Kellaway *et al.*, 1993).

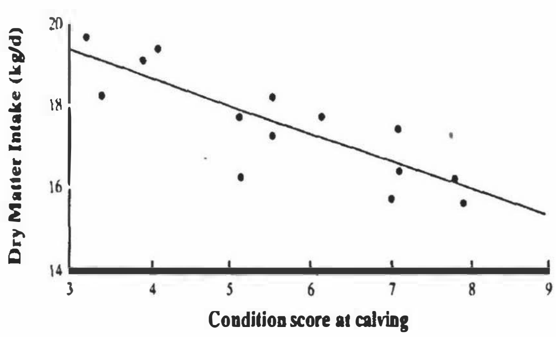

Figure 1-7. Effect of condition score at calving on dry matter intake during early lactation (Garnsworthy, 1988).

1.4.2.2 Stage of lactation

In general, large proportions of any extra energy (60 to 80%) will be partitioned to the udder if:

- ✓ The udder is initially producing at levels well below its maximum capacity; i.e. it has plenty of spare capacity to increase milk production.
- ✓ The cow is in relatively fat body condition; therefore the body tissues need for extra energy is low.
- ✓ The nutrient balance and rumen fermentation are appropriate (i.e. pH not too low; propionate not too high; adequate supply of metabolizable protein).

If supplementation is provided in early lactation improvements in body condition and residual pasture may allow increased responses during mid-lactation, due to preferential partitioning of energy towards milk production (Kellaway *et al*., 1993). Extra feeding in late lactation is more likely to result in improved body condition, which may then allow increased production and fertility in the following lactation, and supplementation may also result in an increase in lactation length.

However, in early lactation, the marginal response was greatest at low pasture allowances and feeding levels, while in late lactation, marginal responses were constant, regardless of pasture allowance (Penno *et al*., 1998).

Responses to protein supplements vary with stage of lactation. In early lactation, mobilized body tissue provides the cow with greater amounts of energy from fatty acids than protein, resulting in some protein deficiency. At the same time, potential milk production is greater than in later lactation. For these two reasons, milk responses to protein supplements are more likely in early lactation than in late lactation (Kellaway *et al.*, 1993). Although in New Zealand, pasture contains too much protein in spring (early lactation) and too little in summer (late lactation) therefore responses to protein are more likely in late lactation.

Penno *et al.*, (1998), suggest the magnitude of the milksolids response to additional feed is affected by the size of the feed deficit experienced by a cow. The more severe the level of underfeeding relative to her potential level of MS production the greater the immediate MS response to additional feed will be.

The marginal milk response to supplementation decreases as lactation progresses, because more feed energy is partitioned towards liveweight gain (Kellaway *et al.*, 1993). Grainger, (1990) show the response to extra pasture; effects of initial milk production capacity, level of feeding and stage of lactation:

Early lactation: Cows with high potential milk capacity, but on low level of feed (i.e. producing well below their capacity) show large marginal responses. For example, Figure 1-8 shows marginal responses of 60 to 80g extra milk solids (MS) per 1 Kg extra pasture DM in such early lactation cows, corresponding to approximately 60 to 80% of the extra energy partitioned to milk production.

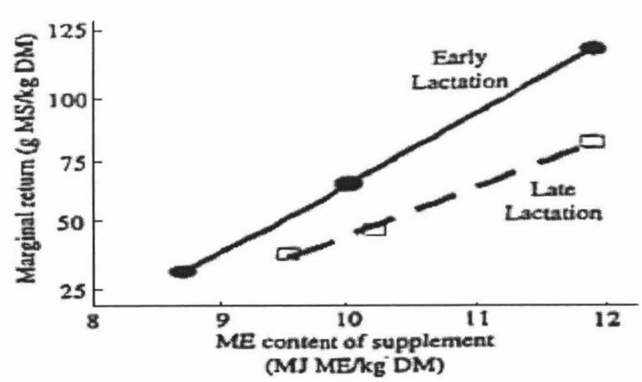

Figure 1-8. Immediate short-term responses to supplementary feeds by cows eating 7kg DM of cut pasture/day. Stockdale *et al.*, (1997).

Late lactation: At the other end of the scale, cows with low milk capacity, and on a high level of feeding, have little to no extra milk producing capacity, and therefore show very small marginal responses, (0 to 20g MS/kg DM) with very little of the extra energy partitioned towards milk (0 to 20%).

Penno, (2000) point out that as breeding worth (BW) increases, there is some evidence to indicate that cows' response to supplemental feed is higher during lactation. Studies of Ferris *et al.,* (1999) showed that for silage and concentrate diets, the milk production response was 48% higher for high genetic merit cows than medium genetic merit cows when concentrates were fed. New Zealand studies in the last ten years higher responses to extra feeds in mid to late lactation to supplementary feed, mean while 20 years ago milk responses to extra feed in late lactation were characteristically small (Macdonald, 1999).

1.5 Supplements

Responses to supplements involve two aspects that need to be considered:

Firstly, there is an immediate response (short term), which is seen as extra milk production per cow at the time of feeding the supplement (Stockdale *et al.,* 1990). This immediate response has varied widely, from 0 kg to 1.8 kg milk per additional kg of supplement eaten (Stockdale *et al.,* 1987). There are many factors that may influence the magnitude of responses of pasture-fed dairy cows to supplements (Stockdale, 1985; Faverdin *et al.,* 1991). These include quality of the pasture and supplement; the levels of feeding of pasture and supplement; the extent to which supplements substitute for pasture when they are added to the diet; stage of lactation; the associative effects between pastures and supplements in terms of digestion of energy-yielding substrates and essential nutrients; and the length of time for which supplements are fed.

Secondly, responses to better feeding not only occur during the period of supplementation, but also may continue for some time after its cessation (long term); this is generally due to the improvement in body condition, which increases during the period of additional feeding. This is referred to as the carryover or residual effect. Black, (1990) found that, for low levels of feeding, the linear regression coefficient of total residual effect on total immediate effect of feeding a supplement was +0.55 (s.e. ± 0.113). For high levels of feeding, the linear regression coefficient was +0.04 (s.e. ± 0.590), indicating that there were no residual effects to feeding supplements.

The use of supplements, in cases where their main effect is to extend the lactation length, supplements have been shown to produce large responses when fed in late rather than early lactation (Clark, 1993; Penno *et al.*, 1995b; Pinares & Holmes, 1996). In theory, supplements response is expected to be higher in early rather than in late lactation, for two reasons. First the ability of a cow to partition nutrients towards the mammary gland is at its maximum during early lactation and second the main effect of supplements when they are fed with restricted pasture allowances is to increase the total DM intake, because the substitution rate (kg pasture DM not eaten per kg of extra supplement DM eaten) usually varies between 0.24 and 0.45 kg (Garcia *et al.*, 1999).

In order to obtain better responses to supplement, high quality supplements must be used in very early calved cows (Garcia *et al.*, 1999), then a double beneficial effect could be obtained. First, a higher immediate response in terms of kg of milk per kg of supplement DM would be expected, and second, lactation length could be extended with less difficulty by calving the cows earlier. In that way, more milk could be produced before pasture quality and availability declines in summer (Garcia *et al.*, 1999). A third response might be an improved fertility.

1.6 Genetic merit and milk production

The genetic correlations between body size and milk yield range from slightly positive values 0.32 (Van der Waaij *et al.*, 1997), 0.18 (Jensen *et al.*, 1995), 0.39 (Ahlborn and Dempfle, 1992), 0.63 (Svendsen *et al.*, 1994) to slightly negative values –0.1 (Veerkamp *et al.*, 1995), -0.01 (Hietanen *et al.*, 1995; Lee *et al.*, 1992), -0.31 (Persaud *et al.*, 1991). Several authors suggests that the genetic correlation between these two traits changes during the lactation period, being positive in early lactation 0.04 (Van Arendonk *et al.*, 1991); 0.29 (Van Elzakker *et al.*, 1993); 0.7 (Svendsen *et al.*, 1994) and negative in mid lactation –0.33 (Perseud *et al.*, 1991); -0.25 (Van Elzakker *et al.*, 1993). As expected, it shows that heavier cows produce more milk in early lactation but after the peak heavier cows produce less milk.

Ahlborn *et al.*, (1992) and Van der Waaij *et al.*, (1997) reported high genetic correlations between the two variables under grazing conditions. Svendsen *et al.*, (1994), found that the genetic correlations between body weight and fat corrected milk yield were significantly higher in cows fed with pasture diets (0.3 to 0.7) than cows fed with high concentrate diets (-0.24 to 0.13). These results suggested that the variability in the genes must be affecting either milk yield or body size (Ahlborn *et al.*, 1992), indicating that selecting cows in favour of the milk yield will result in larger cows with increased growth and higher maintenance costs. Nevertheless, they also suggest 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. These statements and the reported negative economic values for body weight (Dempfle, 1986; Van Raden, 1988) were the main reasons for inclusion of body size with a negative weight in the selection index of the new animal evaluation system proposed by Livestock Improvement Corporation (1996), which would cause the average live weight of the New Zealand dairy cow to decrease by 3 to 4 kg of live weight after 20 years of selection (Spelman and Garrick, 1997).

Kolver, (2000) and Penno *et al.*, (2000) in a multi-year experiment comparing New Zealand (NZ) and Overseas (OS) Holstein-Friesian (HF) genetics under a seasonal grazing system have discovered key differences in production, reproduction and survival between the two genetic strains grazing pasture alone or fed a total mixed ration (TMR) (Table 1-12). Compared with the NZ HF, the OS HF: had shorter lactations (except when fed TMR), produced more milk and produced slightly more milksolids on the TMR, but slightly less milksolids on pasture (Penno *et al.*, 2000). Whilst, in the first season, OS HF had gained 56 kg of live weight when fed TMR but on grass had lost 77 kg, while the NZ HF grazing on pasture had lost only 5 kg of live weight and gained 61 kg on TMR during lactation.

The results indicate that NZ HF cows have the potential for high milksolids production and growth when fed well and that they can be very productive when managed on a sole diet of grazed pasture (Kolver, 2000). They also suggest that the current high use of OS HF genetics in New Zealand will require improved levels of feeding to ensure cows reach target body condition scores at calving and get in calf.

Table 1-12. Comparative performance of NZ HF and OS HF grazing pasture at low stocking rate (2.2 cows/ha) or fed TMR *ad-libitum* during 1998/1999 and 1999/2000 periods. (Extracted from Penno *et al.*, 2000; Kolver, 2000)

		NZ HF		OS HF	
		Grass	TMR	Grass	TMR
Days in milk	1998/1999	261	268	242	261
	1999/2000	255	227	250	236
Milk kg/cow	1998/1999	3317	5036	3597	5898
	1999/2000	3964	5783	3990	6746
Milksolids kg/cow	1998/1999	281	380	271	401
	1999/2000	340	467	307	472
Changes in live weight kg/cow	1998/1999	-5	61	-77	56
	1999/2000	25	69	2	94
Condition score	1998/1999	4.6	6.2	3.9	5.5
	1999/2000	4.8	6.7	3.7	5.8

1.6.1 Live weight a component of merit and efficiency

Comparing genetic correlations between body size and milk production efficiency, can be seem that although the range of values is large, however the tendency is for a negative correlation between size and feed conversion efficiency: -0.33 (Manson, Robertson and Gjelstad, 1957); -0.67 (Syrstad, 1966); -0.12 (Hooven, Miller and Plowman,, 1968); –0.93 (Van Arendonk *et al.*, 1991); -0.82 (Persaud *et al.*, 1991). Care must be taken because the variability of the values reported might probably respond to a particular feature of each trial (Morris and Wilton, 1976). However, Persaud *et al.*, (1991) suggested that including LW in the selection criteria was likely to increase the accuracy of selection for efficiency up to 90% compared to 60% with selection based on yield alone.

Many theoretical studies (Holmes, 1973; Taylor 1973) confirmed the concept that large cows have higher energy maintenance requirements (AFRC, 1993; SCA, 1990; NRC, 1989) and are therefore likely to be less efficient, unless they produce more milk. Yerex, *et al.*, (1988) reported these effects of genetic differences in body size on milk production and feed conversion efficiency. However, after two generations of breeding selected for body size on a complete lactation basis, no differences were found in milk production, but the results showed that small cows were 2.3% more efficient than the large cows, where the two genetic lines of cows differed by 50.8 kg in LW. Holmes *et al.*, (1993), also confirmed that small cows had a higher feed conversion efficiency than heavy cows. The differences in efficiency between genetic lines seems 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).

Selecting for a lower live weight whilst simultaneously selecting for increased yield, or direct selection for gross efficiency, could increase the gap between the rate of progress in yield and the rate of progress in intake capacity, and hence an increase in the dependency on body tissue mobilization during early lactation (Brotherstone, 1994; Veerkamp, 1999). For these reasons, there is interest in including a combination of dry matter intake, live weight and condition score in the dairy cattle breeding goal and therefore genetic parameters for these traits are required.

Measurement of an individual cow's performance for live weight, feed intake capacity or condition score is not common practice for most breeding programs and therefore there is great interest in other traits which may help to predict these potential goal traits (Veerkamp, 1998). Linear type traits describe biological extremes for a large number of visual characteristics, are measured on a relatively large scale, international conversions are available and traits such as body depth, capacity and size are perceived to be important by breeders for many reasons. Therefore it seems appropriate to estimate genetic correlations between type traits and dry matter intake, condition score and live weight and then to evaluate the use of these traits as potential predictors in a selection index.

1.7 The general objective of the present studies

For cows from two genetic lines of HF cows, which have been selected for either heavy or light live weight, but are of similar high genetic merit for milk production, to measure:

- Their intake capacity
- Their reproductive performance

Because these characteristics can have important effects on efficiency of the cow and they may be affected by selection for live weight.

