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THE INFLUENCE OF EARLY AND LATE BREEDING OF DAIRY COWS ON FERTILITY, WEIGHT CHANGES AND ON MILK PRODUCTION OF THE PRESENT AND SUBSEQUENT LACTATION

by

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ABSTRACT

In a Holstein herd (125 cows) the influence of early and late breeding post partum on reproduction and production was investigated. At calving the cows were randomly assigned to two groups. The early bred group was scheduled to be bred at the first visible heat following 50 days post partum which resulted in an average interval of 73 ± 18 days from parturition to the first service. The average interval from parturition to conception was 88 ± 33 days. The cows in the early bred group conceived after an average of 1.50 (range: 1 to 3) services per conception. The late bred group was scheduled to be bred at the first visible heat following 80 days post partum which resulted in an average interval of 93 ± 17 days from parturition to the first service. The average interval from parturition to conception was 120 ± 40 days. The cows in the late bred group conceived after an average of 1.96 (range: 1 to 5) services per conception. The number of services per conception was significantly ($P \leq .05$) higher for the late bred group.

The early post partum reproductive activity was monitored with milk progesterone analyses. A sample of milk strippings was analysed by a radioimmunoassay technique every second day from 6 days post partum until conception occurred or the animal was removed from the

herd. Cows which did not conceive were excluded from the statistical analyses. The average length of the first estrous cycle was 17 ± 7.5 days. The first progesterone detected heat occurred 33 ± 10 days post partum compared to the first visible heat which occurred 48 ± 26 days post partum. Calving associated problems and the calving during the pasture season delayed conception in the late bred group but not in the early bred group. The late bred group produced more fat corrected milk (FCM) in the 305 day lactation and in the first 150 days of the subsequent lactation and also gained more ($P \leq .05$) weight between calvings. Cows calving during the pasture season produced more FCM in the 305 day lactation but gained significantly ($P \leq .01$) less weight between calvings than cows calving in the non-pasture season. There was no difference between early and late bred group, health status groups or groups according to the calving season in terms of average daily milk and FCM yield calculated over the entire period of this experiment (beginning of current lactation to day 150 of the subsequent lactation, including the dry period). Calving difficulties and early post partum reproductive problems were not related to production traits.

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1. INTRODUCTION

Milk yield and reproductive performance are two very important factors determining the profitability of a dairy herd. On many dairy farms reproduction does not follow an optimum course. Therefore, it is important that reproductive problems are traced to their source as rapidly and efficiently as possible.

Impaired reproduction results in a decreased production per day of life and therefore higher production costs. It is essential to analyse and explain as many factors associated with reproductive failure as possible and to quantify the influences on production. A widely used measure of fertility is the calving interval. A calving interval of 12 to 13 months is thought to be ideal and is possible if the service period is kept within 60 to 90 days post partum.

From the physiological point of view, a one year calving interval is feasible, however, calving difficulties, retained placentas, endometritis, veneral infections, silent heats, etc. delay conception and make an optimum calving interval difficult to attain. One step toward reducing the calving interval is to use milk progesterone to characterize estrous cycles and to identify non-pregnant cows as early as possible. The milk progesterone concentration changes during the course of the estrous cycle, being low (2ng/ml) during standing heat and markedly higher (>5ng/ml) between heats. The milk progesterone concentration can be determined by a rapid radioimmunoassay technique which makes it possible to use progesterone levels in milk to monitor estrous cycles in dairy cows. Milk progesterone analyses are widely used in Europe and North America (Heap et al., 1973; Hoffmann et al., 1976; Shelford et al., 1979) to monitor estrous cycles, to establish the reproductive status of problem cows and for an early pregnancy check.

The purpose of the study herein was to establish the occurrence of the first hormonal estrous cycle and the first hormonal estrus with milk progesterone analyses and to compare the results with the visually detected heats. Reproductive data and productive data were analysed in relation to specific breeding times post partum, to days open and to the calving interval.

The influence of calving associated reproductive problems and the influence of the calving season on reproductive and productive performance of the current lactation and on productive performance of the subsequent lactation was investigated.

The objectives of this study were: To compare visually detected heats with milk progesterone detected estrus and to test whether the onset of estrus was influenced by the calving season, calving associated reproductive problems and the level of production. To investigate the influence of early and late breeding, the influence of calving associated problems and the influence of the calving season on the reproductive performance in the current lactation and the productive performance in the current and early subsequent lactation.

2. LITERATURE REVIEW

Inefficient reproductive performance is known as one of the major herd management problems (Rounsaville et al., 1979; Spalding et al., 1975). Larger herds and increased mechanization result in less time spent per cow and can lead to decreasing reproductive success if the management skills and record keeping are not strengthened. The reproductive process is very complex and very difficult to understand fully. A great number of studies have been and still are being conducted dealing mostly with one or a few of the reproductive aspects or productive-reproductive relationships. The purpose of the following part of this study is to review some of the most important information and results.

Age of Cow. The age of the cow has a marked effect on the pregnancy rate after the first insemination (Boyd and Reed, 1961; De Kruif, 1975; Rosenberg et al., 1977). Most investigators conclude that the pregnancy rate is reduced in animals which have calved for the first time. De Kruif (1975) observed a difference of 5% in the pregnancy rate between primiparous and secundiparous cows. In cows 7 years and older the conception rate after the first insemination is also low. Flores (1972) and De Kruif (1975) report that primiparous cows have more days open than multiparous cows. They do not attribute the reduced conception rate in primiparous cows to their age as such, but to the fact that problems associated with calving are more likely to occur at the first calving and during the first post partum period. De Kruif (1975) showed that these differences disappeared when he removed all the primiparous cows which had some problems associated with calving. Wilton et al. (1967) did not find any influence of age on the interval from calving to conception.

Health of cow. Infections caused by Vibrio fetus, Trichomonas fetus, Brucella abortus, Leptospiroa, etc. disturb the fertility of dairy cattle a great deal. Several of these diseases, however, are under control, at least in the industrialized countries. Beside these infectious diseases there are a number of non-infectious disturbances like retained placentas, trauma to reproductive tract and uterine inertia. These disturbances can influence the reproductive performance of a dairy herd very drastically. Roberts (1971) and De Kruif (1978) related part of these disturbances to inadequate hygiene, especially at the time of calving. Retained placenta and endometritis are known to reduce the fertility by 5 to 10% at the first insemination resulting in more days open (Dyrendahl et al., 1976; Morrow et al., 1969; Roine and Saloniemi, 1978; Zamet et al., 1979). De Kruif (1975) stressed the fact that calving hygiene is particularly important in loose housing systems where cows come into closer and more frequent contact with other cows than in stanchion barns, resulting in an increased risk of infection.

Climate and season. The climate is an important factor altering conception rate in cattle (Thatcher, 1974). High temperatures and humidity will depress behavioural estrus signs and with it the conception rate. Early embryonic death is believed to occur more often in the tropics than in temperate regions (Stott and Williams, 1962). High ambient temperatures influence the plasma progesterone level resulting in a decreased conception rate (Rosenberg et al., 1977; Roussel et al., 1977). Season has a very definite influence on fertility in dairy cattle. In temperate regions, pregnancy rates are highest in spring (Miller et al., 1970a; De Kruif, 1975) and are depressed during the winter months. The plasma progesterone levels during estrus are lower in wintertime which is favourable for conception (Roussel et al., 1977), but the heat detection as such is poorer due to constant confinement of the cows and less daylight in the barns (David et al., 1971; King et al., 1976). David et al. (1971) and Mather et al. (1978) found that little behavioural evidence is shown with the first estrus. During the pasture season estrus behaviour is much stronger and more evident for visual detection. Francos et al. (1977) found that the voluntary feed intake in summer is significantly higher than in winter and they also related these findings and the increased exercise in summer to fertility as well.

Body weight change patterns. The body weight change pattern of dairy cows and its relation to fertility has been studied by many authors (Amir and Kali, 1974; Huth and Smidt, 1979; Miller and Hooven, 1970b; Touchberry and Batra, 1976; Youdan and King, 1977). The high early lactation milk production requires nutrients in excess of the dietary intake of the cow. Therefore, the cow starts to mobilize body reserves and consequently loses weight in the first part (up to 50 to 70 days post partum) of the lactation (Amir and Kali, 1974; Miller and Hooven, 1970b; Youdan and King, 1977). This weight loss is dependent on many factors; level of milk production, milk composition, plane of nutrition, and the protein-energy relationship of the diet being only a few of them (Broster, 1973). There is evidence in the literature (King et al., 1976; Youdan and King, 1977) that cows which are gaining weight during the time of insemination have a better rate of conception than cows losing weight. Boyd (1970) demonstrated a beneficial effect of body weight gain on fertility rate but his results were not statistically significant. This finding indicated that early post partum breeding (first service before 60 days post partum) resulted in an inferior rate of conception compared to insemination after a longer rest period. Herz and Graf (1976) and Roberts et al. (1979a) related the difficulties of getting cows pregnant with weight loss or low blood glucose levels at the time of insemination. Blood glucose levels were lower in the early post partum period than in the late pre-partum and later post partum period. Roberts et al. (1979b) related their findings to the mobilization of adipose tissue due to a lack of sufficient dietary energy intake.

Time from parturition to first insemination. The discussion of the early lactation weight changes leads directly to the discussion of the optimal rest period. If we are discussing this subject we have to specify whether we are aiming for a high conception rate at the first insemination post partum, a short interval from calving to conception, a maximum lactation milk yield or a maximum life time production. The conception rate is reported to be low in cows inseminated prior to 50 days post partum (Britt, 1975; Shannon et al., 1952; Touchberry et al., 1959; Whitmore et al., 1974). It is generally accepted that a calving interval of 12 months is a desirable goal (Ayalon et al., 1971; Britt, 1975). The 12 month calving interval is even agreed upon by such a strong critic of early service after calving as Dawson (1967). Louca and Legates (1968) propose a calving interval of 13 months for primiparous cows and 12 months for multiparous cows in order to attain maximum production. Cows must conceive on the average by about 85 days post partum to attain a 12 month calving interval. Therefore, it is necessary to start insemination prior to 60 days post partum for the simple reason that under the best conditions cows vary in the date of appearance of heat and waiting 60 days before breedings results in an average calving to first service interval much longer than 60 days (Ayalon et al., 1971). Furthermore, as discussed previously, early post partum breeding results in lower conception rates which underlines the necessity to start breeding early in order to obtain a short average calving interval.

The relationship between time of breeding post partum and milk production has been discussed repeatedly throughout the years (Bar-Anan and Soller, 1979; Boyd, 1970; Louca and Legates, 1968; Smith and Legates, 1962; Trimberger, 1954; Whitmore et al., 1974; Wilton et al., 1967). Trimberger (1954) considered early breeding as a disadvantage, especially for show cattle, because the lactation milk yield decreases if cows are bred early after parturition. Louca and Legates (1968) stated that from the economical standpoint the yield per unit time, milk per day or year is more important than the total lactation production. Ripley et al. (1970) suggested the inclusion of days open into the performance record of dairy cows. Britt (1975) showed clearly that the milk production per day of life is highest in cows with short calving intervals. Menge et al. (1962) and Smith and Legates (1962) reported on the basis of their literature reviews that the opinion that high producing cows do not conceive as readily as low producers, lacks conclusive experimental evidence. Ayalon et al. (1971) reported that high producing cows react favourably to a rest period of 60 days and that there are no reasons why moderate producing cows of good general and reproductive health should not be bred at the first estrus after 45 days post partum. Whitmore et al. (1974) found that early breeding of high producing cows did not influence the success of subsequent inseminations. Francos and Rattner (1975) compared the calving to conception interval of high producing cows with their milk yield. All the cows were inseminated at the first estrus after 60 days post partum. They found that cows yielding 8000 kg or more in a 305 day lactation on an average did not conceive before 110 days post partum. Herz et al. (1979) investigated the production of return and non-return cows and found a significantly higher production both in milk yield and fat corrected milk yield of the return cows. Neither Francos and Rattner (1975) nor Herz et al. (1979) were able to determine whether the return cows did not conceive after the first insemination because they produced more milk or whether they produced more milk because they did not conceive readily. Bar-Anan and Soller (1979), in their study on the effects of days open on milk yield, definitely rejected the accepted 305 day lactation yield as an unbiased estimate of the production ability. They found that the 305 day records penalize cows which conceive early. For this reason, Israel introduced a system which adjusts lactation milk yield for days open as proposed earlier by Ripley et al. (1970).

