REPRODUCTIVE EFFICIENCY IN DAIRY CATTLE CALVING DURING AUTUMN OR SPRING

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Reproductive Efficiency in Dairy Cattle Calving during Autumn or Spring

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Firstly I dedicate this thesis to God, because through Him I have achieved and got everything I have.

To my beloved Paty. Thank you for your love, help and support; all these things made possible my coming to New Zealand, my persistence in this commitment and the final achievement of this goal.

To my lovely little daughter, Mariana. You were the ideal that made me stronger to continue in this project. You enhance the happiness in our lives and you became a New Zealand living memory that we will never forget.

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ABSTRACT

Reproductive performance of cows is a key element in the productivity and efficiency of a dairy system. Therefore, the aim of this study was to evaluate and compare the reproductive performance of cows calving in different seasons (autumn or spring) in three dairy farm systems: 100 % spring calving (S), 100 % autumn calving (A) and 50 % / 50 % spring and autumn calving (AS). Data recorded at No. 1 Dairy Farm (Massey University) during 1996-1999 was used for the present study. Also, milk samples collected during 1998-1999 from the S and A farmlets were used to determine some metabolites (urea, progesterone and β-hydroxybutyrate) in order to assess possible causes of differences in reproductive function. During the three-year period, the AS farmlet showed a more concentrated calving pattern than the A and S farmlets. The planned start of calving to median calving date was 15, 17 and 19 days for the AS, A and S farmlets, respectively. In line with its calving pattern, S farmlet had a higher proportion of induced calvings (10 %) ($P < 0.01$) than A (3 %) and AS farmlets (5 %) and a lower proportion of cows showing heats before planned start of mating (PSM) ($P < 0.01$) (59 % *vs* 69 and 70 % for the A and AS cows, respectively). Also S cows displayed a higher incidence of metabolic disorders (9 %) than cows in the other farmlets (4 and 3 % for the A and AS farmlets, respectively). Despite a similar submission rate at 28 days for all farmlets (92, 94 and 90 % for the A, S and AS farmlets, respectively), cows in the S farmlet tended to show a lower conception rate to first service (CR1st) (47 %) than cows in the A (54 %) and AS (53 %) farmlets. Therefore, cows in the S farmlet tended to have a longer PSM to conception interval (35 days) ($P < 0.1$) than cows in the A (30 days) and AS (31 days) farmlets. Regardless of farmlet, anoestrus cows were less likely to be submitted for artificial insemination (odds ratio (OR) = 0.43) and to conceive (OR = 0.64) than their cycling herdmates. Similarly, cows calving later in the season, had reduced probabilities of being submitted for artificial insemination (AI) and conceiving than cows calving earlier. The probability of conception either at first service or during the whole mating period was lower for cows experiencing a metabolic disorder (OR = 0.27 and 0.64 for conception to first service and during the whole mating period, respectively) than cows with no events recorded. Similarly, cows having two or more lameness episodes were less likely to conceive (OR = 0.61) than cows with no episodes.

During 1998-1999, the effects of milk urea concentration (MU) and energy balance, assessed by changes in body condition (BC) and concentrations of β-hydroxybutyrate in milk (B-OH), upon fertility (CR1st) of cows in the A and S farmlets were explored. Despite having a higher MU ($P < 0.05$) (8.5 *vs* 6.6 mmol/L for the A and

S cows, respectively), A cows tended to have a higher CR1st (60 %) than S cows (49 %). However, within each farmlet, as MU increased the probability of conception to first service tended to decrease. Through progesterone concentrations (P4) determinations and pregnancy tests, cows in both farmlets were classified into three groups: pregnant (P), non-pregnant with low P4 on day 21 post-AI (EL) and non-pregnant with high P4 on day 21 post-AI (EH). P cows in both herds tended to have lower MU at AI (MU0), higher BC at AI (bcsm) and higher P4 on day 12 post-AI (P12) than EH and EL cows. On the other hand, EH cows tended to have higher MU0 and lower P12 than P and EL cows. In the A farmlet, P cows had similar B-OH to EL cows but higher than EH cows ($P < 0.1$). Regardless of farmlet, the probability of a cow becoming pregnant at first service was decreased by 0.105 for each unit increase in the natural logarithm of MU0. Also, the probability of a cow conceiving to first service when it had one health disorder event was only 35 % of that of a cow with no health disorders recorded. On the other hand, the probability of a cow becoming pregnant was increased by a factor of 5.29 for each unit increase in bcsm, by nearly 3 % for each ng/ml increase in P12, and by 55 % for each increase in the square root of the interval from PSM to first service (PSMFS).

It was concluded that, under the study circumstances, calving during autumn was not associated with an impaired reproductive performance as generally reported in other studies. Calving pattern, health status as well as the duration of the mating period appeared to be the most important factors affecting reproduction of cows in the present study. Also, despite the negative effect of high MU upon fertility, its effects are unlikely to be expressed, unless other concurrent factors such as low bcsm, short PSMFS interval and high incidence of health disorders occur.

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LIST OF ABBREVIATIONS

A = 100 % autumn-calving farmlet
ADF = acid detergent fibre
AI = artificial insemination
AS = 50 % autumn- / 50 % spring-calving farmlet
BCS = body condition score
Bcsc = BCS at calving
Bcsd = difference between bcsm and bcsc
Bcsm = BCS at mating
B-OH = β-hydroxybutyrate
CC = calving to conception interval
CD = calving date
CFS = calving to first service interval
CI = calving interval
CIDR = controlled intravaginal drug release device
CL = confidence limits
CP = crude protein
CR1st = conception rate to first service
DCAD = dietary cation-anion difference
DM = dry matter
EB = energy balance
EH = non-pregnant cows with high progesterone concentration on day 21 post-breeding
EL = non-pregnant cows with low progesterone concentration on day 21 post-breeding
FSC = first service to conception interval
LH = luteinizing hormone
LoF = level of feeding
m.fat = milk fat
ME = metabolisable energy
MU = milk urea concentration
MU0 = milk urea concentration at breeding
MU12 = milk urea concentration on day 12 post-breeding
n = number
NDF = neutral detergent fibre
NEB = negative energy balance
ng = nanogram
NIRS = near infrared reflectance spectrometry
NR = not reported
NS = not significant
OMD = organic matter digestibility

OR = odds ratio
P = pregnant cows
P12 = progesterone concentration on day 12 post-breeding
P4 = progesterone concentration
PSC = planned start of calving
PSM = planned start of mating
PSMC = planned start of mating to conception interval
PSMFS = planned start of mating to first service interval
PUN = plasma urea nitrogen concentration
RDP = rumen degradable protein
RFM = retained foetal membranes
S = 100 % spring-calving farmlet
SCHOs = soluble carbohydrates
SE = standard error
Sig. = significance
SR = submission rate
SR-21 = submission rate at 21 days
SR-28 = submission rate at 28 days
StdCD = standardised calving date (difference between actual calving date an a specific date fixed a 100 days before PSC)
StR = stocking rate
SUN = serum urea nitrogen concentration
Wgtc = weight at calving
Wgtd = difference between wgtm and wgtc
Wgtm = weight at mating
r^2 = coefficient of determination
χ^2 = chi-square
⇧ = probability < 0.1
* = probability < 0.05
** = probability < 0.01
*** = probability < 0.001

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CHAPTER I

LITERATURE REVIEW

New Zealand Dairy Systems

Basically there are two dairy systems used in New Zealand: seasonal supply dairying in which the calving period is in springtime and no milk is produced in winter, and winter milk dairying in which the calving period can be in spring, autumn or throughout the year and some milk production is produced in winter (Holmes *et. al.*, 1987).

Pasture is the predominant source of feed in New Zealand seasonal dairy farms. Spring calving and high stocking rates are adopted so that peak feed requirements coincide with peak pasture growth (Penno *et. al.*, 1995).

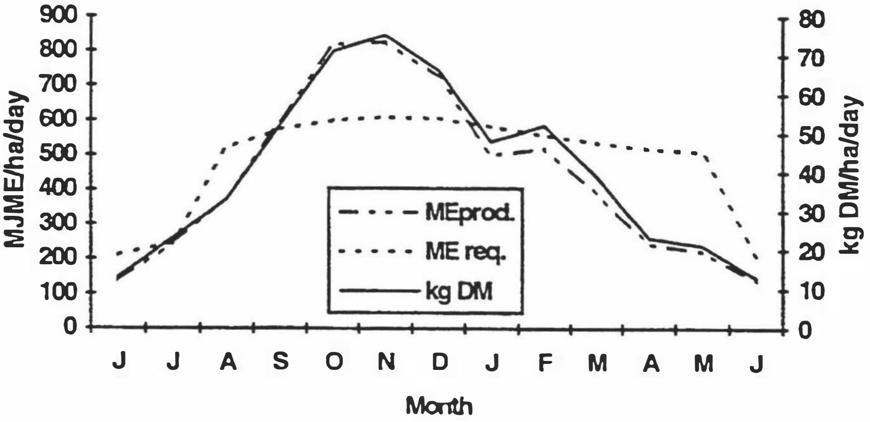
Seasonal supply dairying is the predominant system and due to the marked seasonality of pasture production and therefore feed availability, all of the reproductive events follow a seasonal pattern to match the pasture feed supply with the feed demand (Holmes *et. al.*, 1987; Brightling *et. al.*, 1990). As a consequence, mating and calving are confined to a restricted period in order to achieve a compact calving season compatible with pasture production (Macmillan, 1979; Macmillan *et. al.*, 1996). Winter milk farms must produce a daily contracted volume of milk through the autumn and winter, and therefore cows are mated in winter so as to calve in autumn. The poor pasture growth during winter necessitates the use of supplementary feeding (e.g. pasture or maize silage) in order to meet the cows' requirements (Holmes *et. al.*, 1987; García *et. al.*, 1998).

Three main factors determine the efficiency of conversion of pasture into milk: the amount of pasture grown, the efficiency with which the pasture is harvested and the conversion efficiency of the pasture consumed into milk by the animal (McMeekan, 1956; McMeekan, 1960). The adequate combination of the three is what makes a system highly productive and efficient.

Two fundamental points are essential in achieving such a successful combination, firstly providing an appropriate amount of good quality feed, in the form of pasture and supplements, in order to meet most of the animal requirements, and secondly achieving a good feed utilisation and conversion efficiency by the cows through the use of high genetic merit animals at an appropriate stocking rate and an adequate date and pattern of calving (Bryant, 1984).

The seasonal pasture growth does not provide a uniform feed supply throughout the year and therefore creates the need to fit cattle feed requirements to the pasture growth pattern in order to minimise the use of supplementary feeding (Figure 1).

Figure I–1. Average pasture dry matter (DM) and metabolisable energy (ME) production for No. 2 dairy at Dairy Research Corporation (Hamilton, New Zealand) and the feed requirements for a spring-calving herd stocked at 3.0 Friesian cows/ha and fully fed from peak to end of season.



From: Thomson & Holmes (1995).

At a farm level, stocking rate (StR) is probably the single most important factor affecting pasture utilisation, individual animal performance and productivity as a whole. StR can be seen as the major element driving feed demand/ha. However, calving and drying off dates have as well strong effects on farm productivity affecting the timing of feed demand and pasture supply. Due to the variations in feed demand by the cows depending on their physiological state, a change in either calving or drying off date can have major effects on the herd's feed requirements for any particular date in spring or autumn, in addition to the effect of the herd's StR (Holmes & Macmillan, 1982; White, 1987).

Since the primary objective of grazing management in a dairy system based on pasture is to match feed supply and animal requirements through the year using pasture growth in a first instance (Sheath *et. al.*, 1987), the first managerial strategy is to synchronise feed demand and feed supply. Since pasture growth pattern is governed by the environment, the only way to synchronise the system is by choosing an appropriate calving date which will drive the timing of the herd's feed demand. The highest feed requirements occur after calving when, besides the maintenance cost, cows have to be fed to produce milk. Conversely, dry cows have the lowest feed requirements (Holmes & Macmillan, 1982). By considering these facts, it is obvious to have the cows calved just before the spring flush of pasture growth and have the cows dry when pasture growth is slowest (García & Holmes, 1999). This situation leads to the basis for a seasonal calving pattern (Holmes *et. al.*, 1987).

Importance of Reproduction within the Productivity of a System

Calving date (CD) and compactness of calving have thus large influences on farm productivity and profitability. The selection of CD is one of the most powerful tools available to the dairy farmer in order to provide pasture of adequate quality and quantity to the cow during lactation (Crosse *et. al.*, 1994). 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. Ideally, calving should be completed by the time the seasonal flush in pasture growth has commenced in order to meet this peak in demand by the herd (Macmillan *et. al.*, 1984). The drying off date of the cows is decided on the basis of pasture availability and therefore usually involves most of the herd. Therefore, late calving cows in these systems usually have shorter lactations and produce less milk (Macmillan *et. al.*, 1984; Brightling *et. al.*, 1990). Furthermore, these late calvers are less likely to become pregnant at the desired time and hence they may be withdrawn from the herd (Brightling *et. al.*, 1990). Thus, CD and calving pattern (compactness of calving) have a strong influence on farm productivity and profitability by matching of feed supply and demand. The financial effect of these two variables is influenced by the yield level of the herd, the price received for the farm output and the prices paid for the inputs used (Crosse *et. al.*, 1994).

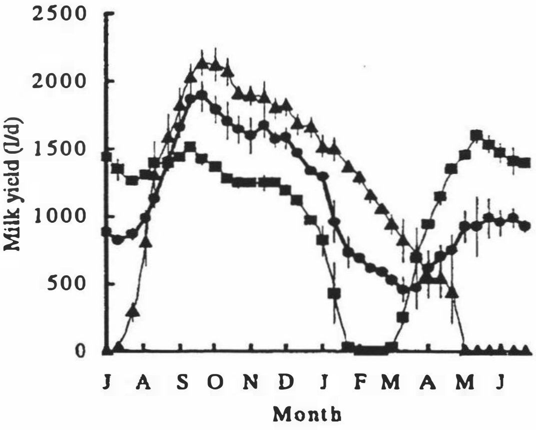
The choice of CD involves a prediction about pasture growth rate in the future (Holmes & Macmillan, 1982; Dillon & Crosse, 1992) whereas the decision about drying off can be based on the actual situation at the time. Calving too early will exceed the daily growth rate of pasture to the extent that the cows may be underfed in early lactation with the associated impaired reproductive performance and decreased milk production, unless pasture is supplemented. If, on the other hand, calving is too late, the cows can be well fed in early lactation but their milk production might be reduced through the grazing of pastures with lower quality and the duration of their lactation may be reduced as well (Holmes & Macmillan, 1982).

From survey data in Waikato herds, Macmillan et. al. (1984) highlighted that on within a herd basis, each extra day increase in lactation length as a consequence of calving one day earlier increased production by almost 0.7 kg m.fat/cow and Bryant & MacDonald (1983) pointed out an increase of 0.59 ± 0.34 kg m.fat/cow and 2.96 ± 1.39 kg m.fat/ha for each extra day in milk prior to 31 December. In this way, increasing lactation length by concentrating the calving pattern or having an earlier planned start of calving can increase production per cow if these changes do not create a prolonged feed shortage in early lactation (Macmillan, 1985).

The milk supply pattern to the dairy industry is also influenced by the calving pattern on dairy farms (Macmillan *et. al.*, 1990; Crosse *et. al.*, 1994). This in turn has an influence in the utilisation of the industry facilities, on the product mix which can be manufactured and ultimately on the milk price paid to the dairy farmer (Crosse *et. al.*, 1994; García & Holmes, 1999).

In the following figure (Figure 2) the milk production profile of three herds calving in early spring, in autumn and with a split calving (50 % of the herd calving in spring and the other 50 % calving in autumn) is shown.

Figure I–2. Average of daily milk supply for a 100 % autumn-calving (■), a 100 % spring-calving (▲), and a split calving (●) (50 % of the herd calving in spring and the other 50 % calving in autumn) system over 3 years.

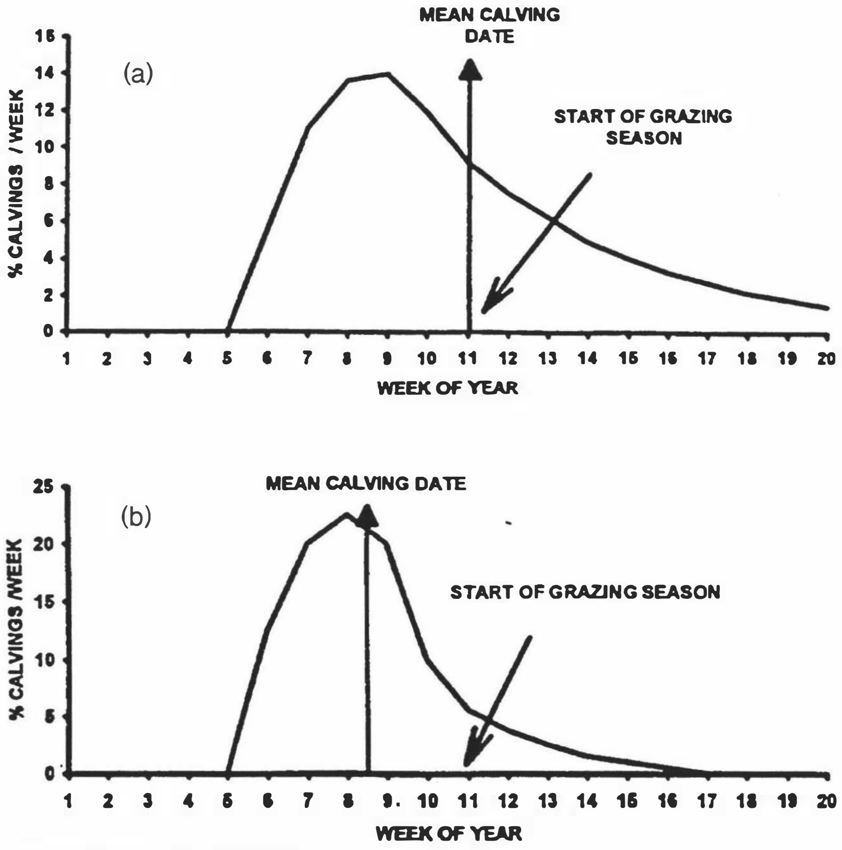


From: García *et. al.* (2000).

As can be observed, CD has a large influence on the seasonality of milk production, and therefore the feed required during lactation will vary throughout the year (e.g. the use of supplementary feeding will be much higher in an autumn calving herd). This will then affect the yield and quality of the milk produced as well as the cost of milk production (Crosse *et. al.*, 1994; García & Holmes, 1999).

The following figure shows a bad (Figure 3a) and a good (Figure 3b) calving pattern.

Figure I–3. Calving patterns.



From: Crosse *et. al.* (1994).

In Figure 3a the mean calving date is in week 11 by which time only 65 % of the herd has calved. This coincides (in Ireland) with the start of the grazing season. This relatively scattered calving pattern will result in inefficient utilisation of pasture. Conversely, in Figure 3b there is a much more compact calving pattern with 90 % of the herd calving before turnout date, and therefore the utilisation of pasture is likely to be more efficient in this latter situation (Crosse *et. al.*, 1994).

From the above explanation the importance can be appreciated of having a consistent feed demand pattern year by year in order to be compatible with the available pasture supply. To achieve this synchrony, it is crucial to attain an adequate reproductive performance that allow to have a calving interval of “365 days” and a compact calving pattern (Crosse *et. al.*, 1994; Grosshans *et. al.*, 1997). Herd reproductive performance can affect the system not only directly by increasing health costs and culling rate and decreasing selection intensity, but also indirectly by altering the calving pattern of the herd which in turn will be reflected in the productivity of the farm (Hodel *et. al.*, 1995).

Considering the primordial role that the herd's reproductive performance has within the productivity and profitability of the system, it is important to look at the main factors that influence this reproductive performance.

Reproductive Efficiency

Reproductive efficiency can be described as a measure of the ability of a cow to become pregnant and produce viable offspring. Infertility or sub-fertility are varying degrees of aberration from typical levels of reproductive performance (Peters & Ball, 1987).

In the system where the main constraint is the synchrony of events, timing becomes of extreme importance. In this way, to achieve a calving interval of 365 days and taking into account the normal gestation length (282 days) (Macmillan & Curnow, 1976), the calving to conception interval should not exceed 83 days. The duration of the calving to conception interval depends on the re-establishment of ovarian activity after calving, the occurrence and detection of oestrus, the planned start of mating date, the ability to conceive and maintain pregnancy after a given service and the continuation of ovarian cycles and the correct detection of oestrus in those cows which do not conceive to initial services. All of these factors, except the planned start of mating, depend on a combination of genotypic and environmental factors affecting the cows (Peters & Ball, 1987; Xu & Burton, 1996; Opsomer *et. al.*, 1996; Smith & Wallace, 1998).

Nevertheless, even under ideal conditions, conception rates will fail to reach 100 %. At best, only 60-70 % of inseminations in cows result in a calf being born, with a large majority of failures occurring before the second trimester of pregnancy. This is due in part to conception failure and in part to embryonic or foetal death. However, fertilisation rates appear to be higher than 90 % and therefore there is a high proportion of failures due to foetal or embryonic death (Peters & Ball, 1987). Zavy (1994) stated that embryonic mortality in cattle is the major source of economic loss for livestock producers since its magnitude can be in the order of 30 to 40 %.

Macmillan (1985) summarised the objectives of a breeding programme in a seasonally calving dairy herd:

1. Producing a calving pattern which allows seasonal differences in pasture growth to be closely synchronised with herd requirements,
2. Producing sufficient heifer calves to maintain herd numbers, to replace poorer producing cows and to achieve constant genetic progress, and
3. Minimising the proportion of cows in the herd which fail to conceive during the programme.

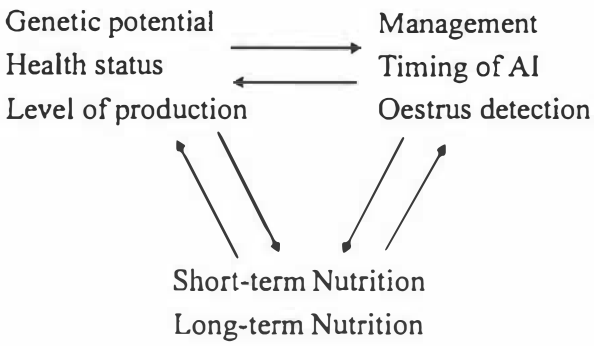
Compact calving in the dairy herd is then dependent upon high submission rates and high pregnancy rates to a single service (Ryan & Mee, 1994). However, the occurrence of these high rates is dependent on a number of combined factors.

Factors affecting reproductive performance.

The heritability of female fertility is generally low, 0.01 to 0.12 (Hoekstra *et. al.*, 1994; Marti & Funk, 1994; Grosshans *et. al.*, 1997), and most of the variation in fertility is due to environmental factors and non-additive genetic variation. The most important environmental elements appear to be nutrition (level of feeding), artificial insemination (AI) unit, technician, age, herd, year and season (Janson, 1980; Silva *et. al.*, 1992; Hayes, 1998). Level of feeding and nutrition appear to be the major factors having an influence on reproductive performance in the New Zealand dairy systems (McDougall, 1993).

The reproductive performance of a herd is hence determined by the interaction between factors such as management, environment and cow physiology, as illustrated in Figure 4.

Figure I–4. Interactions between animal, management and nutritional factors affecting fertility in dairy cows.



From: Garnsworthy & Webb (1999).

After calving, a cow must initiate oestrus cycling to begin her next period of reproductive activity. The resumption of ovarian activity is mainly determined by the time since calving. As each day passes, the likelihood of this onset occurring is influenced by the cow's age, her pre-calving nutritional status (body condition at calving), her post-calving nutrition and the health of her reproductive tract (Brightling *et. al.*, 1990).

Once calved, the reproductive tract of the cow undergoes a recovery period during which the uterus reduces in size, and its endometrium is re-established (involution) (Brightling, 1985; Opsomer *et. al.*, 1996). This process is usually completed within 30 days but may be delayed by events such as calving difficulty, birth of twins, retained foetal membranes or uterine infection (Brightling, 1985). Moller (1970) reported an average involution duration of 32 days for New Zealand cows. He estimated that first postpartum ovulation occurred 42 days after calving on average, with adult cows resuming ovarian activity earlier (36 days) than 2 and 3-year-old cows (52 days). Opsomer *et. al.* (1996) pointed out that under normal circumstances, the first postpartum ovulation occurs between 15 and 21 days after calving. However, they indicated that a wide range of factors can influence resumption of ovarian activity after calving: milk production, energy balance (EB), metabolic diseases, season of calving, age, type of housing, breed, and the course of parturition and puerperium. Brightling (1985) indicated that in pastoral systems the most important factor influencing the length of the calving to first oestrus interval is the nutritional status of the cow before and after calving.

Management factors

The main management factors affecting reproduction are heat detection efficiency, time of service, interval from calving to first service (voluntary wait) and nutrition. Out of those factors, heat detection is the single most important element in achieving good reproductive performance when using artificial insemination (AI) (Ryan & Mee, 1994)

Heat detection.

The single most important factor which influences a herd's conception pattern is the efficiency of oestrus detection (Macmillan, 1985).

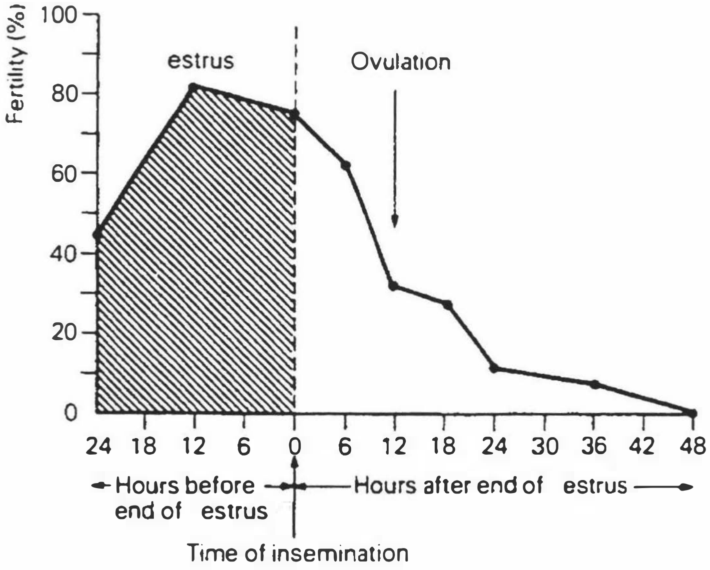
Basically there are two ways in which deficiency to detect heats can incur: failure to submit cows on heat for insemination, and inseminating cows not on heat (Holmes *et. al.*, 1987; Brightling *et. al.*, 1990; Xu & Burton, 1996). Missed heats lead to delayed conception pattern, and mating cows not on heat will reduce conception rate but may not affect conception pattern greatly (Brightling *et. al.*, 1990; Xu & Burton, 1996).

Seasonal calving patterns favour greater sensitivity of heat detection, because the larger number of cows in oestrus simultaneously allows greater behavioural interaction (Macmillan *et. al.*, 1996). However, knowing that the average duration of heat is less than 10 hours and up to 15 % of heats may be shorter than 2 hours in duration, several techniques have been tried to improve heat detection. Some of these aid techniques are: tail painting, pedometers, measurement of intravaginal electrical impedance and milk temperature (Ryan & Mee, 1994). In seasonal dairy systems with a concentrated calving and breeding period, tail painting has proven to be the greatest aid in heat detection (Macmillan & Curnow, 1977). Up to 90 % of heat detection is reported with the use of tail painting and thrice daily observations (O'Farrel, 1992 cited by Ryan & Mee, 1994).

Insemination time.

When making use of artificial insemination (AI), factors such as operator skill, time of AI, handling facilities and semen storage are important factors affecting the outcome achieved in a breeding season. Conception is dependent upon insemination occurring at the correct time (Hunter, 1994; Wiltbank, 1998). Diskin (1996) reported that conception rates are highest when cows are inseminated 12 to 18 hours after observed heat onset. Thus, cows detected in heat in the morning should be served in the afternoon and those in heat in the afternoon should be served the following morning (Ryan & Mee, 1994). Late (after ovulation) or early (beginning of oestrus) inseminations are linked to lower fertility due to post-ovulatory ageing of the egg before its contact by a spermatozoon in the first case, or because of spermatozoon ageing in the latter situation (Figure 5) (Hunter, 1994).

Figure I–5. The influence of the time of insemination on conception rate in cattle. The optimum time of insemination for maximum fertility is some 12 to 18 h before ovulation.



From: Hunter (1994).

Interval from calving to first service (voluntary wait).

One of the most critical periods influencing reproductive performance is the post-partum period. As a general rule, pregnancy rates to a single service increase by approximately 1 % per day until cows are calved about 50 to 60 days, and thereafter pregnancy rate remains constant (Ryan & Mee, 1994). Brightling *et al.* (1990) pointed out that if more than 10 % of the herd have calved less than 40 days before the PSM, average conception rate of the herd may be compromised.

Nonetheless, in an attempt to maintain a compact calving season in seasonal systems (restricted mating season), cows are frequently mated less than 40 days post-calving with the likely occurrence of low pregnancy rates due to an incompletely involuted uterus (Ryan & Mee, 1994; Hunter, 1994). Ferguson (1991 cited by Macmillan *et. al.*, 1996) pointed out that the chances of conception under these circumstances may be only 30 %. However, these services do not compromise pregnancy rate to subsequent inseminations (Ryan & Mee, 1994).

Macmillan & Clayton (1980) observed that the CFS interval and the occurrence or absence of pre-mating heats both influenced pregnancy rates to first service (Table 1). They indicated that from 40 days onwards, CFS interval did not significantly influence pregnancy rates.

Table I–1. Average pregnancy rate (%) to first service after varied intervals from calving to first service (CFS) and occurrence or absence of pre-mating heats.

No. of pre-mating heats	Interval from calving to first service (days) < 30	30 – 3	> 39	Total
0	32	42	59	44
1	39	49	65	51
>1	40	51	67	53

Modified from Macmillan & Clayton (1980).

Fulkerson (1984) also observed a significant linear increase in non-return rates from 46 to 86 % as the calving to first service interval increase. Similarly, in a more recent study Drew (1999) showed an improvement in pregnancy rate as the calving to first interval increased from less than 30 days up to 70 days. After this point he did not observe any improvement (Table 3).

Table I–2. Effect of the interval from calving to first service on pregnancy rates in high yielding cows (> 8000 litres/lactation).

Interval (days)	Pregnancy rate (%)
< 30	18
31 – 40	36
41 – 50	45
51 – 60	56
61 – 70	63
71 – 80	58
81 – 90	58
91 – 100	57

From: Drew (1999).

Nutritional factors

Ferguson (1996 cited by Wiltbank, 1998) indicated that nutritional causes of low fertility are more likely to be due, firstly to energy management, secondly to excess protein feeding, and thirdly to trace element and vitamin deficiencies. Therefore, the major nutritional influences on cattle are the energy and protein input and output relationships (Lean *et. al*., 1998). In fact, the effects of many nutrient deficits on conception are largely mediated through changes in energy balance (Macmillan *et. al*., 1996).