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CHAPTER II

FEED INTAKE CAPACITY IN HOLSTEIN-FRIESIAN COWS DIFFERING GENETICALLY FOR BODY WEIGHT FED TO APPETITE ON HAY OR GRAZED PASTURE

ABSTRACT

In both 1998 and 1999, 16 and 24 pregnant non-lactating high genetic merit Holstein-Friesian cows, which differed genetically in size and weight, were selected from the high (H) and low (L) breeding value for live weight (LW) herd at DCRU Massey University, with eight and 12 animals for each line in 1998 and 1999 respectively. These were fed to appetite on hay (7.52 MJ ME/kg DM in 1998) and on pasture (11.1 MJ MD/kg DM in 1999) in order to measure the maximum voluntary feed intake capacity. The difference between the strains in DMI per cow per day was highly significant ($P<0.01$) in both years. The heavy cows ate 12.52 kg DM of hay and 13.10 kg DM of pasture in 1998 and 1999 respectively, while the light cows consumed 11.11 kg DM of hay and 11.63 kg DM of pasture in 1998 and 1999 respectively. The regression coefficients generated show that for each 100 kg increase in LW, daily dry matter intake per cow increased by 1.43 and 1.81 respectively in 1998, and 1999, a positive correlation between DMI/cow/day and live weight. In the first year H cows ate 11.2% more hay DM than the L cows ($P<0.01$) and in the second year H cows ate 13.2% more pasture DM than L cows ($P<0.01$). Overall least squares means values for DMI/cow/day in 1998 and 1999 were 11.81 and 12.36 which indicates that cows in the first year ate 4.4% less hay DM/cow/day than cows on pasture in the second year. Similarly, the overall least squares means values for DMI/cow/day for H and L cows were 12.81 and 11.37, which indicates that H cows ate 11.2% more DM than L cows. The relation between metabolizable energy intake (MEI)/cow per day and LW was also significant ($P<0.01$) and ($P<0.05$) for both years 1998 and 1999 respectively. Least squares means (s.e.d.) for MEI by line as a treatment and after adjusted by parity number were 94.5 (2.5) and 144.7 (5.7) MJ ME/cow per day for the H cows, and 83.9 (2.3) and 128.4 (5.7) MJ ME/cow per day for the L cows, in experiment one and two respectively. Regression analysis of the data after conversion into $\log_{10}$, showed that DMI was proportional to $LW^{0.66}$ and $LW^{0.65}$ in 1998 and 1998 respectively. These results indicate that lighter cows are not disadvantaged relative to the heavier cows in their capacity to eat feed in excess of their maintenance requirement, which are generally assumed to increase in proportion to $LW^{0.75}$.

INTRODUCTION

Feed intake capacity

In the last decade breeders have had to rely on the correlated responses in feed efficiency when selection was based on milk yield (Persaud, *et al.*, 1991). It was believed that direct selection on efficiency was impractical due to the high cost of measuring feed intake capacity on an individual basis. The genetic aspects of feed intake capacity and efficiency have shown a moderate heritability 0.37 ± 0.11 and 0.13 ± 0.09 for both traits respectively (Persaud *et al.*, 1990). Genetic correlation between live weight and feed intake capacity is positive (Veerkamp *et al.,* 1997), with correlations of 0.34 and 0.45 reported respectively (Persaud *et al.*, 1990) also 0.46 and 0.28 respectively (Persaud, *et al.*, 1991).

Therefore it is important to consider simultaneously these two traits, live weight and feed intake capacity, in the breeding goal (Veerkamp, 1996). At the same time, it can be expected that intake capacity and body condition score are likely to become more important in the future, regardless of the feeding system (Veerkamp *et al.,* 1997). This is because selection for yield increases the gap between energy input and output during early lactation, because the correlated response in food intake, from selection on yield, can cover only 40 to 48% of the extra energy requirements (Arendonk *et al.*, 1991; Veerkamp, 1994) while most of the remaining energy requirements for yield has to come from body tissue mobilization especially in early lactation, because there is no evidence of a large proportion of genetic variation in partial efficiencies (Blake and Custodio, 1984; Veerkamp and Emmans, 1995).

Ruminants try to adjust their voluntary feed intake to be equal to their energy requirement (Baile and Forbes, 1974) and many reviews have analysed the factors affecting regulation of feed intake (Balch and Campling, 1969; Campling, 1975; Baumgardt, 1970). Meanwhile, some of the mechanisms of feed intake regulation have been described (Bines, 1971; Bines 1976; Journet and Remond, 1976).

There is considerable evidence to suggest that, where bulky forages are being fed, ruminants do not eat to their potential intake (Balch and Campling, 1969; Bines, 1971). The capacity of the reticulorumen and the rate of disappearance of digesta from it are the two principal factors controlling intake under these circumstances (Stakelum and Connolly, 1987). This is reflected in the relationship between voluntary intake and digestibility of various roughages. The point at which digestibility of roughages ceases to be important in the physical limitation of intakes, and metabolic factors assume greater importance, depends on the type of roughage.

Feed intake capacity and dry matter

Minson *et at* (1964) have shown a linear relationship between intake of dry matter from fresh herbage offered indoors to wethers and organic matter digestibility over a wide range of digestibilities (0.58-0.83). Osbourn, Thomson and Fleury (1966), Demarquilly and Jarrige (1971) and Jarrige, Demarquilly and Dulphy (1974) have concluded that intake and digestibility were linearly related up to levels in excess of 0.80 of organic matter digestibility where fresh herbage was fed to sheep. Intake of fresh herbage by stall-fed dry cows showed that intake and digestibility of energy was poorly related above 70% (Hutton, 1962) and in the range 70-80% (Stakelum and Connolly, 1987).

With lactating cows there was no relationship between the intake of fresh herbage indoors and energy digestibility in the range 65-77% (Hutton *et at,* 1964) and with dairy cattle in the range of organic matter digestibility of 65 to 83% Demarquilly, 1966). The situation with grazing dairy cows at pasture is less clear due to the influence of such factors as progressive fouling of pastures, daily herbage allowance levels and concentrate feeding. Greenhalgh and Runcie (1962) concluded that there was no obvious causative relationship between digestibility and intake of dairy cows using a range from 72 to 79% organic matter digestibility.

Two factors are normally considered to affect feed intake capacity, the potential intake by the animals and the relative intake offered by the pasture, in which potential is clearly proportional to the size of the animal therefore, nutrient demand and physical capacity are both related (Forbes, 1996). Within a species it is considered that there is a little justification for using an exponent of live weight other than 1.0. To allow for the fact that a fat animal has a lower potential intake than a thin animal of the same body weight, potential intake is predicted from the standard reference weight (SRW) of the animal (i.e. mature and in the middle of the condition score range) (Forbes, 1995). In contrast, the intake offered by the pasture is influenced by the chemical composition of sward and physical features which limit eating (Forbes, 1995).

The relation between basal metabolism and body weight of mature mammals of different species was studied by regressing the logarithm_{10} of metabolic rate against the logarithm_{10} of body weight, which demonstrated that the metabolic rate was proportional to the ¾ power function of body weight (Kleiber, 1965). A comparison of the intakes of good quality feeds by adults of species of different sizes shows that intake is proportional to metabolic body weight $W^{0.75}$

(Kleiber, 1965) and, as implied above, intake is controlled to meet the animal's requirements for basal metabolism unless physical constraints intervene in a particular way (Forbes 1996). The between species relationship of was calculated

$$I = 1.50 \cdot W^{0.75} \qquad (1)$$

(Kleiber, 1975), where I is the energy intake (MJ $kg^{-0.75}$ d^{-1}) and W is body weight (kg). This equation seems to be of such universality that many authors have expressed food intakes as a proportion of metabolic body weight in order to compare results from animals of different size (Forbes 1996). Maintenance costs also increases proportional to $LW^{0.75}$ approximately.

OBJECTIVE

The genetic relationships between milk production, live weight and feed intake capacity were discussed in Chapter 1. There is little real evidence about the effects of genetic differences in live weight on feed intake capacity.

The objective of this experiment were to measure the maximum voluntary feed intake capacity in Holstein-Friesian cows differing genetically for body weight fed to appetite under confinement and grazing conditions, and to determine the relationship between live weight and feed intake capacity.

MATERIALS AND METHODS

Animals

Cows from the herd of high genetic merit Holstein-Friesian cows at the Dairy Cattle Research Unit, Massey University, were used in both experiments during the winters of 1998 and 1999 respectively. This herd contains cows from two strains, which have been selected and mated since 1989 for either genetically high or low breeding value for live weight (García-Muñiz *et al.*, 1998). Full details of the herd and background are given by García-Muñiz, (1998).

The first experiment was carried out with 16 pregnant non-lactating cows, with half of the cows chosen from the heavy (H) strain and half chosen from the light (L) strain and balanced by age at the beginning of the experiment (Table 1-6). The experimental animals were housed indoors, in individual stalls in order to measure feed intake capacity when fed *ad-libitum* in confinement.

Sufficient time should be allowed for animals to become accustomed to new feed before voluntary intake is recorded. Adjustment to a stable intake may take 10 to 15 days if the feed is a major change from previous diets (Blaxter *et al.*, 1961; Chenost and Demarquilly, 1982). This evaluation period results in a measurement error of ± 2% (Blaxter *et al.*, 1961). Heaney and Pigden, (1972) reported that for ruminants at least ten days is the minimum required because of the slow rate of passage and adaptation of the rumen micro population. However, in the present experiment 13 days were allowed for standardization before the sampling period started and the trial lasted 19 days during the winter (June-July) of 1998.

In experiment two, 24 pregnant non-lactating cows were used, with half of the cows chosen from the H strain and half chosen from the L strain, and balanced by age at the beginning of the experiment (Table 2-1). The experimental cows were rotationally grazed as a single group and the length of the experiment was 16 days, which included the stabilization period and the sampling period. An additional 10 days was used, after the sampling period, to collect samples randomly every second day from a smaller number of cows, to determine the final end-point for the release of alkanes and hence the rate of alkane release from the capsules.

Table 2-1. Least squares means and s.e.d[1] for breeding worth (BW), breeding value (BV), Age, body condition score (BCS), live weight (LW) and days in pregnancy (DIPG) for the cows used in experiments one and two.

	1998				1999			
Parameters	Heavy	Light	s.e.d	Significance[3]	Heavy	Light	s.e.d	Significance[3]
n (cows)	8	8	-	-	12	12	-	-
BW	32.6	29.6	3.66	NS	40.2	34.5	4.96	NS
BV for LW	68.1	16.2	2.86	***	68.4	26	3.04	***
Age (years)	5.2	5.7	0.55	NS	4.7	4.7	0.34	NS
Actual BCS	4.5	4.4	0.1	NS	4.4	4.6	0.09	NS
Actual LW (kg)	540	467	12.1	***	528	453	10.7	***
DIPG	211	216	4.93	NS	209	205	5.25	NS

[1]s.e.d. : Standard error of the difference

[2]n : number of observations

[3]significance: NS not significant; † P<0.1; *P<0.05; **P<0.01; ***P<0.001

Feed and feeding

In experiment one, the animals were initially grazing perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) pastures, but during the adaptation period the amount of hay fed was progressively increased to avoid dramatic changes in the rumen fermentation. From 2nd of June the cows received about one third of their ration as hay and the amount of hay was increased until, from 12th of June to 4th of July, the cows were fed to appetite on hay only.

The level of feeding for each day was based on the previous two days intake. Generally, 100% plus *ad-libitum* feeding is practiced to make sure that intake is not limited (Burns *et al.*, 1994). Therefore, the amount offered was calculated to result in about 10% being left uneaten at the end of the 24 hours period, and the hay offered daily to each cow ranged between 13 to 24 kg DM/cow. The animals were fed two times per day in two equal feeds (0830 and 1530 hours) into individual bins. Daily feed intake was measured for each cow from 16th of June to 4th of July.

In experiment two, the cows were offered a generous daily herbage allowance of about 30 kg DM/cow as assessed by a rising plate meter (Ashgrove Pastoral Products, Palmerston North, New Zealand). The cows were grazing perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) pastures. The level of feeding was assessed indirectly by recording 40 pre-grazing and 40 post-grazing readings of compressed sward height with the rising plate meter on the area grazed every day, and the daily area allocated for grazing. Pre and post-grazing pasture masses (kg DM/ha) were estimated from the calibration equation (Earle and McGowan, 1979; Holmes, 1974; Stockdale, 1984):

$$\text{DM kg/ha} = (\text{mean compressed height} * 158) + 200 \quad (2)$$

Daily herbage allowance was calculated from the expression according to Milligan *et al.*, (1987) as:

$$\text{Herbage allowance (kg DM/cow/day)} = \frac{\text{Pre-grazing pasture mass (kg DM/ha) x Area grazed per 24 hours}}{\text{Number of cows}} \quad (3)$$

And apparent herbage intake was calculated as:

$$\text{Apparent herbage intake} = \frac{\text{(Pre-grazing mass – post-grazing mass)*Area grazed /24h}}{\text{Number of cows}} \quad (4)$$

Measurements recorded

Live weight and condition score

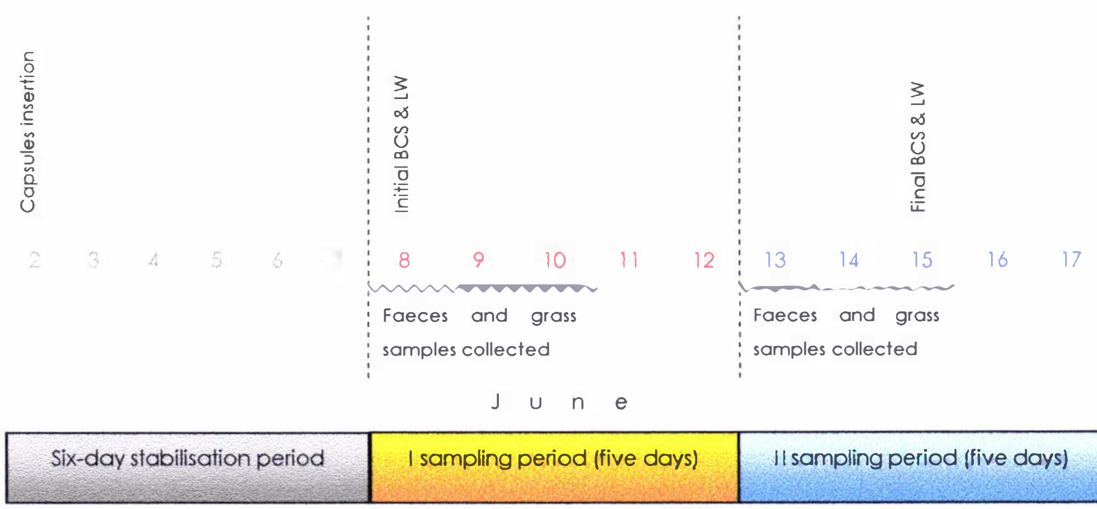
During experiment one, live weight and body condition score (BCS) were recorded at the beginning and at the end of the experiment, on 16th June and 4th July 1998 respectively by the same person, at 0800 hours. The cows did not have access to feed for 14 hours (overnight) prior to being weighed and condition scored, on a scale from 1 (very thin) to 10 (very fat) (Holmes and Wilson, 1987).

In the second experiment, the cows were weighed and body condition score was assessed at the beginning and at the end of the experiment, on 8th and 15th June 1999 respectively. In both experiments live weight was recorded using electronic scales (Tru test Ag 500, NZ Ltd).