Heat detection. In order to breed the cows for a shorter calving interval, it is essential to employ a systematic and efficient method of estrus detection. The larger the herds and the more mechanized the whole operation becomes, the more important it is to use a systematic estrus detection method. While an unsystematic observation technique might be appropriate in small herds, this technique becomes inefficient with larger herds. So far, there is no technique as good and efficient as a systematic observation of the herd. Problems of estrus detection occur especially in the early post partum period because signs of estrus are not as obvious as later on. David et al. (1971) reported that 60% of all first heats remain undetected because the cows are not controlled and observed properly. Pelissier (1976) found that heat detection failure in California was the primary cause of delayed first service and also contributed significantly to the delay of the subsequent services. There is a considerable amount of information available on heat detection methods and heat detection aids. Gartland et al. (1976) measured the vaginal mucus electrically. Kiddy (1977) tested the use of a pedometer to measure the activity of the cow and found a fourfold increase in the activity of cows in estrus. The fourfold increase was observed in a loose housing system. Activity increases in stanchion barns as well but less than in free stalls. Foote (1975) described a whole range of mechanical heat detection aids (video camera and cow or bull mounted detectors and markers). Heat detection aids which require a teaser or gomer bull are quite expensive and still require a fair amount of labour to obtain satisfactory results. Foote (1975) commented: "There is no substitute for the eye of the skilled observer and manager who observes his cows for estrus."

Plasma and milk progesterone analysis. Since the development of radioimmunoassay techniques (RIA), progesterone levels have become one of the major hormonal parameters used to monitor reproductive performance in cattle. Measurements of progesterone in plasma have been made for a number of years (Stabenfeldt et al., 1961). Robertson and Sarda (1971) first used this method to diagnose pregnancy in several domestic species. Laing and Heap (1971) found that progesterone in the milk of cows was closely correlated with the activity of the corpus luteum and, therefore, suggested it be used as an indicator for pregnancy. Hoffmann and Hamburger (1973) described the pattern of milk progesterone throughout the estrous cycle and the increase in progesterone concentration in early pregnancy. During standing heat the milk progesterone concentration is very low and rises from about the 3rd to 4th day after standing heat reaching a peak between the 12th and 16th day. The concentration drops again around days 17 to 20 of the 21-day cycle (Booth, 1979). The development of a rapid radioimmunoassay technique (Heap et al., 1973; Heap et al., 1976) made it possible to use milk progesterone levels for commercial pregnancy testing (Booth and Holdsworth, 1976), for confirmation of estrus (Hoffmann et al., 1976) and for monitoring the estrous cycle of sub-fertile cows (Lamming and Bulman, 1976; Braun, 1977). The milk progesterone levels are highly correlated with the fat content of the milk. In order to obtain reliable results, it is important that one milk sampling method is used consistently. Shelford et al. (1979) recommended the use of the milk strippings, Braun (1977) corrected the samples to 10% milk fat and Hoffmann et al. (1977) recommended the analysis of the progesterone level in samples of milk fat only.

The milk progesterone radioimmunoassay is increasingly being used to assist the management of dairy herds in accomplishing a high level of fertility. It represents a valuable tool required to reach the reproductive goals in dairy herds set by De Kruif (1978):

1. A pregnancy rate of 80% after the first insemination.
2. An average of 1.3 inseminations per conception.
3. An average interval of 85 days between parturition and conception.

3. MATERIAL AND METHODS

The data used in this study was collected from one dairy herd. Milk progesterone levels were used to detect hormonal estrus. The cows also were observed for behavioural estrus signs. At calving each cow was randomly assigned to an early breeding or to a late breeding group in order to achieve an unbiased test of fertility in relation to days from parturition to conception (Whitmore et al., 1974). Health codes were introduced to distinguish between cows with normal and abnormal calving and early post partum histories of health problems. A further distinction was made between calving in the pasture versus calving in the non-pasture season. The data were subjected to an analysis of variance to estimate differences due to breeding time post partum, health status and calving season. A general linear model was employed to test reproduction traits of the current lactation, production traits and body weight changes of the current and subsequent lactation. Sources of uncontrolled variation such as age, milk production in the first 50 days post partum and body weight changes in the first 60 days post partum were introduced as covariables into the statistical model.

3.1. Animals

From October 1977 through May 1979 125 post parturient Holstein-Friesian cows of the dairy herd of the Agriculture Canada Research Station in Agassiz, B.C. were sampled for milk progesterone analyses. The sampling started 6 days after calving and was done every other day until conception occurred or the animal was removed from the herd. The time of this trial coincided with a drastic herd cutback so that only 85 cows had complete data. Another 14 cows were eliminated from the analyses of the subsequent lactation. The reasons for the culling of the cows are listed in Table 1.

Table 1: Reasons for culling of the cows from the herd during the experiment.

Reason	Culled before conception n	Culled after conception n
Herd cutback, poor production old age	15	5
Mastitis, udder problems	9	4
Displaced abomasum, injury, hardware	8	1
Hard breeders, sterile	8	
Back in heat after confirmed conception, abortion		4
Total	40	14

The Agassiz dairy herd was housed in a free stall barn and the cows were milked in a double sawtooth parlor. Part of the grain ration was fed during milking in the parlor. From May to October the cows were pastured on orchard grass pasture with approximately 10% white clover. A strip grazing system was employed (the fence was moved every day so that the cows got a piece of fresh pasture each day). In wintertime (November till April) mainly corn silage with 2 kg of hay per cow per day was fed.

All the cows were artificially inseminated. Possible influences of the service sire on reproductive traits of the cow have not been taken into account in this study. Sires were randomly assigned to mates irrespective of treatment (e.g. early or late breeding post partum) imposed on the cow.

The conceptions were confirmed by rectal palpation 2 months after insemination.

3.2. Milk sampling and milk progesterone analyses

Samples of the milk strippings were taken every other day at the afternoon milking from 6 days post partum until conception occurred or the animal was removed from the herd. The analyses for milk progesterone were done employing the method described by Shelford et al. (1979) which is a modification of the radioimmunoassay technique first described by Heap et al. (1973).

3.3. Visual heat detection

The cows were observed at milking, at feeding time and one additional observation of the herd took place between 9:00 and 10:00 pm. Standing heat, increased activity and vaginal discharge was observed. No cameras, markers or other heat detection aids were used. During the time of this study, a few cows which did not show any visible signs of estrus were observed very carefully on the basis of the progesterone analysis and inseminated when the progesterone levels indicated the cows' estrus.

3.4. Data collection

Information about the individual cows (age, reproduction, health) was taken from the record keeping system of the Agriculture Canada Research Station in Agassiz, B.C. Milk yield was recorded at each milking and percent fat was evaluated at approximately 35 day intervals by an official Record of Performance (ROP) milk tester. All the cows were weighed at calving, 60 days and 80 days post partum.

3.5. Experimental design and statistical analysis

3.5.1. Lactation curve computation

The computation of the lactation curves was done on the basis of milk yield recordings taken every Wednesday throughout the year. A weekday was chosen to exclude a possible influence of weekend milkers and weekend feeders. The 4% fat corrected milk (FCM) was calculated with the following formula:

FCM (kg) = Milk (kg) x (.4 + .15 x fat %).

This formula was first proposed by Gaines (1928). Slopes and intercepts were calculated for each cow using the "Equality of Regression Slopes Test" option of the covariance analysis which is part of the package program: Analysis of variance/covariance (UBC MFAV/1978). Slopes and intercepts were calculated for milk, FCM production and fat-percent for the following lactation intervals:

Current lactation:	0 to 50 days
	0 to 150 days
	0 to 305 days
	50 to 100 days
	100 to 150 days
	150 to 305 days
Subsequent lactation:	0 to 50 days
	0 to 150 days
	50 to 100 days
	100 to 150 days

These slopes and intercepts were introduced into the analysis of variance as dependent variables.

3.5.2. Analyses of variance (ANOVA) model

The data were subjected to an analysis of variance. The following independent variables were introduced:

Groups: At calving time each cow was randomly assigned to one of two groups. The early bred group was inseminated at the first visible heat following 50 days post partum. The late bred group was inseminated at the first visible heat following 80 days post partum.

Health status: A health code was introduced to differentiate between cows with normal and abnormal calving and early post partum histories. Health code 1 represented a cow without calving associated reproductive problems. Health code 2 represented a cow which had suffered one or more of the following conditions at calving or within one month after calving: calving difficulty (more than two men or veterinary assistance), retained placenta or metritis. Ayalon et al. (1971) used similar health code specifications.

Calving season: Since there is evidence in the literature that the calving season has an influence on fertility and production in dairy cattle (De Kruif, 1975; Francos and Rattner, 1975; Roine and Saloniemi, 1978), season was introduced into the general ANOVA model. The year was divided into two seasons: May to October (pasture season) and November to April (non-pasture season).

The number of observations for the three independent variables are listed in Table 2.

Table 2: Number of observations

	Early bred group n	Late bred group n	Total n	
Health code 1	30	30	60	85
Health code 2	12	13	25	
Cows calved in:				
Pasture season	20	18	38	85
Non-pasture season	22	25	47	

<u>Sources of uncontrolled variation</u>: Milk production of the first 50 days in the lactation was introduced in the general model as covariable to account for the differences in milk production between the two groups. A preliminary analysis of the data showed that the late bred group produced more milk in this period. The body weight change from calving to 60 days post partum was introduced as covariable into the model for the same reason: Cows in the late bred group lost more weight in this period. These differences between the two groups approached significance and indicated that the two groups were not randomly assigned in relation to these two traits. Age at calving was introduced as covariable to account for the influence of the age of the cow on its fertility and production.

The following dependent variables were tested in the analyses of variance:

Reproductive traits: Occurrence of first visible and first progesterone detected heats (days post partum), first estrous cycle length (days), days from parturition to the first service, number of services per conception, days open, days from first service to conception and the calving interval (days).

Productive traits: Slopes of lactation curves (as discussed under 3.5.1.). Milk production, FCM production and fat-percent of the following lactation intervals:

Current lactation	0 to 50 days
	0 to 305 days
	50 to 100 days
	100 to 150 days
Subsequent lactation:	0 to 50 days
	50 to 100 days
	100 to 150 days

In addition the average daily milk production from the beginning of the current lactation to day 150 of the subsequent lactation was tested.

Body weights and body weight changes: Calving weights, weight of calves, body weight changes from parturition to 60 days and 80 days post partum in both the current and the subsequent lactation, the body weight gain between calvings and the rate of gain (kg/day) from 60 and 80 days post partum to the subsequent calving.