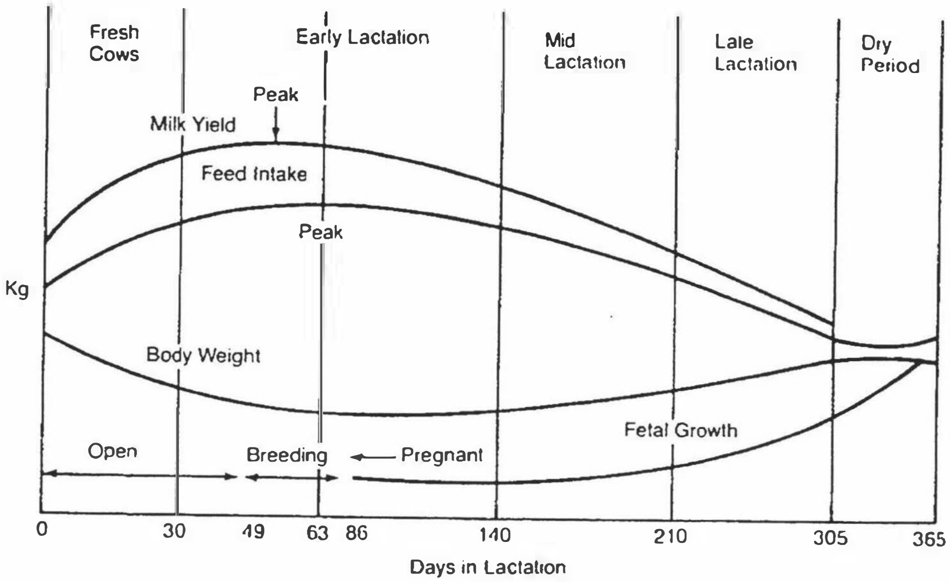
Dairy cows in New Zealand are often subjected to periods of undernutrition occurring around calving and during early lactation, when energy demand for maintenance and milk production exceed energy supply before the flush of spring pasture growth occurs. This results in a period of negative energy balance (NEB) that can have detrimental effects on cow condition and therefore on reproductive and productive performance (Clark et. al., 2000).

ENERGY BALANCE

Energy balance is the difference in net energy consumed minus the net energy required for maintenance and production (Butler & Smith, 1989).

Net energy balance reflects the loss of body tissue in the periparturient period and the capacity to milk, energy intake and the effects of diet on nutrient partitioning (Lean *et. al*., 1998). The insufficient intake of energy to meet current milk output results in a negative energy balance (Butler & Smith, 1989; Lucy *et. al*., 1992; Macmillan *et. al*., 1996; O'Callaghan & Boland, 1999) and cows mobilise body fat reserves in support of lactation (Webb *et. al*., 1999). Most of the variation in energy balance during early lactation is associated with energy intake (r = 0.73) rather than milk yield (r = -0.25) (Villa-Godoy *et. al*., 1988; Lucy *et. al*., 1992). The magnitude of the NEB is perhaps less important than the change from increasing to reducing NEB (Canfield & Butler, 1990). Figure 6 illustrates the relationship between changes in milk yield, dry matter intake, and body weight (Weaver, 1987).

Figure I–6. Relative changes in milk yield, feed intake, and body weight during the lactation cycle.



From: Weaver (1987).

NEB reaches its maximum during the first two weeks postpartum and recovers at a variable rate (Butler & Smith, 1989). However, it can be prolonged up to the mating time or shortly before (O'Callaghan & Boland, 1999). NEB is directly related to the postpartum anoestrus interval (Butler & Smith, 1989).

It has been suggested that energy deficits act to decrease LH pulse frequency (Villa-Godoy *et. al*., 1988; Richards *et al*., 1991 cited by Roche & Diskin, 1995) and energy balance is also positively correlated with the number of large follicles (Lucy *et. al*., 1992). A lack of ovarian response has also been proposed as occurring in cows which are restricted in feed intake (Williamson & Fernandez-Baca, 1992). Fonseca *et. al*. (1983) also found an association between progesterone concentration and energy balance. They reported that Jersey cows gaining weight were more likely to have higher progesterone concentrations and they suggested that higher progesterone concentrations in the cycle preceding insemination increased the probability of conception.

Dairy cows in early lactation represent a situation of undernutrition due to high milk yields coupled with inadequate feed intake and the consequent NEB. NEB appears to interfere with the ability of the hypothalamo-hypophyseal axis to develop the pulsatile LH pattern necessary for fostering ovarian follicular development and ovulation (Butler & Smith, 1989; Canfield & Butler, 1990).

Lean *et. al.* (1998) list a series of possible causes for the occurrence of NEB in dairy cows:

- sufficient availability of feed but reduced appetite (e.g. sickness),
- feed restriction due to competition while grazing or at the feed bunk, which can result in low milk production and increased body tissue loss, and
- extreme drive to milk (very high producing cows or use of bovine somatotropin) without the potential for increased energy intake.

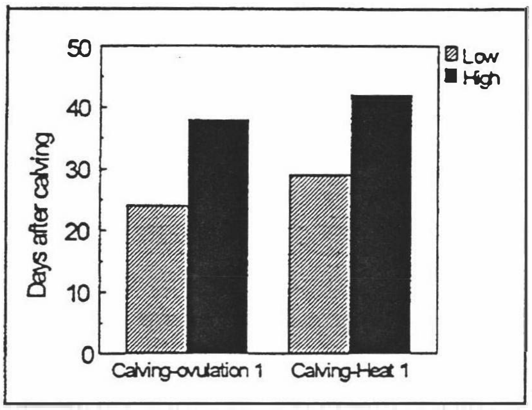
Thence, the severity of the NEB is a function of genetic potential for producing milk, voluntary food intake and diet quality (O'Callaghan & Boland, 1999). The NEB in early lactation determines the timing of resumption of ovulatory ovarian cycles. In turn, the timing of first ovulation determines and limits the number of oestrus cycles which will occur before the recommended period of insemination (Butler & Smith, 1989).

Staples *et. al.* (1990) showed that cows cycling after 60 days postpartum ate less feed, produced less milk, and lost more body weight, resulting in a more negative energy status, than cows cycling between 40 – 60 days postpartum or before 40 days postpartum. The former two groups obtained more energy from body reserves (28 & 16.7 %) for milk production the first 2 weeks of lactation than cows in the latter group (15.9 %). Similarly, Ducker *et. al.* (1985) showed that heifers gaining most weight and increasing in BCS fastest in late pregnancy, which resulted in a higher BCS in the first five weeks of lactation, ovulated earlier after calving. Likewise, heifers in better BCS in weeks 1 to 11 of lactation exhibited oestrus sooner.

In pastoral dairy systems, level of feeding is closely linked to the stocking rate adopted in any farm and the concomitant use of supplements.

McDougall, (1993) compared the effects of two different stocking rates (low and high) on the reproductive performance of Jersey and Friesian cows. He reported that cows in the high stocked herds ovulated and display oestrus later than cows in the low stocked herds (Figure 7). At the same time the high StR herds had a greater prevalence of ovulations which were not accompanied by a detected oestrus and lower submission rate at three weeks.

Figure I–7. Effect of stocking rate (low; n = 48 or high; n = 62) on the average interval from calving to first ovulation (days) and calving to first oestrus (days).

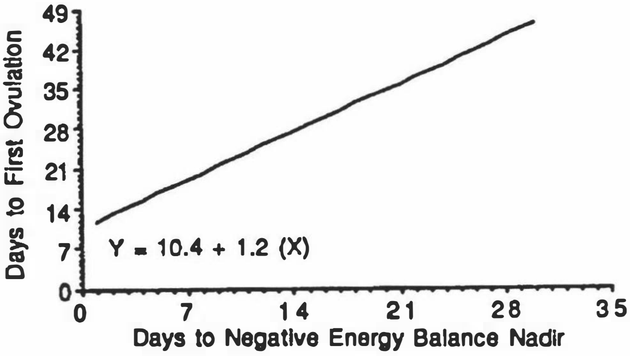


From: McDougall (1993) .

The adverse effects of high StR on reproductive performance can be due to social effects but the main driving factor seems to be a reduction in feed intake and drop in BCS by the cows especially pre-calving (NEB). This was demonstrated by McDougall (1993) in a study where 40 days after calving, 73 % of the high condition score group (HCS) had ovulated whereas only 27 % of the low condition score group (LCS) had. At the same time, the calving to ovulation interval was shorter in the HCS (27 days) than the LCS group (42.4 days). In this way, feed restriction in the last 6 weeks before calving can increase the anoestrus interval by more than 50 %. It was estimated that for each unit decrease in BCS at calving, the interval from calving to first oestrus is increased by eight days. On the other hand, loss of one unit BCS after calving only increased the anoestrus interval by four days suggesting that the loss of BCS appears to be more important before calving (Moller *et. al.*, 1993).

In New Zealand the major effect of a NEB in early lactation is reflected in the proportion of anoestrus cows before PSM. Excessive post partum body condition loss has been associated with an increase in the interval to first post partum ovulation (Butler & Smith, 1989; Lucy *et· al.*, 1992; McGowan *et. al.*, 1996) and a significant decrease in first service conception rate (Ducker *et. al.*, 1985; Butler & Smith, 1989; Roche & Diskin, 1995). Hodges (1977 cited by Lean *et· al.*, 1998) found that for each 0.1 kg of body weight gain per day which a cow achieved above average, her calving to conception interval was reduced by 31 days. Butler *et al.* (1981 cited by Roche & Diskin, 1995) recorded a 2.75 day increase in the interval to first ovulation for every one Mcal of energy deficit experienced during the first 20 days of the postpartum period. In this manner the commencement of postpartum oestrus cycles is closely linked to the time when the postpartum nadir in NEB occurs (see Figure 8) (Villa-Godoy *et. al.*, 1988; Canfield & Butler, 1990; Britt, 1992).

Figure I–8. Relationship between energy balance and first postpartum ovulation.



From: Canfield & Butler (1990).

Although cows in early lactation are expected to be in a NEB, those with the greatest loss of condition have usually the lowest pregnancy rates (Butler & Smith, 1989; Sheldon, 1997; Wiltbank, 1998). Cows that experienced a BCS loss of < 0.5 units during the first five weeks postpartum had a conception rate to first service (CR1st) of 65 % compared with CR1st of 53 % and 17 % for cows that lost 0.5 to 1.0 or > 1.0 units of BCS (Butler & Smith, 1989). Similarly, Ferguson (1994) and Wiltbank (1998) pointed out that pregnancy rate per service decreased as body condition loss from calving to AI increased (Table 3).

Table I–3. Effect of change in body condition from calving to artificial insemination on pregnancy rate per AI.

	Body condition change					
	0.51 to 1.0	0.01 to 0.5	0	-0.01 to -0.5	-0.51 to -1.0	> -1.0
Pregnancy rate per AI	56 %	50 %	46 %	43 %	37 %	29 %

From Wiltbank (1998).

Britt (1994), reanalysing raw data from Fonseca *et. al.* (1983), also observed that cows losing condition during the first 5 weeks postpartum commenced oestrus cycles about 6 days later than those that maintained condition. He also observed that cows maintaining condition had a higher CR1st (62 %) than cows losing condition (25 %) (61 % and 42 % for all services respectively). However, Britt (1992) pointed out that since cows losing higher amounts of BCS soon after calving have cumulative pregnancy rates that are similar to cows losing little condition, the infertility associated with body tissue loss seems to be temporary.

There is also evidence that the magnitude of weight changes occurring at the mating time may have a significant impact on conception rates. Youdan & King (1977 cited by Lean *et. al.*, 1998) found higher conception rates for cows gaining weight in the 14 days before mating than those losing weight in the same period.

CRUDE PROTEIN AND UREA

As explained above, nutrient deficiencies (energy) are logically linked to impaired reproductive performance, however, there are situations where excess of nutrients may also affect reproduction. Such is the case of crude protein.

High levels of dietary protein or urea either in milk or blood have been associated with poor reproductive performance, specially reduced conception rates, in a number of studies (Jordan & Swanson, 1979; Ferguson *et. al.*, 1988; Williamson & Fernandez-Baca, 1992; Moller *et. al.*, 1993; Elrod & Butler, 1993). The effects of protein on fertility are variable between studies, but are more related to the protein concentration of the diet and its degradability (Ferguson & Chalupa, 1989; Ryan & Mee, 1994). Excess rumen degradable protein (RDP) may depress conception by affecting the uterine environment (Elrod & Butler, 1993), sperm transport, serum progesterone concentrations (Jordan & Swanson, 1979), perturbing the hypothalamic-pituitary-ovarian axis and potentially through energetic costs involved in detoxification of ammonia (Macmillan *et. al.*, 1996; Lean *et· al.*, 1998). It has been shown that excess RDP increases serum and milk urea nitrogen concentrations, and cows having serum urea nitrogen (SUN) concentrations equal or above 3.2 mmol/L (Ferguson *et. al.*, 1993; Butler et. al., 1996) or milk urea (MU) equal or higher to 5.0 mmol/L (Gustafsson & Carlsson, 1993) are most at risk of reproductive failure.

Protein intake may affect reproduction via direct effects on the uterine environment where toxic byproducts of nitrogen metabolism, including ammonia from the rumen may impair sperm, ova, or early embryo survival. Alternatively, imbalances in the relative availability of protein and energy may affect efficiency of metabolism and energy status. This situation is particularly acute on lush pastures when nitrogen content is at maximum, dry matter is relatively low and milk yield is high, resulting also in suboptimal energy intakes (Sreenan & Diskin, 1992; O'Callaghan & Boland, 1999). The efficient utilisation of urea depends on the presence of energy to support high levels of protein synthesis. Protein is wasted as it cannot be fully utilised by rumen microbes which lack sufficient energy. Energy is also used in the process of excretion of the protein, thus further exacerbating the energy deficiency (O'Callaghan & Boland, 1999). The interval from calving to first ovulation, first oestrus or first service after calving appears to be influenced less by dietary protein intake than conception rates and calving to conception intervals (Gustafsson & Carlsson, 1993). It has also been suggested that diets with high levels of protein may alter plasma aminoacid profiles reducing feed intake and therefore lowering energy balance (Lean *et. al.*, 1998; Butler, 1998).

Westwood *et. al.* (1998) carried out a meta-analysis of data from several published studies relating dietary protein concentration and reproduction. In general terms they found that as protein content of the diet was increased, there was a significant decrease in conception rates. They suggested that the discrepant results reported in the literature may arise because of inconsistencies between studies, particularly in variations in the protein and energy content of feeds used, which will greatly influence the microbial protein yields, and the escape of proteins and other metabolites from the rumen.

Nevertheless, there is always a major difficulty in interpreting possible effects of nutrition on reproduction because of diet variation, BCS variation and the interrelation existing between nutrients. Sreenan *et. al.* (1999) highlighted the complex relationship between nutrition and conception rate, indicating that nutrition effects are modified by BCS at calving and at mating, by the rate and extent of body reserves mobilisation in early lactation, by early lactation yield and milk yield at the time of AI and by milk composition, with the interval from calving to first service as a confounding factor.

Milk yield and Genetic factors

Although a high genetic merit Holstein cow may lose 10 % of calving body weight during the first three weeks of lactation, and increase its feed intake considerably, it will still be in a significant negative energy balance for at least its first five or ten weeks of lactation (Macmillan *et. al.*, 1996).

Higher producing cows partition ingested energy and mobilise body reserves to meet the demands of an increasing rate of milk production. Furthermore, because daily milk yield increases after calving more rapidly than the cow's appetite, there is a rapid mobilisation of body fat (loss of body condition) which may further depress appetite and increase the difference between energy intake and output. This situation positions the cow in a significant negative energy balance (Harrison *et al.*, 1990 cited by Macmillan *et. al.*, 1996). All of these events contribute to reduced fertility in some high producing herds of high genetic merit cows (Macmillan *et. al.*, 1996), as illustrated by Drew (1999) in Table 4 and by Wiltbank (1998) in Table 5.

Table I–4. Fertility parameters for high (over 8000 litres/lactation) and low (less than 6000 litres/lactation) yielding herds

	High yielding herds	Low yielding herds
Pregnancy rate to first AI (%)	45	53
Days open	101	94
Foetal loss (%)	8	4.3

From: Drew (1999).

The negative association between milk yield and reproduction has been observed mainly in American Holstein cows. In these cows there is a difference in pregnancy rates for cows and heifers (45 *vs* 70 % respectively) suggesting that the American Holstein is inherently fertile but has its reproductive performance significantly compromised by comparative high levels of milk production in early lactation (Macmillan *et. al.*, 1996; Wiltbank, 1998) (Table 5); although the exact mechanism causing this decrease is not clear, this assumption also seems to be supported as well by the work of Faust *et. al.* (1988), who showed that impaired reproductive performance was associated with the cow's milk production rather than with the genetic merit.

Table I–5. Fertility in dairy cattle from the start of artificial insemination (AI) use until the present time.

	Pregnancy rate per AI		Milk production
Year	Lactating cows	Heifers	(lb/ lactation)
1955	60 %	66 %	~ 5,000
1975	50 %	65 %	~ 11,000
1995	40 %	70 %	~ 20,000

From: Wiltbank (1998).

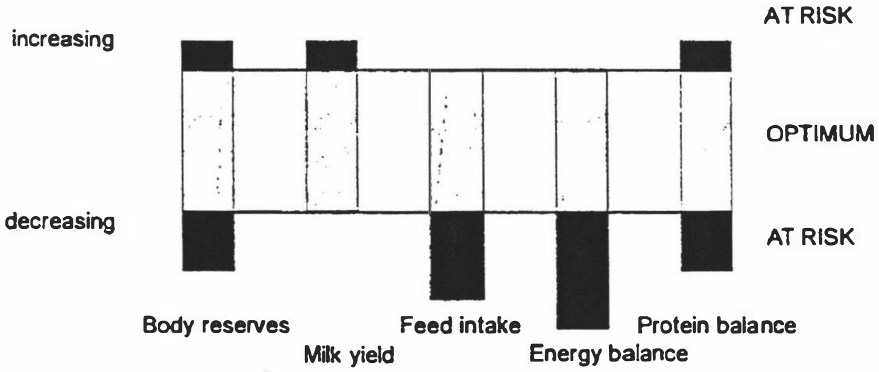
In spite of the above observations made in regard to the negative effects of high milk yield on reproductive performance, it seems that reproductive performance is more prone to be compromised in low producing cows within a herd than cows with high yields (Macmillan *et. al.*, 1996). The former cows may be less successful competitors for the available feed and therefore have lower intakes as well as lower milk yields. Besides, cows which rely more on body tissue mobilisation to meet their nutritional requirements rather than on increasing food intake, as occurs with high genetic merit cows, will have a more severe NEB (Villa-Godoy *et. al.*, 1988; Butler & Smith, 1989; Staples *et. al.*, 1990; Lucy *et. al.*, 1992) and will therefore be at greater risk of reproductive failure (Lean *et. al.*, 1998).

A similar situation occurs with Holstein heifers in New Zealand and southern Australia, where these cows are at most risk of anovulatory anoestrus since they represent the cows with less access to feed in the highly competitive pasture feeding system (Burke *et al.*, 1995; McDougall, 1992 both cited by Macmillan *et. al.*, 1996). In these kind of systems, cows with the greatest NEB may be those with high genetic merit and least access to feed because of lack of social dominance and may not be the highest producing cows in the herd (Macmillan *et. al.*, 1996).

Thus, it seems that the negative association seen between high milk yields and reproduction is most likely to be due to the effects of the higher and longer sustained NEB that high yielding cows are subjected to realise their milk potential, rather than to milk yield itself (Diskin, 1996).

Furthermore, Garnsworthy & Webb (1999) pointed out that poor fertility is not an inevitable consequence of high genetic merit, but may be due to a combination of factors that include genetic susceptibility, management, disease, milk yield, energy balance, body reserves and specific nutritional circumstances. They added that since many factors influence reproductive performance, it is very difficult to predict individual cow fertility. However, it is possible to identify certain risk factors that may predispose cows to infertility (Figure 9).

Figure I–9. Possible risks factors causing infertility in dairy cows.



From: Garnsworthy & Webb (1999).

Health

Cow factors affecting reproductive performance include calving difficulty (dystocia), uterine infection, intercurrent disease and hormonal problems. Stillbirths are associated with a higher incidence of retained placenta, which reduces fertility. With moderate calving difficulty pregnancy rates can be reduced by 5 – 15 %, with severe calving difficulty the reduction in pregnancy rate is in the range of 25 – 45 % (Ryan & Mee, 1994).

Thompson *et. al*. (1983) and Drew (1999) indicated that calving difficulty, milk fever and retained foetal membranes tended to occur as a complex an they can reduce fertility. Similarly, Labernia *et. al*. (1998) observed that cows experiencing retained placenta were 2.4 times more likely to be repeat breeders. Retained placenta also increased the likelihood of ovarian cysts and metritis (odds ratios = 2.1 and 2.2, respectively). At the same time, older cows were at higher risk of retained placenta. Fonseca *et. al*. (1983) also showed that Holstein cows with abnormalities after calving (dystocia, retained placenta, death of calf, twins, milk fever) had 8.8 ± 3.0 more days from calving to first ovulation than normal cows. Nakao *et. al*. (1998) also observed that cows experiencing metabolic or reproductive disorders had a delayed uterine involution.

Similarly, Suriyasathaporn *et. al*. (1998) showed that mastitis within 45 days postpartum and genital infection had negative associations with the probability of submission to first service. Also, mastitis, lameness and milk fever that occur during the first 45 days postpartum, and genital infection that occurred between calving and conception, were negatively associated with the rate of conception.

Lameness can affect between 5 – 30 % of the herd annually. If this illness occurs during the mating period, fertility will be reduced. Lame cows exhibit poor oestrus signs since they are reluctant to stand to allow mounting by other cows (Ryan & Mee, 1994; Peeler *et. al*., 1994). Peeler *et. al*. (1994) also added that if lame cows are separated from the rest of the herd, they have less opportunity to express oestrus. Additionally, they suggested that the cow's ability to compete for food may be impaired by lameness, which could lead to anoestrus. Alternatively, high cortisol levels, resulting from pain-induced stress in lame cows, might inhibit the release of LH and consequently affecting the reproductive function.

Lee *et. al.* (1989) reported that retained placenta, non-systemic metritis, systemic metritis, ovarian cysts and lameness were all negatively associated to the probability of conception and positively with the interval from calving to conception. Similarly, Peeler *et. al.* (1994) showed that twinning, vulval discharge and lameness before mating were negatively associated with oestrus observation.

Cow age also has a significant influence on CR1st and to all services combined. When heifers calve as two-year-olds their post-calving conception rates are lower than in mature cows. This is because of the increased demands on the former animals at parturition to support maintenance, lactation, growth and reproduction. Similarly, old cows nearing the end of their productive life tend to have a lower level of fertility due to their higher incidence of health disorders (Hodel *et. al.*, 1995; Diskin, 1996). Although fertility of cows is considered to decrease with age, in pastoral systems heifers may suffer longer periods of postpartum anoestrus and lower CR1st. This is often due to a combination of nutritional and social stress for young animals entering the herd (Brightling, 1985).

Season.

In New Zealand, Australia and Europe, a better reproductive performance is generally reported in spring-calving cows compared to autumn-calving cows (Shrestha, 1978; Janson, 1980; Fulkerson, 1984; Fulkerson & Dickens, 1985; Hodel *et. al.*, 1995; Chang'endo, 1996; Ouweltjes *et. al.*, 1996). It is suggested that climate conditions (cold weather) and photoperiod (reduced hours of daylight) can have an adverse effect upon fertility (Peters, 1984; Fulkerson & Dickens, 1985; Wiseman, 1988; Baldwin & Holmes, 1990).

Season combined with the effects of nutrition contributes substantially to variation in the post-partum anoestrus interval. Intervals to first ovulation or first oestrus were longer in spring-calving cows compared with autumn-calving cows (Bulman & Lamming, 1978; Montgomery *et al.*, 1980 cited by Montgomery, 1985). Fonseca *et. al.*, (1983) showed that Holstein cows calving in winter had 6.5 ± 2.9 days more days from calving to first ovulation than cows calving in autumn. Post partum anoestrus intervals are shorter for cows calving in early summer than for cows calving in late winter in a herd grazed on pasture. Angus cows calving early (August-September) took longer to return to oestrus than late calving cows (September-October) despite a high level of feeding (Montgomery, 1985). Montgomery (1985) suggested that lower LH pulse frequency and altered timing of oestrus and the LH/FSH peak may be related to the reduced fertility observed in winter. McNatty *et· al*. (1984) studying the effect of season on ovarian and pituitary activity observed that LH peak frequency was significantly lower in May and June than in October. They also observed that corpus lutea were heavier in May-June compared to October and that plasma progesterone concentrations were also higher in May-June than in October.

Montgomery (1985) indicated that in New Zealand, minimum feed supply in winter occurs at the time of lowest potential reproductive performance. Therefore, the seasonal change in feed supply and reproductive performance combine to reduce fertility and prolong postpartum anoestrus in late winter and early spring .

In regard to the effects of season on health, Erb & Martin (1980 cited by Dohoo *et. al*., 1984) found a higher incidence of dystocia during winter than the other seasons. Whithers (1957 cited by Dohoo *et. al*., 1984), reported a higher rate of milk fever between May and October. Eddy & Scott (1980 cited by Dohoo *et. al*., 1984) reported a peak incidence of lameness during autumn whereas Prentice & Neal (1972 cited by Dohoo *et. al*., 1984) reported peaks in both the spring and autumn.

Gröhn *et· al*. (1990) observed that cows calving during the dark, winter stabling season had higher risks of early metritis (diagnosed within 42 days postpartum), silent heat (anoestrus or suboestrus), and ovarian cysts than those calving during the light season.

Fulkerson & Dickens (1985) suggested that seasonal management practices leading to differences in energy balance could also affect reproduction. Furthermore, Silva *et. al*. (1992), despite pointing out that reproductive performance can be influenced by season (year), indicated that this is mostly due to differences in herd nutrition and body condition scores. Thus, it is important to consider the year to year variation in reproductive performance as a function of climatic conditions and feed availability and quality.

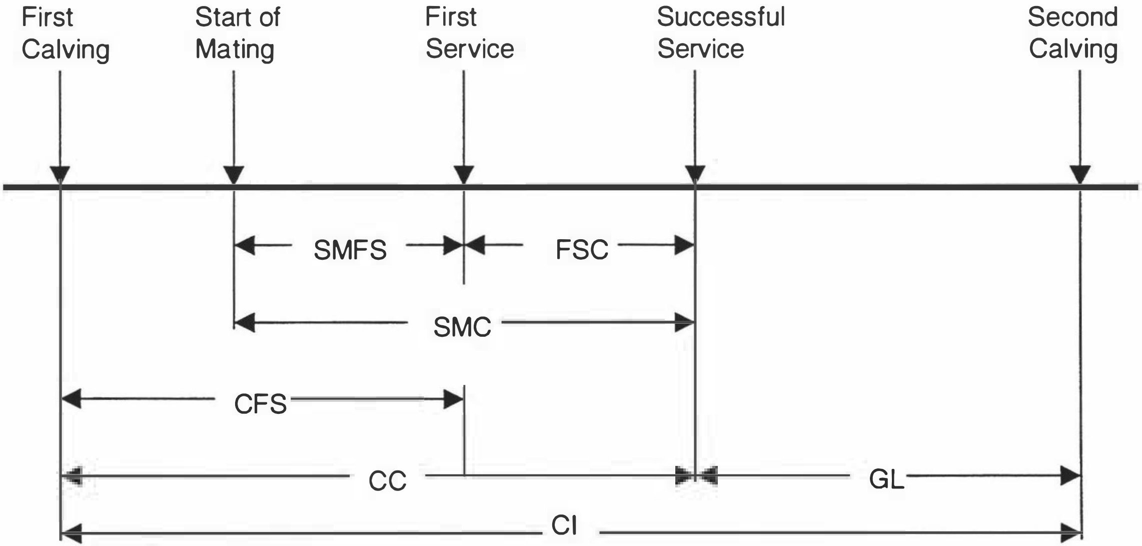
Thus, management, including adequate nutrition, is probably the most important factor determining reproductive performance. Management is responsible for achieving appropriate BCS at calving, to minimise BC loss after calving, to identify and treat anoestrus and reproductive disorders before PSM, to carry out an efficient detection of heats and effective semen handling (Xu & Burton, 1996).

Monitoring reproductive efficiency.

In order to judge if a herd is performing well in terms of reproductive efficiency, it is necessary to have reliable parameters for comparisons with targets or averages (national, regional). Therefore, accurate records of all reproductive and health events and precise measures of performance (e.g. pregnancy test instead of non-return intervals) are both essential (Brightling *et. al.*, 1990; Sreenan & Diskin, 1992; Hayes, 1998).

In order to monitor and evaluate the reproductive efficiency of cows, it is necessary to make use of fertility parameters that describe the reproductive performance of the cows. A large number of indices have been suggested to describe the reproductive performance of dairy herds. However, the most important fertility traits to be considered for seasonal systems are illustrated in figure 10.

Figure I–10. Relevant fertility traits for seasonal dairy systems.



Grosshans *et al.*, 1997.

SMFS: interval from start of mating (SM) to first service; SMC: interval from SM to conception; CFS: interval from calving to first service; FSC: interval from first service to conception; CC: interval from calving to conception (days open); CI: interval between consecutive calvings; GL: gestation length.

In-calf and empty rates are also commonly used in seasonal dairy herds to assess reproductive performance (Hayes, 1998).

Monitoring calving pattern.

Hayes (1998) pointed out that the calving pattern of a herd is the result of the reproductive performance in the previous season (rates of submission and conception principally) (Crosse et. al., 1994), culling strategies, stock purchases, pregnancy loss and inductions.

The calving pattern in a herd does not follow a normal distribution, but a skewed pattern. Due to this, mean calving date does not give enough information about the distribution of calvings. Macmillan (1984) and Crosse *et. al.* (1994) suggested the calculation of intervals from planned start of calving to the median CD and to the end of calving, instead of calculations based on the mean CD. The number of calvings per week over a particular period from the planned start of calving is another good method to evaluate a calving pattern (Crosse *et. al.*, 1994).

In order to assess and compare herds' calving patterns Macmillan *et. al.* (1984) suggested the calculation of the following intervals, once a herd's planned start of calving (PSC) has been established:

- PSC to mid-point; is the interval from PSC to the date by which half the cows in the herd have calved;
- Mid-point to 75 %; is the interval during which the next 25 % of cows calved;
- 75 % to end-of-calving; is the period over which the last 25 % of cows calve, with this latter point being defined as the date from when no cow calved for a period of at least seven days; and
- Total calving period is the interval from PSC to end-of-calving as defined previously.

The latter authors indicated that variation between herds in the previously mentioned intervals can reflect the comparative success of both the first round of AI (PSC to mid-point); and the second round of mating (mid-point to 75 %), as well as the extent and the time of induced calvings (75 % to end-of-calving).

The calving pattern of a herd has a major influence on its subsequent mating performance because it determines the interval between calving to the start of mating.

Due to the relatively poor mating performance of the cows in their first lactation, there is usually a delayed calving (or induction or culling) for cows in their second lactation. After the second lactation there is a gradual improvement in performance until about the 6th lactation where the effect of age and delay calving (Hayes, 1998). McGowan (1981) mentioned that calving pattern can be affected by start of mating period, oestrus detection, conception rate, duration of mating, artificial induction of calving and nutrition (through its effect on postpartum anoestrus interval). However, by using a simulation model, he demonstrated that poor oestrus detection and poor nutrition are the most likely causes of an undesirable calving pattern.

Monitoring mating performance.

PRE-MATING HEATS.

Recording the occurrence of heats four to six weeks before the start of mating can be valuable to reveal those cows which are apparently not cycling normally before mating begins (Holmes *et. al.*, 1987). The more ovulations and consequent oestrus cycles prior to the desired time of breeding results in a greater pregnancy rate assuming other factors are optimal (Ryan & Mee, 1994).

SUBMISSION RATE.

Mating rate or submission rate is usually defined as the number of cows that have been mated at least once during the first four weeks of the mating period, expressed per 100 cows in a herd (Macmillan & Watson, 1973). Good feeding and management should result in a submission rate (SR) of 90 – 95 % in the first four weeks of the breeding period and 100 % by the end of the seventh week (Holmes *et. al.*, 1987). In this way SR is a function of both heat detection efficiency and the proportion of cows cycling (Hayes, 1998).

The SR of a herd gives a picture of the proportion of cows cycling in the herd and those who are possibly anoestrus. By analysing the submission rates it is possible to get an idea about the efficiency on heat detection (Ryan & Mee, 1994; Hayes, 1998). If submission rates are less than 80-90 % then the effectiveness of the method of oestrus detection should be examined. If oestrus detection is adequate a low submission rate would indicate a failure of the cows to come on heat (Hayes, 1998), possible due to the effects of undernutrition or to a very spread calving pattern.

CONCEPTION RATE.