Dry matter intake

In experiment one, the quantity of hay offered (kg DM/cow/day) was initially calculated assuming that each cow required for maintenance 0.8 MJ ME/kg $Lw^{0.75}$ and the energy content of the hay was about 7.52 MJ ME/kg DM. In order to ensure that an effective *ad-libitum* hay allowance was offered, the amount offered was increased by about 30% above the quantity estimated for maintenance. During the experiment, the daily hay allowance of each cow was adjusted to ensure that about 10% was left uneaten each day. Refused hay was collected and measured daily as kg of wet weight (including any saliva, spilled drinking water or faecal contamination) and then dried at 60 °C for 24 hours, and weighed DM content was calculated in order to calculate dry matter intake (DMI). DMI by each cow was measured directly, as the difference between the weights of hay DM offered each day and the weight of hay DM refused at the end of 24 hours. The digestibility of the hay offered was measured *in vitro*.

In experiment two, herbage intake of individual cows was assessed using the *n*-alkane technique (Dove and Mayes, 1991; Dove *et al.*, 1996). On 2nd of June 1999 controlled release alkane capsules (Captec (NZ) Ltd.) were administered into the rumen of each cow. The release rates, as given by the manufacturer, were approximately 400 mg of *n*-dotriacontane (C_{32}) and 400 mg of *n*-hexatriacontane (C_{36}) per day as the indigestible markers to assess individual cow herbage intake estimated from the concentrations of the alkanes in the faeces, and faecal output. Capsules were individually numbered using a sharp heated screwdriver and this number was recorded along with the cow's identification number at the time of the capsule insertion. A specific flexible capsule applicator was used to introduce the capsules via oesophagus, and generally the capsules were swallowed immediately. The cows were kept on concrete yards and observed for one hour after capsule administration to detect capsule regurgitation, but no capsules were found. After a six-day stabilization period in order to reach stable concentrations of *n-alkanes* in faeces, collection of faecal and grass samples started at 0600 hours, on at least three days during each of two consecutive five-day collection periods to allow for cows which might not provide a sample during the first three days. However, in this experiment both faecal and grass samples were collected only during the first three days of each sampling period, as indicated:



Faecal samples were collected into plastic containers (40 g approximately) on the paddock from each cow immediately after defecation and then frozen at –20 °C. Faeces were oven dried at 60 °C for 24 hours and pooled within 3-day sub-periods, for each of the two collection periods. At the same time as the faecal collection, grass samples were plucked manually. The grass samples were pooled within 3-day periods, sub-sampled and stored at –20 °C until freeze-dried. Both faecal and pasture dried samples were ground to 0.1 mm particles. The *n-alkane* concentration of the samples from the two periods were averaged and herbage intake was estimated from the concentration of C_{33} (natural odd-chain) and C_{32} (dosed even-chain) alkanes in the pasture and faeces respectively, using the following equation (Dove & Mayes, 1991):

$$\text{Daily dry matter intake (kg/cow)} = \frac{(Fi/Fj) \times Dj}{Hi - (Fi/Fj) \times Hj} \qquad (5)$$

Where,

Dj is the daily dose, or average release rate (mg/day) from the capsule, of the synthetic even-chain alkane (C_{32}).

Hj and *Fj* are respectively, the herbage and faecal concentrations (mg/kg DM) of the natural even-chain alkane (C_{32}).

Hi and *Fi* are respectively, the herbage and faecal concentrations (mg/kg DM) of the natural odd-chain alkane (C_{33}).

Digestibility of feeds

In experiment one, the hay samples were analysed *in vitro* in the Analytical Laboratory of the Institute of Food Nutrition and Human Health (Massey University) (Table 2-2) for nitrogen (N) content by the Kjeldahl technique and for dry matter (DM), organic matter digestibility (OMD), dry matter digestibility (DMD) and organic matter digestibility of the dry matter (DOMD) were analysed by the method of Roughan and Holland (1977).

In experiment two, herbage dry matter digestibility (DMD) was calculated *in vitro* from the pasture samples and faecal samples for individual cows, using the concentration of *n-alkanes* in the herbage and faeces respectively as shown below. The *n-alkanes* were analysed at Dairying Research Corporation Limited (Hamilton) using the analytical procedure described by Mayes *et al*., (1986). Herbage DMD for each cow was calculated from the ratio of herbage and faecal concentrations of the natural odd-chain alkane C_{33} using the equation (Robaina *et al.*, 1993):

$$\text{DMD (\%)} = 1 - \left[\frac{Hi \times \text{Recovery rate}}{Fi}\right] \tag{6}$$

Where the recovery rate was assumed to be 0.8715, the average of recovery obtained by Stakelum and Dillon (1990) 0.86 and Dillon and Stakelum (1989) 0.883 for C_{31} and C_{33} odd-chain alkane respectively. H*i* and F*i* were defined in the previous section.

Initially the M/D of the pasture was predicted using the generalised equation (7) (Geenty and Rattray, 1987). Therefore the metabolisable energy (ME) content of the pasture (MJ/kg DM) was estimated as:

$$\text{M/D} = 0.16 * \text{DOMD} \tag{7}$$

Nevertheless, NIR predicted *in vitro* results for pasture were used to calculate DOMD^1 according with the previous equation (7) as follows:

$$\text{DOMD}^1 = \frac{\text{M/D (MJ ME/kg DM)}}{0.16}$$

DMD and DMI were calculated using the alkanes concentrations according with equations (6) and (5) respectively. However DMD could be also predicted using the following equation (8) (Geenty and Rattray, 1987):

$$\text{DOMD} = ((0.98 * \text{DMD}) - 4.8) \tag{8}$$

Where, DOMD[1] was previously calculated from equation (7) then DMD was also calculated from the NIR analysis as:

$$DMD = \frac{DOMD^1 + 4.8}{0.98}$$

Finally, DMI can be calculated by following the equation (9) from Doves and Mayes, (1991):

$$DMI = \frac{\text{Faecal output (from alkanes)}}{1 - \text{Digestibility (from NIR analysis)}} \qquad (9)$$

Statistical analysis

In experiment one, a simple non-linear regression model was used to analyse the relation between DMI and LW (the dependent and independent variables respectively) using SAS™ program (1996) version 6.12. However, in this experiment the data were transformed before being statistically analysed as base 10 logarithms (Log_{10}). Log_{10} transformation was used in a simple linear regression analysis of DMI and LW. The equation for the simple linear regression model was:

$$Log_{10}\,DMI = \beta_0 + \beta_1 (log_{10}\,LW) + \varepsilon \qquad (10)$$

This model uses a straight line with slope β_1 and the intercept β_0 to represent the relationship between log_{10} DMI and log_{10} LW. The transformed data were also compared using the one way analysis of variance using PROC GLM to analyse the individual DMI. Least square means were calculated to identify differences between variables: live weight, liveweight change, condition score, condition score change, DMI kg/cow/day, DMI/kg $LW^{0.75}$, MEI MJ/cow/day, lactation and days in pregnancy were analysed with a model that included the main effects of experiment, and genetic line.

In experiment two, the above equation (10) was used for the simple linear regression model to analyse DMI and LW. A one way analysis of variance was used to analyse the individual DMI, the model included line as a treatment effect plus age and parity number as a covariates, cow was considered a random effect and differences between genetic lines were tested using the least squares means of cow nested within genetic group as the error term. Simple linear regression analysis was performed using DMI of each cow as the dependent variable and metabolic LW ($LW^{0.75}$) as the independent variable.

RESULTS

Feed variables

In experiment one and two, the cows were fed on hay and pasture respectively, as indicated by the *in vitro* digestibility analysis showed in Table 2-2.

Table 2-2. *In vitro* mean values for the digestibility of the hay and pasture used in experiment one and two respectively.

Parameter	Digestibility (%)	
	Hay	Pasture
Dry matter digestibility (DMD) (g/100g DM)	49.6	75.4[1]
Organic matter digestibility of the dry matter (DOMD) (g/100g DM)	47.0	69.1[2]
Organic matter digestibility (OMD) (g/100g DM)	51.1	80.6
Estimated metabolizable energy (ME) (MJ/kg DM)	7.52[1]	11.05

[1]DMD = Calculated using equation (8)

[2]DOMD = Calculated using NIR analysis and equation (7)

In experiment two, the digestibility of the DM in pasture was 75.4% (using equation (8)). DMD was also calculated from the alkane concentrations (using equation (6)). These values for DMD were 64.4% and 67.2% respectively for the L and H cows, which are much too low for leafy pasture in winter (Hodgson, 1990; Holmes *et al.,* 1987). Therefore, a pooled value for DMD was calculated from the NIR analysis of the pasture samples as explained in the methods section. Finally the common value for DMD was used, together with the individual values of faecal output for each cow (calculated from alkanes) to calculate dry matter intake by each cow.

Characteristics of the pasture used for the herbage intake measured with the plate meter are presented in Table 2-3. The daily herbage allowance, pre-grazing and post-grazing herbage masses are summarized for the period and together with daily DMI per cow for the group.

Table 2-3. Characteristics of the pasture used for herbage in experiment two.

Parameter	Average
Daily herbage allowance kg DM/Ha (period)	29.58[1]
Herbage mass:	
Pre-grazing/kg DM/Ha (period)	3227
Post-grazing/kg DM/Ha (period)	1734
Dry matter intake kg/cow/day (for the group)	11.16[2]

[1]Calculated using equation (3)
[2]Calculated using equation (4)

Metabolic live weight, liveweight change and dry matter intake

Sixteen pregnant non-lactating cows fed indoors on hay during the winter of 1998 and 24 pregnant non-lactating cows grazing on pasture during the winter of 1999, both years fed *ad-libitum*, were included for the analysis. The least squares means values of some variables used in the analysis carried out are listed in Table 2-4.

After adjusting for differences in age at the beginning of the experiment (see Table 2-1), the results indicate that H cows were on average 73 and 75 kg heavier than the L cows in 1998 and 1999 respectively. In addition, H cows in 1998 were on average 12 kg heavier than in 1999 similarly, and L cows in 1998 were 14 kg heavier than in 1999. Total mean values for live weight were 503 and 490 kg respectively for 1998 and 1999, possibly because cows used in 1998 were on average 0.7 years older than cows used in 1999. In the first year H cows had higher body condition score than the L cows, while in the second year L cows had higher condition score than the H cows.

The relation between metabolizable energy intake (MEI)/cow per day and LW was significant ($P<0.01$) and ($P<0.05$) for both years 1998 and 1999 respectively (Table 2-4). Least squares means (s.e.d.) for MEI by line as a treatment and after adjusted by parity number were 94.5 (2.5) and 144.7 (5.7) MJ ME/cow per day for the H cows, and 83.9 (2.3) and 128.4 (5.7) MJ ME/cow per day for the L cows, in experiment one and two respectively. However, expressed per $kg^{0.75}$ the differences, between the H and L cows, in MEI/$kg^{0.75}$ were not significant in either experiment one or two. Least squares means MJ ME/$kg^{0.75}$ (s.e.d.) for H cows were 0.83 (0.01) on hay and 1.31 (0.04) on pasture, and for L cows were 0.81 (0.01) on hay and 1.31 (0.04) on pasture.

The difference between the strains in DMI per cow per day was highly significant ($P<0.01$), after adjustment by parity number in both years 1998 and 1999 (Table 2-4). The H cows ate 12.52 kg DM of hay and 13.10 kg DM of pasture in 1998 and 1999 respectively, while the L cows consumed 11.11 kg DM of hay and 11.63 kg DM of pasture in 1998 and 1999 respectively.

Table 2-4. Least squares means and s.e.d[1] for BCS, LW, metabolic LW ($LW^{0.75}$), liveweight change (LWC), DMI, and DMI per $kg^{0.75}$ adjusted by lactation number for each genetic line recorded during experiments one and two in 1998 and 1999 respectively.

	1998					1999				
Parameters	H	s.e.d.	L	s.e.d.	Signific[3]	H	s.e.d.	L	s.e.d.	Signific[3]
n[2] (cows)	8	-	8	-	-	12	-	12	-	-
BCS	4.5	0.13	4.5	0.12	NS	4.5	0.11	4.6	0.1	NS
LW (kg)	546	9.83	482	9.23	***	540	10.8	464	10.2	***
$LW^{0.75}$	113	1.54	102	1.45	***	112	1.71	99	1.62	***
LWC (kg/day)	-0.01	0.018	-0.03	0.017	NS	0.81	0.13	0.65	0.13	NS
DMI (kg/cow/day)	12.52	0.33	11.11	0.31	**	13.10	0.51	11.63	0.50	**
DMI/$kg^{0.75}$	0.11	0.002	0.10	0.02	NS	0.118	0.004	0.118	0.004	NS
MEI/cow	94.5	2.5	83.9	2.3	**	144.7	5.72	128.4	5.72	*
MEI/$kg^{0.75}$	0.83	0.01	0.81	0.01	NS	1.31	0.04	1.31	0.04	NS

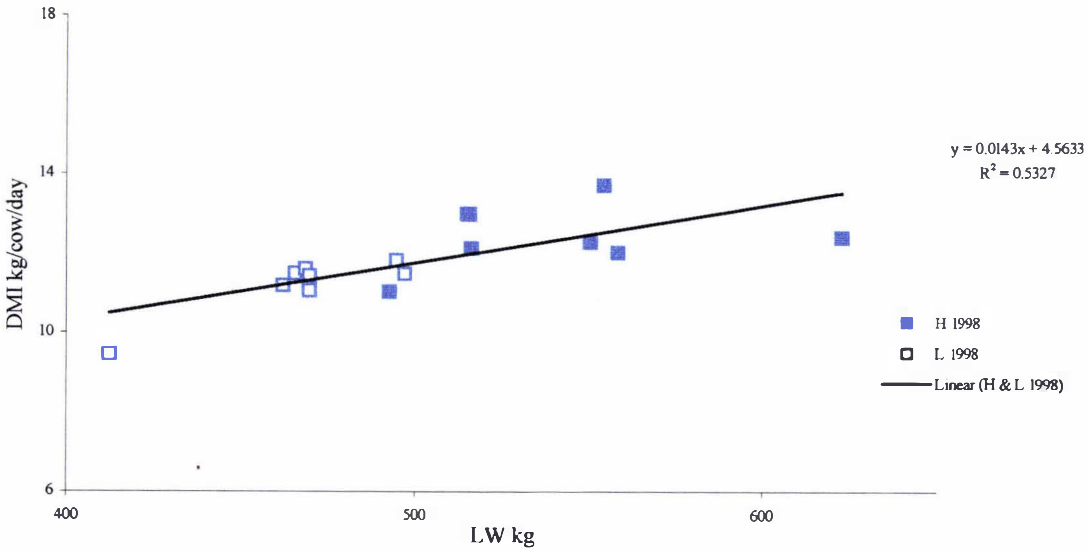
[1]s.e.d. : Standard error of the difference