The following general linear model was employed:

$$Y_{ijkl} = \mu + A_i + B_j + C_k + AB_{ij} + BC_{jk} + ABC_{ijk} + dD_{ijkl} + fF_{ijkl} + fG_{ijkl} + \epsilon_{ijkl}$$

where: Y_{ijkl} = dependent variable (the observation of the l-th cow) as listed above

μ = overall mean

A_i = the effect of the i-th breeding group

B_j = the effect of the j-th health code

C_k = the effect of the k-th calving season

D_{ijkl} = the covariable milk production 0-50 days of the l-th cow in the i-th group with the j-th health code and calving in the k-th season

d = the coefficient associated with the D_{ijk} covariable

F_{ijkl} = the covariable body weight changes 0-60 days post partum of the l-th cow in the i-th group with the j-th health code and calving in the k-th season

f = coefficient associated with the F_{ijk} covariable

G_{ijkl} = the covariable age (mo.) of the l-th cow in the i-th group with the j-th health code and calving in the k-th season

g = the coefficient associated with the G_{ijk} covariable

ϵ_{ijkl} = the unexplained deviations associated with the l-th cow. Assumed to be random with a mean of zero and variance of σ_e^2.

For the calculation of the analysis of variance the package program UBC BMD10V (General Linear Hypothesis) was employed. The tests for significance were generated with the F-test on a basis of error probabilities of $P \leq .05$ and $P \leq .01$. In order to explain significant interactions, analyses were computed within health codes or within seasons using the same general model excluding the appropriate main effects and interactions.

3.5.3. Tests of influence of days open on production in subsequent lactation

Days open were characterized by a large variation and were shown by Ripley et al. (1970) to influence the production in the subsequent lactation. Single regression analyses with days open as a continuous independent variable were computed to test the influence of days open on production traits in the subsequent lactation. For the regression analyses the package program UBC TRP (Triangular Regression Package, 1977) was used.

3.5.4. Correlation coefficients

The correlation coefficients discussed later are simple product moments among all continuous variables. For the calculation of the correlation coefficients the package program UBC TRP (Triangular Regression Package, 1977) was used.

4. RESULTS

4.1. Test for bias in the groups

The test for bias showed that there were no significant differences between the two groups at the time of calving and in the early post partum period in terms of productive and reproductive traits (Table 3). However, the milk production in the first 50 days of the lactation and the body weight changes (BWC) from calving to 60 days post partum approached significance, therefore, these variables were introduced as covariables in the main model of the analysis of variance.

Table 3: Means and standard deviations of traits at the time of calving and in the early post partum period.

Trait	Early bred group		Late bred group	
	$\bar{x}$ *	s.d.	$\bar{x}$ *	s.d.
Age of cows (mos.)	44.90	20.00	46.20	22.70
Lactation number	2.45	1.35	2.56	1.67
Calving wt. (kg)	618	98	611	97
Wt. of calf (kg)	42.50	5.30	43.20	5.70
BWC 0-60 days p.p. (kg)	-40.80	37.10	-54.40	40.90
Milk 0-50 days (kg)	1520	325	1653	380
Fat % 0-50 days	3.48	.53	3.38	.52
FCM 0-50 days (kg)	1401	310	1509	416
Slope of milk 0-50 days	.1509	.1253	.1779	.1349
Slope of fat % 0-50 days	-.0035	.0061	.0030	.0076
Slope of FCM 0-50 days	.1257	.1138	.1535	.1387

*Number of observations: 42 for the early bred group, 43 in the late bred group except for the weight of the calf (33 and 36 respectively).

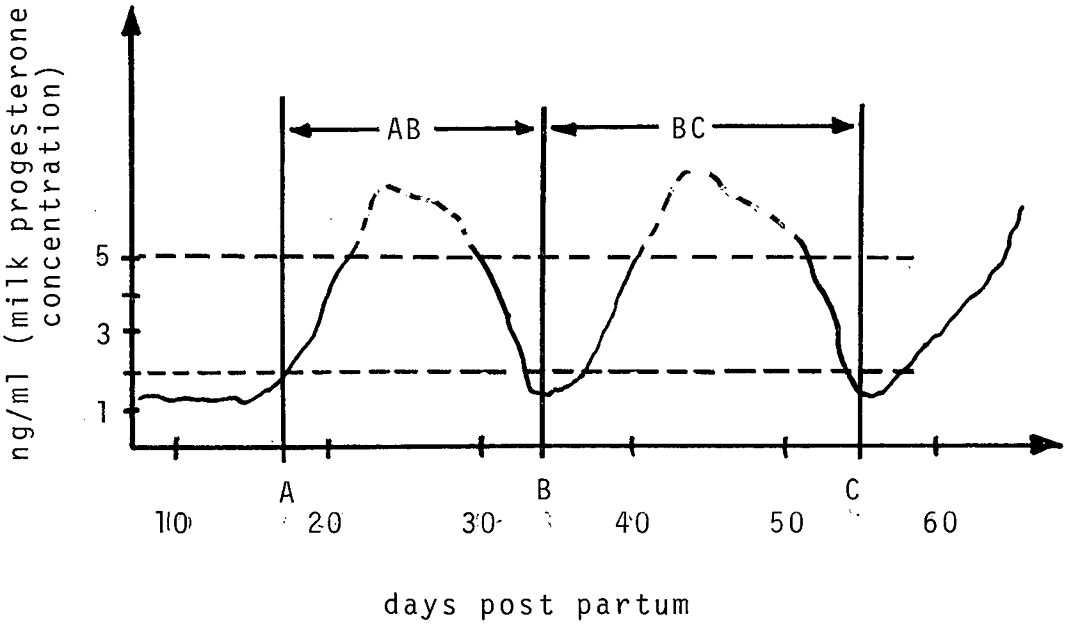
There were no significant ($P \leq .05$) differences between the early bred and the late bred group in the traits listed above.

4.2. Reproductive traits

The detailed tables for reproductive traits of the current lactation are shown in the Appendix (Tables 2a and 2b).

The first cycle length was defined as time period from the first rise of the milk progesterone concentration from 2ng/ml (the early post partum concentration) to a concentration above 5ng/ml and back to 2ng/ml (Figure 1). The duration of a normal estrous cycle of a cow is 19 to 23 days. The average first cycle length in this experiment was found to be only 17.4 ± 7.5 days, with a wide range from 8 days to 40 days. The first progesterone detected heat was defined as the first drop of the milk progesterone concentration below 2ng/ml after the concentration had been above 5ng/ml for the first time after parturition (Figure 1). The first progesterone detected heat occurred 33 ± 10 days post partum with a range of 19 to 78 days. The first visible heat occurred 49 ± 26 days post partum with a range of 8 to 127 days.

Figure 1: Definitions of the first estrous cycle length and the first progesterone detected heat on the base of milk progesterone levels in the early post partum period.



A : first rise of the milk progesterone concentration post partum above 2ng/ml

B : first progesterone detected heat

AB: duration of the first estrous cycle

BC: duration of the second estrous cycle

4.2.1. Influence of early versus late breeding

There was no difference between the early bred group and the late bred group in terms of the occurrence of the first visually or progesterone detected heats and the length of the first estrous cycle (Table 4). The late bred group had more recorded visible heats and progesterone detected heats than the early bred group due to a longer period from parturition to the first service which was imposed on the cows by the treatment (early and late breeding). On the average the early bred group was inseminated 72 ± 18 days after parturition and the late bred group was inseminated 93 ± 17 days after parturition. The early bred group had 88 ± 33 days open while the late bred group had 120 ± 40 days open which resulted in calving intervals of 373 ± 34 versus 404 ± 38 days respectively. The early bred group needed significantly fewer services per conception (1.50; range 1 to 3) than the late bred group (1.95; range 1 to 5). Therefore, the early bred group also had fewer days from the first service to conception (16.4 versus 26.2). None of the covariables accounted for a significant amount of the variation in reproductive traits (means and standard deviations of covariables, Appendix Table 1). Significant interactions will be discussed below.

Table 4: Means and standard deviations of reproductive traits and their differences between the early bred and the late bred group.

Trait	Early bred group		Late bred group		Sign.
	$\bar{x}$	s.d.	$\bar{x}$	s.d.	
1st visible heat (d.p.p.)	50	28.5	47	25.2	n.s.
1st prog. det. heat (d.p.p.)	34	10.0	33	10.5	n.s.
Number of visible heats	2.2	1.0	3.0	1.7	**
Number of prog. det. heats	3.1	1.4	4.2	1.3	**
1st cycle length (days)	18.4	8.6	16.6	6.2	n.s.
Days to 1st. service	72	18.2	93	17.3	**
Number of services	1.50		1.95		*
Days from 1st service to conception	16.40	25.0	26.2	39.8	**
Days open	88	33.0	121	40.6	**
Calving interval (days)	373	34.1	404	38.0	**

Significant differences between groups: * $P \leq .05$, ** $P \leq .01$, n.s. = not significant.

4.2.2. Influence of health

The onset of the estrous cycle and the days from parturition to the first service were not influenced by the health status (Table 5). The duration of the first cycle was slightly shorter in cows with health problems, this difference, however, was not significant. Cows with health problems needed more services per conception (1.96 versus 1.63), had more days open (113 versus 100) and had a longer calving interval (400 versus 385 days) than the cows without calving or early post partum reproductive problems irrespective of date of breeding. Significant interactions will be discussed below.

Table 5: Means and standard deviations of reproductive traits and their differences between the two health codes.

Trait	Health code 1		Health code 2		Sign.
	$\bar{x}$	s.d.	$\bar{x}$	s.d.	
1st visible heat (d.p.p.)	49	27.6	47	25.0	n.s.
1st prog. det. heat (d.p.p.)	34	11.1	34	8.2	n.s.
Number of visible heats	2.5	1.2	2.8	2.0	n.s.
Number of prog. det. heats	3.7	1.4	3.7	1.6	n.s.
1st cycle length (days)	18.1	8.3	15.9	4.7	n.s.
Days to 1st. service	82	21.5	83	18.9	n.s.
Number of services	1.63		1.96		*
Days from 1st service to conception	18.7	29.9	27.9	40.9	**
Days open	100	38	113	46	**
Calving interval (days)	385	35	400	47	**

Significant differences between health codes: * $P \leq 0.05$, ** $P \leq .01$, n.s. = not significant.

The number of observations were 60 for health code 1 and 25 for health code 2, except for the calving interval (49 and 22 observations respectively).

4.2.3. Influence of calving season

Pasture season versus non-pasture season influenced the reproductive performance very little. There were no significant differences in the onset of the estrous cycle, detected heats, days from parturition to the first service and the number of services needed per conception (Table 6). The differences between the calving season for days from the first service to conception, days open and the calving interval reached significance with relatively small differences. These differences have to be explained in relation to some significant interactions between group and calving season or health status and calving season. The interactions will be discussed below.

4.2.4. Interactions

Significant interactions in reproductive traits are listed in Table 7. In order to explain the significant interactions, the results of an analysis within group, health code and/or calving season were used. Within the early bred group health status and calving season did not influence the number of services per conception. Within the late bred group, however, cows with health code 2 (problem cows) needed significantly more services per conception (2.46; range 1 to 5) versus the healthy cows (1.73; range 1 to 4). A similar explanation can be

Table 6: Means and standard deviations of reproductive traits and their differences between pasture season and non-pasture season.

Trait	Pasture season		Non-Pasture season		Sign.
	$\bar{x}$	s.d.	$\bar{x}$	s.d.	
1st visible heat (d.p.p.)	49	28.3	48	25.8	n.s.
1st prog. det. heat (d.p.p.)	32	8.6	35	11.4	n.s.
Number of visible heats	2.5	1.1	2.7	1.7	n.s.
Number of prog. det. heats	3.7	1.3	3.7	1.6	n.s.
1st cycle length (days)	17.4	4.5	17.6	9.2	n.s.
Days to 1st service	83	22.8	82	18.9	n.s.
Number of services	1.74		1.72		n.s.
Days from 1st service to conception	23.0	36.5	20.1	31.2	*
Days open	106	42	103	39	*
Calving interval (days)	391	40	387	39	*

Significant differences between pasture and non-pasture season: * $P \leq .05$, n.s. = not significant

The number of observations were 38 for the pasture season and 49 for the non-pasture season.

given for the group-season interaction: Within the early bred group, calving season had no influence on the number of services per conception (1.53 versus 1.42) while within the late bred group, the cows that calved during the pasture season needed significantly more inseminations per conception than cows calving in the non-pasture season (2.1 versus 1.8). Within the early bred group, days open, days from the first service to conception and the calving interval were not significantly influenced by health status or calving season. However, within the late bred group, days open and the calving interval were significantly influenced by health status; days open and days from the first service to conception were influenced by the calving season (Tables 8 to 11). The health status season interaction for the calving interval was significant in the general model and within the early bred group, but not within the late bred group. Health had a significant influence on the calving interval during the pasture season but not during the non-pasture season (Table 12). The general model showed a significant three-way interaction (group-health-season) for days from first service to conception. This interaction can be neglected because in the pasture season in the late bred group, there was only one animal with health code 2 and this animal had an extreme value (136 days).