Conception rate is the proportion of the cows becoming pregnant at any given service. It is expressed as a percentage of matings. In New Zealand conception rates (based on non-return oestrus) can range from 55 to 75 % with an average of about 67 % (Holmes *et. al.*, 1987). The rate of conception is affected by the calving pattern, sire and semen fertility, technician, nutrition and the accuracy of heat detection (Hayes, 1998).

Conception rates also vary according to lactation number. The performance of first lactation animals is often lower than for the rest of the herd. Furthermore, conception rates in New Zealand generally increase with each subsequent service, because the interval from calving to mating is increasing and reproductive disorders are not a common problem (Hayes, 1998).

The conception rate (based on non-return oestrus) at three weeks should be greater than 70 % in cows genuinely on heat at the time of mating. On average 70 % of the cows which do not conceive will do so if inseminated a second time at their next oestrus period 21 days after the first insemination. Conception rates at day 49 (based on non-return oestrus) should be between 60-65 %. The difference from the value at three weeks is due to embryo and early foetal loss (Holmes *et. al.*, 1987).

The method used to determine that a cow has conceived is important in any analysis of conception rate. Non-return to oestrus at 23 or 49 days (49 day non-return rate) is often used to asses the conception pattern in a herd and is commonly viewed as equivalent to conception rate. However, they can be considered only as estimates of true conception rates, since non return rate is dependent on the true conception rate, the level of early embryonic loss and the efficiency of heat detection (Brightling *et. al.*, 1990). It has been routinely found that a 30 day non-return rate is at least 10 % higher than the conception rate based on pregnancy test 7 to 10 weeks after service (Brightling *et. al.*, 1990; Hayes, 1997).

Matching calving to services in the previous season it is possible to estimate when conception occurred. A service which is 283 ± 11 days prior to calving date is usually counted as the effective service (Brightling *et. al.*, 1990). Even so, the most accurate method of assessing conception rate is by pregnancy testing, which is usually done by rectal palpation of the uterus, its contents and blood supply (Brightling *et. al.*, 1990). This technique is possible beyond day 30 and is highly accurate after seven weeks of pregnancy (Brightling *et. al.*, 1990; O'Connor, 1994).

INTER-OESTRUS INTERVAL.

Assuming that the duration of a normal oestrus cycle is between 18 and 24 days, it is possible to infer possible causes of oestrus return to service by analysing the inter-oestrus intervals (Holmes *et. al.*, 1987; Brightling *et. al.*, 1990). If a cow returns to oestrus within the normal oestrus duration, it is assumed that the cow was truly on heat at the time of mating but it did not conceive or had an early embryo loss (before day 15-16 post-insemination). However, when a cow returns to true heat sooner that 18 days, one of two events could have happened: either that cow was not really on heat at the time of first service or the cow was truly on heat and then exhibited a genuine short oestrus cycle (Macmillan & Watson, 1971 cited by Macmillan & Watson, 1973). When a cow returns to oestrus later than 24 days, either the intervening heat period was not detected or the cow suffered a late embryo loss (after day 15-16 post-insemination) (Sreenan & Diskin, 1986). A high incidence of short returns might indicate a problem with oestrus detection while a high incidence of normal returns might indicate that the bull, semen or insemination is below the expected standard (Holmes *et. al.*, 1987).

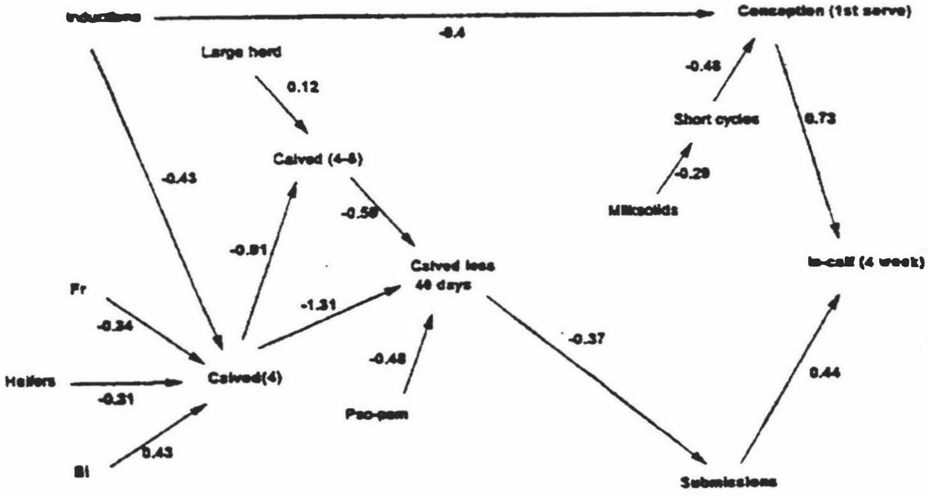
PREGNANCY RATE.

This is the number of cows that become pregnant in a certain period of time, usually the first four weeks of the mating period. The combination of rates of submission and conception will dictate the achieved pregnancy rate (Holmes *et. al.*, 1987; Brightling *et. al.*, 1990). After a total period of 12 to 16 weeks, about 95 % of the herd should be pregnant (Holmes *et. al.*, 1987). The interval in days to achieve 50 % of the herd pregnant and then 75 % pregnant are useful parameters to evaluate reproductive performance (Brightling *et. al.*, 1990).

Pregnancy rates at four weeks for New Zealand dairy herds average 60 to 67 % (Hayes, 1997). At seven weeks, pregnancy rates from 73 to 86 % are usually reported (Macmillan & Watson, 1973; Xu *et. al.*, 1996; Grosshans *et. al.*, 1997).

Taking into account some of the factors affecting reproductive function, Hayes (1998) proposed a path diagram to illustrate the way in which they may act in seasonal dairy herds (Figure 11).

Figure I–11. A path model of some factors that modify reproductive performance in seasonally calving dairy herds. The values indicate the relative magnitude and if the effect is positive or negative. Heifers = % primiparous cows in the herd; Fr = % Friesian; BI = breeding index; Inductions = % induced; Calved(4) = four-week calving rate; Calved 4-8 = % calved in weeks 5 to 8, psc-psm = days between the planned start of calving and planned start of mating; Calved less 40 days = % calved less than 40 days at the start of mating; submissions = 21-day submission rate, Milksolids = average daily per cow milk production; In-calf (4) = four-week in-calf rate.



From: Hayes (1998).

The model highlights the importance of achieving a concentrated calving pattern in order to reduce calving inductions, to have most of the cows cycling at PSM and therefore to attain high rates of submission and conception which will result in an adequate reproductive performance.

OBJECTIVES AND SCOPE OF THIS THESIS.

This thesis had the objective of evaluating and comparing the reproductive performance of autumn- and spring-calving cows in three dairy farm systems. For this purpose, records corresponded to a three-year database (1996-1999) were analysed. Also, during 1998-1999, an experiment was carried out to look at some possible causes for the observed reproductive performance.

Each chapter of this thesis is written as a self-contained document. This first chapter is an introductory one, giving a general overview of the New Zealand dairy systems and the importance of reproduction within the system. The other two chapters are structure as separate papers with their own introduction, material and methods, results, discussion and conclusions.

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CHAPTER II

ASSOCIATIONS BETWEEN BODY CONDITION, CONCENTRATIONS OF UREA, PROGESTERONE AND ß-HYDROXYBUTYRATE IN MILK AND REPRODUCTIVE PERFORMANCE OF AUTUMN- AND SPRING-CALVING COWS

Abstract

The primary objective of this study was to assess the relationship between urea concentration in milk (MU) and reproductive performance (conception rate to first service) of cows in two seasonal dairy herds differing in calving season (autumn and spring). The interrelationship between fertility, MU, progesterone concentration and energy status (body condition score change and milk β-hydroxybutyrate / B-OH) was also explored. Milk samples from individual cows were collected during the mating period. Samples were collected at breeding, and on days 12 and 21 post-breeding. Progesterone concentrations (P4) were determined in all samples. According to progesterone concentrations and pregnancy tests, cows were classified into three groups, a) pregnant (P), b) non-pregnant with low P4 on Day 21 (EL), and c) non-pregnant with high P4 on Day 21 (EH). Autumn-calving cows tended to have a higher conception rate to first service (60 %) than spring-calving cows (49 %). At the same time, MU at breeding (MU0) was higher for the former cows (8.4 *vs* 6.7 mmol/L). In both herds, as MU0 increased, the probability of conception to first service tended to decrease. P cows in both herds tended to have lower MU0 than EL and EH cows. Also, P cows (0.16 mmol/L) in the autumn herd had a similar B-OH at breeding to the EL cows (0.16 mmol/L), but tended to be higher than that in the EH cows (0.14 mmol/L). Although P cows tended to have higher P4 on Day 12 followed by EL and EH cows with the lower P4, an effect of MU on P4 was not observed. However, a negative effect of MU upon conception rate to first service was detected when its effects were analysed together with other factors, such as body condition score at breeding (bcsm), the interval from planned start of mating to first service (psmfs), P4 concentrations on Day 12 (P12), and incidence of health disorders (milk fever, lameness, mastitis, retained foetal membranes). The probability of a cow becoming pregnant at first service was decreased by 0.105 for each unit increase in the natural logarithm of MU0. Also, the probability of a cow conceiving to first service when it had one health disorder event was only 35 % of that of a cow with no health disorders recorded. On the other hand, the probability of a cow becoming pregnant was increased by a factor of 5.29 for each unit increase in bcsm, by nearly 3 % for each ng/ml increase in the concentration of P12, and by 55 % for each increase in the square root of the psmfs interval. It was concluded that under the study circumstances, the negative association between MU and fertility was unlikely to account alone for the observed decrease in reproductive performance. However, the combined effect of high MU0, together with low bcsm, short psmfs interval and high incidence of health disorders affected fertility (conception rate to first service) adversely.

Introduction

The reproductive performance of a dairy herd is fundamental in the achievement of good productivity and efficiency in the seasonal dairy system. It has been established that the productivity of a dairy system is optimised when the intercalving interval is one year (365 days) (Ducker *et. al*., 1985; Esslemont *et. al*., 1999) and this is even more important in pastoral systems, such as those in New Zealand, where there is a need to maintain a constant yearly calving to synchronise the seasonal pasture feed supply with feed demand (Holmes *et. al*., 1987).

However, several factors can exert an influence on reproduction determining the attainment or not of a satisfactory reproductive performance. Since the heritability of fertility is low 0.01 to 0.12 (Marti & Funk, 1994; Hoekstra *et. al*., 1994; Grosshans *et. al*., 1997), the environment is the major element influencing fertility. The most important environmental factors appear to be nutrition (level of feeding), artificial insemination (AI) unit, technician, age, herd, year and season (Janson, 1980; Silva *et. al*., 1992; Hayes, 1998). In New Zealand, level of feeding and body condition are probably the major factors (McDougall, 1993).

Nutritional imbalances, not only deficiencies but also excesses, have been linked to poor fertility. In this regard, excess dietary protein has frequently, but controversially, been claimed to have a detrimental effect upon reproduction. High levels of dietary protein have mainly been related to reduced conception rates (Ferguson *et. al*., 1988; Williamson & Fernandez-Baca, 1992; Moller *et. al*., 1993; Ferguson et. al., 1993) and thereby delayed conception (Gustafsson & Carlsson, 1993). The negative association between protein level and fertility seems to be more related to the degradability of the protein (Ferguson *et. al*., 1988; Ferguson & Chalupa, 1989; Elrod & Butler, 1993; Ryan & Mee, 1994). Hence the urea concentration in serum, plasma or milk has been used as a metabolite reflecting the use of dietary protein by the animal (Elrod & Butler, 1993; Butler, 1998). Excess rumen degradable protein (RDP) is readily degraded in the rumen into ammonia and unless a high level of fermentable carbohydrates is fed, the rumen microbes are not able to utilise this ammonia produced in excess. As a consequence, the excess ammonia is absorbed into the blood and converted into urea in the liver (Waghorn & Barry, 1987; Butler, 1998). Blood and milk concentrations of urea are thereby increased. Urea may depress conception by affecting the uterine environment (Elrod & Butler, 1993), sperm transport (Hossain, 1993; Breau *et al*., 1985 both cited by Lean *et. al*., 1998), serum progesterone concentrations (Jordan & Swanson, 1979), perturbing the hypothalamic-pituitary-ovarian axis and, potentially, through energetic costs (energy balance) involved in detoxification of ammonia (Macmillan *et. al.*, 1996; Lean *et. al.*, 1998). It has been shown that excess dietary RDP increases urea in blood and milk (Schepers & Meijes, 1998) and cows having serum urea nitrogen (SUN) concentration equal to or above 3.33 mmol/L (Ferguson *et. al.*, 1988) or milk urea (MU) above 5 mmol/L (Gustafsson & Carlsson, 1993) are most at risk of reproductive impairment. In New Zealand, where the main feed is pasture based on ryegrass and white clover, the concentration of crude protein in immature pastures can reach 25 to 30 % (Holmes *et. al.* 1987; Moller, 1991) with a degradability of approximately 70 % (Waghorn & Barry, 1987; Moller *et. al.*, 1993). Therefore, high concentrations of MU (above 8 mmol/L) (Moller, 1991; Moller *et. al.*, 1993) and SUN (10 mmol/L (Moller *et. al.*, 1993) are often present.

Level of feeding and nutrition mainly affects reproduction through the changes induced in energy balance. Generally, a positive energy balance will favour fertility while a negative energy balance (NEB) may induce impaired reproductive performance (Randel, 1990). However, the complication arises because high yielding cows (high genetic merit) compromise their energy status in early lactation due to their high feed demand and reduced feed intake. If this situation is extreme, resumption of ovarian activity after calving will be delayed (Butler & Smith, 1989) and, if the NEB is prolonged until the mating period, conception may also be affected.

The exact mechanism by which NEB affects reproduction has not yet been elucidated, although several pathways have been proposed. Spicer *et. al.* (1990) showed that cows in positive energy balance had higher plasma progesterone concentrations in the dioestrus of their first and second cycles than did those in NEB. Fonseca *et. al.* (1983) found that conception rates to first service increased by 12.4 % for each 1 ng/ml increase in mid-cycle progesterone (in the preceding cycle). Additionally, each increase of 1 kg body weight during the four weeks before first service increased progesterone by 0.03 ng/ml.

High producing cows (i.e. those whose peak milk yields exceed 25 kg/day) have elevated metabolic rates, because blood flow to the liver is proportional to energy intake (Huntington, 1990). This high metabolic rate increases the presentation of progesterone to the liver for catabolism (Parr *et. al.*, 1993a; Parr *et. al.*, 1993b). It has therefore been suggested that normal concentrations of progesterone may not be maintained during peak lactation simply because ovarian outputs of this hormone are metabolised more rapidly than at other times when energy is balanced and daily milk production is slowly declining (Macmillan *et. al.*, 1996).

Estimated net energy balance has been positively associated with serum concentrations of glucose and cholesterol and negatively correlated with serum concentrations of free fatty acids (FFA) and ß-hydroxybutyrate in periparturient cows (Lean *et. al.*, 1992 cited by Cook, 1999), indicating the greater reliance on fatty acid and ketone metabolism among cows in NEB.

There is little information about the association between urea levels, progesterone and energy balance and reproductive performance of dairy cows in pastoral systems, and there have been no comparative studies between spring and winter seasonal milk production systems.

The objective of this study was to evaluate the relation between MU and fertility (conception rate to first service) of cows in two seasonal systems differing in calving season (spring and autumn), as well as the relationship between fertility and progesterone concentrations and energy status assessed by ß-hydroxybutyrate in milk and changes in body condition around mating.

Material and Methods

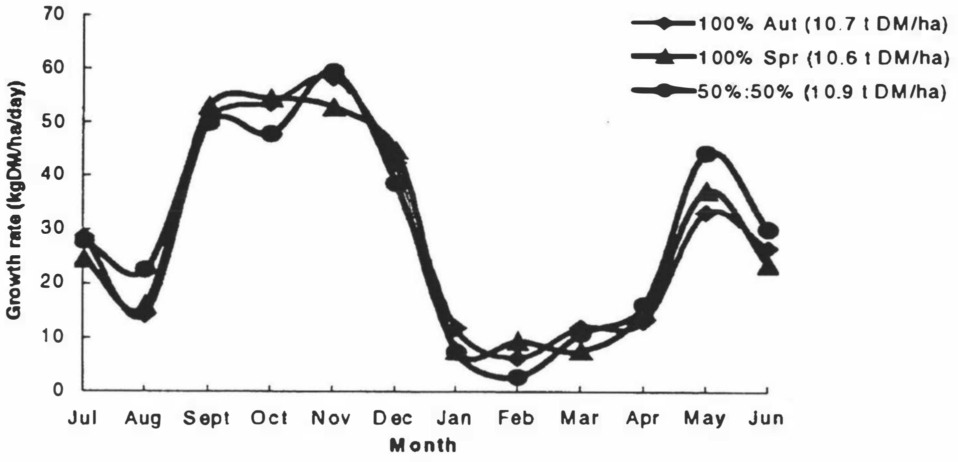
The study was carried out between October 1998 and August 1999 at the number 1 Dairy Farm, Massey University. This study formed part of a system trial conducted over three years to compare the physical, biological and economical efficiency of three farmlets with different calving dates. The three systems were: a) spring calving, b) autumn calving, and c) 50 % spring / 50 % autumn calvings (García et. al., 1998). However, the work reported in this chapter only involved the farmlets in which all the cows calved either in spring or in autumn, that for the purpose of this document will be called the S and A herds respectively.

Animals and management.

There were a total of 103 cows for the S herd and 79 for the A herd. Cows in S were stocked at 2.5 cows/ha while cows in A were stocked at 2.0 cows/ha.

Both herds were composed of Friesian cows whose ages ranged between 2 and 15 years old (> 12 years old n = 2). Cows were rotationally grazed on ryegrass/white clover pastures and milked twice daily and, except for the difference in calving season and stocking rate, these two farmlets were managed similarly to their own best advantage. However, because the feed supply of the farmlets was based on pasture, important differences in diet composition arose between them due to the seasonality of pasture growth. Cows in both farmlets were supplemented with pasture and maize silage when pasture growth was insufficient to meet the herds' feed requirements (Figure 1). This occurred mainly in early lactation (winter) for the autumn calved cows, but mainly in mid to late lactation (summer) for the spring calved cows. Silages were generally fed once daily in troughs before the morning milking or on the paddocks before noon when weather and soil conditions made this possible.

Figure II–1. Average pasture growth rate for the autumn- and spring-calving herds during 1998-99.



From: García (2000).

Reproductive management.

The reproductive management calendars of the farmlets are summarised in the following table (Table 1).

Table II–1. Reproductive management calendars for autumn- and spring-calving cows.

Event	Date Spring herd	Autumn herd
Planned start of calving (PSC)	20 Jul	10 Mar
Calving period (expected)	20 Jul – 20 Sep	10 Mar – 10 May
Premating heat detection	1 month prior to PSM	
Planned start of mating (PSM)	10 Oct	1 Jun
Artificial insemination period	6 weeks	
Natural mating period	4 weeks	
Pregnancy test	Around 6 weeks after finishing mating period	

Inductions of premature calving were practised in cows expected to be late calvers, in order to maintain compact calving patterns. The cows selected for induction were those that, according to the mating records, were likely to calve beyond the required calving season.

From a month before planned start of mating (PSM) heat detection was carried out daily by visual observation of oestrous behaviour during the transit from the paddocks to the milking shed or when allocating new paddocks. Heat detection was aided through the use of tail painting (Macmillan & Curnow, 1977). At the PSM, cows which had not been seen on heat during the pre-mating period were assumed to be anoestrus and were submitted for veterinary inspection and treatment. Cows considered to be anoestrus were treated with the CIDR®-B (controlled intravaginal drug release device) regime (Macmillan & Peterson, 1993) consisting of inserting a progesterone release intravaginal device for six days, plus 1 mg of oestradiol benzoate injected 24 hours after device removal.

During the artificial insemination (AI) period, cows detected in oestrus in the morning were inseminated in the same morning; cows detected in the afternoon were inseminated in the following morning, and those cows seen in oestrus again in the next 24 hours were inseminated for a second time. When this happened, both inseminations were regarded as one service. AI was carried out by Livestock Improvement Corporation inseminators who, in almost all cases, used fresh semen to inseminate the cows. After insemination, cows were visually monitored (tail painting and oestrus signs) to detect return to oestrus. After the period of AI had finished, bulls were incorporated into the herds for four weeks to mate any cow that had not conceived at AI.

Pregnancy test was carried out in the whole herds through palpation per rectum by a veterinarian around 120 days after the PSM.

Information from records.

Information about calving date, breeding worth (BW[1]) parity number, weight, body condition score (BCS), occurrence of pre-mating heats, inseminations, milk production and disease events (lameness, mastitis, milk fever, grass staggers, retained foetal membranes, anoestrus) were recorded routinely in the farm. Additional variables were derived from those recorded. BCS was assessed according to the technique described by Holmes *et. al.* (1987) from visual inspection of the fatness of the hindquarters of the cows and focusing mainly in the loins, the hips, the area about the head of the tail, and the thighs. Then, a score within a scale from 1 to 10 was assigned to each cow. During the experimental period BCS was recorded on a weekly basis.

Derived and adapted variables.

- Calving season (CS) was coded as 0 for the spring herd and as 1 for the autumn herd for some analysis.

- Interval from calving to first service (CFS, days) was obtained by subtracting the calving date (CD) from the date of first AI.
- Interval from PSM to first service (PSMFS, days) was obtained by subtracting the PSM date from the date of first AI.
- The following liveweights were considered for the analysis:
  - After calving (wgtc), which was that first recorded after calving,
  - At first AI (wgtm), which was that recorded closest to first AI.
  - Difference (wgtd), which was obtained by deducting the wgtm from the wgtc.
- The following BCS were used for the analysis
  - At calving (bcsc), which was that first recorded after calving,
  - At first AI (bcsm), which that recorded closest to first AI,
  - Difference (bcsd), which was obtained by subtracting the BCS recorded during the fourth week after PSM from the BCS recorded during the first week after PSM
- Lactation number was divided into two categories coded as follows 1 for first lactating cows and 2 for mature cows with two or more lactations.
- The occurrence of all health related events were coded as dichotomous variables with 0 for no events recorded and 1 for one or more episodes recorded. The only exception was the variable named health which was coded into three categories: 0 no events recorded, 1 for one event recorded and 2 for two or more episodes registered.

  The abbreviations used for each variable were lame = lameness, mast = mastitis, mf = milk fever and/or grass staggers, rfm = retained foetal membranes and anoest = anoestrus.

Pregnancy rate to first service was used to evaluate and compare the reproductive performance of the cows. This rate was calculated by considering that a cow had become pregnant to that service if it had a positive pregnancy test and only one AI recorded. A cow that after the first AI had another recorded service within the next 24 days or did not have any other AI recorded but a negative pregnancy test was considered as non-pregnant to first service. The categorisation of cows as pregnant or

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[1] BW (Breeding worth) = Economic index to evaluate the animals' genetic value. It is composed by several traits: milkfat, protein, milk, liveweight, survival (Livestock Improvement Corporation, 1998).

non-pregnant was confirmed by analysing patterns of progesterone concentration in milk.

Measurements and sample collection procedures.

Samples of feed were collected during the spring of 1998 for the spring herd, and during the winter of 1999 for the autumn herd. Additionally, milk samples were collected for measurement of urea, β-hydroxybutyrate and progesterone concentrations.

Diet composition.

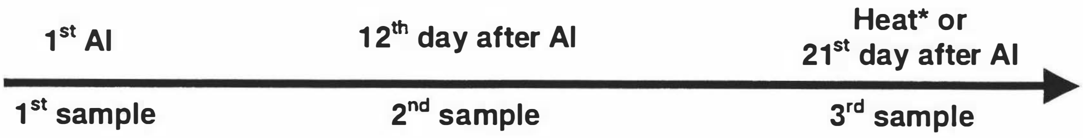
Pasture samples were collected from the paddocks immediately before grazing during the nine weeks of the experimental period (from the start of mating to three weeks after the AI period finished) in each herd. The samples were cut by hand at grazing height and the paddock samples were bulked into weekly samples before analysis. In the autumn herd, pasture and maize silages were fed during the experimental period and, hence, samples from these feeds were also collected. Silages samples were collected twice weekly and these samples were bulked into fortnightly samples before analysis.

The samples were dried for 48 hours at 60°C and in some cases (e.g. pasture silage) for longer due to the high moisture content. Once dried, samples were ground before being sent for analysis to the feedTECH (AgResearch) laboratory. Pasture and silages samples were analysed through the use of Near Infrared Reflectance spectrometry (NIRS) (Corson et. al., 1999) to determine dry matter, crude protein, crude fat, readily fermentable carbohydrates, fibre (NDF and ADF), ash content, organic matter digestibility[2] and metabolisable energy.

Metabolites in milk.

Milk samples were collected for each individual cow in each herd from the time of the first artificial insemination according to the following schedule:

Figure II–2. Timing for collection of milk samples.



*If a heat occurred before or after day 21st, within the 18-24 days range.

Milk was collected in the afternoon milking by directing the milk from the targeted cows into test buckets from which the samples were taken. Whole milk samples were labelled and kept frozen (- 17ºC) without any preservative until processing .

Concentrations of progesterone, urea and ß-hydroxybutyrate were measured in the milk samples.

Milk progesterone.

Progesterone concentration was determined in all samples collected through the use of an eia (enzyme immunoassay) kit (Ridgeway Science®) based on the method described by Sauer *et. al*. (1982). Homogenised whole milk samples were used for the analysis.

For the autumn herd the coefficients of variation intra- and inter-assay were 11.2 % and 8.9 % respectively, whereas for the spring herd they were 8.5 and 9.0 % respectively.

Milk urea.

Urea concentration was measured in all the milk samples from the spring herd. However, in the autumn herd urea was determined only in the samples corresponding to the first two days of sampling (Day 0 and Day 12) from each cow. Milk samples were centrifuged for 10 min at 1300 X *g*. A subsample of the clarified supernatant (whey) was used for the determination of urea concentration using an automatic biochemistry analyser (BM/Hitachi 704®). The resultant whey samples were analysed according to the method described by Oltner & Sjaunja (1982).

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[2] Not determined in maize silage samples

Milk ß-hydroxybutyrate.

This metabolite was measured only in the samples corresponding to the first day of sampling (Day 0) from the autumn herd. Sample preparation was the same as that followed for the urea determination analysis. Then ß-hydroxybutyrate (B-OH) was determined in the milk whey through the use of an auto-analyser (Roche Cobas Fara II®) based on the technique described by Williamson *et. al*. (1962). Samples were analysed in duplicate, and in some cases in triplicates. The resultant coefficient of variation intra-assay was 1 %.

Statistical analysis.

Categorical data such as proportion of pregnant and non-pregnant cows falling in a certain category (e.g. herd, BCS level, urea level) or the proportion of cows with a certain health disorder, were evaluated through the use of chi-square tests.

Some of the continuous variables used in the analysis were not normally distributed and, therefore, they were normalised. Urea concentrations were log transformed, and the square root of the interval PSMFS was obtained. The rest of the variables had a normal or nearly normal distribution. Variables with time series (progesterone and urea) were analysed by using repeated measures analysis of variance (least squares method) with day as repeat (Day 0, Day 12 and Day 21). In all the models, herd, parity number, pregnancy status, day and cow nested within all classes were used as main effects. The effect of urea and body condition score on progesterone concentration was tested by analysis of covariance.

Differences in bcsc, bcsm, bcsd and B-OH concentrations were evaluated by analysis of variance with nested effects by taking herd and status nested within herd as main effects.

To account for the role of the several variables involved in the trial in the final reproductive status of the cows, a multivariate analysis was modelled. Canonical discriminant analysis (STEPDISC and CANDISC procedures, SAS ver. 6.12) and logistic regression (LOGISTIC procedure, SAS ver. 6.12), were used for this purpose.

Linear regression analyses were also carried out to assess the relationship between diet composition and urea concentration in milk.

Results

Seventy-five cows from the autumn herd and 85 cows from the spring herd were included for the analysis. The rest of the cows were excluded because of missing samples, cows which were not in oestrus but were submitted for AI, or cows which were not inseminated at all (i.e. culled before planned start of mating).

The mean values of the variables used for some of the analysis carried out are presented in Table 2. There were significant differences in live weight between the herds. The autumn herd had consistently higher live weight after calving and at mating. However, the autumn herd also had a higher weight loss. The rest of the variables were similar between the herds, except that the autumn herd produced a higher yield of milksolids in the whole lactation.

Table II–2. Least square means and standard errors (SE) of variables used in the analysis of the autumn- and spring-calving cows.

	HERD				
	Autumn		Spring		
Variable	Mean	SE	Mean	SE	Significance
Wgtc (kg)	514.8	8.6	470.8	8.0	***
Wgtm (kg)	475.9	6.9	456.0	6.0	*
Wgtd (kg)	-38.9	6.0	-13.5	5.6	**
Parity number	4.0	0.3	3.7	0.3	NS
CFS (days)	75.1	2.2	76.9	2.1	NS
PSMFS (days)	12.1	1.2	14.1	1.1	NS
Milk (litres)[1]	4053	96.4	3983	90.5	NS
Milksolids (kg)[1]	331	6.8	301	6.4	**

Wgtc = live weight after calving
Wgtm = live weight around first mating
Wgtd = live weight difference between wgtm and wgtc
CFS = interval from calving to first service
PSMFS = interval from planned start of mating to first service
[1] Yields for the whole lactation
NS = Not significant
* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$

In regard to the occurrence of pre-mating heats and the incidence of health disorders, both herds had a similar proportion of cases (Table 3). However, the spring herd had higher proportions of cows experiencing milk fever and induced calvings compared to their counterparts in the autumn herd.

Table II–3. Proportion (%) of cows with pre-mating heats, anoestrus at planned start of mating, milk fever[3], retained foetal membranes (RFM), lameness, and mastitis for cows in the autumn and spring herds.

	HERD		
	Autumn	Spring	Significance
Assisted calvings	4.7	4.0	NS
Induced calvings	0.0	7.1	⇧
Pre-mating heats	74.7	65.9	NS
Anoestrus	24.0	22.3	NS
Milk fever	2.7	14.1	*
RFM	1.3	2.4	NS
Lameness	14.7	18.8	NS
Mastitis	14.7	18.8	NS

NS = Not significant
⇧ $P < 0.1$
* $P < 0.05$

According to the pregnancy test and the progesterone concentration determinations carried out in each herd, cows were classified as either pregnant or empty to the first service.

Of the 160 cows in both herds used for the analysis, 87 cows (54.4 %) were determined to be pregnant after the first service (P). The rest of the cows did not become pregnant to the first service, or not at all. Non-pregnant cows were further categorised into either of two groups according to their progesterone concentrations found in the third sample (Figure 1). One of these groups had low progesterone concentrations and it was assumed that these cows were in, or close to oestrus (EL). The number of cows falling in this category was 44 (27.5 %). The remainder 29 (18.1 %) non-pregnant cows had elevated progesterone concentration in the third sample and it was assumed that they had conceived but pregnancy was not maintained (EH) since an oestrus return after 24 days of first AI and/or a negative pregnancy test was recorded.

Thus, according to the pregnancy test and the progesterone concentration in the 3rd sample, cows were classified into three pregnancy statuses to perform the analysis :

- Pregnant (P) – High progesterone concentration at Day 21 post service and positive pregnancy test.

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[3] Includes the occurrence of grass staggers.

- Empty low (EL) – Low progesterone concentration at 3rd day of sampling and either a subsequent service occurred and/or negative pregnancy test.
- Empty high (EH) – High progesterone concentration at Day 21 post service and either a subsequent service occurred after day 24 post first service and/or negative pregnancy test.

The number and proportion of cows in each pregnancy status differed between herds (Table 4), however the difference was not significant ($\chi^2 = 2.07$; P = 0.355).

Table II–4. Number and percentage of cows in each pregnancy status within the autumn and spring herds.