[2]n : number of observations

[3] Significance: NS not significant; † $P<0.1$; $*P<0.05$; $**P<0.01$; $***P<0.001$

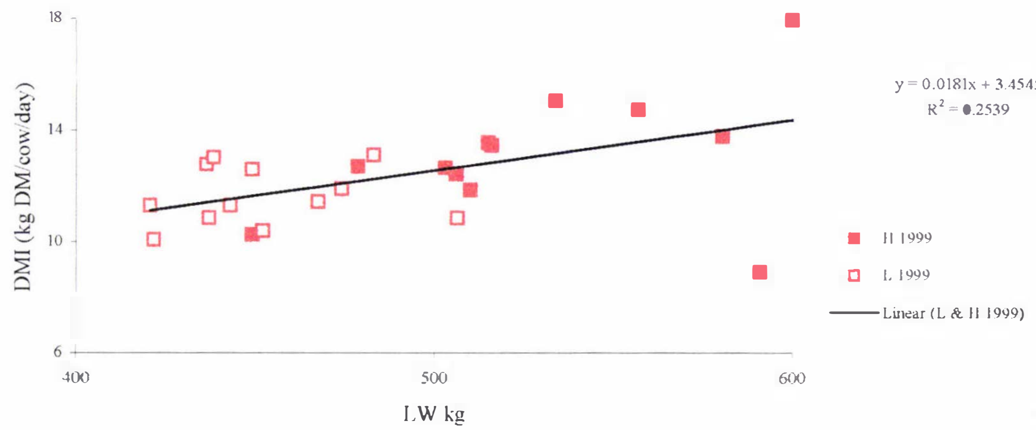
The actual values for kg DM of hay eaten by each cow are shown in Figure 2-1, for experiment one:

Figure 2-1. The relation between dry matter intake (DMI; kg/cow/day) and live weight (LW; kg) for the genetically heavy and light cows in 1998 fed *ad-libitum* on hay



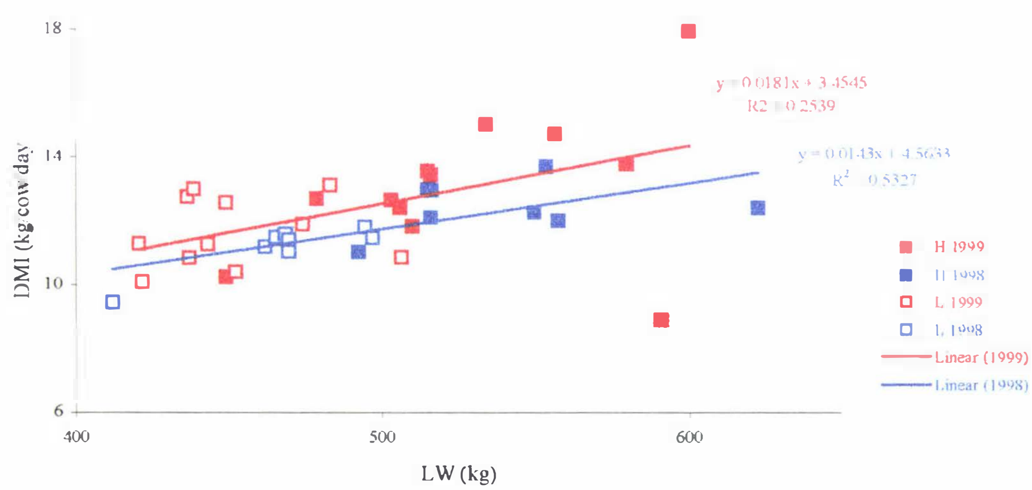
The actual values for kg DM of pasture eaten by each cow are shown in Figure 2-2, for experiment two:

Figure 2-2. The relation between dry matter intake (DMI; kg/cow/day) and live weight (LW; kg) for the genetically heavy and light cows in 1999 fed *ad-libitum* on pasture



Comparison of the actual values for kg DM eaten by each cow are shown in Figure 2-3, for both years.

Figure 2-3. The relation between dry matter intake (DMI; kg/cow/day) and live weight (LW; kg) for the genetically heavy and light cows in 1998 and 1999

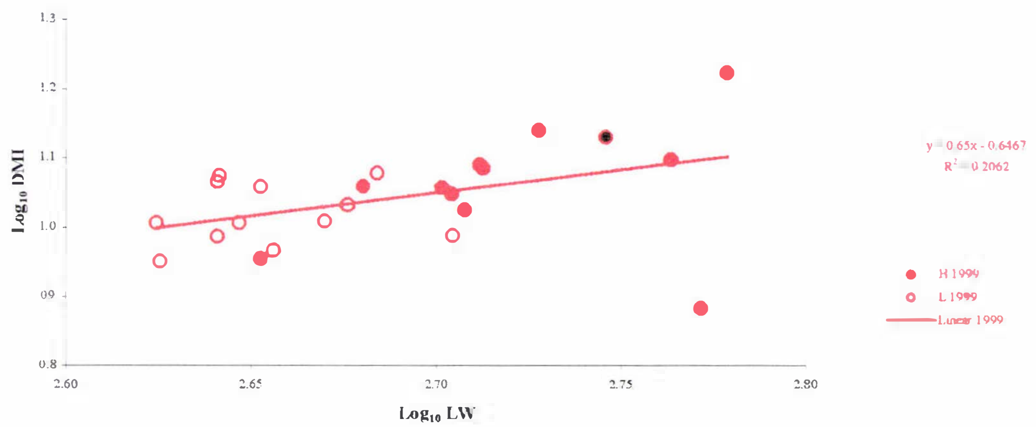


As expected, dry matter intake per cow increased as live weight increased. The regression coefficient generated shows that for each

100 kg increased in LW (x), DMI/cow/day increased by 1.43 and 1.81 respectively in 1998, and 1999, a positive correlation between DMI/cow/day and live weight. In both years, H cows ate more than the L cows (12.52 and 13.10 kg DM/cow/day by the H cows; 11.11 and 11.63 kg DM/cow/day by the L cows, in 1998 and 1999 respectively). In the first year H cows ate 11.2% more hay DM than L cows (P<0.01) and in the second year H cows ate 13.2% more pasture DM than L cows (P<0.01).

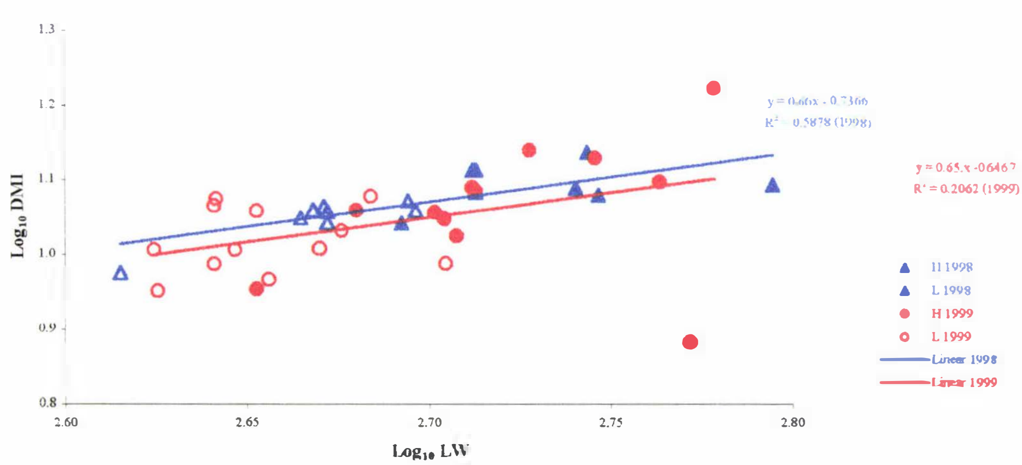
The relation between $\log_{10}$ DMI and $\log_{10}$ LW are shown in Figure 2-5; DMI increased in proportion to $LW^{0.65}$ in 1999.

FIGURE 2-5: The relation between $\log_{10}$ dry matter intake (DMI) and $\log_{10}$ live weight (LW) for the genetically heavy (H) and light (L) cows in 1999 fed *ad-libitum* on pasture



Comparison of the relation between $\log_{10}$ DMI and $\log_{10}$ LW are shown in Figure 2-6; DMI increased in proportion to $LW^{0.66}$ in 1998 and $LW^{0.65}$ in 1999.

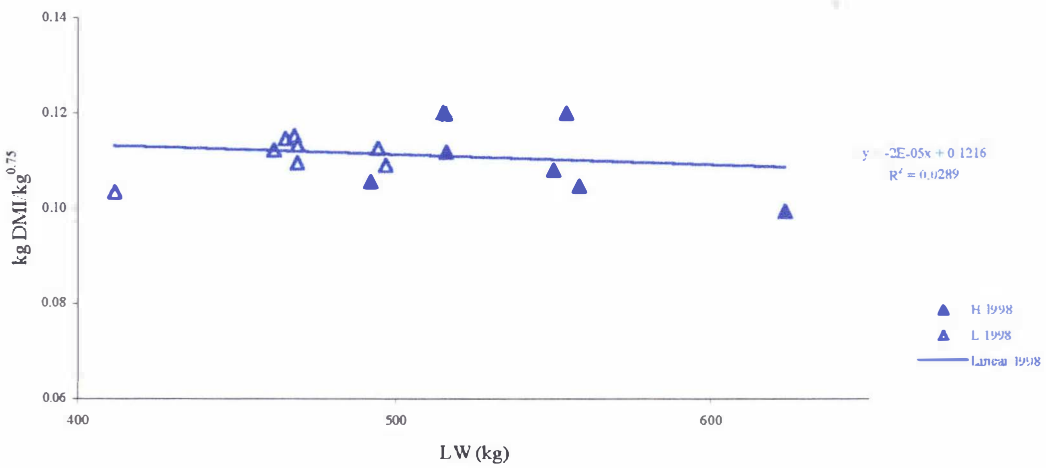
FIGURE 2-6: The relation between $\log_{10}$ dry matter intake (DMI) and $\log_{10}$ live weight (LW) for the genetically heavy (H) and light (L) cows in 1998 and 1999



These show that an increase of 100 percent in LW was associated with an increase of 66 and 65 percent in DMI for 1998 and 1999 respectively.

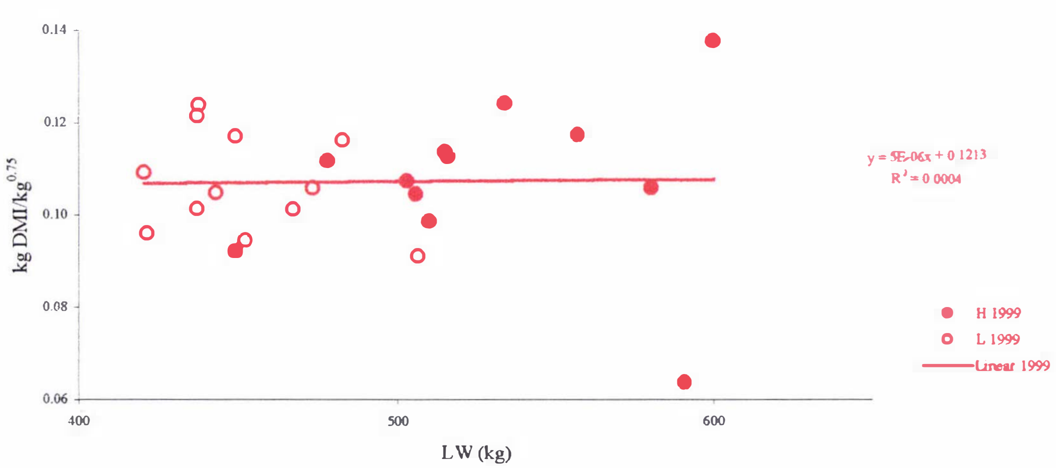
The relation between DMI/kg$^{0.75}$ and live weight for experiment one is shown in Figure 2-7.

FIGURE 2-7: The relation between dry matter intake per kg$^{0.75}$ (kg DMI/kg$^{0.75}$) and live weight (LW) for the genetically heavy (H) and light (L) cows in 1998 fed *ad-libitum* on hay



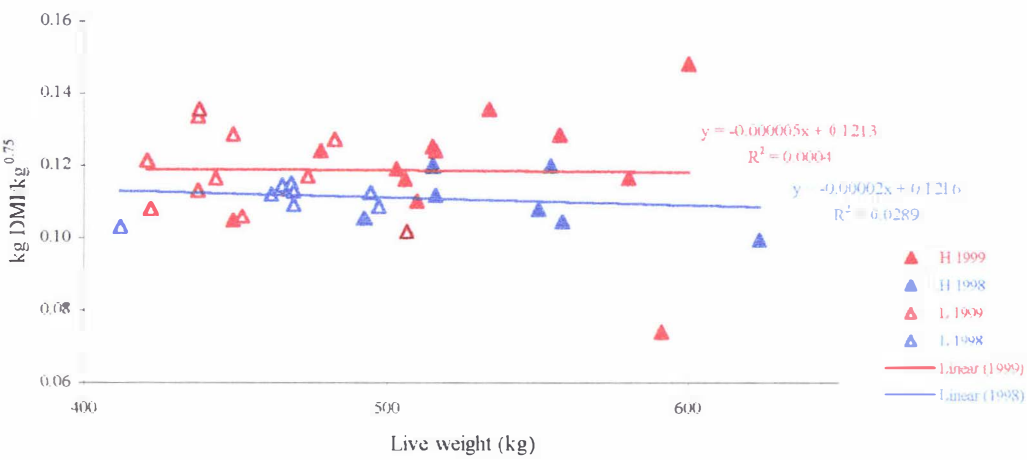
The relation between DMI/kg$^{0.75}$ and live weight for experiment two is shown in Figure 2-8.

FIGURE 2-8: The relation between dry matter intake per kg$^{0.75}$ (kg DMI/kg$^{0.75}$) and live weight (LW) for the genetically heavy (H) and light (L) cows in 1999 fed *ad-libitum* on pasture



Finally the relation between DMI/kg$^{0.75}$ and live weight for both years is shown in Figure 2-9.

Figure 2-9. The relation between dry matter intake per kg$^{0.75}$ (kg DMI/kg$^{0.75}$) and live weight (kg) for the genetically heavy and light cows in 1998 and 1999



DMI, expressed per kg$^{0.75}$ was almost constant across the range of LW from 400 up to 600 kg. However, in 1998 the least squares means in DMI per kg$^{0.75}$ for H cows (0.11) is slightly higher than for L cows (0.10), whereas in 1999 the least squares means in DMI per kg$^{0.75}$ is the same for H and L cows (0.118). The differences in DMI between the two strains expressed per kg$^{0.75}$ were not significant in either 1998 or 1999.