Table 7: Interactions between groups, health codes and seasons in reproductive traits.

Traits	Interaction Group x Health code	Interaction Group x Season	Interaction Health x Season
Number of services per conception	*	*	n.s.
Days open	**	*	n.s.
Days from 1st service to conception	n.s.	**	n.s.
Calving interval	**	n.s.	*

* $P \leq .05$, * $P \leq .01$, n.s. = not significant.

Table 8: Significant group-health code interactions in reproductive traits. Analysis within the early bred group.

Trait	Early bred group						
	Health code 1			Health code 2			
	$\bar{x}$	n	s.d.	$\bar{x}$	n	s.d.	Sign.
Number of services per conception	1.53	30	.68	1.42	12	.79	n.s.
Days open	89	30	35	87	12	27	n.s.
Calving interval	374	23	37	370	10	26	n.s.

n.s. = not significant

Table 9: Significant groups-health code interactions in reproductive traits. Analysis within the late bred group.

Trait	Late bred group: Health code 1 $\bar{x}$	n	s.d.	Health code 2 $\bar{x}$	n	s.d.	Sign.
Number of services per conception	1.73	30	1.48	2.46	13	2.46	*
Days open	113	30	36	139	12	47	**
Calving interval	394	26	29	426	12	46	**

Significant differences: * $P \leq .05$, ** $P \leq .01$

Table 10: Significant group-season interactions in reproductive traits. Analysis within the early bred group.

Trait	Early bred group: Pasture season $\bar{x}$	n	s.d.	Non-Pasture season $\bar{x}$	n	s.d.	Sign.
Number of services per conception	1.45	20	.60	1.55	22	.80	n.s.
Days open	89	20	35	87	22	32	n.s.
Days from 1st service to concep.	15.1	20	22.0	17.6	22	28.0	n.s.

n.s. = not significant

Table 11: Significant group-season interactions in reproductive traits. Analysis within the late bred group.

Trait	Late bred group						
	Pasture season			Non-Pasture season			
	$\bar{x}$	n	s.d.	$\bar{x}$	n	s.d.	Sign.
Number of services per conception	2.06	18	1.73	1.88	25	1.45	n.s.
Days open	125	18	44	118	24	38	*
Days from 1st service to concep.	31.8	18	47	22	25	34	**

Significant differences: * P ≤ .05, ** P ≤ .01
n.s. = not significant

Table 12: Significant season-health code interaction for the calving interval. Analysis within seasons

Trait	Health code 1			Health code 2			
	$\bar{x}$	n	s.d.	$\bar{x}$	n	s.d.	Sign.
Pasture season	382	27	37	412	5	52	*
Non-pasture season	387	22	32	397	17	47	n.s.
Total	385	49	35	400	22	47	**

Significant differences: * P ≤ .05, ** P ≤ .01
n.s. = not significant

4.3. Body weights and body weight changes in the current lactation

The detailed tables for body weights and body weight changes are presented in the Appendix (Tables 4a and 4b).

4.3.1. Influence of early versus late breeding

The early post partum body weight changes were not influenced by the division of the herd into early bred and late bred groups (Table 13). Body weight changes were significantly correlated to production (Appendix Table 8). The weight of the cows at the subsequent calving was significantly higher for cows in the late bred group (689 kg) as compared to cows in the early bred group (657 kg). The body weight gain from calving to calving was also significantly higher in the late bred group (67 kg versus 45 kg). The average daily weight gain from 60 and 80 days post partum respectively to the subsequent calving was also higher in the late bred group. The higher average rate of gain in the late bred group can be explained with the longer dry period of these cows. The weight gain during lactation was highly correlated with age ($r= -.66$), and the covariable age accounted for a significant amount of the variation.

Table 13: Means and standard deviations of body weights and body weight changes (BWC) in the current lactation and at the subsequent calving. The differences between early bred and late bred group.

Trait (kg)	Early bred group			Late bred group			Sign.
	$\bar{x}$	n	s.d.	$\bar{x}$	n	s.d.	
Wt. at calving-(1)	611	42	97.0	625	43	100.7	n.s.
BWC 0-60 d.p.p.	-41	42	37.1	-54	43	40.9	n.s.
BWC 0-80 d.p.p.	-31	42	40.1	-50	42	41.6	n.s.
BWC 60-80 d.p.p.	10	40	23.0	6	40	22.5	n.s.
BWC/day (kg/day):							
60 d.p.p. to calving-(2)	.28	33	.16	.35	38	.14	*
80 d.p.p. to calving-(2)	.27	33	.17	.35	38	.16	*
Wt. at calving-(2)	657	31	60.9	689	38	59.0	*
BWC calving-(1) to calving-(2)	45	31	66.5	67	37	70.2	**
Wt. of calf (1)	42.0	33	4.9	43.2	36	5.8	n.s.
Wt. of calf (2)	47.2	32	7.7	45.4	36	6.5	n.s.

Significant differences: * $P \leq .05$, ** $P \leq .01$, n.s. = not significant.

(1) = current calving, (2) = subsequent calving

d.p.p. = days post partum

4.3.2. Influence of health

Cows with calving difficulties or early post partum reproductive problems had heavier calves than cows without problems (Table 16). The 25 cows with problems had 16 bull calves and 9 heifer calves (Table 14). Bull calves tend to be heavier than heifer calves and are more likely to cause difficulties at calving than heifer calves (Philipsson, 1976). The weight of the calf at the subsequent calving again was heavier for the cows with health code 2 and again they had more bull calves than heifer calves (14 bulls, 8 heifers). The body weight at the subsequent calving was the same for both health code groups. Cows with health code 2 gained more weight during the current lactation, the rate of gain (60 days and 80 days post partum respectively to the subsequent calving) however was significantly different (Table 16).

The group-health status interaction for body weight gain between calvings was significant ($P \leq .05$). The analysis within groups and health codes (Table 15) demonstrated that within the early bred group the health code did not account for a significant amount of the variation while it was significant within the late bred group. Hence, cows with calving or early post partum problems in the late bred group gained much more weight than cows of the same group without problems or all the cows in the early bred group.

Table 14: Sex of calves

	Current calving		Subsequent calving	
	bulls	heifers	bulls	heifers
Early bred group	20	22	21	12
Late bred group	23	20	13	25
Health code 1	27	33	20	29
Health code 2	16	9	14	8
Pasture season	17	21	14	18
Non-Pasture season	26	21	20	19

Table 15: Group health status interaction for body weight gain (kg) between calvings. The analysis within breeding groups.

	Health code 1			Health code 2			
	$\bar{x}$	n	s.d.	$\bar{x}$	n	s.d.	Sign.
Early bred group	42	22	62.1	53	9	79.4	n.s.
Late bred group	45	25	60.3	111	12	70.5	*
Total	44	47	60.5	86	21	78.5	*

Significant differences: * $P \leq .05$, n.s. = not significant

Table 16: Means and standard deviations of body weights and body weight changes (BWC) in the current lactation and at the subsequent calving. The differences between health codes.

Traits (kg)	Health code 1			Health code 2			Sign.
	$\bar{x}$	n	s.d.	$\bar{x}$	n	s.d.	
Wt. at calving-(1)	630	60	94.8	588	25	102.1	n.s.
BWC 0-60 d.p.p.	-51	59	38.3	-39	25	41.4	n.s.
BWC 0-80 d.p.p.	-46	59	39.8	-25	24	43.3	n.s.
BWC 60-80 d.p.p.	6	56	21.0	14	24	26.1	n.s.
BWC/day (kg/day):							
60 d.p.p. to calving-(2)	.30	49	.14	.35	22	.18	n.s.
80 d.p.p. to calving-(2)	.30	49	.15	.33	22	.18	n.s.
Wt. at calving-(2)	674	48	60.8	674	21	64.9	n.s.
BWC calving-(1) to calving-(2)	44	47	60.5	86	21	78.5	*
Wt. of calf (1)	42.1	47	4.9	43.8	22	5.9	*
Wt. of calf (2)	45.1	46	7.2	48.5	22	6.6	*

Significant differences: * $P \leq .05$, n.s. = not significant

(1) = current calving, (2) subsequent calving

d.p.p. = days post partum

4.3.3. Influence of season

The season had a marked influence on body weight and body weight changes (Table 17). The calving weight of the cows calving during the pasture season was significantly higher than the weight of the cows calving in the non-pasture season. The cows calving in the pasture season also lost more weight in the first 80 days of the lactation. The difference between the two seasons was especially marked for the interval between 60 and 80 days post partum, where cows in the pasture season still were losing weight while cows in the non-pasture season already started to gain weight again. The rate of gain showed the same situation: Cows calving during the pasture season had a significantly lower rate of gain from 60 days post partum to the subsequent calving. The same calculation from 80 days post partum to the subsequent calving revealed no significant differences between cows calving during the pasture season versus cows calving during the non-pasture season. Cows calving in the non-pasture season in total gained more weight during the lactation up to the subsequent calving. At the subsequent calving, there were no differences between the two seasons in terms of the body weight of the cow and the calf.

Table 17: Means and standard deviations of body weight and body weight changes (BWC) in the current lactation and at the subsequent calving. The differences between calvings during the pasture season and non-pasture season.

Trait (kg)	Pasture season			Non-Pasture season			
	x̄	n	s.d.	x̄	n	s.d.	Sign.
Wt. at calving-(1)	648	38	90.7	595	47	98.9	*
BWC 0-60 d.p.p.	-53	38	31.2	-43	47	45.1	n.s.
BWC 0-80 d.p.p.	-56	37	26.8	-28	47	47.1	**
BWC 60-80 d.p.p.	- 2	35	21.3	16	45	20.7	**
Wt. at calving-(2)	683	32	55.8	667	37	66.2	n.s.
BWC/day (kg/day):							
60 d.p.p.-calving -(2)	.25	33	.14	.37	38	.15	*
80 d.p.p.-calving -(2)	.26	33	.16	.34	38	.17	n.s.
BWC calving-(1) to calving-(2)	26	31	61.2	80	37	65.8	**
Wt. of calf (1)	44	31	5.8	41	38	4.6	*
Wt. of calf (2)	47	31	8.3	46	37	6.0	n.s.

Significant differences: $*P \leq .05$, $**P \leq .01$, n.s. = not significant.

(1) current calving, (2) subsequent calving

d.p.p. = days post partum

4.4. Productive traits in the current lactation

The detailed tables for productive traits of the current lactation are presented in the Appendix (Tables 3a and 3b).

The covariable milk production 0-50 days post partum as expected, accounted for a significant amount of the variation in most production traits.