		PREGNANCY STATUS			
Herd		**EH**	**EL**	**P**	**Total**
Autumn	N	13	17	45	75
	%	**17.3**	**22.7**	**60.0**	**100**
Spring	N	16	27	42	85
	%	**18.8**	**31.8**	**49.4**	**100**
Total	N	29	44	87	160
	%	**18.1**	**27.5**	**54.4**	**100**

EH = Empty cows with high progesterone concentration at day 21
EL = Empty cows with low progesterone concentration at day 21
P = Pregnant cows

Conception rate.

Conception rates to first service (CR1st) were different for each herd (Table 5). However the observed difference was not significant ($\chi^2 = 1.8$; P = 0.18).

Table II–5. Conception rate at first service for autumn- and spring-calving cows.

	HERD		
	Autumn	**Spring**	**Significance**
Conception rate at first service (%)	60.0	49.4	NS

NS = not significant

UNIVARIATE ANALYSIS.

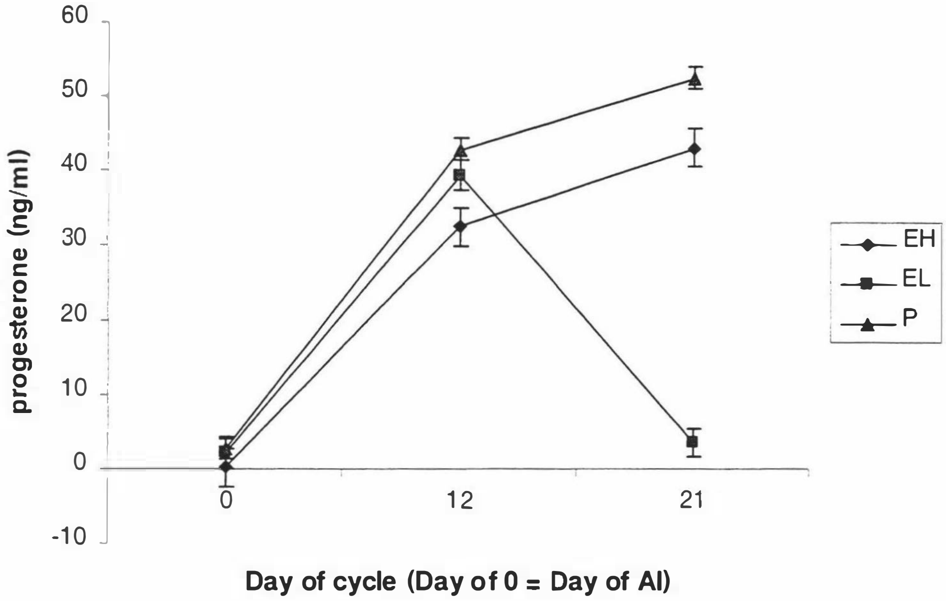
Progesterone.

Progesterone concentrations at insemination time were used to select the cows entering in the analysis (cows really in oestrus), and those at the third sample were used to classify the cows in one of the three already mentioned pregnancy statuses. Mean progesterone concentrations and standard errors in the oestrual cycle corresponding to the first service are shown in Figure 3 for each pregnancy status in both herds.

Progesterone concentrations in the three days were compared across the herds and statuses (Table 6). It was observed that progesterone concentrations at Day 0 and at Day 12 were similar for both herds but those at Day 21 differed significantly ($P < 0.001$) between herds. In a similar way, the progesterone concentrations corresponding to each status were similar for both herds, except for the P status whose difference between herds became significant ($P < 0.05$). Considering both herds together (Figure 3), the progesterone concentrations of EH (32.45 ng/ml) and EL (39.36 ng/ml) at Day 12 differed significantly ($P < 0.05$) and those between EH and P (42.90 ng/ml) differed significantly also ($P < 0.005$). The difference between EL and P at the same Day 12 was not significant. At day 21 the differences between the EH and EL and between the P and EL statuses were significant ($P < 0.0001$), as was the difference between the EH and P statuses at Day 21 ($P < 0.005$).

Within each herd the same sort of differences between statuses were observed (Table 6). However, EH and EL cows in the autumn herd had a significantly different progesterone concentration at Day 12. At day 21, there was a significant difference in the autumn herd between the EH and EL statuses, but not between the EH and P. There was also an expected significant difference between the EL and P statuses. In the spring herd these same trends were noted. However, the difference between the EH and P statuses at Day 21 was also significant.

Figure II–3. Least square means and standard errors for milk progesterone concentration by day and pregnancy status for both autumn and spring herds (combined data).



EH = Empty cows with high progesterone concentration at day 21
EL = Empty cows with low progesterone concentration at day 21
P = Pregnant cows

Table II–6. Least square means (ng/ml) and standard errors for progesterone concentration at Days 12 and 21 by herd and by pregnancy status.

		PREGNANCY STATUS						
Herd		EH		EL		P		Significance
		Mean	SE	Mean	SE	Mean	SE	
Autumn	P12	30.39^{b}	3.49	40.47^{a}	3.01	43.62^{a}	1.89	*
	P21	52.02^{a}	3.49	3.18^{b}	3.01	57.59^{a}	1.89	***
Spring	P12	34.51^{a}	3.30	38.25^{ab}	2.41	42.19^{b}	1.95	*
	P21	34.28^{a}	3.30	3.76^{b}	2.45	47.57^{c}	1.95	***

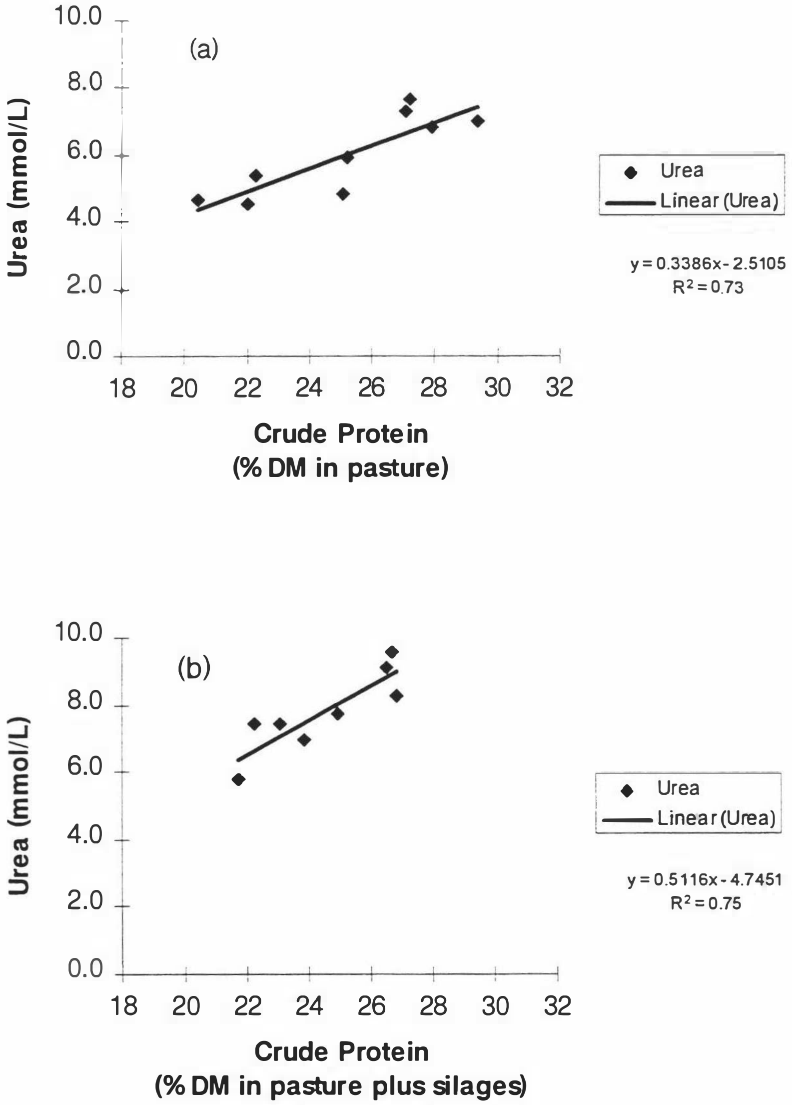
EH = Empty cows with high progesterone concentration at day 21
EL = Empty cows with low progesterone concentration at day 21
P = Pregnant cows
* $P < 0.05$ (rows with different letter are significantly different)
*** $P < 0.001$

When urea concentration and body condition score were fitted into the model as covariates there was no improvement in the model and the effects of urea and body condition score on progesterone concentration were not significant. The effect of urea and body condition score on progesterone concentration was only evaluated at two days, Day 0 and Day 12, due to the lack of data for Day 21.

Urea.

There was a positive relationship (P < 0.01) between the protein content of the diet offered and the urea content found in cows' milk averaged on a weekly basis for both herds (Figures 4a & 4b).

Figure II–4. Relationship between protein content of the whole diet offered and average values for urea concentration in milk from the spring (a) and autumn (b) herds.



MU increased in a linear manner with the CP content of the diet. In the S herd, MU increased by 1 mmol/L for each 0.34 % increase in the protein content of the pasture offered. In the case of the A herd, MU increased by 1 mmol for each 0.51 % increment in the amount of CP contained in the diet.

Weekly average values for pasture composition during the experimental period is reported in Table 7 for the S and A herds.

Table II–7. Pasture composition during the experimental period for autumn-(A) and spring-calving (S) cows.

		WEEK								
		1	2	3	4	5	6	7	8	9
CP (%)	S	27.2	27.9	27.1	25.2	25.1	22.3	22.0	20.4	21.7
	A	32.4	33.4	31.5	30.9	28.7	29.7	27.9	31.0	30.7
ADF (%)	S	24.5	24.1	22.3	22.6	20.8	22.0	22.7	22.9	26.6
	A	19.2	19.8	19.8	19.6	18.9	19.4	19.5	19.8	19.4
NDF (%)	S	46.7	42.5	41.7	41.3	39.2	40.1	40.5	42.1	45.8
	A	38.1	40.6	40.3	39.6	36.0	37.9	38.6	39.3	43.4
SCHOs (%)	S	6.0	7.2	9.0	9.5	12.7	13.4	13.1	13.1	9.2
	A	8.4	7.5	7.6	9.3	12.6	9.7	10.5	8.4	6.8
OMD (%)	S	77.0	75.0	79.5	80.6	82.0	80.8	77.6	77.0	75.6
	A	80.1	82.6	80.1	81.7	82.9	79.8	80.9	79.6	80.2
ME	S	11.5	11.2	11.9	12.0	12.2	12.0	11.6	11.5	11.3
(MJ/kg DM)	A	11.9	12.3	11.9	12.2	12.4	11.9	12.1	11.9	12.0
DCAD	S	538	482	460	483	509	577	511	470	486
(mEq/kg DM)	A	339	323	398	414	516	424	467	408	463

CP = Crude protein
ADF = Acid detergent fibre
NDF = Neutral detergent fibre
SCHOs = Soluble carbohydrates
OMD = Organic matter digestibility
ME = Metabolisable energy
DM = Dry matter
DCAD = Dietary cation-anion difference

The pasture composition described in the previous table represents the entire diet offered to S herd. However, since the A herd was also fed with pasture and maize silages, the diet composition offered to the A animals is better described in Table 8, where the inclusion of silages is taken into account.

Table II–8. Composition of the whole diet offered to the autumn herd (calculated as the weighted average of the composition of pasture and the silages).

	WEEK								
	1	2	3	4	5	6	7	8	9
CP (%)	22.3	26.7	26.5	26.8	23.9	25.0	23.1	21.8	23.5
SCHOs (%)	20.8	15.6	14.4	14.7	20.0	17.2	16.4	18.3	15.4
ME (MJ/kg DM)	11.4	11.9	11.7	12.0	12.1	11.7	11.9	11.7	11.8

CP = Crude protein
SCHOs = Soluble carbohydrates
ME = Metabolisable energy
DM = Dry matter

The nutritional composition of the silages (pasture and maize) offered to the autumn-calved cows is presented in table 9.

Table II–9. Maize and pasture silage composition offered to the autumn herd.

	WEEK						
	Maize silage					Pasture silage	
	1 & 2	3 & 4	5 & 6	7 & 8	9	7 & 8	9
CP (%)	8.4	7.7	6.7	7.4	7.5	19.5	20.1
ADF (%)	23.4	23.0	21.7	18.7	17.6	32.8	31.6
NDF (%)	39.4	40.3	37.9	33.4	31.8	47.1	45.6
SCHOs (%)	37.8	40.0	46.5	47.9	49.9	2.1	2.4
OMD (%)	ND	ND	ND	ND	ND	72.3	73.5
ME (MJ/kg DM)	10.8	10.8	11.0	11.3	11.4	11.6	11.8
pH	3.8	3.8	3.9	3.8	3.8	3.9	3.8
Lactic acid (%)	4.3	3.0	1.8	3.4	3.5	11.4	11.5
Ammonia-N (mg/100 g DM)	11.9	10.9	10.7	12.4	12.5	293.2	290.8
Ammonia-N as fraction of total N (%)	0.9	0.9	1.0	1.1	1.0	9.4	9.1

CP = Crude protein
ADF = Acid detergent fibre
NDF = Neutral detergent fibre
SCHOs = Soluble carbohydrates
OMD = Organic matter digestibility
ME = Metabolisable energy
DM = Dry matter

Mean MU concentrations found in each group within each herd at day of insemination (MU0) and on day 12 (MU12) are shown in Table 10.

Table II–10. Least square means and standard errors for milk urea (mmol/L) by herd, day and pregnancy status.

		PREGNANCY STATUS						
		EH		EL		P		
Herd		Mean	SE	Mean	SE	Mean	SE	Significance
Autumn	MU0	8.95	0.48	8.59	0.41	8.07	0.26	NS
	MU12	8.24	0.48	8.61	0.41	8.32	0.26	NS
Spring	MU0	6.99	0.47	6.90	0.33	6.35	0.27	NS
	MU12	6.79	0.47	6.55	0.33	6.29	0.27	NS

For all statuses, cows in the autumn (A) herd had consistently higher MU concentrations ($P < 0.05$) than spring (S) cows in both MU0 and MU12.

The differences observed in MU concentrations at the time of insemination between statuses within each herd were not statistically significant ($P > 0.1$). However, pregnant cows tended to have the lowest MU0 in both herds.

Categorising cows into three groups according to MU0 (low, medium and high) in each herd separately, it was apparent, although the differences were not significant by a χ^2 test, that cows with low MU0 were more likely to become pregnant than cows with medium or high MU0 (Table 11). Groups were formed by considering the overall mean in each herd and one standard deviation (SD) above and one SD below the overall mean.

Table II–11. Likelihood ratio (Pregnant/Empty) for three categories of milk urea at Day 0 in the autumn and spring herds.

MU0 Category (mmol/L)	PERCENTAGE Empty	Pregnant	Likelihood ratio[4]
AUTUMN HERD			
< 5.25	33.3	66.7	2.00
5.25 – 8.13	52.5	47.5	0.90
> 8.13	63.6	36.4	0.57
SPRING HERD			
< 6.41	18.2	81.8	4.49
6.41 – 10.41	43.4	56.6	1.30
> 10.41	45.5	54.5	1.2

Body condition.

There were no significant differences in bcsc and bcsm between the A and the S herds (Table 13). However, bcsm was slightly higher for the A herd and whereas the S herd gained a little condition during the first month after the planned start of mating, the A herd did not (Table 12).

Table II–12. Least square means and standard errors for body condition score at calving (bcsc), at mating (bcsm), and body condition score change (bcsd) after planned start of mating for the autumn and spring herds.

	HERD Autumn Mean	SE	Spring Mean	SE	Significance
Bcsc	4.76	0.07	4.73	0.07	NS
Bcsm	4.29	0.05	4.19	0.05	NS
Bcsd	-0.01	0.05	0.15	0.05	*

NS = not significant
* P < 0.05

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[4] Percentage of cows pregnant divided by the percentage of empty cows.

Bcsc and bcsd were not significantly different across the three statuses in each herd separately (Tables 13). However, bcsm for P cows in both herds tended to be higher than both groups of empty cows and in the spring herd this difference was significant ($P < 0.05$) (Table 13).

In the A herd, P cows had a negative bcsd, a finding that was not observed in the S herd (Table 13).

Table II–13. Least square means and standard errors for body condition score at calving (bcsc), at mating (bcsm), and body condition score change (bcsd) after mating of each pregnancy status in the autumn and spring herds.

	PREGNANCY STATUS						
	EH		EL		P		
	Mean	SE	Mean	SE	Mean	SE	Sig.
AUTUMN HERD							
bcsc	4.62	0.17	4.79	0.16	4.79	0.09	NS
bcsm	4.18	0.12	4.18	0.11	4.37	0.07	NS
bcsd	0.07	0.11	0.04	0.10	-0.06	0.06	NS
SPRING HERD							
bcsc	4.85	0.16	4.55	0.12	4.80	0.10	NS
bcsm	4.16^{ab}	0.11	4.04^{a}	0.09	4.30^{b}	0.07	*
bcsd	0.12	0.10	0.21	0.08	0.12	0.07	NS

EH = Empty cows with high progesterone concentration at day 21
EL = Empty cows with low progesterone concentration at day 21
P = Pregnant cows
NS = not significant
* Rows with different letter are significantly different ($P < 0.05$)

Body condition score at mating.

Following a similar procedure to that described for MU, cows were categorised into five groups according to their BCS at the time of insemination and the proportion of pregnant and non-pregnant cows in each group were calculated. Cows with higher scores for body condition at insemination were more likely to become pregnant than those having lower scores (Table 14) although the difference was not significant.

There were differences in progesterone concentrations at day 12 between the BCS categories at mating (Table 14). However, these only approached significance in the A herd but were significant in the S herd. Cows with BCS higher than 4.5 had significantly higher progesterone concentrations than did cows with BCS lower than 4.2.

Table II–14. Likelihood ratio (Pregnant/Empty) and mean progesterone concentration on Day 12 (P12) for different body condition score categories at insemination time for autumn- and spring-calving cows.

	BCS CATEGORY					
	< 4.0	4.0 – 4.1	4.2 – 4.3	4.4 – 4.5	> 4.5	Sig.
AUTUMN HERD						
Empty (%)	50.0	50.0	35.7	45.0	15.4	
Pregnant (%)	50.0	50.0	64.3	55.0	84.6	
Likelihood ratio	1.00	1.00	1.80	1.22	5.49	NS
P12 Mean (ng/ml)	36.46^{a}	36.71^{a}	44.39^{ab}	39.17^{ab}	46.33^{b}	⇧
SE	3.48	3.48	3.48	2.91	3.61	
SPRING HERD						
Empty (%)	58.3	64.3	50.0	38.9	33.3	
Pregnant (%)	41.7	35.7	50.0	61.1	66.7	
Likelihood ratio	0.72	0.56	1.00	1.57	2.00	NS
P12 Mean (ng/ml)	35.65^{a}	36.70^{ab1}	38.92^{ab}	43.89^{b}	46.90^{b1}	*
SE	2.66	3.48	2.91	3.07	4.34	

NS = not significant

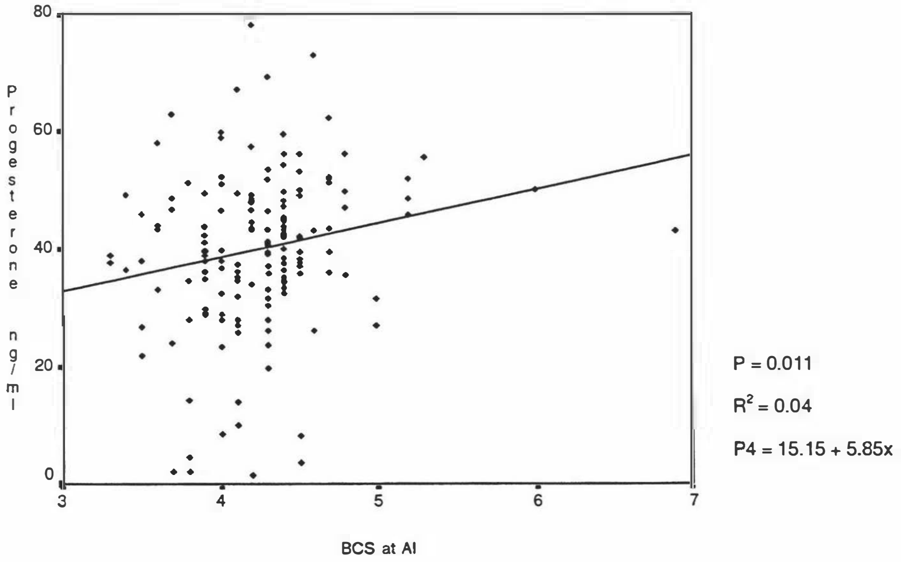
⇧ $P < 0.1$

* Rows with different letter are significantly different ($P < 0.05$)

[1] Categories significantly different at $P < 0.1$

There was a weak, but significant, linear relationship ($P = 0.011$) between progesterone concentration at day 12 and BCS at mating for the combined data of both herds as illustrated in Figure 5.

Figure II–5. Relationship between milk progesterone concentration on Day 12 and body condition score at the time of insemination.



Progesterone concentration on day 12 increased by 5.85 ng/ml with every BCS unit at mating.

Body condition score change after PSM.

In regard to BCS changes after PSM, it was observed that cows gaining condition were, in general terms, less likely to become pregnant than those losing or remaining with the same condition. However, the differences were not statistically significant (Table 15). The difference was more apparent in the spring herd.

Table II–15. Likelihood ratio (Pregnant/Empty), for autumn- and spring-calving cows gaining, losing or with no change in body condition during the month after the planned start of mating. Concentrations of β-hydroxybutyrate (B-OH) for each group in the autumn herd are also included.

	BCS DIFFERENCE		
	Gaining	**Losing or unchanged**	**Significance**
AUTUMN HERD			
Empty (%)	43.3	39.5	
Pregnant (%)	56.7	60.5	
Likelihood ratio	1.31	1.53	NS
B-OH Mean (mmol/L)	0.144	0.165	**
SE	0.005	0.006	
SPRING HERD			
Empty (%)	56.0	43.3	
Pregnant (%)	44.0	56.7	
Likelihood ratio	0.79	1.31	NS

NS = not significant
** $P < 0.01$

It was also observed in the autumn herd that cows losing or with no change in BCS had significantly higher B-OH concentrations than did cows gaining condition (Table 15).

Beta-hydroxybutyrate.

In the A herd only, β-hydroxybutyrate concentrations were determined in milk samples taken at insemination time. The difference between pregnant and non-pregnant cows was not significant. However, there was a trend of EH cows to have lower B-OH concentrations ($P = 0.06$) than either P or EL cows. (Table 16).

Using the B-OH overall mean and one standard deviation above and one standard deviation below the mean, cows were categorised into three groups, low, medium and high. There was no significant difference in the proportion of pregnant cows between groups. However, cows with higher values of B-OH tended to have a higher proportion of pregnant cows (Table 17).

Table II–16. Means and standard errors (SE) for concentration of β-hydroxybutyrate (B-OH) in milk at insemination time of each pregnancy status in the autumn herd.

	PREGNANCY STATUS						
	EH		EL		P		Sig.
	Mean	SE	Mean	SE	Mean	SE	
B-OH (mmol/L)	0.135	0.009	0.158	0.008	0.155	0.005	⇧

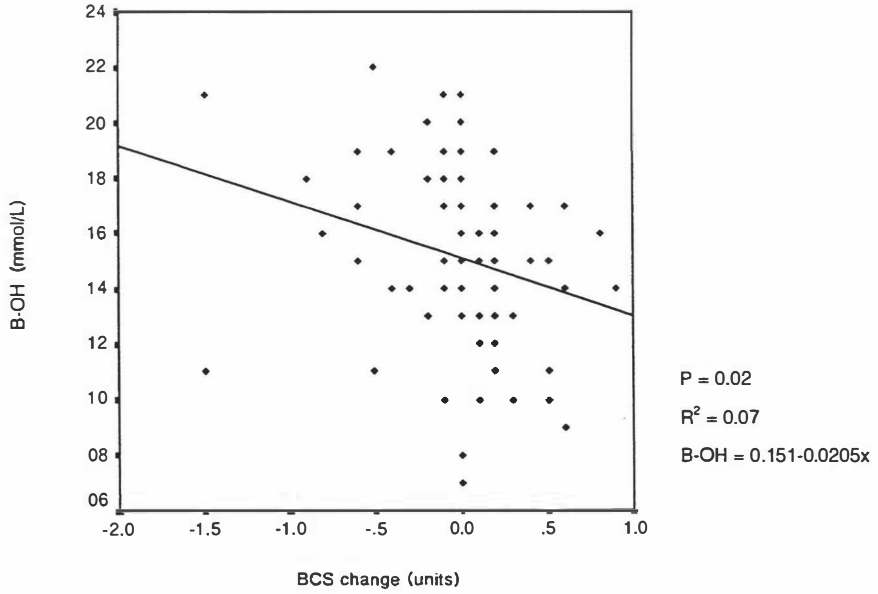
⇧ P = 0.06

Table II–17. Likelihood ratio (Pregnant/Empty) for autumn-calving cows categorised according to their beta-hydroxybutyrate concentration (B-OH) at insemination time.

B-OH (mmol/L)	PERCENTAGE Empty	Pregnant	Likelihood ratio[5]
< 0.119	50.0	50.0	1.00
0.119 – 0.185	39.2	60.8	1.55
> 0.185	33.3	66.7	2.00

A significant negative relationship (P = 0.02) was found between bcsd and B-OH (Figure 6).

Figure II–6. Relationship between body condition score change after planned start of mating and beta-hydroxybutyrate concentration in milk (B-OH).



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[5] Percentage of cows pregnant divided by the percentage of empty cows.

MULTIVARIATE ANALYSIS.

The variables examined in the study appeared to be highly interrelated and therefore, a multivariate analysis of variance was conducted. Canonical discriminant analysis and logistic regression were used to examine those variables that could better predict the final outcome of the first service, and to test if urea concentration had a significant influence upon the final status achieved by the animals.

All the variables, original, derived and adapted were included in the analysis to detect if they had a significant influence on the pregnancy outcome (P, EH or EL) of each cow.

Canonical discriminant analysis.

The stepwise option for the discriminant analysis procedure in SAS selects the variables to be included in the model according to the following default criteria:

Significance level to enter in the model: 0.15
Significance level to stay in the model: 0.15

To build the model, calving season (herd effect) was forced to be included into the model first since this was the main variable of interest. The resultant model included the variables bcsm, anoest, psmfs and p12 as they were the combination that gave the best discrimination between groups at a significant level (Wilk's Lambda = 0.785; $P < 0.0001$). The model obtained was further explored by analysing the structure of the canonical variates constituted by each of the variables included in the model (Table 18).

The canonical variate 1 (CAN 1) explained 77.5 % of the variation at a significant level (likelihood ratio = 0.761; $P < 0.0001$) and the canonical variate 2 (CAN 2) explained 21.3 % of the variation approaching significance (likelihood ratio = 0.940; $P = 0.08$).

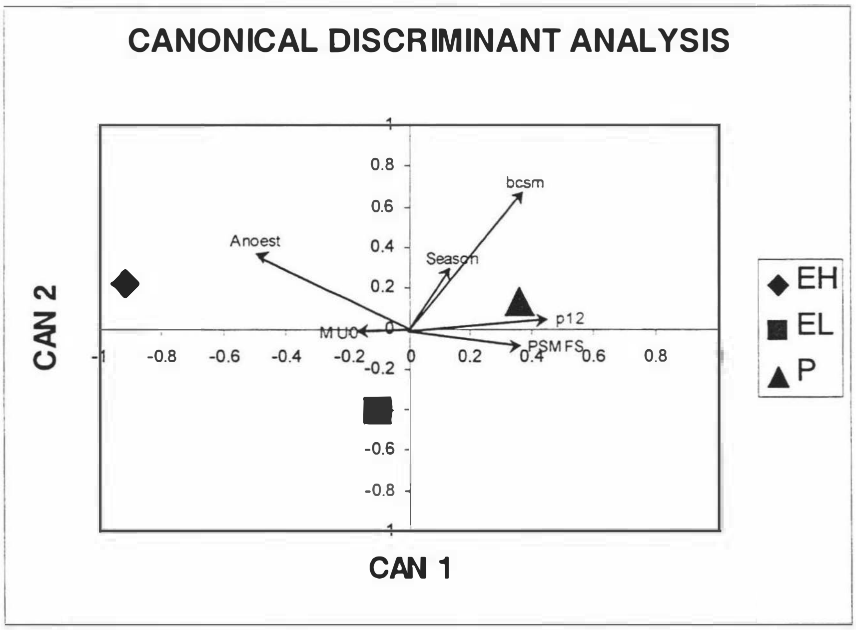
Table II–88. Total canonical structure and class means for the variables of the canonical discriminant analysis performed for pregnancy status.

	CAN 1	CAN 2
Calving season	0.137	0.363
Bcsm	0.378	0.708
Anoestrus	-0.503	0.416
PSMFS	0.467	-0.115
MU0	-0.231	-0.031
P12	0.503	0.045
STATUS	**Class means**	
EH	-0.914	0.225
EL	-0.101	-0.410
P	0.360	0.134

Bcsm = body condition score at first service,
PSMFS = interval from planned start of mating to first service,
MU0 = milk urea concentration on Day 12,
P12 = progesterone concentration on Day 12
EH = Empty cows with high progesterone concentration at day 21
EL = Empty cows with low progesterone concentration at day 21
P = Pregnant cows

In this way it was possible to discriminate between pregnancy statuses by observing the effect of each variable on the canonical structure as illustrated in the next figure (Figure 7).

Figure II–7. Canonical discriminant analysis for pregnancy status.



EH = Empty cows with high progesterone concentration at day 21
EL = Empty cows with low progesterone concentration at day 21
P = Pregnant cows
bcsm = body condition score at first service,
PSMFS = interval from planned start of mating to first service,
MU0 = milk urea concentration on Day 12,
p12 = progesterone concentration on Day 12

Figure 7 shows that the distinction between the three statuses, EH, EL and P, is made basically by the horizontal axis, CAN 1, whereas the vertical axis is essentially differentiating between the empty cows, EH and EL. The variable season discriminated between P and empty cows though not strongly, but it mainly distinguished between the EH and EL groups. PSMFS, p12, bcsm, anoest and MU0 differentiated between P, EH and EL statuses. The former four variables had a strong impact on the distinction, whereas MU0 had a limited impact. Anoest and bcsm were the variables that had more discriminative power to make a distinction between the two groups of empty cows, EH and EL.

Logistic regression.

Results for the logistic regression analysis for the probability of a cow becoming pregnant at first AI are summarised in Table 19.

Table II–19. Regression coefficients, standard errors, odds ratios and 95 % confidence limits (CL) from the stepwise logistic regression analysis to model the probability of a cow becoming pregnant at first service for both autumn- and spring-calving cows.

	Regression coefficient	Standard Error	Odds Ratio	95 % CL	Significance
Intercept	-6.605	3.334	.	.	
Season					
Spring	-0.193	0.477	0.825	0.32 – 2.11	NS
Autumn	0		1.0		
P12	0.029	0.014	1.029	1.00 – 1.06	*
MU0	-2.252	0.929	0.105	0.02 – 0.62	*
MU12	0.265	0.156	1.303	0.97 – 1.79	⇧
Bcsm	1.667	0.581	5.296	1.85 – 17.89	**
PSMFS	0.440	0.169	1.552	1.13 – 2.20	**
Health1	-1.043	0.413	0.352	0.15 – 0.78	*

p12 = progesterone concentration on Day 12,
MU0 = log of milk urea concentration on Day 0,
MU12 = milk urea concentration on Day 12,
bcsm = body condition score at first service,
PSMFS = interval from planned start of mating to first service,
Health1 = occurrence of one health disorder event.
NS = Not significant
⇧ P < 0.1
* P < 0.05
** P < 0.01

The variables included in the model were those selected by a stepwise logistic regression set to include variables that met a 0.1 significance level for entry and for staying in the model. The resulting model contained essentially the same variables as that built for the canonical discriminant analysis. Concentration of milk urea on Day 12 and health were included in the results of the logistic regression, but not in the discriminant analysis; the latter variable replaced the variable anoest. There was no significant effect of season (herd) upon the probability of conception to first service. Urea concentration at AI and the incidence of health problems events were negatively related to the probability of a cow becoming pregnant at a significant level ($P < 0.05$). Conversely, BCS at mating, progesterone concentration on Day 12, and the interval from PSM to first AI were all positively and significantly associated to the probability of a cow becoming pregnant at first service ($P < 0.05$, $P < 0.01$, and $P < 0.01$ respectively). Milk urea concentration on Day 12 was also positively related to the probability of a cow becoming pregnant. However, its effect only approached significance ($P < 0.1$).