DISCUSSION

Live weight and body condition score

The H cows were on average 64 and 76 kg heavier than the L cows in 1998 and 1999 respectively. In addition, H cows in 1998 were on average 6 kg heavier than in 1999, similarly L cows in 1998 were 18 kg heavier than in 1999. Total mean values for live weight were 514 and 502 kg respectively for 1998 and 1999, possibly because cows used in 1998 were slightly older than cows used in 1999. These differences in body weight between the genetic lines agree with those reported previously (Garcia Muñíz *et al.*, 1997; Yerex *et al.*, 1988).

On the other hand, there were no significant differences in BCS between the two lines in the present studies. In addition there were no significant differences in LWC between the two lines in both experiments; however LWC, especially when measured over short periods of time, is not a very reliable indicator of real changes in body because of the possible misleading effects of gut fill (Wallace, 1961; Van Arendonk *et al.*, 1995).

Feed intake

The generous provision of hay in experiment one showed that at least 10% of the quantity offered was left uneaten at the end of each 24 hour period. Similarly in experiment two, the generous daily pasture allowance (29.6 kg DM/cow) offered and the relatively high post-grazing residual herbage mass (1734 kg DM/Ha) also provide strong indications that actual intake was probably not constrained by the quantity of herbage available (Bryant *et al.*, 1980; Glassey *et al.*, 1980; Peyraud *et al.*, 1996). Therefore, from a quantitative point of view there was no limitation to feed intake. In contrast, the quality of the hay (7.52 MJ ME/kg DM) was lower than the quality (11.1 MJ ME/kg DM) of the pasture, which must be taken into account when the two experiments are compared.

Dry matter intake per cow

After adjusting LW and $LW^{0.75}$ for differences by parity number on each genetic line (see Table 2-4), there were significant differences in DMI ($P<0.01$) between H and L cows either fed indoors on hay or grazing on pasture in 1998 and 1999. The least squares means for DMI/cow/day for H and L cows were 12.81 and 11.37 respectively, with a difference of 11.2% per cow. These results agree and confirm the moderate, positive genetic correlation between live weight and feed intake in a range of 0·44 to 0·65 (Veerkamp, 1999), suggesting that heavier animals consume more feed and may therefore be less efficient than the lighter animals (Persaud *et al.*, 1990; Persaud *et al.*, 1991). However, in the present studies, cows in the first year had daily DMIs per cow lower than in the second year (11.81 vs 12.36) respectively, indicating that cows on hay in the first year ate 4.4% less daily DM/cow than cows on pasture in the second year. Nevertheless, in 1998 H cows ate 11.3% more hay than the L cows while in 1999 H cows ate 13.2% more pasture than the L cows.

The pasture DMI measured by the alkane technique was similar to the values reported by other authors working with lactating cows at similar pastures allowances (Glassey *et al.*, 1980; Bryant *et al.*, 1980; Peyraud *et al.*, 1996). On average L cows ate slightly less than the H cows by 1.41 kg DM and 1.47 kg DM in 1998 and 1999 respectively, and the differences in both years were statistically significant ($P<0.01$).

Furthermore, the overall increase in DMI (kg DM) for each increase of 100 kg of LW in the present studies were 1.43 and 1.81 kg DM per 100 kg of LW for experiment one and two respectively.

This effect of live weight on DMI in the present experiments is in the range of those reported by other authors (Table 2-5). For instance, Donker *et al.*, (1983) found differences of 0.7 kg DM; Stakelum & Connolly (1987) in the indoors trial using lactating cows fed *ad-libitum* with harvested grass reported differences between 1.5 to 2.2 kg DM; Laborde (1998) also found a difference in DMI of 0.8 kg DM between H and L cows grazing on pasture.

Table 2-5. Increase in DMI (kg DM) of dairy cows for each increase of 100 kg of LW (estimated values from the regression coefficient for LW from the equations presented by the authors

Source	Increase DMI/100 kg LW (kg DM)	Trial conditions
Wallace (1961)	1.1	Grazing
Hutton (1962)	1.3	Grazing
Holmes and Jones (1964)	1.3	Grazing
Journet *et al.*, (1965)	0.7	Concent + forage
Curran and Holmes (1970)	2.3	Grazing + indoors
Bines (1976)	1.7	Roughage
Brown *et al.*, (1977)	1.1	Concent + forage
Stakelum *et al.*, (1987)	1.5	Indoor
Jarrige *et al.*, (1989)	1.2	Grazing + indoors (heifers)
Jarrige *et al.*, (1989)	0.8	Grazing + indoors (cows)
Holmes *et al.*, (1993)	2.0	Grazing
Tamminga and Van Vuuren (1995)	1.1	Indoor
Laborde (1998)	0.8	Grazing lactating cows
Dean (1998)	1.2	Indoor dry cows
Present study (1998)	1.43	Indoor dry cows
Present study (1999)	1.81	Grazing dry cows

However, when DMI was expressed per $kg^{0.75}$, differences between the H and L cows were not significant in year one on hay nor in year two on pasture.

Relation between DMI and LW; $\log_{10}$ LW and $LW^{0.75}$

There is little evidence about variation in feed intake and live weight in cows which differ genetically in LW. Least squares means shows that, in both years the H group was significantly heavier than the L group 546 kg LW v. 482 kg LW for cows fed on hay and 540 kg LW v. 464 kg LW for cows fed on pasture, indicating that on average H cows were 64 kg and 76 kg heavier than the L cows in 1998 and 1999 respectively; demonstrating an overall difference of 12.9% in LW for the H group against the L group in both years and the H cows ate more DM per cow daily then the L cows, by 11.26% and 11.22% in experiment one and experiment two. The present results agreed closely with those reported by Dean, (1998); Garcia Muñiz, (1998) and Laborde, (1998) carried out with cows differing genetically by body weight fed *ad-libitum* on pasture or hay (Table 2-6).

Table 2-6. Comparisons of least squares means for LW, BCS, DMI of genetically heavy or light Holstein-Friesian cows in different trials.

Parameter	Genetic line: Heavy	Genetic line: Light	Significance[1]
LW (kg)			
Garcia Muniz, (1998)	489	415	***
Laborde, (1998)	482	406	**
Dean, (1998)	578	461	***
Present study, (1998)	546	482	***
Present study, (1999)	540	464	***
BCS (units)			
Garcia Muniz, (1998)	4.49	4.35	*
Laborde, (1998)	4.68	4.47	NS
Dean, (1998)	4.70	4.32	NS
Present study, (1998)	4.50	4.50	NS
Present study, (1999)	4.50	4.60	NS
DMI (kg DM/cow/day)			
Garcia Muniz, (1998)	13.7	12.4	*
Laborde, (1998)	15.1	14.3	*
Dean, (1998)	13.3	12.1	***
Present study, (1998)	12.5	11.1	**
Present study, (1999)	13.1	11.6	**

[1] Significance: NS not significant; † P<0.1; *P<0.05; **P<0.01; ***P<0.001

The higher values for DMI reported by Garcia Muñiz, (1998) and Laborde, (1998) were probably because the cows used in their trials were lactating.

As mentioned in the previous section, the genetic correlation between live weight and feed intake capacity is positive (Veerkamp *et al.,* 1997; Veerkamp *et al.,* 1999), with correlations of 0·34 and 0·45 reported respectively (Persaud *et al.,* 1990) also 0·46 and 0·28 respectively (Persaud, *et al.,* 1991). In addition, the studies of Oldenbroek, (1997), where selection was for increased yields, live weight was found to be highly positively correlated genetically with feed intake and moderately positively genetically correlated with milk production, resulting in a small to moderate negative genetic correlation between efficiency and live weight (Veerkamp, 1998). However, linear type traits proved to have moderate genetic correlations with some of the traits of economic importance discussed here and therefore, might be used as indicator traits in a selection index, which obviously would be a great advantage to measuring weight or intake (Veerkamp, 1997).

At the same time, selection for improved feed efficiency has to focus on improving the partitioning of feed eaten into valuable components while ensuring that the energy supplied for other important functions is not involved. There are several options to use live weight and feed intake in genetic selection for improved economic efficiency. Of these, selections for increased milk yield and lower live weight are the first choice as there is no doubt that smaller cows have lower feed requirements for maintenance (Veerkamp, 1998; Lemus Ramirez, 2000).

The relationship between LW and DMI was investigated by simple linear regression analysis after transformation of the data for DMI and

LW to logarithms $base_{10}$. The resulting regression coefficient data gave an estimate of the appropriate exponent of LW^b in the following equation:

$$DMI\ (kg\ DM/cow/day) = a\ LW^b \qquad (11)$$

In the present studies the combined results presented in Figure 2-6 shows that DMI increased in proportion to $LW^{0.66}$ and $LW^{0.65}$ in 1998 and 1999 respectively, while Dean (1998) reported that DMI increased in proportion to $LW^{0.41}$. Unfortunately in the literature no other research was found which establish the relation between Log_{10} of DMI and Log_{10} LW in cows which differ genetically in LW. Therefore even the most relevant trials found are not directly comparable to the present experiments simply because the animals or the conditions were different. Corbett (1960) used a group of 12 cows with average LW of 530 kg to measure intake and performances during stall feeding on cut herbage and strip grazing; regression analysis of these variables provided a coefficient which was similar to that reported by Wallace (1956) ($LW^{0.73}$) using 45 Friesian cows and 55 Jersey cows with average LW of 505 and 400 kg respectively. Whereas Holmes (1961), used mature dry cows, heifers and calves grazing on pasture at the same time, obtaining a regression coefficient ($LW^{0.43}$) which was considerably lower. However the cows were pregnant, with large losses in live weight; the cow data were therefore discarded, and the resultant regression showed that DMI was proportional to $LW^{0.62}$ using the data from heifers and calves only. It is unlikely that any single exponent of live weight can be adopted for animals at all ages and live weights.

The literature reported that values of the exponent, which are close to 1.0, indicate direct proportionality of the DMI to body size (LW). While values close to 0.67 supports the contention that feed intake is related to body surface area and those close to 0.75 suggest that feed intake varies with metabolic weight (Table 2-7).

The data reviewed in Table 2-7 shows that the present values are within the range from previous studies. The results in the present studies shows that maximum DMI increases with $LW^{0.66}$ and $LW^{0.65}$, while Dean, (1998) in a stall feeding trial with dry pregnant cows fed on hay, showed that feed intake capacity increased in proportion to $LW^{0.41}$ which is in the lower range of the analysed data.

Studies carried out by Caicedo & Lemus during 1998 and 1999 using other cows from the heavy and light strains (Lemus-Ramirez, 2000) showed that requirements for maintenance costs increased in proportion to $LW^{0.63}$ and $LW^{0.75}$ in 1998 and 1999 respectively.

Table 2-7. Relations reported between feed intake and live weight for cattle grazing on pasture or fed with hay trials

Source	Exponent for LW	Trial conditions
Winchester *et al.*, (1953	$LW^{0.66}$	Pasture (beef calves)
Wallace, (1965)	$LW^{0.73}$	Pasture (cows)
Corbett, (1960)	$LW^{0.73}$	Pasture (lactating cows)
Holmes *et al.*, (1961)	$LW^{0.43}$	Pasture (dry cows, heifers, calves)
Hodgson *et al.*, (1964)	$LW^{0.61}$	Pasture (dry cows)
Dean, (1998)	$LW^{0.41}$	Hay (dry pregnant cows)
Caicedo & Lemus, (1998)[1]	$LW^{0.63}$	Hay (dry pregnant cows)
Caicedo & Lemus, (1999)[1]	$LW^{0.75}$	Hay (dry pregnant cows)
Present study (1998)	$LW^{0.66}$	Hay (dry pregnant cows)
Present study (1999)	$LW^{0.65}$	Pasture (dry pregnant cows)

[1]Lemus-Ramirez (2000)

Therefore, the results in the present studies indicate that the value for the difference between (maximum intake capacity (MJ ME) minus maintenance costs) does not increase with increase in live weight and is nearly constant for the H and L cows. This suggests that the difference between maximum intake capacity and maintenance costs, an important determinant of productive capacity, is not affected by genetic differences in LW.

CONCLUSIONS

There appears to be great potential to improve economic efficiency by selection for increased feed intake and decreased live weight, but there is still uncertainly about some of the genetic parameters involved, especially for traits related to health, reproduction, and energy balance. This limitation is the reason for the current interest in an appropriate selection index as to increase yield, decrease live weight and increase intake or may be to improve energy balance. Certainly, there is no definite answer at this stage, and may be all the traits must be considered simultaneously, otherwise there is the risk that improving just one trait may incur an adverse response in another trait. Therefore, further investigation of the input parameters of the biological model of genetic merit is needed. The understanding of such a model might help to establish the index that is economically most important.

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CHAPTER III

REPRODUCTIVE PERFORMANCE IN COWS DIFFERING GENETICALLY FOR BODY WEIGHT

ABSTRACT

The reproductive performance of Holstein-Friesian cows differing genetically for live weight was evaluated for the 1998-1999 period at Massey University. The aim of the study was to evaluate and compare the reproductive performance between the heavy (H) and light (L) cows two year old, three year & older and all age groups. Differences between genetic lines were evaluated for calving intervals: three week calving rate, calving to first service (CFS), planned start of mating to first service (PSMFS), calving to conception (CC), planned start of mating to conception (PSMC), first service to conception (FSC) and calving interval (CI) and percentage of induced cows. In addition, 21 days submission rate (SR), conception rate to first service (CRFS), percentage of cows treated with CIDRs and empty rate were also evaluated. Light cows showed a more concentrated calving pattern than the H cows, and a higher percentage of L cows calved in the first 3 weeks than H cows (72% and 62% respectively). Cows in the H line had a higher proportion of induced calvings. There were no significant differences between H and L cows in CFS, CC, PSMC, FSC and CI. However, the difference in PSMFS between the strains was significant ($P<0.01$): H cows had shorter intervals than L cows (8 days and 13 days respectively). Submission rate at 21days was significantly higher ($P<0.001$) for H cows than L cows (96% and 85% respectively), and H cows had lower CRFS than L cows (50% and 74% respectively; $P<0.05$). Similarly H cows tended to have a higher proportion of empty rates and CIDRs than the L cows. The combination of lower conception rate at the first insemination and the later calving extended the conception and calving pattern for the H cows and at the same time increased the probability of an induced calving. These results indicate that light cows had higher CRFS, achieved a more concentrated calving pattern and fewer needed to be induced to calve than heavier cows.