4.4.1. Influence of early versus late breeding

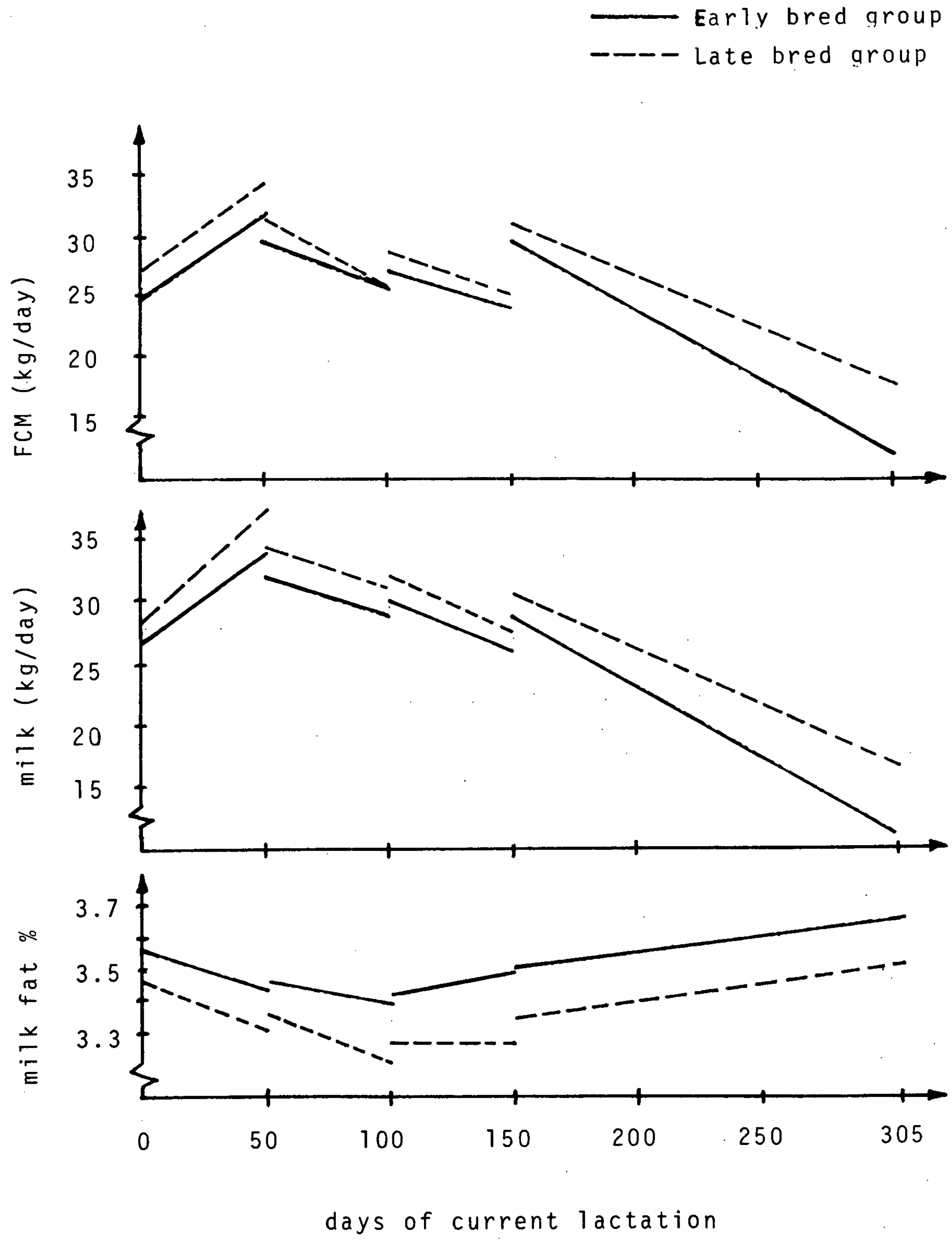
The cows in the late bred group produced more milk in the 305 day lactation and also more fat corrected milk (FCM) (Table 18). The slopes for the period from 150 days to 305 days of the lactation for milk and FCM were also significantly different. Cows in the late bred group had a greater persistency in the latter part of the lactation (Figure 2).

Table 18: Means and standard deviations of productive traits in the current lactation and the differences between early bred and late bred group.

Trait	Early bred group		Late bred group		
	$\bar{x}$	s.d.	$\bar{x}$	s.d.	Sign.
FCM 0-50 days (kg)	1401	310	1509	416	n.s.
FCM 50-100 days (kg)	1386	285	1412	612	n.s.
FCM 100-150 days (kg)	1284	233	1313	303	n.s.
FCM 305 days (kg)	7276	1565	7995	2304	*
Milk 305 days (kg)	7595	1659	8550	2484	*
Fat % 305 days	3.71	.47	3.57	.38	n.s.
Slope milk 0-150 days	-.0271	.0366	-.0372	.0639	n.s.
Slope fat % 0-150 days	-.0013	.0034	-.0016	.0036	n.s.
Slope FCM 0-150 days	-.0290	.0420	-.0405	.0648	n.s.
Slope milk 150-305 days	-.1178	.0487	-.0955	.0448	**
Slope fat % 150-305 days	.0009	.0008	.0010	.0119	n.s.
Slope FCM 150-305 days	-.1059	.0430	-.0825	.0419	**

Significant differences between groups: * $P \leq .05$, ** $P \leq .01$, n.s. = not significant.

Figure 2: Mean production and slopes of early and late bred group for fat %, milk and fat corrected milk (FCM) of the current lactation.



4.4.2. Influence of health

The grouping of the herd according to health codes did not influence the productive performance of the cows. None of the analysed production traits of the current lactation showed a significant difference between the two health code groups. Figure 3 shows that there were small differences in the fat % in the milk; cows with early post partum reproductive disorders produced less fat than the healthy cows (Figure 3). In terms of milk or FCM production, there were no significant differences in the first part of the lactation. Milk or FCM production in the latter part of the lactation was exactly the same for both of the health code groups (Figure 3).

4.4.3. Influence of season

The influence of the calving season on production in the current lactation was not substantial (Figure 4). Cows calving in the pasture season had a significantly ($P \leq .05$) higher fat test up to 150 days in the lactation (3.51% ± .48% versus 3.25% ± .36%) and produced significantly ($P \leq .05$) more FCM in the total lactation (7880 kg ± 2011 kg versus 7507 kg ± 1992 kg). The uncorrected milk yield was not significantly different. The slopes of fat %, milk and FCM production did not show any significant differences between the two calving seasons (Figure 4).

Figure 3: Mean production and slopes of health code group 1 and health code group 2 for fat %, milk and fat corrected milk (FCM) of the current lactation.

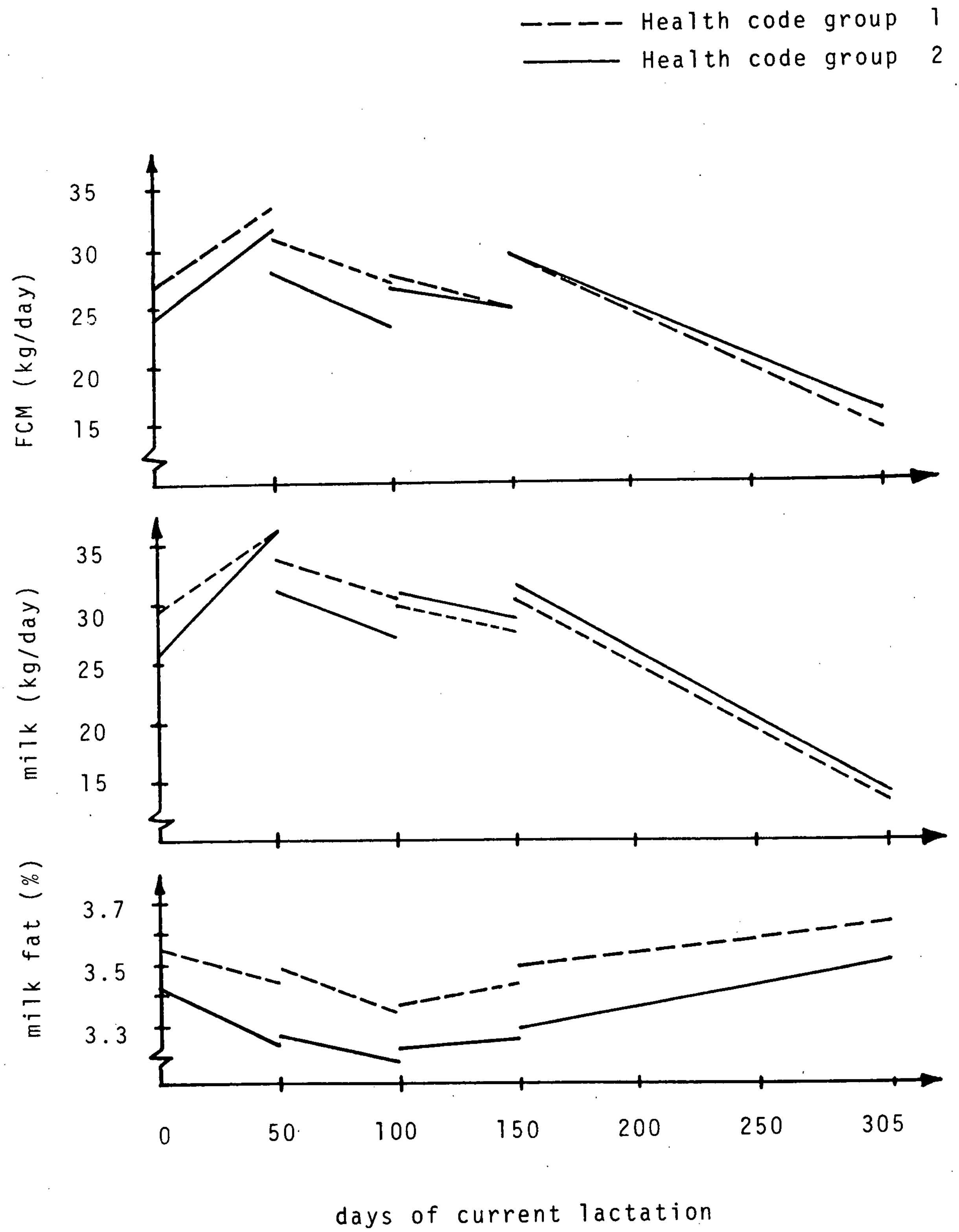
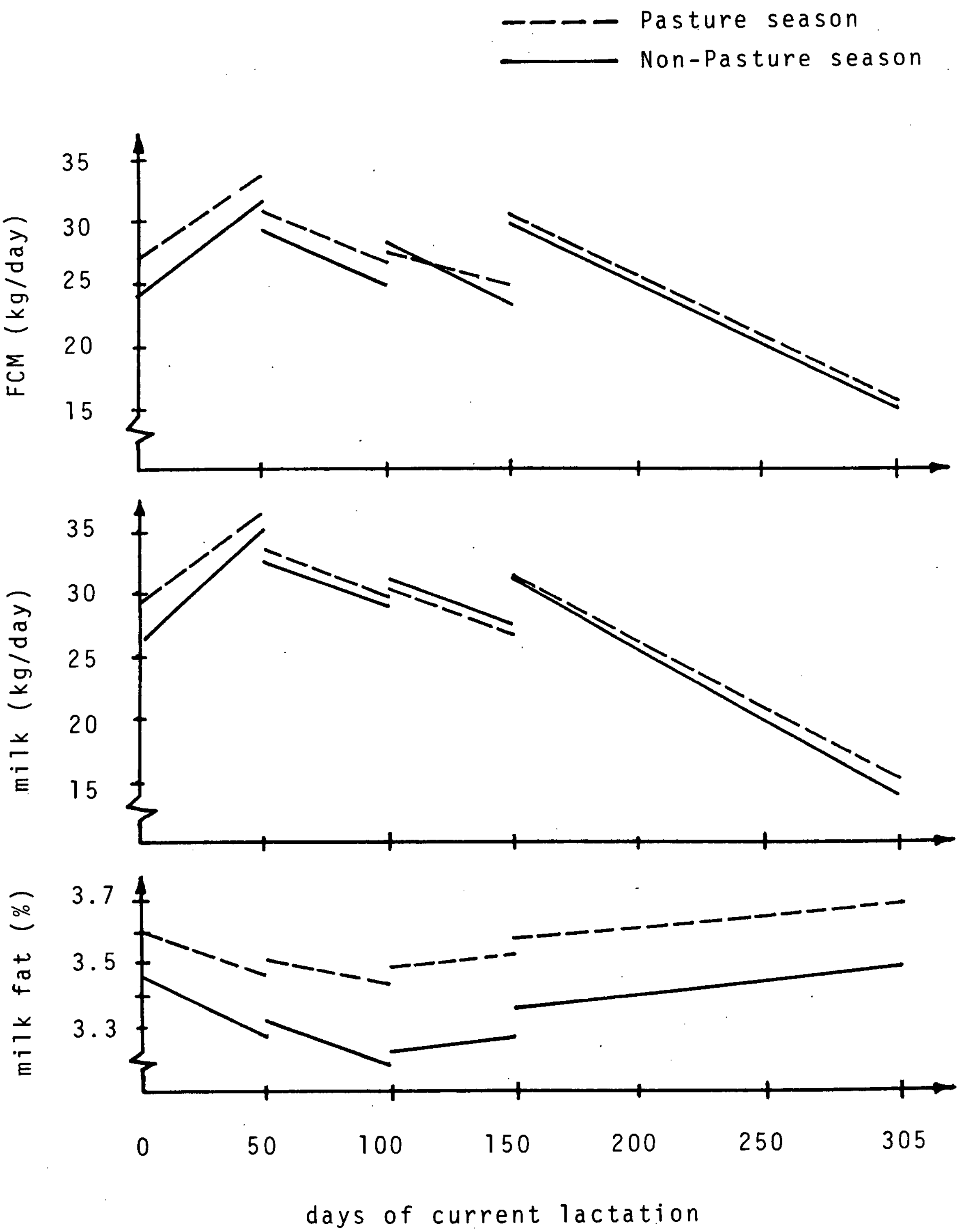