The probability of a cow becoming pregnant at first service was decreased by 0.105 for each unit increase in the natural logarithm of milk urea concentration at AI. Also, the probability of a cow conceiving to first service when it had one health disorder event was only 35 % of that of a cow with no health disorders recorded. On the other hand, the probability of a cow becoming pregnant was increased by a factor of 5.29 for each unit increase in BCS at mating, by nearly 3 % for each ng/ml increase in the concentration of progesterone on Day 12, and by 55 % for each increase in the square root of the interval from PSM to first service.

Discussion

Several studies have demonstrated a negative association between high concentrations of dietary protein or high concentrations of urea in milk or blood with reproductive performance of dairy cows. The present study was undertaken to examine this relationship in two pastoral dairy systems differing in calving season. The association of the above mentioned factors with other variables such as progesterone concentrations, condition score and health disorder events were also explored.

Conception rate to first (CR1st) service was higher for the A (60.0 %) cows than S cows (49.4 %) but the difference was not significant. However, this difference would have been significant if the number of cows used had been two-fold larger.

In seasonal spring-calving herds in New Zealand average CR1st is around 60 % (see Table III-14a). However, there is little information about conception rate to first service in autumn-calving herds based on pastures (see Table III-13). Furthermore, in all of the reported studies in Table III-13, conception rate to first service in autumn-calving herds was estimated based in non-return oestrus with no pregnancy diagnosis being carried out nor progesterone measurements recorded. Thus, whereas in the literature a better CR1st is generally reported for spring-calving cows, the autumn herd in the present study had a better CR1st than the spring herd, that performed below the values usually recorded in New Zealand herds.

In the literature a better reproductive performance has generally been reported for spring- than for autumn-calving cows (Janson, 1980; Faust *et. al.*, 1988; Baldwin & Holmes, 1990; Farin *et. al.*, 1994; Westwood *et. al.*, 1998). It is suggested that in colder weather (e.g. winter) the cows' negative energy balance can be exacerbated because of higher energy demands to maintain body heat. Wiseman (1988), Baldwin & Holmes (1990) and Fulkerson & Dickens (1985) also added that the reduced hours of daylight in winter could adversely affect reproduction. Fulkerson & Dickens (1985) also suggested that seasonal management practices leading to differences in energy balance could affect reproduction. Thus, it appears that spring-calving cows usually have a better reproductive performance. However, it is important to consider the year to year variation in reproductive performance as a function of climatic conditions and feed availability and quality in each year (Shrestha, 1978).

In the present study, the lower reproductive performance (CR1st) seen in the spring-calving cows could have been due to the occurrence of calving inductions and a higher incidence of milk fever, combined with a more spread calving pattern and therefore shorter intervals from calving to first service (refer to chapter three in this thesis).

Milk urea and progesterone.

The results presented in this study demonstrated that high urea concentrations were associated with reduced fertility in both autumn- and spring-calving cows. This is in agreement with several other studies that have shown a deleterious effect of high urea on fertility (Ferguson *et. al.*, 1988; Williamson & Fernandez-Baca, 1992; Elrod & Butler, 1993; Ferguson *et. al.*, 1993; Larson *et. al.*, 1997).

It has been demonstrated that serum urea concentrations above 3.33 mmol/L (Ferguson *et. al.*, 1993) or milk urea above 5 mmol/L (Gustafsson & Carlsson, 1993) put the cows at higher risk of reproductive failure. Butler *et. al.* (1996) reported that lactating cows with plasma urea nitrogen (PUN) or milk urea nitrogen (MUN) concentration at AI higher than 3.2 mmol/L had a reduced pregnancy rate by 18 –21 % (respectively) compared to those cows whose PUN or MUN were below 3.2 mmol/L. Milk urea concentrations recorded in the present study were well above of those suggested to be adverse for an adequate reproductive performance (mean 6.6 and 8.5 mmol/L for S and A herds respectively). However, the conception rates achieved by the autumn herd at first service were satisfactory even though this herd had the higher concentration of urea in milk.

Nevertheless, in agreement with Ferguson *et. al.* (1993) and Butler *et. al.* (1996), when the cows in each herd were categorised according to their MU0, it was observed that as MU0 increased, the likelihood for pregnancy decreased. Through this procedure, the difference in conception rates across MU categories became more apparent. However, the data had to be analysed by chi-squared (χ^2) analysis, and the number of animals involved in each category was not large enough to show that the observed differences were significant (Whitaker *et. al.*, 1993).

Milk urea concentrations were consistently higher in the autumn herd than in the spring herd. This is in agreement with Moller (1991) who reported higher values of serum urea in autumn (9-10 mmol/L) than in late winter/early spring (5.8-8.2 mmol/L). It has been shown that a great proportion of the variation found in PUN or MU is explained by dietary factors such as protein and energy content of the diet and protein degradability (Oltner & Wiktorsson, 1983; Ropstad *et. al.*, 1989; Roseler *et. al.*, 1993; Broderick & Clayton, 1997; Schepers & Meijes, 1998). In the present study, weekly averages of urea concentration within each herd increased as the crude protein content, the ratio of CP/SCHOs (not shown) or the ratio CP/ME (not shown) of the diet offered increased. Moller *et. al.* (1993) reported a strong correlation (r = 0.69) between MU and pasture CP/SCHOs ratio. However, this ratio did not account accurately for the differences in MU seen between the herds in the current study. The CP content of pastures alone appeared to be more related to MU when considering both herds together. Despite the inclusion of soluble carbohydrates (maize silage) in the autumn herd's diet, MU was quite high. This is in agreement with Trevaskis & Fulkerson (1999) who noticed no effect on milk urea concentration from cows grazing pastures based on kikuyu (*Pennisetum clandestinum*) and ryegrass (*Lolium spp.*) when given higher levels of concentrates. Those authors suggested that this could be due to factors such as synchronisation of nutrient release and a reduced rumen pH when concentrates are fed to cows grazing pasture. Silages in the present study were generally fed once a day to the autumn herd, before the morning milking. It is therefore possible that by the time that milk samples were collected (afternoon milking) the urea concentration in milk was a reflection of the pasture composition rather than the combination of pasture and silage. It has been demonstrated that there is a lag of about 1 to 2 hr between MU peak and serum urea peak and a lag of about 1.5 to 2.0 hr between the latter and the rumen ammonia peak (Gustafsson & Palmquist, 1993). This means that the higher MU values can be found 3-5 hr after the beginning of feeding (Carlsson & Bergström, 1994). It may therefore be possible that the higher MU in the milk samples taken in the afternoon from the autumn herd was simply because of a higher CP content in the winter pastures, which provided all of their diet after they had finished their silage in the morning.

There are several other factors that may influence MU, such as live weight, parity number (Oltner *et. al.*, 1985), milk yield (Oltner *et. al.*, 1985; Gustafsson & Palmquist, 1993), sample collection time (Gustafsson & Palmquist, 1993; Kolver & Macmillan, 1993; Carlsson & Bergström, 1994; Eicher et. al., 1999), lactation stage (Gustafsson & Palmquist, 1993; Trevaskis & Fulkerson, 1999). However, none of them appeared to have had a significant effect upon the MU differences observed between herds in this study since both herds had similar characteristics and milk samples were collected from them at the same time. Nevertheless, sample collection time could have had an indirect effect upon MU (see above).

Through the analysis of the progesterone profiles in each herd, it was possible to differentiate from the empty cows those that failed to conceive or those that had a very early embryo loss before maternal recognition of pregnancy and therefore had a repeated oestrus within a normal range (18 - 24 days) (EL). It was also possible to detect those cows that possibly conceived with a maternal recognition of pregnancy, but in which an embryo loss could have occurred thereafter since a repeated extended oestrus and/or a negative pregnancy test was recorded. Between 17 and 19 % of the cows within each herd fell in the latter category. However, the proportion of EL cows in the S herd (32 %) was higher than that in the autumn herd (23 %), which accounted for the observed difference in pregnancy rate to first service between the herds. Sreenan & Diskin (1986) pointed out that fertilisation failure and early embryonic mortality account approximately for 10-12 % and 33-35 %, respectively with most of the embryo losses (75-80 %) occurring between day 8 and 18 and therefore, without altering the normal oestrus cycle duration.

In table 20 the proportion of early and late embryo losses reported in several studies are presented. It can be observed that, in the studies carried out specifically to account for embryo losses, the proportion of early embryo losses and fertilisation failure (equivalent to the EL cows in the present study) is higher (36 – 36.4 %) than that found in the present study. Furthermore, the proportion of late embryo losses (equivalent to the EH cows in the present study) is generally much lower (except for the 15.2 % reported by Butterfield & Lishman, 1988) than that observed in the present study.

Table II–20. Insemination fate and concentrations of urea in milk or plasma.

	INSEMINATION FATE (%)			
	Late embryo loss[1]	**Early embryo loss**[2]	**Pregnant**	**Reference**
	7.7	NR	NR	Lamming *et. al.* (1989)
	9.3	NR	NR	Britt (1992)
	15.2	NR	NR	Butterfield & Lishman (1988)
	9.9	36.0^{3}	54.1^{4}	Lamming & Darwash (1998)
	7.6	36.4^{3}	56.0^{4}	Sreenan & Diskin (1986)
	Studies assessing urea effects			
	$47.1\ (3.8^{b})^{5}$		$52.9\ (3.6^{a})^{5}$	Butler *et. al.* (1996)
	$26.9(3.6^{d})^{5}$	$20.5\ (3.9^{c})^{5}$	$52.6\ (3.6^{d})^{5}$	Larson *et. al.* (1997)
↑ *RDP*	$17.0\ (3.9)^{6}$	$22.0\ (3.9^{e})^{6}$	$61.0\ (3.9^{e})^{6}$	Elrod & Butler (1993)
↓ *RDP*	0.0	$17.9\ (2.9^{f})^{6}$	$82.1\ (2.9^{f})^{6}$	
Autumn	**17.3 (9.0)**^{5}	**22.7 (8.6)**^{5}	**60.0 (8.1)**^{5}	**Present study**
Spring	**18.8 (7.0)**^{5}	**31.8 (6.9)**^{5}	**49.4 (6.4)**^{5}	

NR = not reported

[1] Embryo loss occurring after maternal recognition of pregnancy (day 15 or 16 post insemination)

[2] Fertilisation failure or embryo loss occurring before maternal recognition of pregnancy (day 15 or 16 post insemination)

[3] Calculated by adding to the value for early embryo losses given by the authors a 10 % for fertilisation failure.

[4] Calculated by considering the percentages for embryo losses.

( ) Concentrations of urea in mmol/L and reported as

[5] Milk urea

[6] Plasma urea

[a, b] Means within a row with different letter differ ($P < 0.05$)

[c, d] Means within a row with different letter differ ($P < 0.1$)

[e, f] Means within a column with different letter differ ($P < 0.05$)

In the present study, EH cows had consistently lower P12 which could indicate the occurrence of an inadequate embryo signal to promote a satisfactory corpus luteum activity and to avoid luteolysis. Sheldon (1997) suggested that embryos vary in their ability to secrete interferon tau (IFN tau) from the trophoblast and the timing of onset of luteolysis is also variable. Thus, smaller, or damaged, embryos are less likely to produce an adequate signal in time to prevent luteolysis and so may be lost. Mann *et. al.* (1996) showed that the post-ovulatory rise in progesterone is of critical importance to the development of the embryo during the early stages of pregnancy. They observed that the post-ovulatory rise in progesterone occurred later in cows with small recovered embryos than in cows with medium and large recovered embryos. They suggested that an inadequately developed embryo is less able to inhibit the development of the luteolytic mechanism, thus compromising the successful outcome of pregnancy.

Larson *et. al.* (1997) showed that low progesterone concentrations postbreeding can reduce fertility and Mann *et al.* (1998 cited by O'Callaghan & Boland, 1999) reported that the concentrations of progesterone and embryonic interferon tau are positively correlated. Thus, minor changes in maternal progesterone concentrations during the initial period of embryo development may alter the secretion of this antiluteolytic agent and may be critical to embryo survival (O'Callaghan & Boland, 1999).

In regard to the effects of urea on embryo survival, it is interesting to note that the proportion of early and late embryo losses found in the present study matches better with that reported in the studies in Table 20 that were undertaken to evaluate the effect of high dietary protein and/or high urea in milk or plasma on fertility. Moreover, in all those studies and in the present one, the trend for the pregnant cows to have the lower concentrations of urea is consistent across the studies.

Elrod & Butler (1993) suggested that heifers fed high RDP and with extended luteal phases could have experienced embryonic death sometime after the critical period (Day 15 to Day 16) for maternal recognition of pregnancy and suggested an excess degradable protein as a possible cause, since this could alter the uterine environment lowering its pH and making it unsuitable for embryo growth. Additionally, Larson *et. al.* (1997) reported that EH cows had a significant delay in the onset of the luteal phase and lower progesterone concentrations than P cows from day 4.5 onwards. Thus embryo development was compromised, and pregnancy could not be maintained. They also showed that EL cows had higher MU than P and EH cows, suggesting that high MU concentrations at breeding may cause fertilisation failure or very early embryonic losses prior to maternal recognition of pregnancy due to a disruption in the oviductal or uterine environment, rendering it inhospitable to the early embryo.

It was of interest to investigate whether or not MU had an impact on progesterone concentration. The effect of feeding high protein diets (high urea) on progesterone concentration has been equivocal (Table 23). However, Butler (1998) pointed out that the discrepancies found seem to be due to the use of lactating cows in some studies but dry cows in others. Another factor that could have explained some of the disagreements observed between studies, is the degradability of the dietary protein and also the energy content of the diets used in those studies. In almost all of the studies reported in Table 21, a reduced progesterone concentration was observed when feeding high levels of dietary protein to lactating dairy cows. In the present study all cows were lactating, however it was not possible to detect an effect of MU on progesterone concentration. This is in agreement with Butler *et. al*. (1996) who did not find a difference in plasma progesterone concentration during early dioestrus (five-day period following AI) of lactating cows with PUN or MUN concentrations higher than 3.2 mmol/L and those with PUN or MUN < 3.2 mmol/L.

Table II–11. The effects of high dietary crude protein (CP) concentrations on plasma progesterone concentrations (PPC) during the oestrus cycle of lactating and non-lactating dairy cows.

CP in diet (%)	Effects on PPC	Lactating	Reference
19.3	Reduced 25 %	Yes	Jordan & Swanson, 1979
20.0	Reduced 30 %	Yes	Sonderman & Larson, 1989
20.0	Reduced 50 %	Yes	Staples et al., 1993
20.0	NS	Yes	Barton et al., 1996
27.4	NS	No	Garcia-Bojalil et al., 1994
25.0	NS	No	Blauwiekel et al., 1986
21.8	NS	No	Elrod & Butler, 1993

NS = Not significant
Adapted from: Butler (1998).

Even though it was not possible to detect an effect of urea on progesterone concentration in the present study, it is still likely that high urea concentration might have had an adverse effect by worsening an existing NEB. Interestingly, P cows had the lowest urea concentration at insemination time and consistently the highest scores for body condition at mating. Conversely, EH cows had the highest MU0 concentration and lower bcsm, which could have been indicative of a higher NEB. Similarly, EL cows had an intermediate MU0 and a similar bcsm to that of the EH except in the S herd were they got the lowest bcsm of all the cows in the study. These findings also suggest a higher NEB for EL cows than P cows.

It has been demonstrated that plasma progesterone concentration can be lowered by the effects of negative energy balance (Villa-Godoy *et. al*., 1988; Spicer *et. al*., 1990). Therefore, it seems that excess dietary protein and/or urea may act indirectly to reduce progesterone concentration by exacerbating NEB in early lactation due to the energetic cost involved of detoxifying ammonia escaping from the rumen when feeding excess RDP (Oldham, 1984; Butler, 1998). Additionally, Hutjens &

Jordan (1994) suggested that if ruminal available energy is deficient or marginal, such as during the early postpartum period when DM intake lags behind energy demands, the effects of feeding surplus RDP may be exacerbated. O'Callaghan & Boland (1999) also reported that the deleterious effects of high urea are likely to be due to alterations in the oviduct environment or changes in the follicle rather than changes in the uterine environment. They added that it is possible that the harmful effects of high dietary crude protein or urea on pregnancy rate are evident only when animals are in an energy deficit and microbial protein synthesis is reduced. Thus, the deleterious effects may be more evident in animals on a low plane of nutrition compared with those in a high plane of nutrition.

Body condition, beta-hydroxybutyrate and energy balance.

It is generally accepted that body condition scoring is a non-invasive, quick and inexpensive method to estimate body reserves and energy balance (EB) (Suriyasathaporn *et. al.*, 1998). Therefore, changes in BCS are a useful tool for relating suboptimal reproductive performance to inadequate nutrition in early lactation (Butler & Smith, 1989). Changes in energy intake (pasture allowance) may induce changes in body condition score and liveweight (Dunne *et. al.*, 1999). In this manner, a decrease in BCS is generally associated with negative energy balance (NEB) (Britt, 1994; Ferguson, 1994).

In the present study cows in all statuses presumably experienced a NEB in early lactation as indicated by the loss of BCS observed between calving and mating. However, it is possible that empty cows were in a more severe NEB than pregnant cows since they had a higher proportion of anoestrus cows at PSM, a higher MU0 and they lost slightly more BCS from calving to first service, resulting in a lower BCS at mating than the pregnant cows.

It has been demonstrated that commencement of postpartum oestrus cycles is closely linked, in time, to the occurrence of the postpartum nadir in NEB. Thus, when NEB reaches its lowest point sooner and then begins returning toward a positive EB, cows resume cycles sooner and conceive quicker than when the NEB nadir occurs later (Butler & Smith, 1989; Lucy *et. al.*, 1992; Britt, 1994). Staples *et. al.* (1990) showed that cows which did not begin to cycle until after 60 days postpartum ate less feed, produced less milk, and lost more body weight, resulting in a more negative energy status, than cows cycling between 40 – 60 days postpartum or before 40 days postpartum. The former two groups obtained more energy from body reserves (28 & 17 %) for milk production the first 2 weeks of lactation than cows in the latter group (16 %). Grainger & Wilhelms (1979), by using two different levels of feeding (LoF) or pasture allowances after calving during the first and second 5 weeks postpartum, observed that cows maintained on a low LoF had a significantly longer interval from calving to conception (+ 18 days) than cows maintained on a high LoF. They suggested that this could have been due to an increase duration of postpartum anoestrus because of underfeeding.

High urea concentrations can also indicate a reduced feed intake. Gath *et. al.* (1999 cited by O'Callaghan & Boland, 1999) observed that when heifers were supplemented while being fed at approximately half of maintenance or twice maintenance ME requirements, serum urea was higher in heifers on the low plane of nutrition despite similar intakes of exogenous urea and reduced intakes of crude protein in the animals on the low plane of nutrition. They suggested that this occurred because, on a low plane of nutrition, the liver function is reduced which slows the metabolic clearance of urea.

It is also documented that cows losing more condition postpartum had comparatively lower CR1st than those with smaller losses (Table 22) (Butler & Smith, 1989), no loses or gaining condition (Folman *et. al.*, 1973; Britt, 1994; Ferguson, 1994; Sheldon, 1997; Westwood *et. al.*, 1998). Also, cows losing condition have longer intervals from calving to first ovulation (Butler & Smith, 1989), to first observed oestrus (Britt, 1994; McGowan *et. al.*, 1996; O'Callaghan & Boland, 1999), and to conception (Folman *et. al.*, 1973; O'Callaghan & Boland, 1999), as well as requiring more services per conception (Folman *et. al.*, 1973; McGowan *et. al.*, 1996).

Table II–22. Relationship between body condition loss during the first five weeks postpartum and reproductive performance.

	Body condition loss (units)		
Variable	**< 0.5**	**0.5 – 1.0**	**> 1.0**
No. of cows	17	64	12
Days to first ovulation	27 ± 2[a]	31 ± 2[a]	42 ± 5[b]
Days to first observed oestrus	48 ± 6[ab]	41 ± 3[a]	62 ± 7[b]
Days to first service	68 ± 4[a]	67 ± 2[a]	79 ± 5[b]
First service conception rate (%)	65[a]	53[a]	17[b]
Services per conception	1.8 ± 0.4	2.3 ± 0.2	2.3 ± 0.4
Pregnancy rate (%)	94	95	100

From (Butler & Smith, 1989).

[a,b] Rows with different letter are significantly different ($P < 0.05$).

In the present study, a higher BCS at first AI was associated with a higher probability of conception, which is in agreement with Fulkerson (1984) and Ducker *et. al.* (1985). On the other hand, it was also observed that cows losing or remaining with the same BCS in the month after PSM and cows with higher B-OH were, though not significantly, more likely to conceive at first service than cows gaining body condition and with lower B-OH concentration. However, this apparently unexpected result was also found by Ducker *et. al.* (1985), who observed that heifers gaining weight (0.45 kg/day) in the four weeks prior to first AI had a reduced pregnancy rate (0.31), while those gaining weight in weeks 1 to 5 of lactation had higher pregnancy rates than those maintaining or losing weight (0.76 vs. 0.46). In a similar way, heifers with a BCS at AI of 2.5 or higher were more fertile, but there were no relationships with energy balance in the three weeks before or at the time of first AI.

It has been hypothesised that events occurring prior to maternal recognition of pregnancy, and possibly prior to fertilisation, may determine embryo viability. Since the ovulatory follicle develops under maternal influences 150 days before ovulation, environmental influences (e.g. plane of nutrition) may influence the embryo subsequently derived from that oocyte (Sheldon, 1997). Britt (1994) also suggested that changes in metabolism in the early postpartum period could influence preantral follicles destined to ovulate weeks later during the mating season. Follicles which begin to grow when energy balance is more negative might be exposed to adverse metabolic conditions that would render them less functional (Britt, 1992). O'Callaghan & Boland (1999) in reviewing several studies, pointed out that nutrient requirements for optimum follicle growth and embryo development may be quite different. They highlighted the importance of diet around the time of mating and in particular the significance of overfeeding, in regulating pregnancy rate. Overfeeding will decrease embryo quality which seems to be at the level of the follicle or oocyte. The effect being more evident in animals on extremely high dietary intake, with animals offered *ad libitum* diets particularly at risk. Data from heifers suggest that restricted nutrition for a short period of time will enhance pregnancy rates; most of this benefit appears to occur before AI, indicating that oocyte quality may be adversely influenced by high levels of nutrition.

In the light of these observations, it is possible to speculate that during the first weeks after calving cows which did not subsequently conceive had been subjected to a more severe NEB than cows which did conceive, possibly due to lower intakes and/or higher milk production. This situation could have affected follicular development and subsequent mating performance. Additionally, it is also possible that around mating, P cows experienced a lower plane of nutrition as reflected by their negative bcsd observed in the autumn herd, the unchanged or increasing trend in MU concentration over time, and the high B-OH concentrations observed in these cows. These conjectures seem to be supported by the observations of Ducker *et. al.* (1985), who showed that heifers receiving a higher LoF around the expected time of AI had significantly lower mean concentrations of serum B-OH. B-OH concentration at week nine of lactation was significantly correlated to days to conception. Heifers which became pregnant showed an increase in B-OH between weeks 5 to 9 but no change between weeks 9 to 13. Conversely, non-pregnant heifers, showed no change from weeks 5 to 9 but an increase from weeks 9 to 13. Heifers with higher B-OH at week 9 ($\geq$ 0.7 mmol/L) had a higher pregnancy rate (0.82) than those with lower B-OH (< 0.7 mmol/L) (0.44). The former heifers were losing weight from weeks 9 to 13 whereas the latter were gaining (Ducker *et. al.*, 1985). Whitaker *et. al.* (1993) also showed that cows in a better energy status during the first two weeks postpartum, as assessed by their plasma B-OH concentration (< 15 mg/100ml), took less time to the onset of cyclicity, had a better CR1st, had a shorter interval from calving to conception, and required fewer services per conception. However, at 21 days after calving or during the week of first service, they found no differences in fertility between the cows with better and worse EB.

Beta-hydroxybutyrate (B-OH) has been used to identify energy deficiency, mainly resulting from restrictive feed intake and the associated lipomobilisation (Hamann & Krömker, 1997). Even so, the usefulness of B-OH in milk to determine EB has been reported as equivocal. In this way, Cook (1999) quantifying concentrations of B-OH in milk by an enzymatic method, found that the sensitivity (the ability to detect small physical amounts or differences) of the test was high (0.96), but its specificity (the quality of being specific to the substance) was low (0.25), with too many false positives and with a weak relationship with plasma B-OH (r^2 = 0.17). Under grazing conditions, Verkerk & Guiney (1999) found a good relationship (r^2 = 0.68) between plasma and milk B-OH. However, the intra-assay coefficient of variation was very high (42 %) for B-OH in milk. The highest concentrations were found during the four weeks post-partum (range from 0.04 to 0.12 mmol/L). In the present study, the B-OH were higher (0.07 to 0.22) than those reported by Verkerk & Guiney (1999), especially during the same approximate sampling time postpartum. The concentrations that they reported corresponding to weeks 9 & 10 postpartum were 0.04 mmol/L. Dirksen & Brettner (1993) reported similar B-OH concentrations in milk as those found in the present study but with a wider range and variation between cows. The correlation between plasma and milk was high for one cow but low for the others.

Gravert *et. al.* (1986) found a significant positive correlation (0.23) between B-OH in milk and energy deficit during the first weeks of lactation. However, they found that the best metabolite indicator in milk was acetone. Conversely, Andersson (1984) during the first eight weeks postpartum, did not find a significant correlation between plasma and milk B-OH, nor an effect of lactation number or week of lactation on these concentrations.

Hamann & Krömker (1997) citing Gebhardt (1993) pointed out the marked variation between cows existing in B-OH, despite strictly controlled feeding management, and suggested 0.10 mmol/L as a physiological threshold. In the present study, B-OH concentrations in the autumn herd range from 0.07 to 0.22, with only 8 cows with 0.1 or less B-OH concentration suggesting that most of the cows, according to the above criteria, were in a negative energy balance.

Thus, there is the possibility that the B-OH test did not accurately reflect the EB of the cows, although the significant correlation between B-OH and the changes in BCS occurring after PSM must be remembered (see Figure 6).

Taking all the above information together, it seems that the negative effects of high urea concentrations on reproductive performance are unlikely to be decisive in isolation of other factors. This was demonstrated by the fact that despite having the higher MU concentrations, the autumn herd had also the higher rate for conception at first service compared to the spring herd. Moreover, the observed positive relationship between bcsm and fertility as well as the negative association between health disorders and fertility could have partially accounted for the differences observed between herds, since the S herd had a slightly lower bcsm and higher incidence of health disorders (milk fever) than the autumn herd. This is in agreement with Barton *et. al.*, 1996) who showed that the detrimental effects of feeding high dietary crude protein (20 %), and the consequent high plasma urea concentration, occurred at a significant level when they were associated with health problems. They found that healthy cows fed the high CP diet had lower median days open than did cows that experienced a major health problem. Healthy cows were detected in oestrus 13.5 days earlier, were pregnant 12.2 d earlier, had a higher CR1st and a higher pregnancy rate than cows with major problems. They also suggested that elevated concentrations of ammonia or urea may impair the reactivity of lymphocytes suppressing the cows' immune system which could have a negative impact on the cows' health status. Moreover, urea seems to exert its deleterious effects by exacerbating NEB in early lactation.

Conclusions

High milk urea concentrations are not directly associated with a depressed reproductive function, whereas the autumn herd had a higher MU0 than the spring herd, the conception rate to first service for the former herd was also higher, indicating that MU alone could not explain reproductive performance. Level of feeding (bcsm), postpartum interval (psmfs) and health status (incidence of health disorders) are key factors that will drive the breeding performance in a herd. It is more likely that MU acts negatively upon fertility by exacerbating an existing negative energy balance in early lactation. Contrary to feedlot systems, high concentrations of urea *per se* does not seem to affect reproductive function in grazing dairy cows. Nevertheless, high MU0 combined with low bcsm, short PSMFS interval and a high incidence of health disorders can reduce fertility.

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CHAPTER III

REPRODUCTIVE PERFORMANCE OF AUTUMN- AND SPRING-CALVING COWS IN THREE DAIRY FARM SYSTEMS

Abstract

The aim of this study was to evaluate and compare the reproductive performance of autumn- and spring-calving cows in three different farm systems; 100 % autumn-calving (A), b) 100 % spring-calving (S), and c) 50 % autumn- / 50 % spring-calving (AS). Records for type of calving (normal, assisted or induced), calf fate (dead or live), parity number, weights, body condition scores, milk production and occurrence of health disorders over a three-year period (1996-1999) were used for the analyses. The AS farmlet showed a more concentrated calving pattern than the A and S farmlets. The interval from planned start of calving to median calving date was 15, 17 and 19 days for the AS, A, and S farmlets, respectively. Cows in the S farmlet had a higher proportion of calving inductions, lower proportion of cows showing heats before planned start of mating (PSM), and a higher incidence of metabolic disorders than cows in the A or AS farmlets. The interval from calving to first service (CFS) was also shorter for the S farmlet (71 days) than for the A (75 days) and AS (73 days) farmlets. Conversely, the interval from PSM to conception (PSMC) as well as those from calving and from first service to conception (CC, FSC) tended to be longer for the S than the other two farmlets. Submission rate at 28 days (92, 94 and 90 % for the A, S and AS farmlets, respectively) was similar between farmlets. However, the S farmlet tended to have lower CR1st (47 %) than the other two farmlets (54 and 53 % for the A and AS farmlets, respectively) but the difference was not significant. Similarly the rate of pregnancy and calving were both lower in the S farmlet. Number of services per lactation and per conception tended to be higher in the S farmlet (1.66 & 1.61) than in the A (1.57 & 1.55) and AS (1.60 & 1.56) farmlets. Despite all the mentioned differences, empty rate was high for all farmlets (range: 14.0 – 15.7 %). Considering season of calving regardless of farmlet, spring-calving cows needed more services to conceive and therefore received more services per lactation than autumn-calving cows. Although spring-calving cows were more likely to be submitted for artificial insemination (AI), they tended to have a lower CR1st than autumn-calving cows. Anoestrus and late-calving cows had reduced probabilities of being submitted for AI (odds ratio (OR) = 0.43) and conceiving during the mating period (OR = 0.64) than their cycling herdmates. Likewise, the occurrence of a metabolic disorder (e.g. milk fever) was associated with a decreased probability of conception both at first service (OR = 0.27) and during the whole mating period (OR = 0.64). Similarly, cows experiencing two or more episodes of lameness had a reduced probability of conceiving to first service (OR = 0.61). Conversely, a cow giving birth to a live calf had a higher probability of conception to first service (OR = 2.9) and during the whole mating period (OR = 2.1)

than a cow with a dead calf. Also, cows with a longer interval from calving to planned start of mating (CPSM) were more likely to conceive to first service than those with a shorter CPSM interval.