INTRODUCTION

In New Zealand the seasonal pasture based dairying system dictates that cows should have an average calving interval of 365 days between consecutive calvings (Holmes *et al.*, 1987; Macmillan, 1979; Stevens *et al.*, 2000). Most of the New Zealand herds calve in late winter or early spring, in order to maximize utilization of the spring pasture flush and then have a compact calving pattern and longer cow days in milk (Macmillan *et al.*, 1984; Macmillan, 1998). However, for detailed review of the reproductive performance refer back to the general review section 1.2 and 1.3 (Chapter I).

The efficiency and management of the farm system will in turn have a significant influence on the calving pattern (Macmillan *et al.*, 1990). External factors and management decisions in relation to feed availability have a significant impact on the body condition, which influence anoestrus and fertility rates (Garcia *et al.*, 1999).

Good reproductive performance is required to maintain a tight calving pattern required to maximise milk yield and feed utilisation (Macmillan *et al.*, 1994; Xu & Burton, 2000). The major factor influencing the calving pattern is the preceding season's conception pattern (Bailey, 1999; Macmillan *et al*, 1996; McDougall & Jolly, 2000). Where it is based on the date for the start of the artificial breeding (SAB) program which must be 282 days before the planned start of calving (PSC) because this is the average of pregnancy length (Holmes *et al.*, 1987; Macmillan *et al.*, 1976). The calving to conception interval should not exceed 83 days. The duration of the calving to conception interval depends on the ovarian involution after calving (Smith and Wallace, 1998; Xu and Burton, 1996; Opsomer *et al.*, 1996).

The numbers of cows inseminated in the first three-weeks of the breeding program is an important indicator of breeding management, which is defined as the herd submission rate (SR) (Cannon, 1994). The most important requirement for effective breeding management in any herd in which artificial breeding (AB) is used is accurate oestrus detection (Bailey, Dascanio and Murphy, 1999; Ryan and Mee, 1994). The most common cause of poor reproductive performance on dairy farms is poor heat detection (Hardin, 1993; Pecsok, 1994; Britt, 1985; Ferguson, 1989; Nebel. 1992). A simple missing oestrus detection will delay the conception date and reduce the SR. Also, cows with later conception dates should be induced to calve prematurely if the concentrated seasonal calving pattern is to be maintained in the ensuing production season.

The calving pattern is planned synchrony between feed demand and feed supply, in order to achieve the maximum utilization of pasture by grazing and to convert only surplus amounts into pasture hay or silage (Holmes, 1986; McCall and Smith, 1998; Macmillan, 1998; Xu & Burton, 2000). These surpluses may be utilized either in periods of feed shortage when pasture growth does not adequately meet the herd's feed demand or when feed requirements are lowest and pasture is being deferred for later grazing by recently calved cows (Bryant *et al.*, 1982; Bryant, 1984; Holmes *et al.*, 1993). Therefore a herd owner must choose a stocking rate between the extremes of having cows fully fed most of the time because growth rates exceed herd requirements or, having a high pasture utilization rate for most of the year which will result in periods of controlled underfeeding for cows when pasture growth rates are less than adequate for the herd's requirements (Bryant, 1990; Bailey *et al.*, 1999; Penno, 1999). This results in a period of negative energy balance that can have detrimental effects on cow condition and therefore on reproductive and productive performance (Clark *et al.,* 2000). The extent to which the herd owner may choose to move between these limits will also influence the date when that herd's calving is planned to start (Bryant *et al.,* 1987).

Poor reproductive performance should be considered as a range of effects rather than focused on a single cause (Clark *et al.*, 1998). For example, in-calf and empty rates are commonly used to assess the overall reproductive performance for seasonally mated dairy herds (Macmillan, 1998). The submission pattern and the conception rates achieved for artificial and natural breeding during the mating period determine mating performance (Macmillan *et al.,* 1973). This will determine the average interval from the start of the artificial breeding program to conception, the percentages pregnant in the first 3 weeks, in-calf to AB sires, or in-calf to a herd sire used after AB (natural mating). Good management and feeding will result in a submission rate of 90 to 95% in the first four weeks and 100% by the end of the seven weeks of the breeding period respectively (Holmes *et al.,* 1987). Submission rates are a function of both heat detection efficiency and the proportion of cows cycling (Brightling, 1985; Hayes, 1998). Previous calving dates and nutrition are the most important factors that determine the level of anoestrus within a herd.

The calving pattern, sire and semen fertility, technician, nutrition and the accuracy of heat detection are important modifiers of conception rates (Hayes, 1998). Breed and milk production are also associated with changes in reproductive performance. Over 90% of New Zealand dairy herds have a single seasonally concentrated calving pattern (Macmillan, 1998). About 50% of the cows within a herd will calve within a period of 14 to 28 days (Hayes, 1998; Brightling *et al.,* 1990). This marked degree of seasonality is the consequence of a management decision that precedes the date when spring pasture growth is expected to accelerate and produce the maximum amount of dry matter at a time when lactations have peaked and cows are able to efficiently convert pasture to milksolids (Hoogendoom *et al.*, 1988). The shape of the calving pattern as well as it's timing in relation to the pattern of grass growth will influence the efficiency of the whole farm system (Sheath *et al.*, 1996). Therefore, the reproductive performance of each herd determines the sustainability of this system from one year to the next. Grosshands *et al.*, (1997) summarized in Figure 3-0 the principal reproductive events for the seasonal systems.

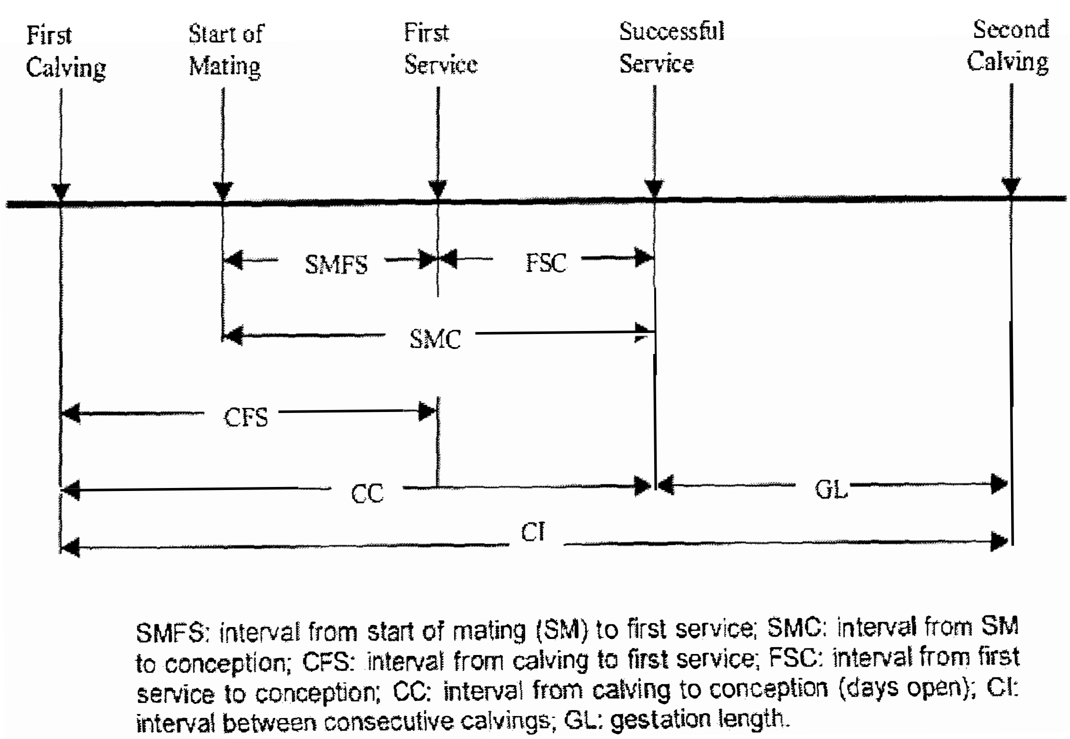


Figure 3-1. Relevant fertility traits for seasonal dairy systems. Grosshans *et al.*, (1997).

Good feed management is required to achieve mating targets that provide the basis of the sustainable production system in New Zealand. Especial attention must be taken in prolonged anoestrus, late carving cows and failure in oestrus detection efficiency to reach a good reproductive performance (McKay, 2000). It is essential to minimize the number of late calving cows and empty cows to achieve low rates of induction and culling in the herd.

Good heat detection, and a planned approach using a veterinarian to minimize the effects of non-cycling cows, is an integral part of dealing with the non-cycling cow problem. Non-cyclers must be deal with early if pre-mating rates suggest a problem (Cavalieri *et al., 2000)*.

Finally, *it is* becoming apparent that the poorly understood interactions between the metabolic and reproductive systems are the key limitors to both reproductive performance itself and the ability to manipulate reproduction through pharmacology and management.

OBJECTIVE

The relationships between genetic traits, including milk yield and live weight and fertility were discussed in chapter 1. The objective of this experiment were to evaluate the effect of selection for heavy or light mature live weight on reproductive performance cows from the two genetic traits during 1998/1999 period.

MATERIALS AND METHODS

The reproductive performance of the two genetic lines of cows for the 1998/1999 period was analysed. The information about calving date, parity number, pre-mating heats, inseminations, live weight and body condition score were collected from individual files recorded routinely at Dairy Cattle Research Unit (Massey University) for each cow. Most of the indicators pointed out by Grosshans *et al.,* (1996) for the evaluation of fertility traits in New Zealand dairy cows were analysed: planned start of calving to calving, calving date to first heat, planned start of mating to first service, planned start of mating to conception were analysed. Considering the importance of compact calving under a seasonal system, analysis of the ratios for the cows in each line were achieved for: calving date at first mating and cows which failed to conceive; submission rate at 21 and 42 days; percentage of calved cows at 21, 42 and 42+ days; the percentage of cows induced to calve prematurely and cows treated with CIDRs also were analysed.

Calving intervals

Calving to first service (CFS)

The managers at DCRU recorded visible heat activity during the twice-daily milking sessions by simple observation assisted by the use of the tail paint method. In seasonal dairy systems with a concentrated calving and breeding period, tail painting has proven to be the greatest aid in heat detection (Macmillan *et al.,* 1977). A cow was considered to be on heat when it stood to be mounted by other cow.

Anoestrous cows were checked by manual palpation one week before the planned start of mating (30th October), when the cows confirmed with anoestrus were treated with CIDRs. The CFS interval was obtained by subtracting the calving date (CD) from the day of first AI.

Planned start of mating to first service (PSMFS)

PSMFS interval was calculated as the difference between the date of first service and the date of planned start of mating.

First service to conception (FSC)

The difference between the date of first service and the conception date was considered as the FSC interval.

Calving to conception (CC)

This interval was calculated as the difference between the calving date and the conception date.

Planned start of mating to conception interval

The AB started on the 30th of October and was carried out until the 15th of December. Cows detected on heat were artificially inseminated (AI) by a technician from Livestock Improvement Corporation (LIC). Cows from each line were AI'd with predetermined H or L bulls according with the aims of the two genetic lines experiment. The natural mating started from the end of the AB period and continued for approximately 4 weeks. The herd managers also recorded the natural matings. Cows were pregnancy tested in March by a Veterinarian using manual palpation diagnostic. Conception date was estimated from the date of the last service recorded and from the calving date of the following year. If there was a discrepancy between the last service and the calving date, conception date was estimated by subtracting the pregnancy length (282 days) from the calving date of the following year.

Conception rate to first service (CRFS)

Conception rate to first service was obtained by considering that a cow had become pregnant to the first service only. Pregnancy confirmation was assumed if the cow did not show another heat within the next 24 days or did not have any further AI. However, the cows were pregnancy tested and were diagnosed as pregnant or non-pregnant by manual palpation.

Reproductive management

The reproductive management calendar for the DCRU during the period 1998/1999 are summarised in Table 3-1.

Table 3-1. Reproductive management calendar for DCRU during the period of 1998/1999.

Reproductive Event	Date
Planned start of calving (PSC)	20 of July
Calving period	20 July to 20 September
Pre-mating heat detection	1 month prior to PSM
Planned start of mating (PSM)	10 October
Artificial Breeding period	6 weeks
Natural mating period	4 weeks
Pregnancy test	6 weeks after finishing mating period

Statistical analysis

The reproductive data were subjected to analysis of variance using PROC CATMOD using SAS™ program (1996) version 6.12. Calving data and the post partum intervals: calving to first service (CFS), planned start of mating to first service (PSMFS), calving to conception (CC), planned start of mating to conception (PSMC) and days open (DO) and intervals between calving (CI) were evaluated through the use of chi square test (X^2). The model included the genetic line as the treatment effect and the data were adjusted by the parity number variable with the interaction of line and parity number effect were used. For continuous variables, least squares means were used to analyse the data. Some of the continuous variables used in the analysis were not normally distributed and, therefore, they were normalised.

RESULTS

Live weight, liveweight gain and body condition score

Sixty-eight cows from the two strains differing genetically in LW were included for the reproductive performance analysis. Cows culled before the planned start of mating were excluded (15 cows), and cows with missing data were not included (5).

Least squares means of initial and final LW, BCS (of the corresponding lactation period) and liveweight gain variables used for the analysis are presented in Table 3-2. There were highly significant differences in initial and final LW between genetic lines (P<0.001). Both genetic lines had a positive LWG however there were no significant differences in LWG between the lines. Both genetic lines also had consistent losses in body condition but the differences between the lines in body condition were not significant.

Table 3-2. Least squares means (s.e.d.)[1] for initial live weight (ILW), final live weight (FLW), liveweight gain (LWG), initial body condition score (IBCS) and final body condition score (FBCS) for the heavy (H) and light (L) genetic lines of cows.

Parameter	H	Sig[2]	L	Sig[2]
n[3]	30	-	38	-
Initial LW (kg)	461 (8.9)	***	424 (6.0)	***
Final LW (kg)	489 (9.3)	***	447 (8.3)	***
Gain in LW (kg/day)	0.146 (0.019)	NS	0.118 (0.017)	NS
Initial BCS	4.7 (0.05)	NS	4.5 (0.04)	NS
Final BCS	4.1 (0.04)	NS	4.1 (0.03)	NS

[1] s.e.d. : standard error of the difference

[2] Significance: NS not significant; † P<0.1; *P<0.05; **P<0.01; ***P<0.001

[3]n : number of observations (cows)

Calving performance

The number (n) and proportion (%) of cows which calved in the first 3 weeks, second 3 weeks, > 7 weeks, and the cows induced to calve for the two genetic lines during the 1998/1999 calving period are presented in Table 3-3.