Figure 4: Mean production and slopes of cows calving during the pasture season versus the non-pasture season for fat %, milk and fat corrected milk (FCM) of the current lactation.



4.5. Carry-over effects from the current to the subsequent lactation

The detailed tables for traits in the subsequent lactation are presented in the Appendix (Tables 5a and 5b).

4.5.1. Influence of early versus late breeding

The body weight changes in the early post partum period of the subsequent lactation were not significantly different between the two groups (Table 19). There were some significant differences in terms of milk production: Cows in the late bred group produced significantly more fat corrected milk (FCM) in the periods 50 to 100 and 100 to 150 days post partum. Mean production and slopes of fat %, milk and FCM of the subsequent lactation are presented in Figure 5. The common slopes for milk and FCM for the period 0-150 days of the two groups were significantly different. However, the slopes of the different segments of the lactation did not show any significant differences (Figure 5).

Table 19: Means and standard deviations of traits in the subsequent lactation and the differences between early and late bred groups.

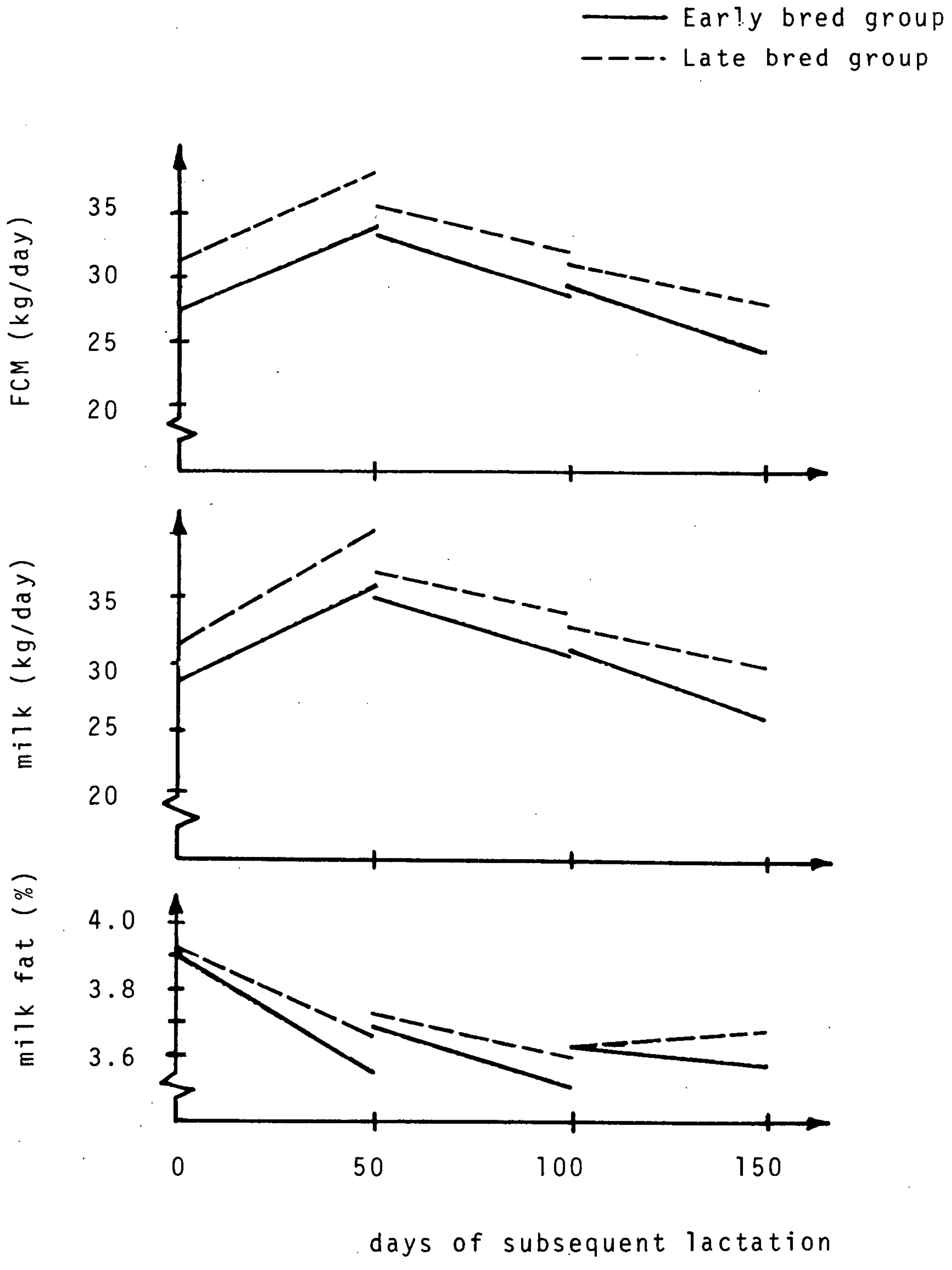
Trait	Early bred group		Late bred group		
	$\bar{x}$	s.d.	$\bar{x}$	s.d.	Sign.
BWC 0-60 d.p.p. (kg)	-55	33.0	-66	39.4	n.s.
BWC 0-80 d.p.p. (kg)	-32	45.9	-54	43.9	n.s.
BWC 60-80 d.p.p. (kg)	18	22.5	8	27.9	n.s.
FCM 0-50 days p.p. (kg)	1540	40.6	1745	253	n.s.
FCM 50-100 days p.p. (kg)	1554	160	1689	212	*
FCM 100-150 days p.p.(kg)	1351	161	1479	188	*
Slope milk 0-150 d.p.p.	-.0640	.0353	-.0318	.0361	**
Slope fat % 0-150 d.p.p.	-.0025	.0055	-.0036	.0054	n.s.
Slope FCM 0-150 d.p.p.	-.0709	.0302	-.0492	.0390	*

Significant differences: * $P \leq .05$, ** $P \leq .01$, n.s. = not significant

Number of observations were 25 for the early bred group and 27 for the late bred group.

BWC = body weight changes, d.p.p. = days post partum

Figure 5: Mean production and slopes of early and late bred group for fat %, milk and fat corrected milk (FCM) of the subsequent lactation (0-150 days).



4.5.2. Influence of health

Among the production traits, the only significant difference between the two health code groups was the fat % test in the milk of the first 50 days of the subsequent lactation (Table 20). The cows in health code 1 had the higher fat test (3.84% versus 3.62%). Cows in health code group 2 lost more weight in the early post partum period of the current lactation and they also lost more weight in the subsequent early post partum period. In terms of mean production and the slopes for fat %, milk and FCM, no differences between health code groups reached a significant ($P \leq .05$) level (Figure 6).

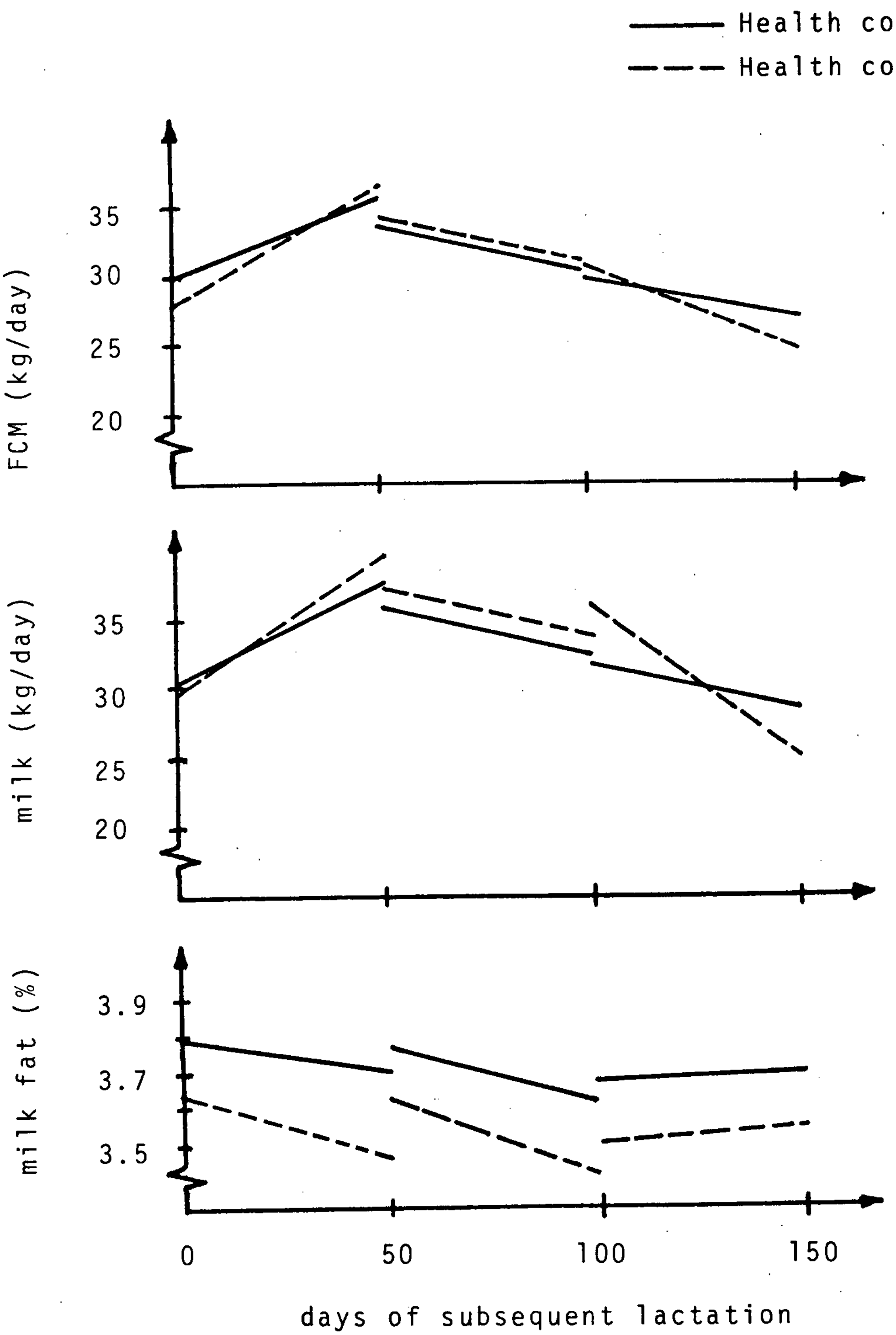
Table 20: Means and standard deviations of traits in the subsequent lactation and the differences between the health code groups (health codes of the current lactation).