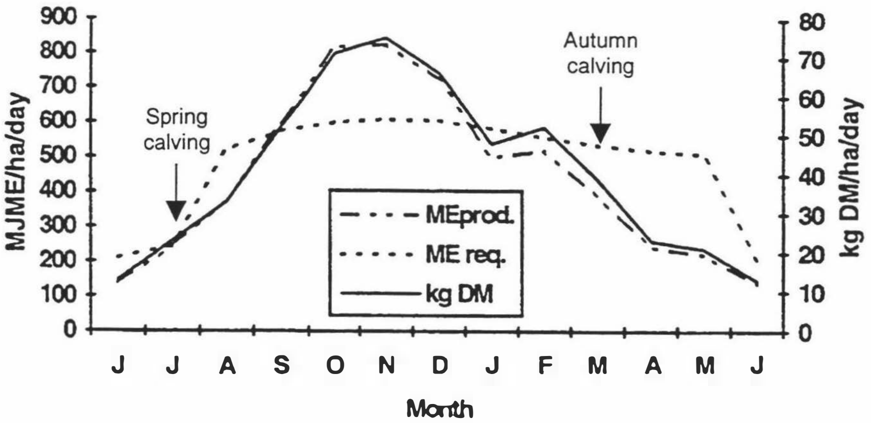
It was concluded that under the study circumstances, calving during autumn does not represent a problem in terms of reproductive function. In fact, the S farmlet showed the worst reproductive performance possibly due to a more spread calving pattern, a higher incidence of metabolic disorders, a higher usage of calving inductions and a shorter CFS interval. This meant reduced CR1st and therefore longer CC, PSMC and FSC intervals for the S cows, suggesting that calving pattern and health are more important than season of calving *per se*. However there is no obvious explanation for the overall high empty rates observed in all farmlets. The combination of relatively low CR1st and short CFS intervals, together with a short mating period (10 weeks) could have been some of the factors contributing to the observed empty rates.

Introduction

In seasonal dairy systems based on pastures (e.g. New Zealand), efficiency is strongly influenced by an appropriate synchrony between feed supply and feed demand, as well as by a high proportion of the pasture grown being harvested and converted into milk by high genetic merit cows (McMeekan, 1956; Bryant, 1984). A concentrated calving pattern and a constant yearly calving to maintain that pattern are indispensable in the attainment of such a goal (Macmillan, 1979; Macmillan *et. al.*, 1984). However, this can only be achieved if there is an adequate reproductive performance in the previous season, particularly an occurrence of both high submission rates and high conception rates to a single service (Macmillan & Watson, 1973).

In New Zealand there are two main seasons of calvings, late winter/early spring and autumn (Holmes *et. al.*, 1987). Even though the feed requirements of an autumn calving system does not synchronise fully with the common pasture growth pattern (Figure 1), a concentrated calving pattern is still needed in order to simplify management. However, the difference in calving season may induce several other differences. Since the main feed resource is pastures and the pasture growth and quality is mainly governed by the environment (Scott *et. al.*, 1985), important differences in diet composition through the year arise between seasons (García *et. al.*, 1998). Another important difference is the presentation of health disorders some of which are favoured by certain climatic conditions (e.g. lameness is associated with a wet environment / soil) (Baldwin & Holmes, 1990).

Figure III–1. Average pasture dry matter (DM) and metabolisable energy (ME) production for No. 2 dairy at Dairy Research Corporation (Hamilton, New Zealand) and the feed requirements for a spring-calving herd stocked at 3.0 Friesian cows/ha and fully fed from peak to end of season.



Adapted from: Thomson & Holmes (1995).

Fulkerson & Dickens (1985) reported inferior reproductive performance of autumn-calving cows, in terms of submission and non-return rates, than in spring-calving cows in Tasmania. Conversely, Hodgson & Chesnut (1999) showed, in preliminary results corresponding to the first year of a calving system trial, that the proportion of empty cows was higher in the spring herd than in the autumn herd. However, comparative information involving two seasons of calving in pastoral systems is scarce (see Chang'endo, 1996 and Shrestha, 1978).

The aim of this study was to compare the reproductive performance of autumn- and spring-calving cows in three different farm systems and to determine the main factors affecting their reproductive function.

Material and Methods

The study was carried out by using the information recorded over three years (1996 – 1999) at No. 1 Dairy Farm, Massey University. This study formed part of a system trial conducted in this farm to compare the physical, biological and economical efficiency of three farmlets with different calving dates. The three set systems were: a) 100 % spring calving, b) 100 % autumn calving, and c) 50 % spring / 50 % autumn calvings (García *et. al.*, 1998).

Animals and management.

The three farmlets were approximately 40 ha each and the number of cows in each farmlet and in each year was between 80 and 100 depending on the system (Table 1) (Cayzer, 1997).

Table III–1. Main characteristics of the three farmlets: 100 % Autumn-, 100 % Spring- and 50 % Autumn- / 50 % Spring-calving.

	100 % Autumn	100 % Spring	50 % Autumn & 50 % Spring	
No. cows (peak milk)	80	100	48	48
Land area (ha)	40.1	40.0	42.6	
Planned start of calving	10 March	20 July	20 March	1 August
Stocking rate (cows/ha)	2.0	2.5	2.25	

Adapted from: Cayzer (1997).

The three farmlets were composed of Friesian cows whose ages ranged between 2 and 15 years old and their general management was the same as that described for the 100 % Autumn and 100 % Spring farmlets in chapter two of this thesis.

Reproductive management.

For the purpose of this thesis, the three farmlets will be called A for the 100 % Autumn, S for the 100 % Spring and AS for the 50 Autumn % / 50 % Spring in the rest of the document.

The reproductive management calendars for each farmlet are summarised in the following table (Table 2).

Table III–2. Reproductive management calendars of the three farmlets: 100 % Autumn- (A), 100 % Spring- (S) and 50 % Autumn- / 50 % Spring-calving (AS).

	FARMLET			
	A	S	AS	
Event			autumn	spring
Calving period (expected)	10 Mar – 10 May	20 Jul – 20 Sep	20 Mar – 20 May	1 Aug – 1 Oct
Premating heat detection	1 month prior to PSM			
Planned start of mating (PSM)	1 Jun	10 Oct	10 Jun	20 Oct
Artificial insemination period	6 weeks			
Natural mating period	4 weeks			
Pregnancy test	Around 6 weeks after mating period finished			

Reproductive management activities carried out in all farmlets were similar and have been described in chapter two of this thesis.

Information from records.

Information about calving date, calving type (normal, assisted or induced), calf fate (dead, alive), calf sex (male or female), parity number, weight, body condition score (BCS), occurrence of pre-mating heats, inseminations, yields of milk (L) and milksolids (kg), and disease events (lameness, mastitis, milk fever, grass staggers, retained foetal membranes, anoestrus) were recorded routinely in the farmlets and they were used to execute the analysis and to derive some other variables also used in the analysis.

Derived and adapted variables.

Calving pattern.

Planned start of calving (PSC) in each farmlet was calculated as 283 days after the planned start of mating (PSM). From all calving records for each farmlet, frequency distributions of calvings were created to evaluate their calving pattern. In addition, the following intervals were calculated for each farmlet in each year according to Macmillan *et. al.* (1984):

1. Interval from PSC until 50 % of the herd had calved (PSC-to-50 %),
2. Interval during which the next 25 % of the herd calved (50-to-75 %),
3. Interval over which the last 25 % of the cows calved (75 %-to-end),
4. Interval from PSC to end of calving period (total calving period), and
5. Interval from the first to the last calving (calving spread).

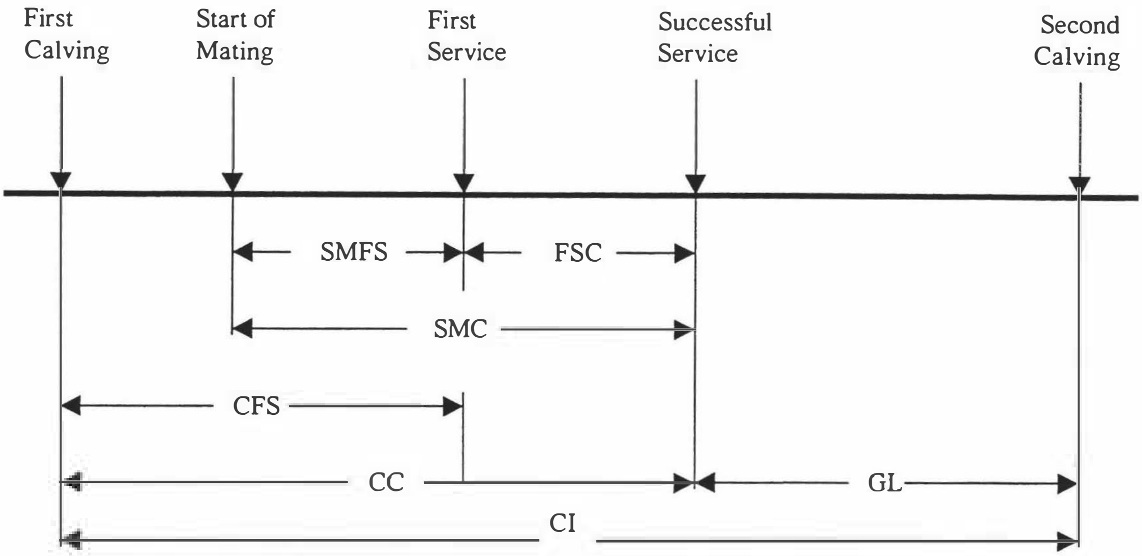
The interval between PSC to actual calving (PSCC) was also calculated for each cow in each farmlet. However, due to the presentation of negative numbers, an adjusted parameter was derived, standard calving date (StdCD), by considering the difference between actual calving date (CD) and a specific date fixed a 100 days before PSC in each farmlet. PSCC and StdCD displayed exactly the same distribution.

Postpartum intervals.

Postpartum intervals to evaluate the reproductive performance in seasonal dairy systems were calculated in accordance with Grosshans *et. al.* (1997) (Figure 2).

- Calving interval (*CI*, days),
- Interval from calving to first service (*CFS*, days), which was obtained by subtracting the calving date (CD) from the date of first AI,
- Interval from calving to conception (*CC*, days) which was calculated by counting the days between calving and the effective service. Effective service was determined by counting 282 days (average gestation length (Macmillan & Curnow, 1976) back from the CD in the next season and matching the corresponding recorded service. When the next CD was not available, the last service was regarded as the effective one, provided a positive pregnancy test was recorded. Thus, conception was assumed to have occurred when a subsequent calving and/or a positive pregnancy test was recorded,
- Interval from PSM to first service (*PSMFS*, days), was obtained by subtracting the PSM date from the date of first AI,
- Interval from PSM to conception (*PSMC*, days), which was estimated by counting the days between PSM and the effective service. The criteria to consider a service as effective was the same as that described for the interval CC.
- Interval from first service to conception (*FSC*, days). It was estimated as the difference in days between the effective service and the first service.

Figure III–2. Relevant fertility traits for seasonal dairy systems.



Grosshans *et al.* (1997).

SMFS: interval from start of mating (SM) to first service; SMC: interval from SM to conception; CFS: interval from calving to first service; FSC: interval from first service to conception; CC: interval from calving to conception (days open); CI: interval between consecutive calvings; GL: gestation length.

Submission, Conception and Pregnancy rates.

The percentage of cows submitted to a first insemination (submission rate) during 28 days following the PSM (*SR-28*) were calculated for each farmlet following Macmillan & Watson (1973).

Conception rates to first service (*CR1st*) were also calculated in each farmlet based on the established effective service, according to the criteria described above for CC and PSMC. Pregnancy rate in the entire mating season was obtained for each farmlet by considering the proportion of cows calved in the next season and/or with a positive pregnancy test, if they died or were culled before calving. Only those cows whose pregnancy status was confirmed by a pregnancy test and/or the occurrence of a calving in the next season were used to calculate these parameters.

The number of services, both artificial and natural, resulting in a pregnancy as well as the total received by a cow in each lactation were counted within each farmlet for a further use in the analysis.

Other variables.

Other variables taken into account for the analysis were:

- Live weight:
    - After calving (*wgtc*), which was that first weight recorded after calving,
    - At first AI (*wgtm*), which corresponded to that recorded more closely to the first AI.
    - Difference (*wgtd*), which was obtained by deducting wgtm from the wgtc.
- Body condition score (BCS)
    - At calving (*bcsc*), which was that first recorded after calving,
    - At first AI (*bcsm*), which corresponded to that recorded more closely to the first AI,
    - Difference (*bcsd*), which was obtained by deducting bcsm from bcsc,
- Lactation number, which was divided into two categories coded as follows 1 for first lactating cows and 2 for mature cows with two or more lactations.
- Calving type (*CT*) was classified in either of three categories, 0 for normal, 1 for assisted, and 2 for induced calving.
- Calf fate and sex were also considered. A dead calf was coded as 0 and 1 was assigned for an alive calf. With respect to sex, bull calves were coded as 0 and heifers calves as 1.
- Health related events, which most of them were coded as dichotomous variables with 0 for no events recorded and 1 for one or more episodes recorded. The only exceptions were for lameness, mastitis and the variable named health. The first two variables were coded as 0 for no events recorded, 1 for one event recorded and 2 for two or more events recorded. The variable health was coded into four categories: 0 for no events recorded, 1 for one event recorded, 2 for two events recorded or 3 for three or more episodes registered. These three exceptions were made because their frequency distribution of episodes allowed to have more categories with a considerable number of observations in each one of them.

Statistical analysis.

Categorical data such as occurrence of pre-mating heats, incidence of calving inductions, calving difficulties, health disorders, dead calves, and proportion of females born within each farmlet were evaluated through the use of chi-square tests.

For continuous variables, least-squares repeated measures analysis of variance and survival analysis were used. Calving interval, services per conception and the total number of times that a cow was mated in each lactation were analysed with a model that included the effects of farmlet, season, year, parity number, and cow nested within all the previously mentioned classes. Year was used as a repeat measure. For the postpartum intervals, CFS, PSMFS, CC, PSMC, FSC, and also for the variable StdCD, survival analysis was used to test differences between farmlets' performance. In the intervals that involved the occurrence of conception (e.g. CC, PSMC, FSC), censored observations were included for the analysis. Censoring occurred when a cow did not become pregnant during the mating season.

From the cumulative distribution functions obtained in the survival analysis, submission rates at 21 and 28 days, conception rates to first service, herd in-calf rates at 28 and 42 days as well as calving rate at 28 days were calculated for each farmlet.

To explore the effect of independent variables on the postpartum intervals, stepwise proportional hazards multiple regression analysis was used. The analysis for each interval modelled the probability that a cow was submitted or became pregnant at *n* days after PSM. The variables included in the analysis were farmlet, season, calving type, parity number, pre-mating heats occurrence, weights, BCS, calf fate and sex, health related events, StdCD and milk production. The effects of farmlet and season were forced to be included into the model first. To build the model, the stepwise procedure was set to include variables that met a 0.1 significance level for entry and for remaining in the model.

It was also of interest to investigate the relationship between independent variables and the pregnancy status achieved by the cows after first service. Therefore, stepwise logistic regression analysis was used to model the probability of a cow becoming pregnant at first service. The variables included in the analysis were basically the same used in the proportional hazards multiple regression analysis for the postpartum intervals. However, the postpartum intervals (CFS and PSMFS) were also included as independent variables. In this analysis, the variables farmlet and season were also forced to be included first in the model and the stepwise procedure was also set to include all other variables that met a 0.1 significance level for entry and for remaining in the model.

Results

PARITY NUMBER, LIVE WEIGHT AND BODY CONDITION SCORE.

Lactation number between the farmlets was not significantly different. However, cows in the AS farmlet tended to be younger than cows in the A and S farmlets (Table 3). Live weight and body condition was significantly different across the farmlets with cows in the A farmlet having the heavier weights after calving and around first service as well as the higher weight loss from calving to first service, followed by cows in the AS farmlet and the S farmlet with the lower weights and also with weight gain from calving to first service. However, in regard to body condition, at calving the A cows showed the higher scores followed by the S and then the AS cows, whereas at mating, the S farmlet had the higher scores and then the A and AS farmlets with similar scores. Differently to the live weights, cows in all farmlets lost body condition between calving and first mating with the A cows losing more condition followed by the S and then the AS cows (Table 3).

It is important to note that despite the differences between farmlets outlined previously, the main differences in liveweight and body condition between cows in the present study were due to the season of calving and its associated management (e.g. feeding regime). In this way, autumn-calving cows were heavier at calving and at mating and also lost more weight from calving to mating than spring-calving cows. Similarly, autumn-calving cows tended to have higher scores at calving and lower at mating than their spring-calving counterparts, and consequently, the former cows showed a higher body condition loss from calving to mating than the spring-calving cows.

CALVING TYPE, FATE AND SEX OF CALF, PRE-MATING HEATS, AND INCIDENCE OF ANOESTRUS.

The S farmlet had a significantly ($P < 0.01$) higher proportion of calving inductions followed by the AS and A farmlets (Table 4). However, there was a higher proportion of calving difficulties in the A farmlet compared to both the S and AS farmlets. The AS and A farmlets showed a similar proportion of cows having at least one oestrus before the PSM. This proportion was significantly higher ($P < 0.01$) than that displayed in the S farmlet.

Table III–3. Means and standard errors in brackets for parity number, live weight (Lwt) and body condition score (BCS) of cows in the A, S and AS farmlets.

	FARMLET			Sig.
	A	S	AS	
Parity number	**3.7** ± 0.15	**3.6** ± 0.14	**3.2** ± 0.14 (3.3, 3.2)	NS
Lwt at calving (kg)	**490.4** ± 4.2^{a}	**458.8** ± 4.6^{b}	**471.2** ± 4.1^{c} (487.6, 451.9)	*
Lwt at mating (kg)	**484.3** ± 3.8^{a}	**458.7** ± 3.4^{b}	**464.3** ± 3.6^{b} (474.4, 454.3)	*
Lwt change (kg)	**-6.9** ± 2.3^{b}	**0.5** ± 2.5^{c}	**-6.8** ± 2.2^{b} (-9.6, -3.8)	*
BCS at calving	**5.16** ± 0.05^{a}	**4.79** ± 0.05^{b}	**4.64** ± 0.04^{c} (4.69, 4.59)	*
BCS at mating	**4.31** ± 0.03^{b}	**4.41** ± 0.03^{c}	**4.34** ± 0.03^{bc} (4.22, 4.47)	*
BCS change	**-0.87** ± 0.04^{a}	**-0.37** ± 0.04^{b}	**-0.29** ± 0.04^{b} (-0.45, -0.13)	*

NS = Not significant

$^{a,b\,/\,a,c}$ Significantly different $P < 0.01$

^{b,c} Significantly different $P < 0.05$

( ) The number in parenthesis correspond to the separate autumn and spring herds in the AS farmlet.

Table III–4. Proportion (%) of cows induced to calve, with assisted calvings, with dead calves, with female calves, anoestrus at planned start of mating, and with pre-mating heats for cows in farmlets A, S and AS during 1996-1999.

		FARMLET			
	n	A	S	AS	Sig.
Induced calvings	759	3.2	9.6	4.8 (5.9, 3.7)	**
Assisted calvings	759	12.0	3.3	5.2 (7.4, 3.0)	**
Dead calves	827	6.9	6.7	3.9 (4.9, 2.9)	NS
Female calves	824	49.0	43.0	47.0 (50.0, 43.9)	NS
Anoestrus	835	15.0	13.9	17.5 (19.9, 15.0)	NS
Pre-mating heats	835	69.2	59.3	70.3 (67.1, 73.6)	**

NS = Not significant

** $P < 0.01$

( ) The number in parenthesis correspond to the separate autumn and spring herds in the AS farmlet.

INCIDENCE OF HEALTH DISORDERS.

The S farmlet showed the highest incidence metabolic disorders (milk fever and grass staggers) (8.6 %), whereas the A farmlet displayed the highest incidence of lame cows, followed by the AS farmlet. Incidence of RFM and mastitis was similar between farmlets (Table 5).

Table III–5. Proportion (%) of cows with lameness, mastitis, metabolic disorders (milk fever and grass staggers), and retained foetal membranes (RFM) for cows in farmlets A, S and AS during 1996-1999.

		FARMLET			
	n	A	S	AS	Sig.
Metabolic disorders	835	3.6	8.6	2.8 (2.1, 3.6)	**
RFM	835	2.8	5.0	3.5 (2.1, 5.0)	NS
Lameness	835	32.0	22.2	28.3 (39.7, 16.4)	*
Mastitis	835	17.0	23.2	23.8 (26.7, 20.7)	NS

NS = Not significant
* P < 0.05
** P < 0.01
( ) The number in parenthesis correspond to the separate autumn and spring herds in the AS farmlet.

CALVING INTERVAL, SERVICES PER CONCEPTION, AND SERVICES PER LACTATION.

Cows from the S farmlet had a significantly ($P < 0.05$) shorter calving interval than cows in the A and AS farmlets (Table 6). This is in agreement with the higher proportion of induced calvings observed in the S farmlet than in the other two farmlets (see Table 4), however, there was no significant difference between season of calving. The number of services per lactation and per conception were similar between farmlets but not between season of calving (Table 6). Autumn-calving cows received fewer services per conception and per lactation. A difference was also noted between years within farmlets (A farmlet) and within seasons (spring season) for both services per lactation and services per conception. Additionally, a significant effect of parity upon number of services was observed. First calvers received a higher number of services per lactation (1.68 ± 0.06 *vs* 1.55 ± 0.03) and per conception (1.65 ± 0.06 *vs* 1.49 ± 0.03) than mature cows.

Table III–6. Least square means and standard errors (SE) for calving interval, services per conception and services per lactation of cows by farmlet: A, S and AS, and by season of calving: autumn (Aut) and spring (Spr) during 1996-1999.

	FARMLET							Season of calving				
	A	**SE**	**S**	**SE**	**AS**	**SE**	**Sig.**	**Aut**	**SE**	**Spr**	**SE**	**Sig.**
Calving interval (days)[1]	368.4^a	2.2	360.3^b	2.1	369.4^a	1.5	*	364.4	1.8	367.7	1.8	NS
Services per lactation[2]	1.57	0.07	1.66	0.07	1.60	0.05	NS	1.50	0.05	1.72	0.06	*
Services per conception[3]	1.55	0.07	1.61	0.07	1.56	0.05	NS	1.47	0.06	1.67	0.06	*

[1] 415 calving intervals in three calving years. The least square means include the effect of the interval from planned start of calving to calving as covariate.

[2] 795 cows in three lactations. The least square means include cows that were mated and became pregnant and those mated but failed to conceive. The effect of the interval from calving to first service was added as covariate.

[3] 666 cows in three lactations. The least square means include only those cows that were mated and became pregnant. The effect of the interval from calving to first service was added as covariate.

CALVING PATTERN.

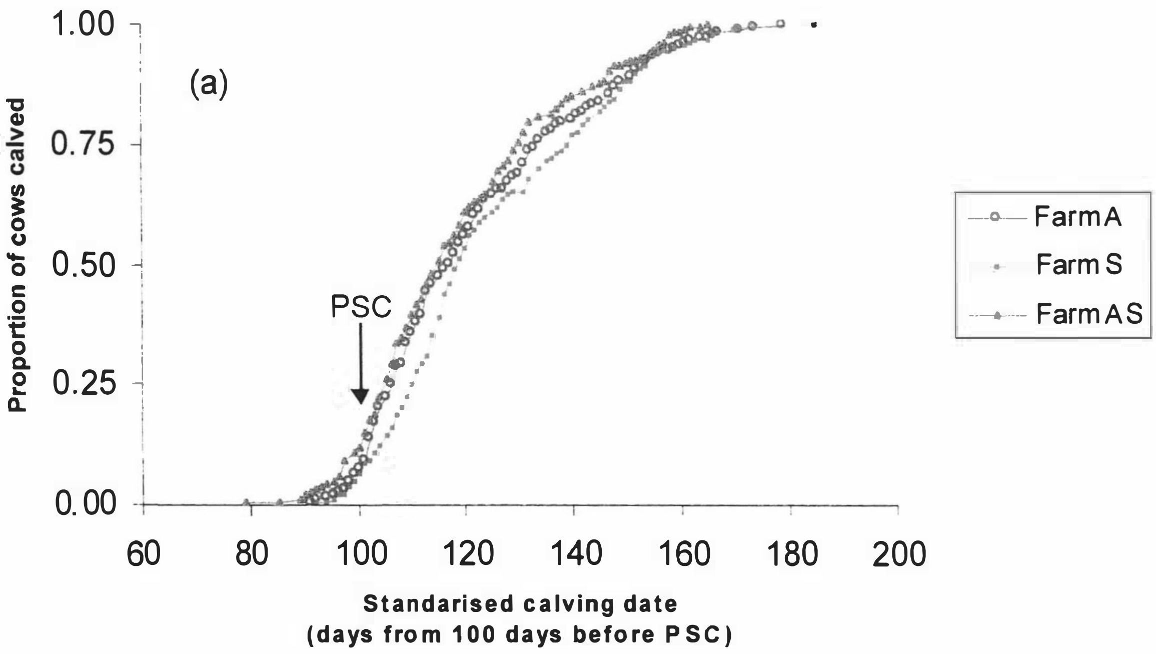
The intervals to evaluate the calving pattern in each farmlet are reported in Table 7 and they are also illustrated in Figure 3. Both herds in the AS farmlet showed more concentrated calving patterns than the other farmlets, and even more than those showed by Macmillan *et. al.* (1984) (Table 7). This meant that by day 65 after PSC the entire AS farmlet had already calved, whereas the A and S farmlets took 14 and 20 days longer to finish (Figure 3a). Thus, even with a higher proportion of induced calvings, the S farmlet had a more spread calving pattern, a difference more clearly seen in Figure 3b.

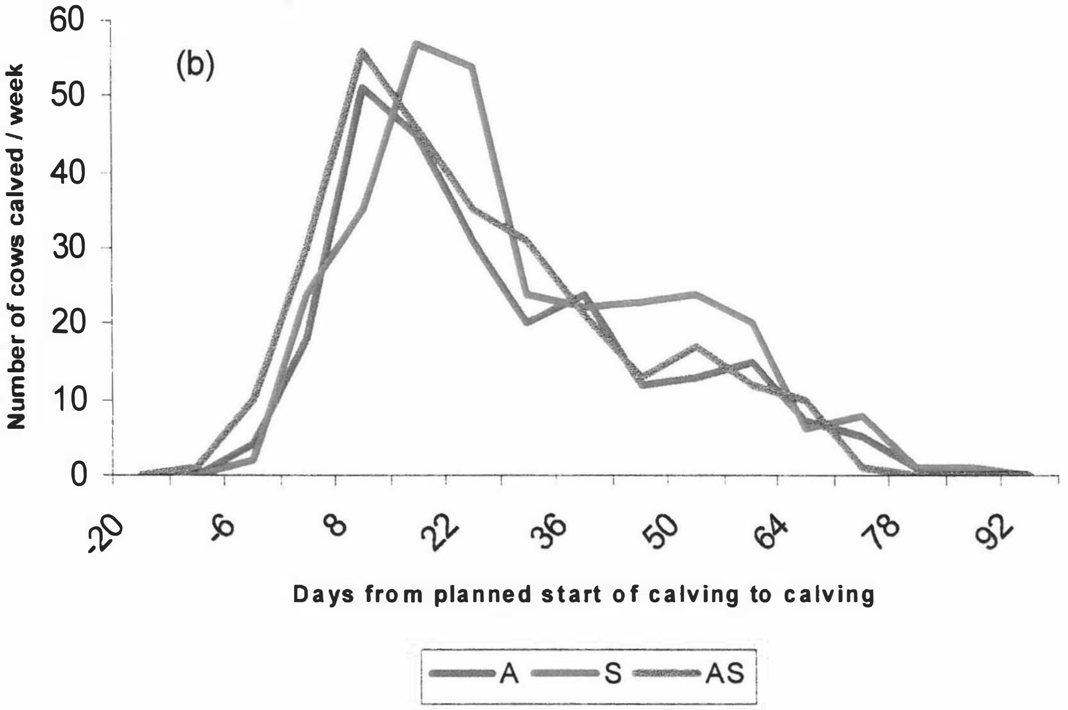
Table III–7. Planned start of calving (PSC), mean, and median calving dates (CD), proportion of cows calving before PSC and intervals to describe the calving pattern of cows from farmlets A, S and AS during 1996 to 1999.

	FARMLET					
	A	S	AS			Macmillan *et al.*, 1984
			autumn		spring	
PSC	10 Mar	20 Jul	20 Mar		1 Aug	5 Aug
Median CD	25 Mar	6 Aug	3 Apr		13 Aug	22 Aug[1]
Mean CD	29 Mar	11 Aug	7 Apr		16 Aug	26 Aug[1]
Cows calved before PSC (%)	**6.5**	**5.0**	12.5	**10.6**	7.9	NR
Interval from PSC to median CD (days)	**17**	**19**	16	**15**	14	18.3
Interval from median CD to 75 % (days)	**17**	**21**	18	**15**	15	17.5
Interval from 75 % to end of calving (days)	**45**	**45**	31	**35**	29	36.3
Interval from PSC to end of calving (days)	**79**	**85**	65	**65**	58	71.9
Interval from the first to the last calving (days)	**88**	**93**	80	**86**	79	NR

[1] From: Macmillan *et. al.* (1990).
NR = not reported.

Figure III–3. Survival cumulative distribution curve for standardised calving date (a) and frequency distribution for the planned start of calving to calving (b) of farmlets A, S and AS.





POSTPARTUM INTERVALS.

Cows from the three farmlets had similar mean intervals for PSMFS and CC. (Table 8). However, the S cows had a shorter CFS interval and a longer PSMC and FSC intervals than the A and AS cows (Figure 4a, 4b and 4c). On average, S cows took approximately 4 and 6 days longer to conceive from PSM and first service respectively than cows in the A or AS farmlets (Table 8). In addition, AS cows calved consistently earlier reflecting a more compact calving pattern (Figure 3b). The number of observations involved in the survival analysis for each interval ranged from 231 to 301 cows in each farmlet. In the intervals that included the occurrence of conception, the proportion of censored observations in each farmlet ranged from 13.7 to 16.5 % with the A farmlet having the lower percentages (mean = 13.9 %) and the other two farmlets a similar proportion (means = 16.2 and 16.4 % for the S and AS farmlets respectively).

Table III–8. Means, standard errors (SE), and tests of significance for the survival curves for some reproductive related intervals of cows in farmlets A, S and AS during 1996-1999.

	FARMLET			Significance tests	
	A	S Means ± SE	AS	Log rank	Wilcoxon
CFS (days)	**74.7** ± 1.3	**70.9** ± 1.2	**73.3** ± 1.2 (73.6, 73.0)	NS	*
PSMFS (days)	**13.3** ± 0.6	**13.3** ± 0.6	**13.7** ± 0.6 (15.5, 11.9)	NS	NS
CC (days)	**92.9** ± 1.9	**96.4** ± 2.0	**94.4** ± 2.0 (94.2, 93.9)	NS	NS
PSMC (days)	**30.3** ± 1.7	**34.7** ± 1.5	**30.9** ± 1.5 (31.5, 29.5)	NS	⇧
FSC (days)	**17.6** ± 1.6	**23.7** ± 1.7	**17.2** ± 1.4 (17.1, 17.2)	NS	NS
StdCD (days)	**121.9** ± 1.2	**124.7** ± 1.1	**119.1** ± 1.1 (121.0, 117.1)	**	**

CFS = Interval from calving to first service
PSMFS = Interval from planned start of mating to first service
CC = Interval from calving to conception
PSMC = Interval from planned start of mating to conception
FSC = Interval from first service to conception
StdCD = Standardised calving date (interval from 100 days before planned start of calving to actual calving)
( ) The number in parenthesis correspond to the separate autumn and spring herds in the AS farmlet.
NS = Not significant
⇧ $P < 0.1$
* $P < 0.05$
** $P < 0.01$

RATES OF SUBMISSION, CONCEPTION, HERD IN-CALF, AND CALVING.

Rates of submission, conception, herd in-calf and calving were calculated form their respective survival cumulative distribution curves (SCDC) summarised in Table 8, and they are presented in Table 9. Submission and conception rates derived from the SCDC of the intervals PSMFS and FSC (Figure 4c) respectively, were similar between farmlets. However, cows from the spring season, farmlets S and AS, tended to have lower conception rates to first service. Although the pregnancy rate for the entire mating season was not significantly different between farmlets, S cows took longer to conceive (lower herd in-calf rate at 6 weeks) than their counterparts in the A and AS farmlets (Figure 4b). As a result, the S farmlet showed the lowest calving rate at four weeks, despite its highest proportion of inductions (see Table 4), whereas the AS farmlet achieved the tightest pattern with more than 70 % of the cows calved by the end of week four after PSC. The overall empty rate, though high in all farmlets, did not differ between farmlets.