Table 3-3. Number and percentage of cows in 1998/1999 calving period of the heavy (H) and light (L) genetic lines of cows, two years old, three years & older, and total age groups.

Calving period		2 years old		3 years & older		Total	
		H	L	H	L	H	L
Week 1 to 3	n	6	6	22	28	28	34
	%	60	67	63	73	62	72
Week 4 to 6	n	4	2	13	9	17	11
	%	40	22	37	24	38	23
Week > 7	n	0	1	0	1	0	2
	%	0	11	0	3	0	5
Cows induced to calve prematurely	n	0	0	7	2	7	2
	%	0	0	20	5	15	4

n : number of observations (cows)

Chi square values (X^2) and standard errors (s.e.) shows the level of significance between treatments (lines) after adjustment by parity number with the effect of parity*line included during the 1998/1999 calving period (Table 3-4).

Table 3-4. Calving performance in 1998/1999 period of the Heavy (H) and Light (L) genetic lines of cows, two years old, three years & older, and total age groups.

Calving period		2 years old					3 years & older					Total				
		H	L	X^2	s.e.	Sig[1]	H	L	X^2	s.e.	Sig[1]	H	L	X^2	s.e.	Sig
Week 1 to 3	%	60	67	1.32	0.47	NS	63	73	9.38	0.25	**	62	72	10.6	0.22	**
Week 4 to 6	%	40	22	0.24	0.70	NS	37	24	3.82	0.56	*	38	23	4.10	0.42	*
Week > 7	%	0	11	66.3	1.06	***	0	3	95.5	1.01	***	0	5	0.04	0.20	***
Cows induced to calve prematurely	%	0	0	NA	NA	NA	20	5	25.8	0.42	***	15	4	33.4	0.41	***

[1] Significance: NS not significant; † P<0.1; *P<0.05; **P<0.01; ***P<0.001

n : number of observations (cows)

NA: not applicable

Figure 3-1 shows the percentage of the H and L cows, two years old calved at the end of the 3rd and 6th week of the 1998 calving period. In the first 3 weeks approximately 45 % of the L cows calved in the first week and 22% in the 3rd week while 30% of the H cows calved in the first week, 20% in the 2nd week and 10% in the 3rd week.

Figure 3-1. Calving rate in 1998 of the Heavy (H) and Light (L) genetic lines of Holstein cows, two years old

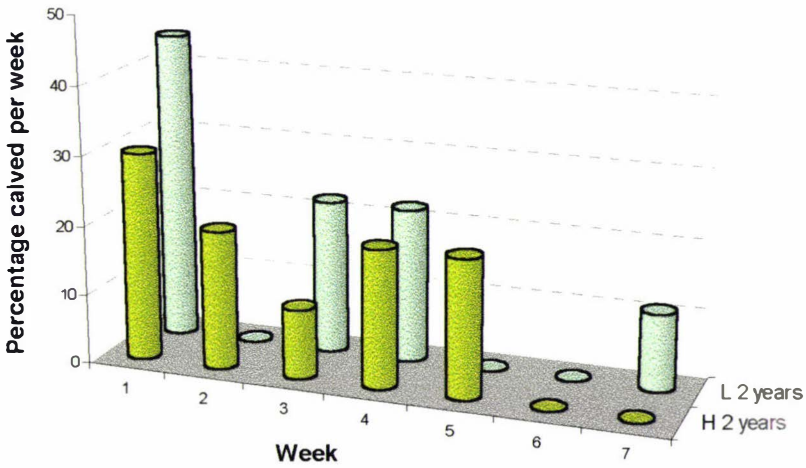


Figure 3-2 shows the percentage of the H and L cows, three years old and older calved at the end of the 3rd and 6th week of the 1998 calving period. In the first 3 weeks approximately 29% of the L cows calved in the first week, 32% in the 2nd week and 13% in the 3rd week while 29% of the H cows calved in the first week, 14% in the 2nd week and 20% in the 3rd week.

Figure 3-2. Calving rate in 1998 of the Heavy (H) and Light (L) genetic lines of Holstein cows, three years and older

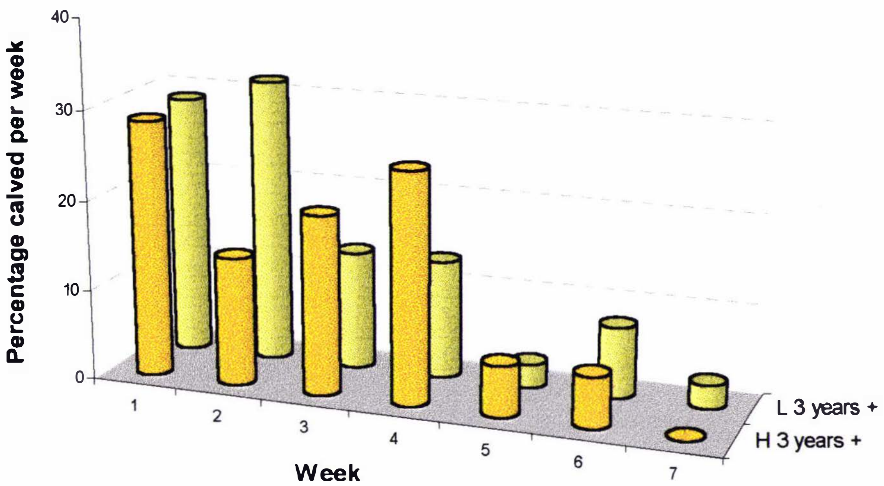


Figure 3-3 shows the percentage of the total H and L cows, calved at the end of the 3rd and 6th week of the 1998 calving period. In the first 3 weeks approximately 32% of the L cows calved in the 1st week, 26% in the 2nd week and 15% in the 3rd week while 29% of the H cows calved in the 1st week, 16% in the 2nd week and 18% in the 3rd week.

Figure 3-3. Calving rate in 1998 of the Heavy (H) and Light (L) genetic lines of Holstein cows (all age groups)

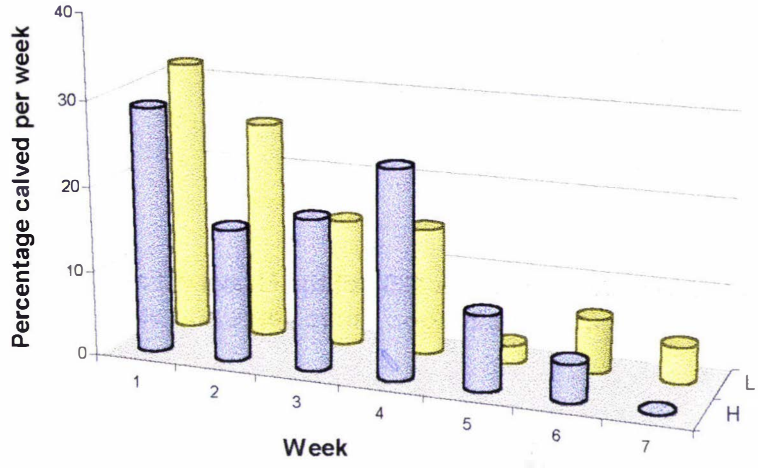
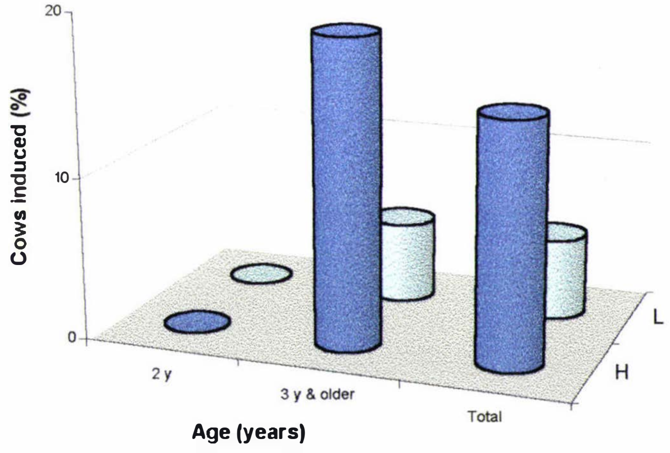


Figure 3-4 shows the percentage of cows induced during the1998 calving period. The percentage of L cows induced were 0%, 5% and 4% for the two years old, three years & older and the total age groups respectively. In contrast the percentage of H cows induced were 0%, 19% and 15% for the two years old, three years & older and the total age groups respectively.

Figure 3-4. Percentage of cows induced in 1998 calving period of the Heavy (H) and Light (L) genetic lines of Holstein cows, two years old, three years & older and the total (all age groups)



Postpartum intervals

Table 3-5 presents the mean intervals for some of the reproductive intervals between the two genetic strains of cows, two years old, three years & older and the total age groups during 1998/1999, and the level of significance for the differences between the two strains

Table 3-5. Calving intervals in 1998/1999 period of the Heavy (H) and Light (L) genetic lines of cows, two years old, three years & older and the total age groups.

	Two years old			Three years & older			Total		
Interval	H	L	Sig[1]	H	L	Sig[1]	H	L	Sig[1]
CFS (days)	71	81	NS	88	79	NS	80	79	NS
PSMFS (days)	5	14	†	11	12	NS	8	13	**
CC (days)	86	90	NS	102	87	NS	94	88	NS
PSMC (days)	22	23	NS	24	21	NS	28	24	NS
FSC (days)	16	9	NS	14	8	NS	15	9	NS
CI (days)	0	0	NA	368	365	NS	368	365	NS

CFS: Calving to first service interval

PSMFS: Planned start of mating to first service interval

CC: Calving to conception interval

PSMC: Planned start of mating to conception interval

FSC: First service to conception interval

CI: Intervals between calving

[1] Significance: NS not significant; † $P<0.1$; *$P<0.05$; **$P<0.01$; ***$P<0.001$

For all age groups, the H cows had higher mean intervals for CFS, CC, PSMC, FSC and CI than the L cows. However, in the two year old group, H cows had a shorter CFS, PSMFS, CC, PSMC and FSC intervals than the L cows. On average, two year old group had shorter intervals for CFS, for PSMFS and for CC than the older group.

Mating performance

Table 3-6 shows the number (n) and proportion (%) of cows mated in the first 3 weeks of breeding, second 3 weeks of breeding, cows treated with CIDR's, conception rate to first service (CRFS) and cows which failed to conceive for the two genetic lines during the 1998/1999 breeding period.

Table 3-6. Number and percentage of cows mated in the 1998/1999 breeding period of the heavy (H) and light (L) genetic lines of cows, two years old, three years & older, and total age groups.

		Two years old		Three years & older		Total	
		H	L	H	L	H	L
SR week 1 to 3	n	10	7	34	33	44	40
	%	100	78	94	87	96	85
SR week 4 to 6	n	0	2	2	5	2	7
	%	0	22	6	13	4	15
Cows treated with CIDR's	n	4	4	8	5	12	9
	%	40	44	22	13	26	19
CRFS	n	6	8	17	27	23	35
	%	60	89	47	71	50	74
Cows which failed to conceive	n	2	3	10	4	12	7
	%	20	33	24	10	23	15

SR: Submission rate

CRFS: Calving rate to first service

n: number of observations

Chi square values (X^2) and standard errors (s.e.) show the level of significance between treatments (lines) after adjustment by parity number with the effect of parity*line included for the breeding period 1998/1999 (Table 3-7).

Table 3-7. Mating performance in 1998/1999 period of the Heavy (H) and Light (L) genetic lines of cows, two years old, three years & older and the total age groups.

		Two years old					Three years and older					Total				
		H	L	X^2	s.e.	Sig[1]	H	L	X^2	s.e.	Sig[1]	H	L	X^2	s.e.	Sig[1]
SR week 1 to 3	%	100	78	105	0.80	***	94	87	29.3	0.43	***	96	85	33.8	0.41	***
SR week 4 to 6	%	0	22	1.28	0.47	NS	6	13	0.22	0.23	NS	4	15	0.87	0.20	NS
Cows treated with CIDR's	%	40	44	0.46	0.46	NS	22	13	25.2	0.31	***	26	19	24.6	0.25	***
CRFS	%	60	89	4.01	0.62	*	47	71	2.59	0.24	†	50	74	5.76	0.22	*
Cows which failed to conceive	%	20	33	3.84	0.58	*	24	10	22.9	0.32	***	23	15	32.0	0.26	***

SR: Submission rate

CRFS: Conception rate to first service

n: number of observations

[1] Significance: NS not significant; † P<0.1; *P<0.05; **P<0.01; ***P<0.001

DISCUSSION

The present study evaluated and compared the reproductive performance and some factors influencing the reproduction, of the heavy and light Holstein-Friesian cows differing genetically in live weight.

The results in the present study agree with the experimental evidence with Holstein-Friesian cows differing genetically for live weight (Table 3-8). Heavy cows had higher percentage of OS genes than the L cows, on average H cows were heavier than L cows 14.2% (Holmes *et al.*, 1999); 15.8% (Laborde, 1998) and 8.4% in the present study.

Table 3-8. Experimental evidence of reproductive performance for Holstein-Friesian cows differing genetically for live weight.

Source	Heavy	Light	Country
Live weight (kg)			
Holmes *et al.*, (1999)	490	420	New Zealand
Laborde, (1998)	481	405	New Zealand
Present study (1999)	475	435	New Zealand
Submission rate 21 days (%)			
Holmes *et al.*, (1999)	91	93	New Zealand
Laborde, (1998)	60	71	New Zealand
Present study (1999)	96	85	New Zealand
Dillon & Buckley, (1998)*	88	93	Ireland
Conception rate to 1st service (%)			
Holmes *et al.*, (1999)	54	65	New Zealand
Laborde, (1998)	58	70	New Zealand
Present study (1999)	50	74	New Zealand
Pryce *et al.*, (1999)	39	49	Scotland
Dillon & Buckley, (1998)*	41	53	Ireland
Empty rate (%)			
Present study (1999)	23	15	New Zealand
Dillon & Buckley, (1998)*	24	10	Ireland

Dillon & Buckley, (1998) compared high and medium genetic merit cows.

The results from Holmes *et al.*, (1999); Laborde, (1998) and Dillon *et al.*, (1998) shows that heavy cows had lower 21 days submission rates than light cows, while the present study shows higher 3 weeks submission rates for the H cows than the light cows in both age groups. However, L cows had higher conception rates to first service than the H cows in both groups, with the overall proportion of 74% for the L cows vs. 50% for the H cows, which in turn caused a less compact calving pattern in the following year. At the same time, higher percentage of the light cows calved in the first 3 weeks of the calving period than the heavy cows; 72% versus 62% for the light and heavy cows respectively, and a higher percentage of the heavy cows were induced to calve prematurely than the light cows 15% vs. 4% respectively. For the three year olds and older, there were more empty cows in the heavy line than in the light line 24% vs. 10%, similar to the results of Dillon & Buckley, (1998) who compared cows of high an medium merit.