Trait	Health code 1			Health code 2			
	$\bar{x}$	n	s.d.	$\bar{x}$	n	s.d.	Sign.
BWC calving-(1) to calving-(2) (kg)	44	47	60.5	86	22	78.5	*
Wt. at calving (2) (kg)	674	47	61	674	21	65	n.s.
BWC 0-60 days p.p. (kg)	-56	38	33.4	-71	16	42.6	n.s.
BWC 0-80 days p.p. (kg)	-36	38	47.5	-63	16	35.2	*
BWC 60-80 d.p.p. (kg)	17	38	26.6	8	16	22.3	n.s.
Fat % 0-50 d.p.p.	3.84	38	.56	3.62	18	.53	*

Significant differences: * $P \leq .05$, n.s. = not significant

(1) current calving, (2) subsequent calving

Figure 6: Mean production and slopes of health code group 1 and health code group 2 for fat %, milk and fat corrected milk (FCM) of the subsequent lactation (0-150 days).



4.5.3. Influence of season

The calving season of the current lactation influenced the onset of the lactation in the subsequent lactation (Table 21, Figure 7). The milk production of the cows calving during the pasture season in the current lactation increased faster than the production of cows calving during the non-pasture season in the current lactation. In terms of total milk production or FCM production in the first 150 days of the subsequent lactation, there were no significant (P > .05) differences between the two seasons.

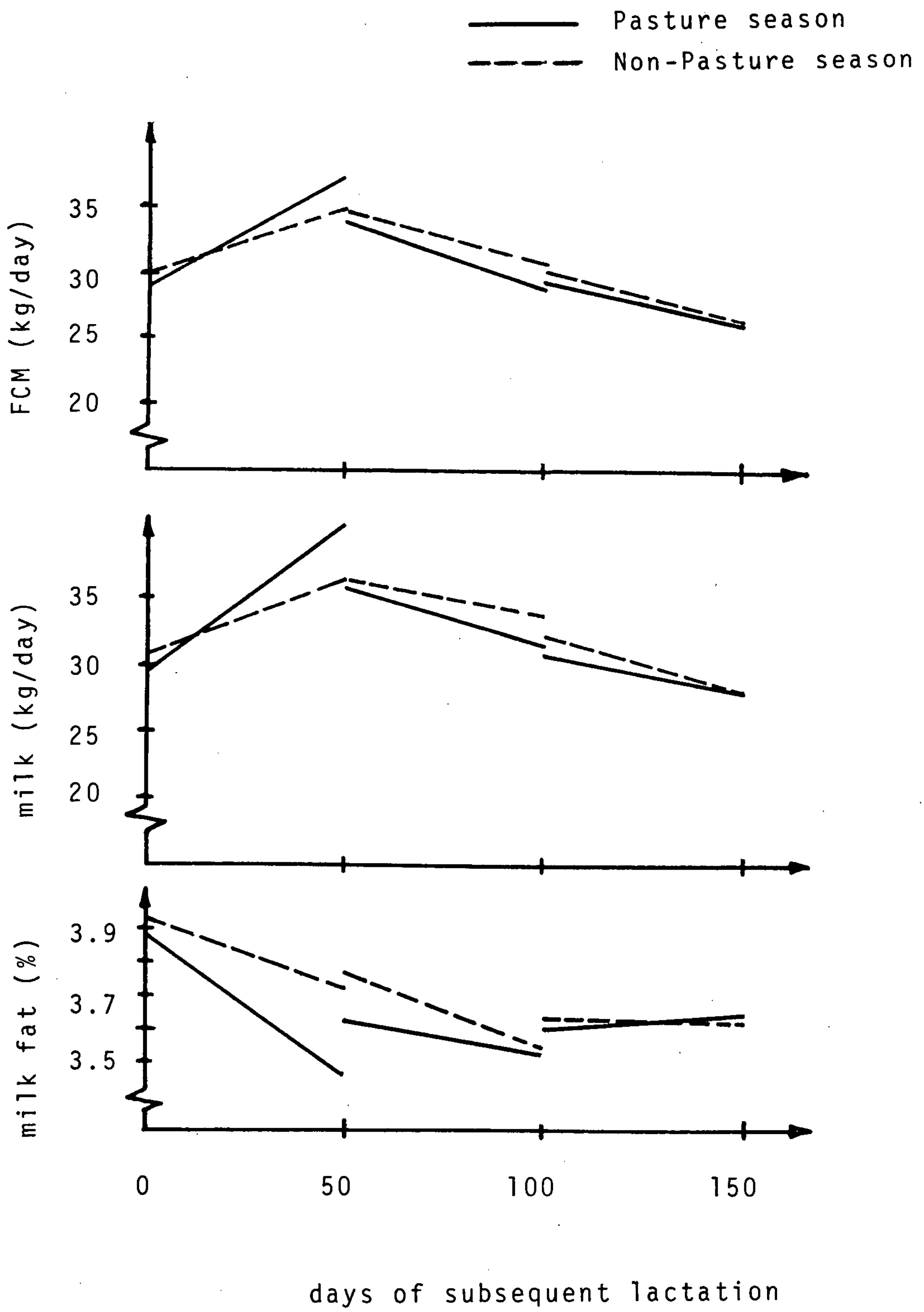
Table 21: Means and standard deviations of traits in the subsequent lactation influenced by the calving season of the current lactation.

Trait	Pasture season			Non-Pasture season			
	$\bar{x}$	n	s.d.	$\bar{x}$	n	s.d.	Sign.
Slope milk 0-50 d.p.p.	.2125	26	.1108	.1115	31	.1921	**
Slope fat % 0-50 d.p.p.	-.0090	23	.0135	.0042	29	.0100	n.s.
Slope FCM 0-50 d.p.p.	.1679	23	.1187	.0939	29	.1813	*

Significant differences: * P ≤ .05, ** P ≤ .01
n.s. = not significant

d.p.p. = days post partum

Figure 7: Mean production and slopes of fat %, milk and fat corrected milk (FCM) of the subsequent lactation (0-150 days). Differences due to the calving season of the current lactation.



4.6. Average daily milk production over the two lactations

The analyses of the milk production showed that the late bred cows produced more milk and FCM in both the current and the beginning of the subsequent lactation. The longer interval from parturition to conception of the late bred group also resulted in a longer dry period. In order to compare the daily milk production of the early and the late bred group, the health status groups and the groups according to the calving season, the average daily milk production from the beginning of the current to day 150 of the subsequent lactation was calculated. The results of this calculation showed that there were no differences in the average daily milk and FCM production between early and late bred groups, health status groups or groups according to calving season (Table 22). These results demonstrated that there was no superiority of the late bred group in terms of milk production when the longer dry period (due to more days open) was taken into account.

Table 22: Average daily milk and FCM production from the beginning of the current lactation to day 150 of the subsequent lactation.

Trait	Early bred group			Late bred group			Sign.
	$\bar{x}$	n	s.d.	$\bar{x}$	n	s.d.	
milk (kg)	22.11	33	5.07	22.79	38	5.65	n.s.
FCM (kg)	20.69	33	5.64	20.63	38	6.00	n.s.
	Health code group 1			Health code group 2			Sign.
	$\bar{x}$	n	s.d.	$\bar{x}$	n	s.d.	
milk (kg)	22.66	49	5.15	22.05	22	5.90	n.s.
FCM (kg)	20.68	49	5.96	20.62	22	5.54	n.s.
	Pasture season			Non-Pasture season			Sign.
	$\bar{x}$	n	s.d.	$\bar{x}$	n	s.d.	
milk (kg)	23.73	32	5.00	21.44	39	5.49	n.s.
FCM (kg)	21.64	32	6.15	19.86	39	5.44	n.s.

n.s. = not significant ($P > .05$)

4.7. Correlations and regressions

The complete correlation tables are presented in the Appendix (Tables 6 to 9).

4.7.1. Correlations between reproductive traits

The first visually detected heat was correlated with the first progesterone detected heat and with the days from parturition to the first service (Table 23). The first progesterone detected heat was highly correlated with the duration of the first estrous cycle. The later the first progesterone heat was detected, the longer was the duration of the first estrous cycle. In terms of milk progesterone levels, this indicated that milk progesterone levels were high for a long time prior to a late detection of the first progesterone heat (see definition of duration of first estrous cycle, page 27). The first cycle length was not correlated with the first visually detected heat. The remaining significant correlations listed in Table 23 were cause relations: days to first service were correlated with days open and the calving interval. The number of services per conception were correlated to days open, to the interval from the first service to conception and to the calving interval.

Table 23: Correlations between reproductive traits of the current post partum period.

	1st visible heat	1st prog. heat	1st cycle length	days to 1st service	number of services	days open	Days 1st service to conception
1st visible heat	1.00						
1st prog. heat	.32*	1.00					
1st cycle length	.19	.62*	1.00				
Days 1st service	.33*	.03	.04	1.00			
# of services	-.11	-.01	-.07	.05	1.00		
Days open	.06	-.01	-.04	.55*	.77*	1.00	
Days to 1st serv. to conception	-.13	-.01	-.06	.05	.90*	.86*	1.00
Calving interval	.07	.03	-.01	.59*	.69*	.96*	.80*

*Significant correlation ($P \leq .01$)

Table 24: Correlations between reproductive and productive traits of the current lactation.

	1st cycle length	days to 1st service	number of services	days open	calving interval
FCM 0-50 days	.26**	.15	.18	.15	.13
FCM 50-100 days	.24*	.20	.21*	.19	.18
Milk 305 days	.17	.36**	.34**	.39**	.36**
FCM 305 days	.18	.30**	.37**	.37**	.37**
Slope milk 305 d.	.04	.13	.29**	.32**	.36**
Slope FCM 305 d.	.04	.13	.29**	.32**	.37**

Significant correlations * $P \leq .05$, ** $P \leq .01$

4.7.2. Correlations betweeen reproductive and productive traits of the current lactation

The first cycle length was positively correlated with the FCM production of the first and second 50 days of the current lactation (Table 24). The interval from calving to first service was positively correlated with the total milk and FCM production of the current lactation. The number of services per conception was positively correlated with milk and FCM production for the period 50-100 days, the entire lactation, as well as with the slopes for milk and FCM production of the entire lactation. The number of services per conception, days open and the calving interval were positively correlated with the total milk and FCM production of the current lactation and with the slopes of the 305 day milk and FCM production. These correlations indicated that the later the cows conceived, the more they produced or vice-versa.

4.7.3. Correlations between reproductive traits of the current and productive traits of the subsequent lactation

The first progesterone detected heats were significantly correlated with the FCM production of the 50 to 100 days period of the subsequent lactation and with the slope of the fat test of the first 150 days in the subsequent lactation (Table 25). The first estrous cycle length in the current lactation was significantly correlated with the fat test in the first 50 days of the subsequent lactation and with the slope of the fat test and the FCM production in the first 150 days of the subsequent lactation. Days from parturition to first service, days open and the calving interval were correlated with several production traits in the subsequent lactation. In order to explain these correlations, a regression analysis was conducted, the results of which will be discussed below.

Table 25: Correlations between reproductive traits of the current and productive traits of the subsequent lactation.