Table III–9. Submission rate, first service conception rate, herd in-calf rate and calving rate of cows in farmlets A, S and AS during 1996-1999.

	FARMLET			Sig.
	A	S	AS	
Submission rate (%)[1]				
Three weeks	86.6	84.0	81.1 (78.8, 83.5)	NS
Four weeks	91.6	93.8	90.0 (89.1, 91.0)	NS
Six weeks	98.7	99.0	98.9 (98.6, 99.3)	NS
First service conception rate (%)[1]	53.7	47.1	52.6 (55.9, 49.2)	NS
Herd in-calf rate (%)[1]				
Four weeks	54.1	51.3	54.9 (56.6, 53.1)	NS
Six weeks	73.0	65.0	71.2 (68.2, 74.2)	⇧
Seven weeks	79.8	71.8	75.5 (72.9, 78.1)	*
Entire season	86.3	83.8	83.7 (82.2, 85.2)	⇧[6]
Calving rate (%)[2]				
Three weeks	57.9	56.2	62.0 (58.3, 65.7)	⇧[7] **[1]
Four weeks	67.6	64.5	71.8 (68.8, 75.0)	*[2] **[1]
Empty rate	14.0	15.7	15.5 (16.8, 14.2)	NS

[1] It does not include heifers
[2] It includes primiparous cows
( ) The number in parenthesis correspond to the separate autumn and spring herds in the AS farmlet.
NS = Not significant
⇧ $P < 0.1$
* $P < 0.05$
** $P < 0.01$

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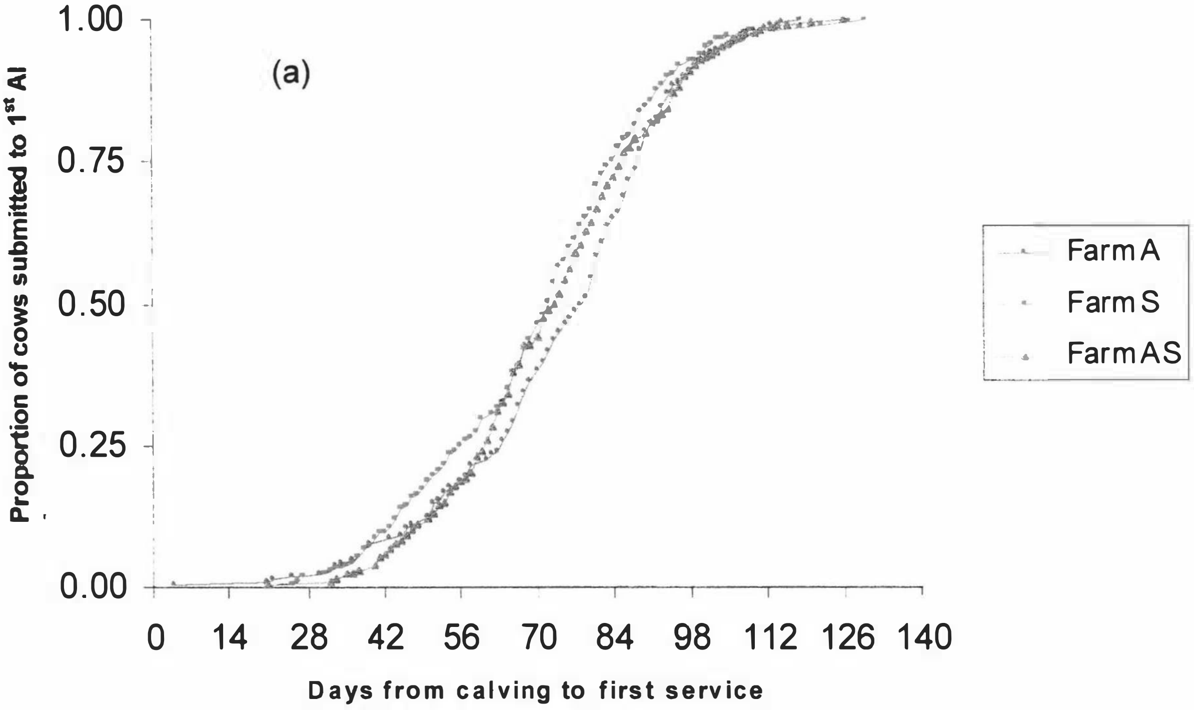
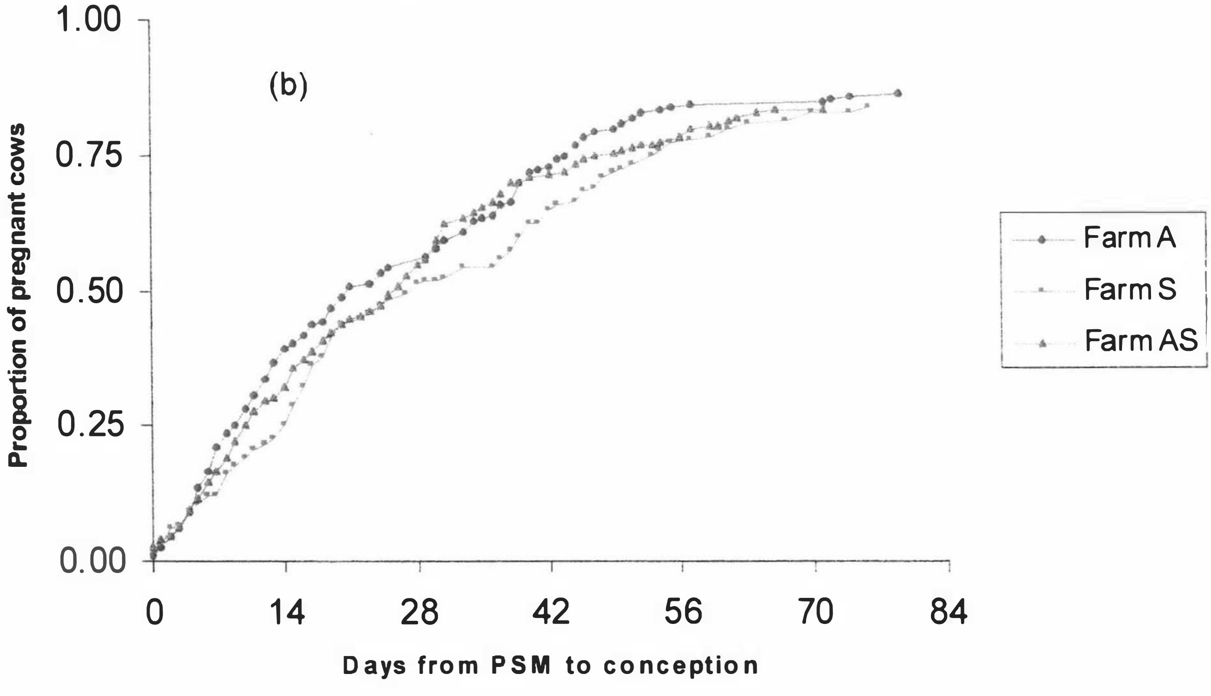
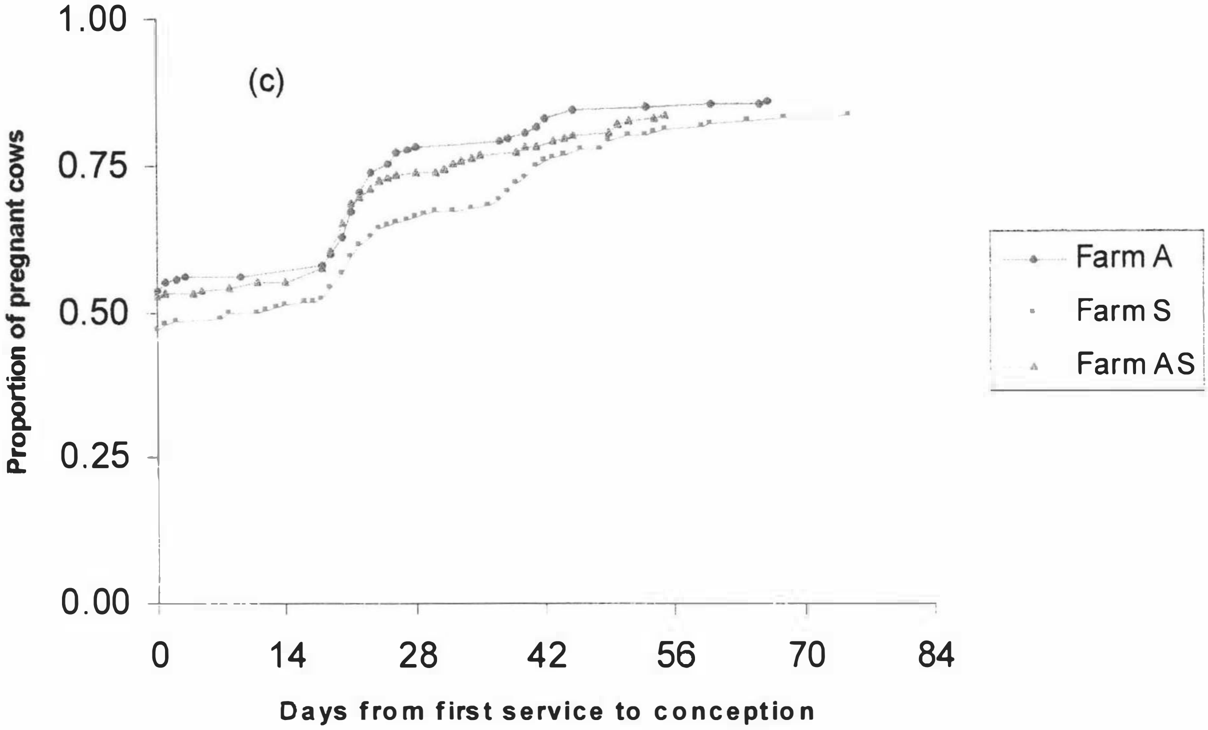
[6] Wilcoxon test

[7] Log-rank test

Figure III–4. Survival cumulative distribution curves for the intervals CFS (a), PSMC (b) and FSC (c) of cows in farmlets A, S and AS.







MULTIPLE REGRESSION ANALYSIS OF POSTPARTUM INTERVALS AND CONCEPTION RATE.

A concentrated calving pattern is necessary, and this depends on the achievement of high submission rates and high conception rates to a single service in the previous season. Therefore, the pregnancy status achieved by the cows after the first service, and the postpartum intervals PSMFS and PSMC were further explored for their associations with independent variables through the use of multiple regression analysis.

Interval from planned start of mating to conception.

The results of the regression analysis for the interval PSMC are presented in table 10. The probability of a cow becoming pregnant at any given day after the PSM, provided that she was submitted to AI, is modelled. In this way, although there was no significant effect of farmlet or season upon that probability, it was observed that health related events did have a significant effect. The probability of becoming pregnant for a cow presenting anoestrus before the PSM was only 64 % of that for a cow cycling at the same time. In the same way, cows with two or more lameness events had a reduced (61 %) probability of becoming pregnant compared to those with one or no events recorded. Milk fever and retained foetal membranes were also negatively associated to the probability of becoming pregnant. However, their effect only approached significance ($P < 0.1$). Cows giving birth to a live calf were twice as likely to become pregnant than those having a dead calf. Finally the probability of becoming pregnant for a cow calving one day later during the calving season was 0.991 of those calving one day earlier.

Table III–10. Regression coefficients estimates, standard errors, risk ratios, and 95 % confidence limits (CL) for risk ratios from the stepwise proportional hazards regression analysis for the interval from planned start of mating to conception (PSMC) of cows in farmlets A, S and AS during 1996-1999.

	Regression coefficient	SE	Risk ratio	95 % CL	Sig.
Farmlet					
AS	-0.115	0.132	0.891	0.69 – 1.15	NS
S	-0.219	0.182	0.803	0.56 – 1.15	NS
A	0.0		1.0		
Season of calving					
Spring = 1	0.049	0.150	1.050	0.78 – 1.41	NS
Autumn = 0	0.0		1.0		
Metabolic disorders					
Yes = 1	-0.442	0.229	0.642	0.41 – 1.01	⇧
No = 0	0.0		1.0		
Anoestrum					
Yes = 1	-0.440	0.123	0.644	0.51 – 0.82	***
No = 0	0.0		1.0		
Calf fate					
Alive = 1	0.759	0.242	2.137	1.33 – 3.43	**
Dead = 0	0.0		1.0		
Lameness[a]					
Two or more events	-0.501	0.221	0.606	0.39 – 0.94	*
No events	0.0		1.0		
Retained foetal membranes					
Yes = 1	-0.441	0.242	0.643	0.40 – 1.03	⇧
No = 0	0.0		1.0		
StdCD	-0.009	0.002	0.991	0.99 – 1.00	***

StdCD = Standardised calving date (interval from 100 days before planned start of calving to actual calving).

[a] = The regression estimator for one event of lameness was not significantly different from no events.

NS = Not significant

⇧ $P < 0.1$

* $P < 0.05$

** $P < 0.01$

*** $P < 0.001$

Interval from planned start of mating to first service.

Results from the multiple regression analysis for the interval PSMFS are given in Table 11. The regression analysis modelled the probability of a cow being submitted for AI at any given day after PSM. There was a significant difference ($P < 0.05$) between farmlets in the probability of submission after PSM. The probability of an AS or S cow of being submitted for AI was 78 % and 66 % respectively of that of an A cow. However, in regard to the effect of season of calving, cows from the spring season were 1.5 times more likely to be submitted than their counterparts in the autumn season, which showed the acute differences in the PSMFS interval existing between the herds in farmlet AS (see Table 8). As in the interval PSMC, anoestrus cows had less than half (43 %) the probability of being submitted for AI than cows cycling at PSM. Finally, cows calving later in the season had a reduced probability of being submitted than those calving earlier, and cows with a heavier weight at mating had a marginal advantage in their probability of submission.

Table III–11. Regression coefficients estimates, standard errors, risk ratios, and 95 % confidence limits (CL) for risk ratios from the stepwise proportional hazards regression analysis for the interval from planned start of mating to first service (PSMFS) of cows in farmlets A, S and AS during 1996-1999.

	Regression coefficient	SE	Risk ratio	95 % CL	Sig.
Farmlet					
AS	-0.244	0.119	0.784	0.62 – 0.99	*
S	-0.410	0.166	0.664	0.48 – 0.92	*
A	0.0		1.0		
Season of calving					
Spring = 1	0.425	0.135	1.530	1.18 – 1.99	**
Autumn = 0	0.0		1.0		
Anoestrus					
Yes = 1	-0.846	0.122	0.429	0.34 – 0.55	***
No = 0	0.0		1.0		
Wgtm	0.001	0.0007	1.001	1.00 – 1.003	⇧
StdCD	-0.006	0.002	0.994	0.99 – 1.00	**

Wgtm = live weight around first mating

StdCD = standardised calving date (interval from 100 days before planned start of calving to actual calving).

⇧ $P < 0.1$

* $P < 0.05$

** $P < 0.01$

*** $P < 0.001$

Conception rate to first service.

Results from the logistic regression modelling the probability of a cow becoming pregnant to first service are shown in Table 12. Farmlet and season did not have a significant effect on the probability of getting pregnant at first service. A cow giving birth to a live calf had nearly three times higher likelihood of becoming pregnant than a cow having a dead calf. In line with the regression analysis for the interval PSMC, the occurrence of metabolic disorders had a negative effect upon the probability of getting pregnant to first service, with a cow experiencing milk fever having only 27 % chance of conceiving compared to a cow with no recorded events of metabolic disorders. Ultimately, as the interval from calving to PSM increased, the probability of a cow becoming pregnant to first service also increased significantly ($P < 0.01$). For each day increased in the interval CPSM, the probability of conception to first service increased by 1.5 %.

Table III–12. Regression coefficients estimates, standard errors, odds ratios, and 95 % confidence intervals (CI) for odds ratios from the stepwise logistic regression analysis of the probability of becoming pregnant at first service (CR1st) for cows in farmlets A, S and AS during 1996-1999.

	Regression coefficient	SE	Odds ratio	95 % CI	Sig.
Intercept	-1.652	0.538	.	.	
System					
AS	-0.036	0.245	0.964	0.60 – 1.56	NS
S	0.329	0.373	1.389	0.67 – 2.90	NS
A	0.0		1.0		
Season of calving					
Spring = 1	-0.347	0.307	0.707	0.39 – 1.29	NS
Autumn = 0	0.0		1.0		
Calf fate					
Alive = 1	1.071	0.441	2.917	1.27 – 7.31	*
Dead = 0	0.0		1.0		
Metabolic disorders					
Yes = 1	-1.326	0.485	0.266	0.09 – 0.65	**
No = 0	0.0		1.0		
Calving to PSM[1] interval	0.015	0.005	1.015	1.01 – 1.02	**

[1] Planned start of mating.
NS = Not significant
* P < 0.05
** P < 0.01

Discussion

The aim of the present study was to evaluate and compare the reproductive performance of three dairy farm systems differing in calving season (autumn and spring), and to explore some of the factors influencing their reproductive performance.

Reproductive performance of autumn- and spring-calving cows from New Zealand and Australian studies is shown in Table 13.

Table III–13. Reproductive performance of autumn- and spring-calving cows. Information from the A and S farmlets in the present study is also included for comparison.

	Season		
Parameter	**Autumn**	**Spring**	**Reference**
Submission rate (%)-24	79	69	Fulkerson (1984)
	75	87	Fulkerson & Dickens (1985)
	100[1]	97	Hodgson & Chesnut (1999)
SR-28	71	81	Chang'endo (1996)
	92	**94**	**Present study**
Non-return rate to first service (%) – 21 days	44[2]	59	Fulkerson (1984)
	40[2]	68	Fulkerson & Dickens (1985)
	70	72	Hodgson & Chesnut (1999)
– 42 days	55	64	Chang'endo (1996)
Calving rate to first service (%)	60	69	Shrestha (1978)
Conception rate to first service (%)[a]	**54**	**47**	**Present study**
Calving interval (days)	391	372	Chang'endo (1996)
	383	367	Shrestha (1978)
	368	**360**	**Present study**
Calving to first service (days)	84	76	Shrestha (1978)
	75	**71**	**Present study**
Calving to conception (days)	106	90	Shrestha (1978)
	93	**96**	**Present study**
First service to conception (days)	12	10	Shrestha (1978)
	18	**24**	**Present study**
Services per conception	1.9	1.5	Shrestha (1978)
	1.9	1.6	Chang'endo (1996)
	1.6	**1.6**	**Present study**
Calving rate (%) – 4th week[b]	41	54	Chang'endo (1996)
	68	**65**	**Present study**
Empty rate (%)	12	10	Chang'endo (1996)
	8	15	Hodgson & Chesnut (1999)
	14	**16**	**Present study**

[1] Cows were subjected to a synchronisation programme

[2] True non-return rate (21 days) = 100 - ((1-(non-return rate to first service/100)) / (submission rate/100) X 100).

[a] It does not include heifers for the present study

[b] It includes primiparous cows for the present study

The information of the previous table shows a general trend for the spring-calving cows to display a better reproductive performance than autumn-calving cows.

This observation seems to agree also with findings made in Europe (Janson, 1980; Hodel *et. al.*, 1995; Ouweltjes *et. al.*, 1996). It is suggested that in colder climates (e.g. winter) the cows' negative energy balance can be exacerbated because of higher energy demands to maintain body heat. Fulkerson & Dickens (1985); Wiseman (1988); Baldwin & Holmes (1990) and Mereier & Salisbury (1947 cited by Ashwood, 1985) also suggested that the reduced hours of daylight in winter could affect reproduction adversely (e.g. more difficult oestrus detection). However, the 100 % spring-calving farmlet in the present study showed the worst reproductive performance.

In the following table (Table 14), reproductive performance of spring-calving dairy cows reported mainly in New Zealand studies have been summarised as a basis for comparisons with those in the present study.

Table III–14a. Reproductive performance of seasonally spring-calving cows. Information from the A and S farmlets in the present study is also included for comparison.

	Season		
Parameter	**Autumn**	**Spring**	**Reference**
Submission rate (%)-21		84[1]	Macmillan *et. al.* (1987)
SR-24	79	69	Fulkerson (1984)
	75	87	Fulkerson & Dickens (1985)
SR-28		84	Macmillan & Watson (1973)
		89	Macmillan *et. al.* (1975)
		85 - 91	Hayes (1997)
	92	**94**	**Present study**
Non-return rate to first service (%) – 21 days	44[2]	59[2]	Fulkerson (1984)
	40[2]	68[2]	Fulkerson & Dickens (1985)
49 days		59	Macmillan & Watson (1973)
Conception rate to first service (%)[a]		59[1]	Macmillan *et. al.* (1987)
		64[3]	Macmillan *et. al.* (1987)
		59	Macmillan & Taufa (1983)
		56	Hayes (1998)
		59	Macmillan *et. al.* (1997)
		64[4]	Xu *et. al.* (1996)
	54	**47**	**Present study**
Herd in-calf rate (%)[a]			
3 weeks		55[1]	Macmillan *et. al.* (1987)
		56[3]	Macmillan *et. al.* (1987)
4 weeks		60 - 67	Hayes (1997)
		54	Macmillan & Watson (1973)
	54	**51**	**Present study**
7 weeks		74	Grosshans *et. al.* (1997)
		73	Macmillan & Watson (1973)
		86[4]	Xu *et. al.* (1996)
	80	**72**	**Present study**
Calving interval (days)		366	Grosshans *et. al.* (1997)
		364	Macmillan & Moller (1977)
	368	**360**	**Present study**

[1] Analysis includes just cows calving normally during the 6 weeks following PSC in 5 herds.

[3] Includes all cows in three herds.

[4] Includes only cycling cows with at least 42 days interval from calving to PSM

[a] It does not include heifers

Table III-14b. Reproductive performance of seasonally spring-calving cows. Information from the A and S farmlets in the present study is also included for comparison.

	Season		
Parameter	**Autumn**	**Spring**	**Reference**
Calving to first service (days)		76	Grosshans *et. al.* (1997)
		76	Macmillan & Moller (1977)
		77[1]	Macmillan *et. al.* (1987)
	75	**71**	**Present study**
PSM to first service (days)		19	Grosshans *et. al.* (1997)
		13[1]	Macmillan *et. al.* (1987)
		15[3]	Macmillan *et. al.* (1987)
	13	**13**	**Present study**
Calving to conception (days)		90	Grosshans *et. al.* (1997)
		88[1]	Macmillan *et. al.* (1987)
	93	**96**	**Present study**
PSM to conception (days)		33	Grosshans *et. al.* (1997)
		28	Macmillan & Clayton (1980)
		25[1]	Macmillan *et. al.* (1987)
		24[3]	Macmillan *et. al.* (1987)
		21[4]	Xu *et. al.* (1996)
	30	**35**	**Present study**
First service to conception (days)		13	Grosshans *et. al.* (1997)
		11	Macmillan & Clayton (1980)
	18	**24**	**Present study**
Services per conception		1.5	Grosshans *et. al.* (1997)
		1.3	Macmillan & Clayton (1980)
		1.8	Hayes (1998)
		1.6[4]	Xu *et. al.* (1996)
	1.6	**1.6**	**Present study**
Calving rate[b] (%) 4th week		66	Hayes (1998)
		68	Macmillan *et. al.* (1984)
	68	**65**	**Present study**
Empty rate (%)		9	Macmillan & Clayton (1980)
		5	Macmillan & Moller (1977)
		6 – 11	Hayes (1997)
		5[1]	Macmillan *et. al.* (1987)
		8[3]	Macmillan *et. al.* (1987)
		5[4]	Xu *et. al.* (1996)
	14	**16**	**Present study**
Duration of mating (weeks)		9 AI[5] + 4-6 NM[6]	Macmillan & Clayton (1980)
		5-6 AI +7-9 NM	Macmillan & Moller (1977)
		6 AI + 6-9 NM	Macmillan *et. al.* (1987)
		7 AI + 5-9 NM	Xu *et. al.* (1996)
	6 AI + 4 NM	**6 AI + 4 NM**	**Present study**

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[1] Analysis includes just cows calving normally during the 6 weeks following PSC in 5 herds.

[2] True non-return rate (21 days) = 100 - ((1-(non-return rate to first service/100)) / (submission rate/100) X 100).

[3] Includes all cows in three herds.

[4] Includes only cycling cows with at least 42 days interval from calving to PSM

[5] AI = artificial insemination

[6] NM = natural mating

[b] It includes primiparous cows

CALVING TYPE, FATE AND SEX OF CALF, PRE-MATING HEATS, AND INCIDENCE OF ANOESTRUS.

Cows from the S farmlet were more likely to be induced than those in the A or AS farmlets. This, in conjunction with a significantly later calving date and therefore a significantly shorter interval from calving to first service, could partially explained the lower reproductive performance achieved by the S farmlet particularly in terms of services per conception, conception rate to first service (CR1st) and compactness of calving. Conversely, the higher CR1st and fewer inductions in farmlets A and AS were translated into fewer inductions, and a more concentrated calving pattern. The AS farmlet was mainly favoured by its earlier calving pattern.

S cows had an average induction rate of 9.6 % which is similar to published values, for example 5.5 – 11.4 % (Macmillan *et. al.*, 1984; Hayes, 1997; Hodgson & Chesnut, 1999), and less than the 10 % maximum recommended (Malmo, 1985). However, calving induction can have deleterious effects, on reproduction and production.

Hayes (1997) showed that induced cows had lower milk production, a similar SR-21 (at 21 days) (88 %), and slightly lower CR1st (56 *vs* 60 %) and overall pregnancy rate (90 *vs* 94 %). He also showed that the mean calving date for induced cows was nearly 8 days later than non-induced cows, and that induced cows had only 80 % probability of conception at first service compared with non-induced cows and only 60 % probability of pregnancy during the whole mating season compared to a non-induced herdmate. He suggested that induction may have an indirect positive effect by increasing the interval from calving to first service in expected late calvers if it is done early enough to counteract the direct negative effects of induction. In the present study, calving inductions were carried out when the end of the calving season was approaching, and therefore the negative effects of induction were more likely to be present than the positive ones.

Hayes (1997) and Morton & Butler (1995) showed that induced cows had lower milk production than non-induced cows. The later authors noted that even though there was no difference in lactation length (255 & 256 days), induced cows produced 8 and 9 % less milk volume and milksolids respectively than non-induced cows.

In the present study, induced cows (n=42), regardless of farmlet, produced on average less milk (L) and milksolids (4,065 L and 316 kg, respectively) per cow per lactation than non-induced cows (n=647) (4,450 L and 349 kg, for milk and milksolids, respectively). Also, induced cows had significantly lower overall pregnancy rates (74 %) than non-induced cows (86 %), and a trend to lower CR1st (40 *vs* 50 % for induced and non-induced cows, respectively).

In New Zealand, anoestrus at the beginning of the mating season represents probably the major reproductive inefficiency in seasonally calving dairy herds (Xu & Burton, 1996; Macmillan, 1997). The proportion of anoestrus cows (14 - 20 %) was similar between the farmlets in the present study, and it was also similar to those figures usually reported, 10 – 35 % (Xu & Burton, 1996; Macmillan, 1997; Rhodes *et. al.*, 1998; Hodgson & Chesnut, 1999; Verkerk & Guiney, 1999). However, the lower proportion of cows showing heats before PSM in the S farmlet seems to be in disagreement with the similar proportion of anoestrus cows for all farmlets. Since the present analysis was based on the events recorded in the farmlets, it is possible that the discrepancy observed could have been due to a omission of recording either of pre-mating heats or anoestrus events.

Macmillan (1997) indicated an anoestrus period of up to six weeks is desirable to allow uterine involution, but when it persists beyond six weeks it can delay dates of insemination and conception. He and also Diskin (1997) pointed out the main factors that influence the length of postpartum anoestrus:

- BCS at calving
- Level of feeding in early lactation relative to daily milk yield,
- Genetic merit relative to actual daily milk yield,
- Age (postpartum anoestrus is about 15 days longer in primiparous than multiparous cows (Diskin, 1997)), and
- Breed.

Rhodes *et. al.* (1998) also added that the probability of anoestrus was significantly influenced by herd and was negatively related to interval from calving to veterinary examination and age. Therefore, they indicated that the likelihood of anoestrus is greatest in young and late calving cows.

The main cause for anoestrus is an increased net energy deficit existing during the early postpartum period due to the increased lactation demands of the higher producing cows which is not being met by feeding strategies (Butler & Smith, 1989; Wiltbank, 1998) . Date of calving relative to PSC has also a strong impact in the incidence of anoestrus (Xu & Burton, 1996). Thus, induced, primiparous, and high-stocked cows take longer to resume ovarian activity after calving (McDougall, 1993).

Diskin (1997) indicated that both the extent and duration of negative energy balance (NEB) during early lactation may also affect subsequent conception rates. In this respect he emphasised that feed intake is a major determinant of EB and therefore duration of postpartum anoestrus, rather than milk yield *per se*. Wiltbank (1998) indicated that cows that lose greater amounts of body condition from calving until breeding have lower conception rates. Thus, greater loss of body condition increases days to first ovulation and may reduce pregnancy rate per AI. In grazing systems, younger animals are also likely to be dominated by older cows, resulting in lower pasture intakes and increased NEB (Rhodes *et· al*., 1998). A reduced probability of both submission for AI and conception during the mating period was observed for anoestrus cows (cows likely to be in a NEB) in the present study.

In the present study the incidence of calving difficulty (assisted calvings) (3 – 12 %) and calf mortality (3 – 7 %) was similar to that reported in the literature. Thompson *et· al*. (1983) reported a calving difficulty and calf mortality incidence of 13.1 and 6.9 %, respectively, while Hayes (1997) reported a calf mortality of 10.6 %.

Calving difficulties are associated with twins, malpresentations, premature births and oversized calves relative to the size of the birth canal. They predispose the cows to retained foetal membranes and uterine infections and therefore reduced reproductive performance. Stillbirths are also associated with a higher incidence of retained placenta, which reduces fertility (Diskin, 1996; Ryan, 1997). Thompson *et. al*. (1983) showed that calving difficulty negatively affected reproductive performance in terms of days open, CFS interval and number of services at both first and later parities. Cows with an extreme calving difficulty had 20.4 days longer interval from calving to conception than cows with unassisted births.

Diskin (1996) showed that as the severity of calving difficulty increases, conception rate to the first and to all services combined also decreases (Table 14). This is due to abnormalities directly arising from the calving difficulty including delayed uterine involution and increased uterine infection, damage to the reproductive tract and the development of uterine and ovarian adhesions. Furthermore, the interval to first oestrus is often extended after a difficult calving.

Table III–15. Effect of calving difficulty on subsequent calving rate (%).

Calving difficulty score[1]	Calving rate to 1st service (%)	Calving rate to all services (%)
1	55	86
2	49	86
3	48	89
4	38	71
5	27	75

[1] Score 1 = unassisted birth to score 5 = severe dystocia

From: Diskin (1996).

A negative association between calving difficulty and fertility was not observed in the present study, even in the A farmlet which showed the highest incidence (12 %).

Although the proportion of cows showing pre-mating heats (59.3 – 70.3) in all farmlets involved in the present study was below the 85 % considered to be ideal (Malmo, 1985), it was higher than the 54 % reported by Macmillan & Clayton (1980).

Malmo (1985) indicated that the proportion of cows seen on heat during the 30 days before PSM will depend on the previous calving pattern, on how well the cows are cycling and on the level of oestrus detection. The S farmlet had a more spread calving pattern and a higher proportion of late-calving cows than the other farmlets. This could have accounted for its lower proportion of pre-mating heats. It is also possible that the efficacy of heat detection in this farmlet was lower. However, this seems to be unlikely since they were managed by the same personnel under the same guidelines as the other farmlets.

INCIDENCE OF HEALTH DISORDERS.

S cows had the highest incidence of metabolic disorders (milk fever and grass staggers) which could partially account for the lower CR1st, the higher number of services per conception and the longer interval from PSMC observed in this farmlet.