Postpartum intervals

In New Zealand to maintain a seasonal calving herd, is required that cows must calve on average every 12 months (Malmo, 1985; Esslemont, 1993). Given an average gestation length of 282 days, calving to conception intervals of ≤83 days are required in order to maintain a 12-month production cycle. In order for the New Zealand seasonal calving herds to maintain an annual calving cycle that consists on 10 month period of lactation, a two month dry period and a minimum interval of 30 days between calving and PSM (to complete uterine involution), all cows must conceive within 53 days of the PSM (equivalent to 2.5 oestrus cycles) (Cavalieri *et al.*, 2000). Table 3-9 compares the results of the postpartum intervals in the present study with others similar studies carried out with Holstein-Friesian cows differing genetically for live weight.

Table 3-9. Comparison of the calving intervals in different studies for Holstein-Friesian cows differing genetically for live weight

Interval Source	H	L	Significance[1]	Period
CFS (days)				
Garcia-Muñíz, (1998)	78	82	†	1992-1997
Present study	80	79	NS	1998-1999
PSMFS (days)				
Garcia-Muñíz, (1998)	11.7	11.6	NS	1992-1997
Laborde, (1998)	12	11	NS	1992-1997
Laborde, (1998)	10	11	NS	1996-1997
Present study	8	13	**	1998-1999
CC (days)				
Garcia-Muñíz, (1998)	93.5	93.6	NS	1992-1997
Present study	94	88	NS	1998-1999
PSMC (days)				
Garcia-Muñíz, (1998)	28	24	†	1992-1997
Laborde, (1998)	25	21	NS	1992-1997
Laborde, (1998)	11	14	NS	1996-1997
Present study	23	22	NS	1998-1999
FSC (days)				
Garcia-Muñíz, (1998)	17	13	†	1992-1997
Present study	15	9	NS	1998-1999
CI (days)				
Garcia-Muñíz, (1998)	375	373	NS	1992-1997
Present study	368	365	NS	1998-1999

[1] Significance: NS not significant; † P<0.1; *P<0.05; **P<0.01; ***P<0.001

CFS: Calving to first service interval

PSMFS: Planned start of mating to first service interval

CC: Calving to conception interval

PSMC: Planned start of mating to conception interval

FSC: First service to conception interval

Calving to first service interval

For all age groups and three years & older group, H cows had longer CFS interval (80 days and 88 days respectively) than L cows (79 days and 79 days respectively). While for the two year old group, H cows had shorter CFS interval than L cows (71 days and 81 days respectively). The values in the present study are comparable to those reported by Garcia-Muñíz, (1998) and Laborde, (1998) with HF cows differing genetically by live weight Table 3-9

Shorter CFS intervals have been associated with lower conception rate to the first service, especially with high producing cows (Dhaliwal *et al.*, 1996). However, longer CFS intervals are associated with increased open days (Oltenacu *et al.*, 1980), and longer calving intervals (Macmillan, 1979). However the CFS interval observed for the L cows in the present study are also comparable to those reported for New Zealand Holstein-Friesian cows in other studies 77 days (Macmillan & Moller, 1977[b]); 76 days (Macmillan *et al.*, 1987) and 76 days (Grosshans *et al.*, 1997).

Opsomer *et. al.*, (1996) and O'Farrell, (1998) also indicated that, together with the efficacy of heat detection, the management decision on when to start breeding and the overall conception rate, the early resumption of ovarian cyclicity is one of the most important factors determining the length of the calving interval.

The calving to first service interval depends on the re-establishment of the ovarian activity after calving, the occurrence and detection of oestrus and the farmer's planned start of mating date, if this occurs later than the previous factors (Malmo, 1985; Peters & Ball, 1987).

Ouweltjes *et. al.*, (1996) showed a significant effect of herd on CFS interval indicating the strong influence that a farmer has on the timing of first insemination.

Planned start of mating to first service interval

For the all age groups, L cows had longer PSMFS interval (13 days) than the H cows (8 days), confirming the tight calving pattern achieved by the latter group. The three year olds group had very similar PSMFS between two strains. However, in the two year olds group, H cows had much shorter PSMFS intervals than the L cows (5 days and 14 days respectively), because of their slightly more spread calving pattern.

The results in the present study are in a similar range to those reported by Garcia-Muñíz, (1998) and Laborde, (1998) Table 3-9. In other studies with Holstein-Friesian cows, Macmillan, (1987) reported the overall mean of PSMFS intervals was 13 days, however Grosshans *et al.*, (1997) reported on average a much longer PSMFS interval (19 days).

Macmillan, (1985) pointed out that the accuracy of oestrus detection and the proportional incidence of postpartum anoestrus would influence the PSMFS interval. For example, if detection rate were 90%, then the PSMFS interval would be 13.5 days, and if it were only 80%, then the PSMFS would be 16.2 days.

Calving to conception interval (open days)

The calving to conception interval determined in this study for the combined group was longer for H cows than for L cows (94 days and 88 days respectively). These results were slightly different from those reported by Garcia-Muñíz, (1998) (Table 3-9). However, the two year old group had shorter CC interval for H cows than for L cows (86 days and 90 days respectively); while the three year & older group had considerable longer CC interval for the H cows than the L cows (102 days and 87 days respectively). These results are also in agreement with other studies reported by Macmillan *et al.*, (1987) and Grosshans *et al.*, (1997), for which the overall mean for the Holstein-Friesian cows were 88 days and 90 days respectively.

Planned start of mating to conception interval

The PSMC interval for the all age groups was similar for the H cows and for the L cows (23 days and 22 days respectively). These difference and the lower CRFS for the heavy strain indicates that H cows were comparatively less likely to conceive than L cows. However, in the two year old group L cows had slightly longer PSMC interval than the H cows (23 days and 22 days respectively).

The present results agreed with the results presented by Garcia-Muñíz, (1998) and Laborde, (1998), from the analysis of the 1992-1997 period (Table 3-9). These results are also in the range of other studies in Holstein-Friesian cows reported by different authors: 28 days (Macmillan & Clayton, 1980); 24 days (Macmillan *et al.*, 1987); 21 days (Xu *et al.*, 1996), and Grosshans *et al.*, (1997) reported a higher mean for PSMC interval 33 days.

Macmillan (1985) pointed out that conception rate and distribution of return intervals, as well as the submission rate will influence the interval PSMC. In combination with CRFS or subsequent inseminations, the oestrus detection rate will also influence the intervals PSMC and FSC (Macmillan, 1985). Therefore, the longer PSMC interval for the H group is compared to the other L group, which is consistent with its lower CRFS.

First service to conception interval

First service to conception interval was six days longer for the H cows in the all age groups and in the three year & older group respectively; while in the two year old group, this interval was seven days longer for the H cows (Table 3-5). There were no significant differences between H cows and L cows in the present study. The longer interval in the H cows reflected their lower conception rates to first service. The results in the present study agree with those reported by Garcia-Muñiz, (1998) H cows (17 days) and L cows (13 days) (Table 3-9). Also similar values were reported by Grosshans *et al.*, (1997) and Macmillan & Clayton, (1980) 13 days and 11 days respectively.

The first service to conception interval depends on the ability to conceive and maintain pregnancy after a given service, and on the continuation of ovarian cycles and the correct detection of oestrus in those cows, which do not conceive to initial services (Peters & Ball, 1987). A short FSC and CC are essential to maintain a concentrated calving pattern and a calving interval of 365 days in seasonal dairy herds (Grosshans *et. al.*, 1997).

Intervals between calving

For the estimation of calving interval in this study, calving dates for the multiparous cows were used only. The H cows had longer calving interval than the L cows (368 days and 365 days respectively) reflecting a higher incidence of inductions. However the results in the present study show a compact calving pattern compared that reported by Garcia-Muñiz, (1998). Nevertheless, there were no differences between the two strains.

Macmillan *et al.*, (1984) suggested that a more concentrated calving pattern should result in a higher submission rate and a higher conception rate simply because of a longer interval from calving to the next mating season.

The role of live weight in reproductive performance

There can be no doubt that genetic improvement has indeed resulted in significant production and profit gains. However, the challenge is to keep that genetic potential but at the same time minimize the risk of negative effects on reproductive performance (Verkerk, 2000[a]).

Since 1989 studies were initiated at Massey University in order to validate the efficiency component of the breeding worth index of genetic merit. The two herd lines have been bred using sires with different breeding values for live weight. The sires used for the heavy line had a higher proportion of USA genetic background, which by 1999 contained 28% of overseas Holstein-Friesian genes compared to only 9% for the L cows. Heifers from the heavy line reached puberty 25 days later than those from the light line. Submission rates to AI were similar, but the conception rate to first service was 54% for the H cows compared to 65% in the L cows, which resulted in a different pregnancy rate after 4 weeks of breeding of 58% and 70% for the H and L cows respectively (Holmes et al., 1999). Table 3-10 shows some variables of lactation performance, live weight and body condition score for heifers.

Table 3-10. Comparative performance of Holstein-Friesian cows bred for heavy (H) and light (L) live weights at Massey University (from Garcia Muñiz *et al.*, 1998; Holmes, *et al.*, 1999)

	Heavy	Light
Live weight (kg):		
At birth (kg)	40.7*	34.7*
At first calving	411*	386*
Onset at puberty:		
Age (days)	325*	300*
Live weight (kg)	241	220
% cycling at 12 months	83*	94*
First lactation:		
Milk solids (kg)	278	277
Production efficiency (g MS/kg DM)	135	134
Calving to ovulation interval	28*	32*
Submission rate 21 days (%)	91	93
Conception rate to 1st service (%)	54*	65*

*Significant difference ($P<0.05$)

Reproductive performance

For many decades there has been a concern that reproductive performance in the New Zealand dairy herd is declining. Analysis of the national database showed that the overall 21-day submission rate (SR) decreased from 93.5% to 82.1% (from 1973 to 1996), a rate of decrease of 0.5% per annum, with an increase in the percentages of anoestrous cows in the herd, which became the major reproductive problem experienced in New Zealand (Holmes, 1999; Verkerk, 2000[a]). Undoubtedly, milk production levels have increased as a result of genetic improvement so that feed requirements of cows in early lactation have also increased. Since anoestrus is largely a consequence of failure to fu lly feed cows, this is likely to be a contributing factor. Also average herd sizes have increased which might contribute to less effective detection of heat and consequently to less effective breeding. Therefore the reduced fertility of high genetic merit cows has been recognised world wide, and fertility is now being included in the genetic index of several countries (Holmes, 1999). Some evidence of the reproductive performance is presented in Table 3-11. For instance conception rates have decreased by about 3% units per 10 years in USA, 6% units per 10 years in Ireland, both in association with increased use of high genetic merit cows with high increases in milk yield and protein.

Table 3-11. Evidence of reproductive performance in different countries

Country	Year	Holstein-Friesian	Jersey	Source
48-day non-return rate (%)				
NZ	1989	69	69	Burton & Harris, (1999)
NZ	1998	67	68	Burton & Harris, (1999)
Submission rate (%)				
NZ	1973	94	94	Verkerk, (2000a)
NZ	1996	82	89	Verkerk, (2000a)
Conception rate 1st service (%)				
USA	1960	51		Lamming et al., (1998)
USA	1980	46		Lamming et al., (1998)
USA	1995	40		Lamming et al., (1998)
IRELAND	1991	53		O'Farrell & Crilly, (1998)
IRELAND	1996	49		O'Farrell & Crilly, (1998)

Recent studies by Kolver *et al*., (2000), have been evaluating the performance of Holstein-Friesian (HF) cows with either 100% overseas (OS) ancestry or with less than 12.5% overseas genes (New Zealand selection lines) fed either total mixed ration (TMR) or on high quality pasture at a generous allowance (>60 kg DM/cow/day). In this trial there were only a small number of animals including 2 and 3 year olds. However calving dates were earlier in the NZ HF cows, a carry over effect of an unfavourable reproductive performance by the OS strain in the previous season. The reproductive performance of the OS strain differed from that of the NZ animals, with a trend to longer postpartum anoestrous intervals, for the pasture fed cows. Poor fertility reflects reports from overseas studies in which repeat breeding is a common reported problem, and would appear to be compounded by factors related to the grass based diet, even though pasture' was fed at a generous allowance. All these differences could be associated with the inability of the OS strain animals on pasture to maintain energy balance and body condition score. Data from the study are presented in Table 3-12.

Table 3-12. Reproductive performance of 2 and 3 year old cows during the 1999/2000 lactation. (Extracted from Verkerk *et al.*, 2000[b])

	NZ		OS		Significance	
Reproductive performance:	Grass	TMR	Grass	TMR	Grass	TMR
Mean Calving date	24 July	29 July	19 Aug	10 Aug	0.05	NS
Postpartum anoestrus interval (days)	39 (6)	29 (4)	27 (6)	23 (2)	NS	0.07
Calving to conception interval	74 (5)	72 (5)	66 (6)	70 (8)	NS	NS
Proportion empty after 13 week breeding period	1/14	2/14	5/13	3/14	0.08	NS

The proportion of OS HF genes in the NZ dairy herd has increased from 0.7% in 1980 to 38% in 1998. Harris & Winkelman, (2000) studied the influence of OS HF genetics on NZ dairy cattle. This study involved 49.6% HF, 22.8% Jersey and 27.6% HF-Jersey cross cows. The reproductive performance of the predominantly OS HF group was significantly poorer than that of other breed groups, with particular concern about the lower conception percentage (60.3%) to AI resulting in a significant negative deviation of -10.1% for the OS HF in contrast to the NZ HF group's deviation of + 1.1 % above average.

CONCLUSIONS

The decrease in the 21 days submission rate in New Zealand dairy herds may be due in large part to underfeeding in early lactation that has occurred and despite the increased use of CIDRs and inductions, in the last decades, in order to maintain a compact calving pattern. Therefore, this problem will have been accentuated by increased high genetic merit cows in the New Zealand herd, contributing to increases in the cow's energy demand and also increases in stocking rates. In turn it could be the reasons for decreasing conception rate, but also the fact that more cows will now have to be mated at their first post partum heat subsequently expecting low conception rates.

The high empty rate could be reduced by increasing the use of inductions and CIDRs in order to maintain a compact calving pattern, which is required in the New Zealand pastoral based dairy system. These will help to achieve good fertility for the New Zealand conditions increasing the proportion of 3 weeks submission rates, and conception rated, while also maintaining a lower proportion of empty cows with obvious less returns rates.

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