The incidence of metabolic disorders (mainly milk fever) in the S farmlet (8.6 %) was higher than the 6.9 % and 5.9 % reported by Suriyasathaporn *et. al.* (1998) and Thompson *et. al.* (1983), respectively. However, the incidence of retained foetal membranes across the farmlets in this study (2.1 – 5.0 %) was lower to that reported in the literature (5.7 – 8.8 %) (Thompson *et. al.*, 1983; Lee *et. al.*, 1989; Suriyasathaporn *et. al.*, 1998; Labernia *et. al.*, 1998).

Erb & Martin (1980 cited by Dohoo *et. al.*, 1984) found a higher incidence of dystocia during winter than in the other seasons. Whithers (1957 cited by Dohoo *et. al.*, 1984), reported a higher rate of milk fever between May and October. However, Labernia *et. al.* (1998) observed that cows calving in spring or summer and experiencing retained placenta, were 2.4 times more likely to be repeat breeders. Retained placenta also increased the likelihood of ovarian cysts and metritis (odds ratios = 2.1 and 2.2, respectively). At the same time, older cows were at higher risk of retained placenta. Fonseca *et. al.* (1983) also pointed out that Holstein cows with abnormalities after calving (dystocia, retained placenta, death of calf, twins, milk fever) had 8.8 more days from calving to first ovulation than normal cows.

Nakao *et. al.* (1998) observed that cows experiencing metabolic or reproductive disorders had a delayed uterine involution, and Drew (1999) also pointed out that a difficult calving, metabolic disease or retained placenta can reduce fertility. Thompson *et. al.* (1983) indicated that calving difficulty, milk fever and retained foetal membranes tended to occur as a complex.

In the present study retained placenta was associated with a reduced probability of conception during the whole mating period. Similarly, the occurrence of a metabolic disorder was associated with a reduced probability of conception both at first service and during the whole mating period.

Jonsson *et. al.* (1999) suggested that the mechanisms by which hypocalcaemia may impair reproductive performance include poor uterine contractility, effects on energy balance, reduced blood flow to the hypothalamus and ovary and interference with normal endocrine signal transmission on a cellular level.

The incidence of lameness in all farmlets in this study was higher (16.4 – 32 %) than that commonly reported (3.7 – 8.0 %) (Lee *et. al.*, 1989; Hayes, 1997; Offer *et. al.*, 1999). However, Suriyasathaporn *et. al.*, 1998) reported an incidence per lactation of 40.7 % lameness and Ryan & Mee (1994) indicated that lameness can affect between 5 – 30 % of the herd annually.

Eddy & Scott (1980 cited by Dohoo *et. al.*, 1984) reported a peak incidence of lameness during autumn whereas Prentice & Neal (1972 cited by Dohoo *et. al.*, 1984) reported peaks in both the spring and autumn. In New Zealand, the New Zealand Dairy Board (1974) indicated that 33 % of town supply farms surveyed reported cases of lameness compared to a 9 % for factory supply farms. It was also reported that cows calving in autumn and winter seemed more likely to became lame than those calving in spring or summer. Similarly, younger animals were also more prone to suffered of lameness. Conversely, the New Zealand Dairy Board (1978) reported a higher incidence of lameness in spring (57 %) than in autumn (6 %) but also a higher occurrence and a higher culling rate due to lameness in town milk supply farms than factory supply farms. Offer *et. al.* (1999) indicated that calving, lactation, housing, environment and season are the major influences in lameness and lesion formation.

Suriyasathaporn *et. al.* (1998) found that mastitis, lameness and milk fever that occur during the first 45 days postpartum, and genital infection that occurred between calving and conception, were negatively associated with the rate of conception. Ryan & Mee (1994) pointed out that If lameness occurs during the mating period, fertility will be reduced, since lame cows exhibit poor oestrus signs due to reluctance to stand to allow mounting by other cows.

In the present study, the highest incidence of lameness occurred in the autumn herd of the AS farmlet followed by the A farmlet. This could have had a more adverse effect on the former herds' reproduction since the overall pregnancy rate for lame cows regardless of farmlet was lower (80 %) than that of non-lame cows (87 %).

CALVING INTERVAL, SERVICES PER CONCEPTION, AND SERVICES PER LACTATION.

For the estimation of calving interval in this study, available calving dates were used. Since three calving dates, in three consecutive years, were available for each cow in each farmlet, there were only two calving interval estimations per cow.

Average calving interval in all farmlets was between 360 and 369 days which reflected the system's need to have a constant yearly calving to synchronise feed demand and feed supply. However, cows in S farmlet had a significantly shorter calving interval reflecting their higher incidence of inductions.

The calving interval observed in all the farmlets in this study is similar to that reported by Grosshans *et. al.* (1997) and by Macmillan & Moller (1977) (see Table 14).

Macmillan & Moller (1977) indicated that calving pattern, incidence of anoestrus and CFS interval are major factors influencing calving interval. They also observed that cows recorded as conceiving to a first AI had an average calving interval of 9 days shorter than those conceiving to a second AI.

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 combination of heat detection rate and conception rate on calving interval is shown in Table 15.

Table III–16. Effect of different levels of heat detection and conception rate on days lost assuming that 90 % heat detection and 60 % conception rates are optimal.

Conception	Heat detection rate				
rate (%)	90 %	80 %	70 %	60 %	50 %
60	0	6	11	18	27
50	9	14	20	28	39
40	20	25	34	49	59

From: O'Farrell (1998).

Nevertheless, due to the absolute need to maintain a yearly calving interval, Macmillan (1985) pointed out that calving interval is not a sensitive indicator for reproductive efficiency in seasonal dairy herds. He added that the interval PSC-to-50 % is more relevant. However, Macmillan & Moller (1977) indicated that if the lactation length is to be increased, reducing the variation in calving interval within herd by means of high submission and conception rates and use of inductions would be advantageous, since it will allow the calving pattern to be concentrated.

Number of services per lactation and per conception were similar across farmlets in the present study. However, the number of services per conception seen for the spring-calving cows (1.67), and for the first-calving cows (1.65) irrespective of season were higher than those for mature (1.49) and autumn-calving (1.47) cows The numbers reported by Grosshans *et. al.* (1997) and Macmillan & Clayton (1980) (see Table 14) are lower than those found for the spring-calving and first-calving cows in the present study, however, they are similar to those observed for mature and autumn-calving cows. Conversely, the values reported by Hayes (1998) for seasonally spring-calving herds (see Table 14) were higher than those found in any farmlet in the present study.

Services per conception are influenced by conception rate, pregnancy losses, and heat detection accuracy. Other factors influencing number of services per conception are timing of insemination and occurrence of diseases (Hardin, 1993).

Macmillan (1985) pointed out that approximately 25 % of first calvers will not be cycling at PSM and hence, submission and conception rates are lower than mature cows. Therefore, primiparous cows are expected to require for more services per conception.

In the present study, cows calving in spring, especially those in the S farmlet, tended to have more services than cows calving in autumn which is a reflection of the lower CR1st achieved by the spring-calving cows (see Table 9).

CALVING PATTERN.

Even though the S cows had the highest rate of inductions, they calved on average 5 and 3 days later than cows in the AS and A farmlets, respectively. Thus, cows in the AS farmlet had the most concentrated calving pattern of the three farmlets, which was evidenced in their higher calving rate at four weeks (72 *vs* 68 and 65 % for the A and S farmlets, respectively), and their shorter PSC-to-50 %, 50-to-75 %, and 75 %-to-end intervals. On average, 11 % of cows in the AS farmlet had calved before PSC.

AS and A farmlets achieved similar or better figures to those reported by Macmillan *et. al*. (1984). Conversely, S farmlet had consistently longer intervals in all periods (see Table 6).

Macmillan *et. al*. (1984) and Malmo (1985) pointed out that the PSC-to-50 % interval is a reflection of the success of the herd's insemination programme in the previous season. Intervals of 15 days or less will usually be achieved with a high submission rate and a satisfactory CR1st. The 50-to-75 % interval, will be influenced by the conception rate and the efficiency of oestrus detection during the second three weeks of mating (second round of breeding). The 75 %-to-end interval will be influenced by the overall length of the previous season's breeding programme and by the way in which induced calving was used in the current season. Total spread of calving (PSC-to-end) in conjunction with the 75 %-to-end interval indicates whether the late-calving cows had sufficient time to recommence normal oestrus cycles either before the start of the PSM or by the end of the first three weeks of that programme (Macmillan, 1985).

Thus, Ryan (1997) and Diskin (1996) suggested that in order to achieve a compact calving pattern, accurate oestrus detection in the first three weeks of the mating season must be high (90 %), and pregnancy rate to first service should be around 60 % (see Table 15).

Having a compact calving pattern, a high proportion of the cows would have calved 60 to 80 days before the onset of the mating season and have passed peak yield at the time of insemination (Diskin, 1996). Conversely, late-calving cows are not expected to have recommenced cycling before the end of the first round of AI (Brightling, 1985) and they usually have a short CFS interval. Therefore, they are, of necessity, frequently inseminated at their first heat after calving when conception rate is often as low as 20-30 %. Therefore, they tend to require more services per conception than do earlier-calving herdmates (Sreenan & Diskin, 1992). Furthermore, with a short breeding season, many of these late calvers are not pregnant at the end of the mating period and end up being culled for failure to conceive. Sreenan & Diskin (1992) indicated that many cows are culled for failure to conceive simply reflecting late calving and insufficient time to become pregnant, and not true infertility.

In this way, the more spread calving pattern of the S farmlet resulted in a higher proportion of late calving cows and calving inductions, shorter intervals from calving to first service and consequently lower conception rates to first service.

Besides the effects on reproduction, concentrating a calving pattern can extend the period of peak milk production and increase average per cow milk production by increasing average lactation length, with the extra production achieved by "extending" the period of "flush" production rather than increasing the average production per cow per day during the flush (Macmillan *et. al.*, 1984; Macmillan, 1985). In an earlier study, Macmillan (1979) reported a higher milkfat production for cows with a more compact calving pattern and therefore an earlier mean calving date than those with a less compact calving pattern. The observed difference in milkfat production occurred mainly in early lactation. This higher production is possible provided that adequate feeding levels are achieved during early lactation.

POSTPARTUM INTERVALS.

Interval from calving to first service (CFS)

The S cows showed the shortest interval to first service (70.9 days) compared to the A (74.7) and AS (73.3) cows. The shorter interval for the S farmlet reflected their later calving date and less concentrated calving pattern. Macmillan (1985) pointed out that achieving a concentrated calving pattern allows a longer interval from calving to PSM, and therefore more cows will have commenced cycling before the PSM, and will cycle during the first three weeks after PSM.

The CFS intervals observed in the A and AS farmlets in this study were similar to those reported by Grosshans *et. al.* (1997) and by Macmillan & Moller (1977) (see Table 14). However, the CFS interval in the S farmlet was shorter than those reported by the previous authors and agreed well with the CFS interval (71 days) for cows conceiving to a second AI following a normal return interval reported by Macmillan & Moller (1977).

The calving to first service interval depends on the re-establishment of 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 this parameter indicating the strong influence that a farmer has on the timing of first insemination.

Under New Zealand circumstances farmers are advised to submit for AI any cow observed in oestrus regardless of its interval from calving (Macmillan & Watson, 1973; Brightling, 1985). However, Ouweltjes *et. al.* (1996) showed that herds where cows were first inseminated early have longer CC intervals and a larger number of services. They also showed a positive relationship between CFS interval and non-return rate to 56 days and calving rate to first service.

Interval from PSM to first service (PSMFS)

All farmlets showed a similar interval. However, whereas the autumn herd in the AS farmlet showed the longest interval (15.5 days) the spring herd in the same farmlet showed the shortest (11.9 days), confirming the tight calving pattern achieved by the latter herd. Grosshans *et. al.* (1997) reported a longer PSMFS interval than those found in the farmlets involved in the present study (see Table 14).

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

In this way, the similar values for PSMFS for all farmlets in this study, indicated that the accuracy of oestrus detection and the rate of submission in all farmlets were similar. However, the similar short PSMFS interval for the S cows also meant that these cows had shorter intervals from calving to first service, because of their slightly more spread calving pattern.

Interval from calving to conception (CC) (Days open)

In accordance with the differences observed in CR1st and services per conception between farmlets, the average interval from calving to conception (CC) was longest for the S farmlet while the A farmlet showed a slightly shorter CC interval.

The CC intervals determined in this study were longer than the mean of that reported by Grosshans *et. al.* (1997) (see Table 14).

If a herd is to calve every 12 months, its CC interval should average 83 days (Malmo, 1985; Esslemont, 1993). Also Esslemont (1993) indicated that in economic terms, the optimum CC interval should be between 75 and 85 days, and a dairy herd with a reasonably high standard of fertility has a CC interval of less than 95 days.

The CC interval is influenced by the CFS interval, heat detection efficiency, conception rate (Malmo, 1985) and by parity (Marti & Funk, 1994; Labernia *et. al.*, 1998). Labernia *et. al.* (1998) observed a direct effect of lactation number on days open with 2.5 days increase per lactation. In addition, Marti & Funk (1994) showed that cows calving during spring (most likely bred during summer) had more days open followed by cows calving during winter. They suggested that heat stress during mating could have had an effect. However, this temperature effect is unlikely to have been an important factor in the present study since the temperature during the mating season is not usually so high as to cause stress in the animals.

Interval from PSM to conception (PSMC)

S farmlet had a longer interval (4 days on average) than cows in A or AS farmlets. This, together with the slightly higher services per conception required by these cows and their lower CR1st indicated that cows in the S farmlet were comparatively less likely to conceive than cows in the A and AS farmlets.

The PSMC intervals for the farmlets in the present study were similar to that observed by Grosshans *et. al.* (1997) and by Macmillan & Clayton (1980) (see Table 14).

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 CR1st or subsequent inseminations, the oestrus detection rate will also influence the intervals PSMC and FSC (Macmillan, 1985). Therefore, the longer PSMC interval for the S farmlet compared to the other two farmlets, is consistent with its lower CR1st and its slower rate to get pregnant.

Interval from first service to conception

This interval was six days longer for cows in the S farmlet, however, due to the number of censored observations included in the analysis, the difference was not statistically significant. This longer interval in the S farmlet reflected the higher number of services required for this cows to get pregnant due to their lower rate of conception.

Although the FSC interval for A and AS (17.6 and 17.2 days, respectively) farmlets were comparatively shorter than that of the S farmlet (23.7 days), they were longer than the means reported by Grosshans *et. al.* (1997) and by Macmillan & Clayton (1980) (see Table 14).

The first service to conception interval depends on the ability to conceive and maintain pregnancy after a given service and 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).

Thus, the longer FSC interval for the S farmlet reflected its poorer CR1st and higher number of services required to conceive. The overall longer interval for all farmlets could have been the result of the low CR1st observed in all farmlets as compared to New Zealand averages (see Table 14).

RATES OF SUBMISSION, CONCEPTION, HERD IN-CALF, AND CALVING.

Two important parameters of fertility in seasonal herds are the rates of submission and conception (Brightling, 1985; Macmillan, 1985). In order to have a concentrated seasonal calving pattern, a high proportion of cows must be inseminated within a limited mating period (a high submission rate) (Macmillan *et. al.*, 1975). To achieve a high SR-28 it is often necessary to inseminate cows to their first heat postpartum within 30 to 40 days of calving, even though this will reduce the average conception rate for the herd (Gill, 1985). If a high rates of submission and conception are not reached, then a concentrated calving pattern next year is not possible without the use of expensive management techniques such as induced calving (Gill, 1985).

In the present study, submission rates were similar across all farmlets, with 90 % or more cows submitted for AI after four weeks of PSM. This figure is similar or even higher than those reported by Macmillan & Watson (1973), Macmillan *et. al.* (1975) and Hayes (1997) (see Table 14).

Wiltbank (1998) pointed out the main factors causing variation in submission rate: number of heat detections during the day, timing and duration of heat detection, the person doing heat detection, use of heat detection aids, and use of synchronisation procedures. Ryan (1997) indicated that the use of tail paint as an aid in oestrus detection with three daily observations will be necessary to achieve a 90 % oestrus detection rate. Burton *et. al*. (1999) suggested that besides heat detection efficiency, the incidence of anoestrus can affect the rate of submission. In fact, Macmillan *et. al.* (1975) observed a lower SR-28 for primiparous cows due to a high proportion of these cows (10 %) not seen in oestrus. They suggested that they were probably anoestrus due to lower intakes caused by their lower ability to compete while grazing.

A similar SR-28 for all farmlets in the present study could indicate that late-calving cows (e.g. S cows) were possible mated to their first oestrus after calving and therefore this could have resulted in a lower CR1st for these cows.

Conception rate to first service (CR1st) in the present study was calculated as a function of the cows confirmed to be pregnant and therefore it was not based only on non-return intervals. CR1st in all farmlets was apparently lower than that reported to be normal in New Zealand (see Table 14). Nevertheless, cows calving in autumn showed a higher CR1st (53.7 and 55.9 % for A and AS farmlets, respectively) than cows calving in spring (47.1 and 49.2 % for S and AS farmlets, respectively) although the difference was not significant. The lowest rate was observed in the S farmlet which is consistent with the shorter CFS interval, lower proportion of cows showing heat before PSM and higher proportion of induced calvings observed in this farmlet. All these mentioned circumstances are generally associated with a lower reproductive performance.

However, in a recent survey, Hayes (1998) reported a 55.7 % (range 51 – 59 %) conception rate to first service in 48 seasonally calving dairy herds which used pregnancy test. By comparing these rates with those achieved by the cows in the present study, it can be observed that CR1st for cows calving in autumn was within the normal range reported, even though the reported rates were for seasonal spring-calving herds. However, cows calving in spring had a lower rate. Considering the reference values given in Macmillan's studies (1973, 1983, 1984, 1987, 1997) (see Table 14) the CR1st in all farmlets were below average. However, most of the Macmillan's studies are older than Hayes' and they used a fewer number of selected herds for the analyses.

In accordance with the differences observed in CR1st, herd in-calf rate was lower at four weeks and significantly lower at seven weeks for the S farmlet (71.8 %) compared to the A (79.8 %) and AS (75.5 %) farmlets. However, overall pregnancy rate was low in all the farmlets with the autumn herd in the AS farmlet having the lowest rate (82.2 %) and the A farmlet the highest (86.3 %). This resulted in very high empty rates compared to New Zealand averages (see Table 14).

Macmillan & Watson (1973) defined herd in-calf rate as the proportion of the herd recorded in calf to a first or subsequent insemination at a specific time after PSM. The values reported in this study were not only herd in-calf rates but were true pregnancy rates, since they were based on the pregnancy tests. The herd in-calf (pregnancy) rates at four weeks observed in this study were lower than those reported by Hayes (1997) and similar to those reported by Macmillan & Watson (1973) (see Table 14). At seven weeks, the rates in this study were above those reported by Grosshans *et. al.* (1997) and by Macmillan & Watson (1973) (see Table 14). However, the S farmlet always performed below the average values reported. The overall lower in-calf rate for the S cows was reflected in their less concentrated calving pattern.

Macmillan & Watson (1973) pointed out that the factors that influence the proportion of the herd in-calf to AI, and the rate at which they become pregnant, include the proportion of the herd submitted for AI, the period over which they are submitted, the conception rate, and the period for which AI is used. Malmo (1985) pointed out that the aim in seasonal herds is to have over 85 % of the cows in the herd pregnant in the first two months of the mating period. Only the A farmlet and the spring herd in the AS farmlet in the present study, barely achieved these recommended values but in the entire 10-week mating season (see Table 8).

The S farmlet had the lowest calving rate at four weeks, whereas the AS farmlet had the highest. Their rates are similar to those reported by Hayes (1998) and by Macmillan *et. al.* (1984) (see Table 14). However, the S farmlet was still below these reported values. Macmillan *et. al.* (1984) suggested that a high calving rate is associated to a high conception rate, and the lowest calving rate for the S farmlet was related to its lower rate of conception. The apparent disagreement between the rates of pregnancy and calving seen in all farmlets is explained by the fact that pregnancy rates were calculated without considering the heifers, which were naturally mated, whereas for the calculation of calving rates, primiparous cows were taken into account.

Thus, It is likely that the shorter CFS interval for the S cows had a negative influence in their probability of conception to first service and therefore they required more services to get pregnant with a delayed conception, a more spread calving pattern and the need for more inductions.

However, the overall empty rates in the present study (14.0 – 15.7 %) were higher than those considered to be normal (see Table 14). Esslemont (1993) indicated that a dairy herd with a reasonably high standard of fertility has a culling rate for failure to conceive of less than 7.5 %. However, in a similar system trial being carried out in Northland, New Zealand, Hodgson & Chesnut (1999) reported a significantly higher empty rate (15 %) for spring- than autumn-calving cows (8 %).

Macmillan (1985) indicated that differences in empty rates are produced by oestrus detection efficiency, anoestrus and conception rate. Macmillan (1976) also demonstrated that the length of the mating period influences the empty rate in a herd. He showed that the proportion of non-pregnant cows at the end of the mating period declined by 0.04 % for every day the breeding season was prolonged beyond 60 days. In this way, each additional three weeks beyond 9 weeks of a mating programme, would be expected to reduce the empty rate by an average of 0.8 %.

In the present study there is no apparent reason for the low overall pregnancy rates achieved in all farmlets. However, it seems that the general low CR1st and the short CFS intervals together with a relatively short mating season (10 weeks) (Table 14) could have accounted for the observed performance.

MULTIPLE REGRESSION ANALYSIS OF POSTPARTUM INTERVALS AND CONCEPTION RATE.

Interval from planned start of mating to first service.

The probability of submission for AI after PSM was higher for the A farmlet than for the S and AS. However, this same probability was 53 % higher for a cow calving in spring than for a cow calving in autumn. This apparent disagreement is explained by the fact that whereas the spring herd in the AS farmlet achieved the shortest PSMFS interval, the autumn herd within the same farmlet had the longest PSMFS interval.

This finding is in agreement with Westwood *et. al.* (1998), who showed that cows calving during winter were 6.8 times more likely to have a prolonged interval from calving to first ovulation than cows calving in other months. Also Pryce *et. al.* (1999) reported that the interval between calving and first service was significantly longest in autumn, while that from calving to first heat was shorter. McNatty *et. al.* (1984) studying the effect of season on ovarian and pituitary activity observed that LH peak frequency was significantly lower in May and June than in October. Conversely, Bulman & Lamming (1978) and Montgomery *et al.* (1980 cited by Montgomery, 1985) observed that the intervals to first ovulation or first oestrus were longer in spring-calving cows compared with autumn-calving cows. Fonseca *et. al.* (1983) also showed that Holstein cows calving in winter had 6.5 ± 2.9 days more days from calving to first ovulation than cows calving in autumn.

Thus, it is possible, though not conclusive, that autumn-calving cows in the AS farmlet took longer to resume ovarian activity after calving as seems to be indicated by its slightly higher proportion of anoestrus cows (20 %) at PSM and therefore, this was reflected in their longer PSMFS interval.

Macmillan (1997) showed that non-treated anoestrus cows diagnosed at PSM had lower SR-21 (55 *vs* 96 %) and longer PSMFS (26 *vs* 10 days) and PSMC (37 *vs* 22 days) intervals than their cycling herdmates. Westwood *et. al.* (1998) also showed that cows that did not ovulate (anoestrus) until day 53 of lactation were at 1.6 times greater risk of a delayed interval from calving to first oestrus and at 1.5 times greater risk of delayed time to CFS than cows in the lowest quartile of time to first oestrus and service, respectively.

Pryce *et. al.* (1999) reported that cows calving earlier in the calving season appear to resume oestrus sooner than later calving cows. Early calving cows had a longer period before insemination resumed.

Anoestrus cows, in the present study, had only 43 % probability of being submitted compared to a cycling herdmate. Similarly, cows calving later in the season had a reduce probability of submission for AI. In both cases, anoestrus and late-calver cows are exposed to a shorter mating period, and therefore they have less opportunity to be submitted for AI and conceive to subsequent AI if they failed to conceive at first service (Macmillan, 1985).

The marginal positive effect of live weight at mating upon probability of submission is in agreement with Fulkerson (1984), who noted a significant linear increase in SR from 60 to 97 % as condition score increased from 3 to 5.5 (Table 16).

Table III–17. Condition scores at three weeks after the start of mating and submission rates at 21 days.

	Body condition score					
	3.0	3.5	4.0	4.5	5.0	5.5
Submission rate (%)	60	61	72	77	82	97

From: Fulkerson (1984).

Also Suriyasathaporn *et. al*. (1998) using survival analysis showed that cows calving with BCS < 3 (scale 1 to 5) had a lower "risk" of first insemination than average or fat cows (BCS > 3). Similarly, after day 45 postpartum, a cow with BCS > 2 had a higher risk of first AI compared with cows that had a BCS between 1 and 1.75.

Interval from planned start of mating to conception.

All farmlets had similar probabilities of becoming pregnant regardless of season of calving. However, anoestrus and late-calving cows as well as those cows experiencing a health disorder event had a reduced probability of conception. In a similar way to the PSMFS interval, anoestrus cows have a reduced period of mating that put them at a disadvantage compared with their cycling herdmates in terms of the probability of conception (Macmillan, 1985). With the same underlying cause, the probability of conception was reduced by 0.9 % for each day later to calve during the calving season. On the other hand the birth of an alive calf increased the probability of conception by more than twice that of the occurrence of a dead calf.

Macmillan (1997) observed that anoestrus cows had a slightly higher empty rate than cycling cows (7 *vs* 4 %). Grainger & Wilhelms (1979) and Westwood *et. al*. (1998) also found an association between prolonged CC interval and both longer postpartum anoestrus and higher number of services per conception (lower conception rates).

Similarly, Macmillan & Clayton (1980) observed that cows which failed to conceive had an associated average calving date 10 days later than their pregnant herdmates and an average date to first AI 7 days longer than pregnant cows, reinforcing the view that anoestrus and late-calving cows have a reduced mating period and therefore less probability of being mated and conceive.

The incidence of two or more events of lameness was associated negatively with the probability of conception. Likewise, the occurrence of metabolic disorders or retained foetal membranes had a negative impact upon probability of pregnancy, although their effects only approached significance.

Lee *et. al*. (1989) showed that lameness and retained foetal membranes were associated with increases in the interval from calving to conception of 28 and 5 days, respectively. Cows experiencing retained foetal membranes or lameness had conception rates that were only 66 and 69 % respectively, of those cows not experiencing the diseases. Hayes (1997) also observed that cows with a recorded event of lameness during lactation had a reduced probability of conception (40.4 %) than those with no lameness events (46.5 %). Since his study did not consider the temporal association, as the present did not, between lameness and a reproductive event, he suggested that poorer reproductive performance in lame cows could have been due to reduced feed intake and decreasing body condition.

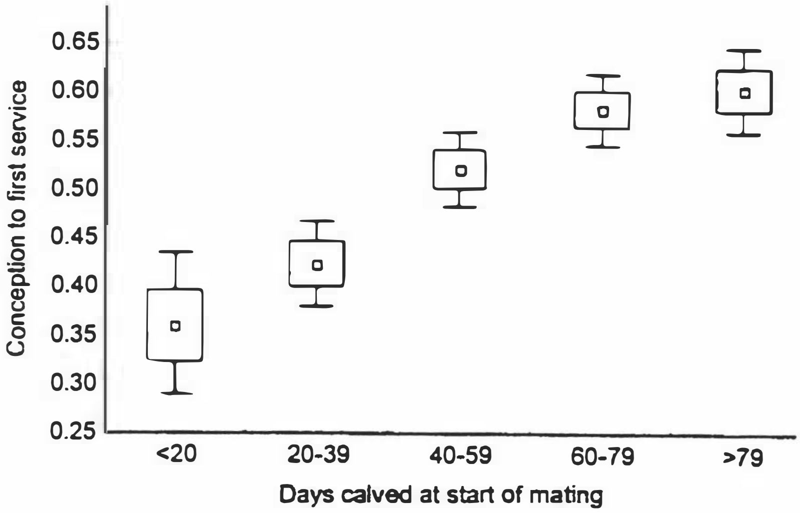
In the present study, the autumn herd of the AS farmlet showed the highest incidence of lameness and this herd also had the highest empty rate. Similarly, cows in the S farmlet presented the highest incidence of metabolic disorders and they also had the poorest reproductive performance.

Conception rate to first service.

Despite the higher CR1st for the cows calving in autumn, the difference between the autumn- and the spring-calving cows was not significant. As in the probability of pregnancy regardless of service number (PSMC), the occurrence of a metabolic disorder affected negatively the probability of conception at first service and even more severely. On the other hand, cows having a live calf at birth and with a longer interval from calving to PSM (CPSM) had a higher probability of conception. For each day increased in the CPSM interval, the probability of conception to first service increased by 1.5 %.

Hayes (1998) showed that as the interval from calving to PSM increased, the CR1st increased almost linearly (Figure 5), and therefore, the presence of cows that had calved between 40 and 60 days before PSM will still have a negative effect on overall performance. He indicated that conception rates increase as mating progresses because the number of days from calving to mating is increasing.

Figure III–5. First service conception rates for cows grouped by days calved at the planned start of mating.



From: Hayes (1998).

Macmillan & Clayton (1980); Fulkerson (1984) and Hayes (1997) observed that the probability of conception to first service had a positive association with the CFS interval. Similarly, cows with no recorded pre-mating heats (possibly anoestrus) had a lower probability of becoming pregnant to first service (40.6 %) than those experiencing at least one heat before PSM (46.4 %).

Moller (1970) suggested that incomplete uterine involution was the main reason for poor conception rates before 30 days postpartum, while anovulation, silent heats and false heats were the main contributors from 30 to 60 days postpartum. Diskin (1996) added to these causes, that many of the recently calved cows are inseminated at their first post-calving heat and he suggested that cows should not be mated until their second or later post-calving oestrus. This latter suggestion is possible only if the herd has a compact calving pattern.

Thus, serving cows at less than 40 days results in low pregnancy rates (Hodel *et. al*., 1995; Drew, 1999). However, delaying service beyond 60 days means that it is almost impossible to achieve a calving interval of 365 days (Drew, 1999).

Suriyasathaporn *et. al*. (1998) using survival analysis reported that mastitis, lameness and milk fever that occurred during the first 45 days postpartum, and genital infection that occurred between calving and conception, were negatively associated with the rate of conception.

Thus, the higher incidence of metabolic disorders and a more spread calving pattern resulting in shorter intervals from calving to PSM could produce the lower CR1st achieved by the cows in the S farmlet.

CONCLUSIONS.

This study demonstrated that calving during autumn did not compromise cows' reproductive performance. In fact, the 100 % spring-calving farmlet showed the worst reproductive performance that could be mainly attributed to a more spread calving pattern and a higher incidence of metabolic disorders (milk fever principally). A spread calving pattern (e.g. S farmlet) resulted in a higher proportion of cows being induced, a lower proportion of cows cycling at the PSM and a shorter CFS interval. Consequently, conception rate to first service was lower and cows took longer to conceive. Similarly, the occurrence of health disorder events (metabolic disease and lameness basically) resulted in lower probabilities of conception. Therefore, adequate nutrition, compactness of calving and health appeared to be the main factors determining reproductive performance of grazing dairy cows in the present study. However, considering the overall high empty rates observed, it is important to consider other management factors such as the length of the mating period since reproductive performance might be impaired by those too.

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CONCLUSIONS

The present study demonstrated that calving during autumn is not necessarily associated with a reduced reproductive performance. Calving pattern and health status were the most important determinants of reproductive performance. A spread calving pattern resulted in higher rates of calving inductions, lower proportion of cycling cows at planned start of mating, shorter intervals to first service, and therefore lower conception rates to first service and longer intervals to conception. The occurrence of health disorders (e.g. milk fever, lameness) reduced the probabilities of submission and conception, highlighting the strong influence that this factor can have upon fertility. It was also demonstrated that even though high milk urea concentrations may affect reproduction adversely, its effects are unlikely to be determinant without the combination of other important factors such as low body condition at mating, short interval from planned start of mating to first service and high incidence of health disorders. Moreover, the high empty rate observed in all farmlets, emphasised the need for study of simple managerial strategies such as duration of the breeding period if an adequate reproductive performance is to be attained. Ultimately, the better performance observed in the autumn-calving cows compared to the spring-calving cows, confirmed that management factors have a stronger effect upon fertility than environmental (e.g. season, climate) factors.