Trait	1st prog. heat	1st cycle length	days to 1st service	days open	calving interval
Fat % 0-50 days	.18	.41**	-.12	-.06	-.07
FCM 50-100 days	.33**	.25	.32**	.43**	.28*
FCM 100-150 days	.13	.11	.29*	.40**	.34**
Slope milk 0-150 days	.06	-.21	.37**	.39**	.35**
Slope fat % 0-150 days	-.34**	-.34**	-.04	-.14	-.10
Slope FCM 0-150 days	-.23	-.54**	.30*	.23	.22

Significant correlations: * P ≤ .05, ** P ≤ .01

4.7.4. Correlations between reproductive traits and body weight changes in the current and subsequent lactation

The first visible heat and the first progesterone detected heat were both positively correlated with the body weight changes in the first 60 and 80 days respectively of the current lactation (Table 26). The negative correlation coefficient indicated that the more weight a cow lost in the early post partum period the later the onset of estrus and the later the cow showed a visible estrus behaviour. Since late onset of estrus and estrus behaviour delayed the first service, days to first service was correlated with the early lactation body weight changes in the same manner as the first progesterone and the first visually detected heat. Days open and the calving interval were not correlated with body weight changes in either lactation. The first progesterone detected heat and the days to the first service were both negatively correlated with the 0-60 day weight changes in the subsequent lactation, indicating that the later the onset of progesterone detected estrus and the later the first insemination took place, the more weight the cows lost in the early portion of the subsequent lactation. Early post partum body weight changes were correlated with production traits (Appendix Table 9). Correlations with production traits and body weight changes can be explained better if the correlations between body weight changes and production are taken into account.

Table 26: Correlations between reproductive traits and body weight changes (BWC) in the current and subsequent lactation.

Trait (kg)	1st visible heat	1st prog. heat	days to 1st service	days open
Current lactation:				
BWC 0-60 days p.p.	-.24*	-.24**	-.20	-.19
BCW 0-80 days p.p.	-.26**	-.19	-.24*	-.15
BWC 60-80 days p.p.	-.06	-.01	.06	.05
BWC 1st calving to 2nd calving	-.19	-.13	.01	.01
Subsequent lactation:				
BWC 0-60 days p.p.	-.07	-.26*	-.25*	-.17
BWC 0-80 days p.p.	-.03	-.21	-.21	-.03
BWC 60-80 days p.p.	.08	.00	.03	-.05

Significant correlations: * $P \leq .05$, ** $P \leq .01$

d.p.p. = days post partum

4.7.5. Test of influence of days open on production in the subsequent lactation

The analysis of variance showed that the groups (early and late breeding) did not have a marked influence on the production and body weight changes of the early subsequent lactation. The hypothesis is that factors other than the days from parturition to the first service, like days open or the calving interval, have a greater influence on the subsequent lactation. In order to show these influences, a simple regression analysis was computed with days open as independent continuous variable.

This analysis resulted in the following observations: Days open contributed significantly to the prediction of milk and FCM production in the first lactation (Table 27). In the subsequent lactation days open of the current lactation influenced the weight of the calf in the subsequent lactation but not the body weight changes in the early post partum period of the subsequent lactation. The contribution of days open to the prediction of production traits in the early subsequent lactation was moderate. Days open influenced the slope of the milk production curve in the first 150 days but neither the slope of fat % or FCM production was influenced. The regression of milk production during the first 50 days versus days open was not significant, the regression of days open on FCM production from 100-150 days, however, was significant.

Table 27: Results of the simple regression analyses with days open as independent continuous variable.

Dependent variables	Regression coefficient	Coefficient of determination R^2	Sign.
Current lactation:			
Milk 305 days	19.3376	.19	*
FCM 305 days (kg)	14.2039	.14	*
Subsequent lactation:			
Weight of calf (kg)	-.07694	.57	*
Weight change 0-60 d.p.p. (kg)	-.31395	.03	n.s.
Weight change 60-80 d.p.p. (kg)	.07309	.00	n.s.
Milk 0-50 days (kg)	1.77031	.05	n.s.
FCM 100-150 days	2.05411	.16	*
Slope milk 0-150 days	.000420	.15	*
Slope fat % 0-150 days	-.000021	.02	n.s.
Slope FCM 0-150 days	.000230	.05	n.s.

* Significant contribution to the regression equation ($P \leq .01$).

n.s. = not significant

BWC = body weight changes, d.p.p. = days post partum

5. DISCUSSION

5.1. The onset of the estrous cycle, visual and progesterone detected heat

The involution of the bovine uterus after parturition takes approximately 30 days (Lamming, 1978; Roberts, 1971). The first progesterone rise was reported by Lamming (1978) to occur 25 ± 10 days post partum. The results of this study indicated that the first progesterone detected heat occurred 33 ± 10 days with a range from 19 to 78 days post partum and are comparable with the findings of Morrow et al. (1969). He reported that the first estrus was between 30 and 76 days post partum, and that follicular development started between 16 and 21 days post partum. In indicating the wide range from 30 to 76 days Morrow et al. (1969) stressed the importance of the individual cow. The wide range in the onset of the first progesterone heat also showed that the wide range of the detection of the first visible heat (8 to 127 days) was not only a result of inadequate observation of the cows but that there actually was a large variation between cows. De Kruif (1978) included chance in his list of factors influencing the fertility of dairy herds. He concluded that in small herds (up to approximately 40 cows) due to the large variation between individual cows the fertility by chance (for no apparent reason) may be impaired. Different intervals to the first estrus have been reported by King et al. (1976) with 19.5 days, Mather et al. (1978) with 21 days and Wagner and Hansel (1969) with 14 days. The time difference between the first progesterone detected heat and the first visible heat (16 days) indicated that most of the first heats were silent or with little behavioural evidence, therefore, they remained undetected by the herdsmen. Early post partum heats are reported to be difficult to detect visually (David et al., 1971; Morrow et al., 1969; King et al., 1976). The time from parturition to the first progesterone detected estrus (33 days) was similar to the findings of Callahan et al. (1971) and King et al. (1976). These workers observed the herds continuously and did not find any difference between the occurrence of the first progesterone detected and the first visual detected heats. First estrous cycles were reported to vary considerably in length and very often were shorter than 21 days (Mather et al., 1978; Britt, 1980), therefore the average duration of 17 days found in this experiment can be considered normal. Although Britt (1980) excluded all the cows with calving associated reproductive disorders, he found an average first cycle length of 17 days as well. In this study the first progesterone detected heats were significantly correlated ($r = .62$) with the first cycle lengths. The later the first progesterone detected estrus occurred, the longer was the duration of the preceeding estrous cycle (see definition of first estrous cycle, page 27) Mather et al. (1978) found a positive correlation between the first progesterone peak level post partum and the duration of the first cycle. He also found an increase in the peak progesterone concentration and in the cycle length over the first three cycles before the system was back to steady progesterone cycles and normal cycle lengths.[1] Britt (1980) reported average cycle lengths of 21.1 and 21.4 days for subsequent cycles which followed a first cycle length of 17 days.

Calving problems or calving associated early post partum reproductive problems did not influence the onset of the progesterone detected estrous cycles in this study. Baier et al. (1973) reported that a later onset of the estrous cycle in cows with calving associated problems was mostly related to a slower involution of the uterus. Baier et al. (1973) observed the cows for estrus signs and used rectal palpations to check uterine involution and follicular development.

The calving season did not influence the onset of the estrous cycle or the first cycle length. Stott and

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1 The pattern of the milk progesterone concentration of the first and subsequent estrous cycles of the same cows in the same experiment are being studied in a different Master of Science project by W.L. Slack, Department of Animal Science, University of British Columbia, Vancouver, B.C.

Williams (1962) showed that cows exposed to high temperatures in the summer months had depressed fertility. They related the lower fertility to very long estrous cycles. The pasture season temperatures in the temperate Fraser Valley climate apparently were not high enough to influence the cycle lengths of the cows. The fact that neither calving associated reproductive problems, the calving season, nor the covariables (age, milk production 0-50 days, body weight changes 0-60 days) accounted for a significant part of the variation of the onset of estrus was an obvious expression of the large inexplainable variation between individual cows.

5.2. Days from parturition to the first service, number of services per conception, days open and the calving interval

The early bred group conceiving 88 days post partum after 1.50 services per conception as opposed to the late bred group conceiving 120 days post partum after 1.96 services per conception showed a positive effect of the earlier breeding on fertility in this herd. A number of cows scheduled to be bred at the first visible heat following 50 days post partum did not show any visible heat until much later. Therefore, the average interval from the scheduled breeding to the actual breeding was longer in the early bred group (50 to 73 days = 23 days) than in the late bred group (80 to 93 days = 13 days).

In comparison to the literature, intervals from calving to the first service of 73 days and from calving to conception of 88 days were not considered short and were necessary to achieve a one year calving interval (Ayalon et al., 1971; Bar-Anan and Soller, 1979; Machnai and Kali, 1971).

Many authors have reported that the conception rate from services prior to 40 days post partum was lower than conception from services between 50 and 70 days or later in the post partum period (Kräusslich, 1974; Kupferschmid, 1975). The same workers also reported that there was no difference in conception rate of inseminations between 50 and 70 days as compared to services later in the post partum period. Significantly increased numbers of services per conception 80 days post partum or later, as found in this experiment, have not been reported previously. The significant difference between the early bred group and the late bred group in terms of number of services per conception and days from first service to conception was eliminated when cows with calving associated problems were excluded from the analysis. This analysis showed that cows in the early bred group conceived after 1.53 services and that cows in the late bred group conceived after 1.73 services. This still showed a better fertility in the early bred group but the difference was no longer significant. Problem cows in the early bred group conceived as readily as the healthy cows (1.42 versus 1.53 services per conception). Problem cows in the late bred group required significantly more services per conception than healthy cows in the same group (2.46 versus 1.73) and also required more services per conception than all other cows in the experiment (2.46 versus 1.60). These facts can not be readily explained in the context of this study and need further investigation. Possible reasons were: the severity of the disorders of the affected cows might have been different in the two groups; or treatment and treatment effects might have been different.

Onset of estrus, length of the first estrous cycle and the number of visually and progesterone detected heats were the same for normal and problem cows. These facts indicated that the reason for delayed conception was not due to ovarian inactivity. More likely the uterus was not ready for the implantation of the fertilized ovum at the time of the unsuccessful inseminations. Morrow et al. (1969) reported that ovarian activity after parturition normally resumed before uterine involution was completed. Baier et al. (1973) reported that calving difficulties delayed uterine involution. Retained placenta and metritis also are known to be adverse to the implantation of the embryo (Roine and Saloniemi, 1978).

The seasonal influences on fertility were only significant within the late bred group. Cows which calved in the pasture season had a decreased fertility. These findings again showed that in the late bred group the apparent optimal time for insemination was passed so that influences like season and health problems became significant. Braun (1977) was able to improve the fertility in problem herds by breeding all cows in those herds as soon as they showed normal estrous cycles. Braun (1977) monitored the cycles with milk progesterone analysis. Zerobin (1979) recommended breeding problem cows as soon as they show estrus (either visual or progesterone detected ones). His recommendation was based on the belief that an unsuccessful insemination did not influence the conception rate of subsequent breedings.

A low fertility rate during late summer and fall months was reported by Hewett (1968) and De Kruif (1975). The lower fertility in the pasture season also might have been associated with the body weight changes in the early post partum period. Cows which calved in the pasture season still lost weight between 60 and 80 days post partum while cows which calved in the non-pasture season were already gaining weight in the same period. King et al. (1976) and Youdan and King (1977) reported a beneficial influence of body weight gain on fertility at time of insemination.

The goal of a one year calving interval was achieved in the early bred group (373 days) but not in the late bred group (404 days). These findings support the statement of Ayalon et al. (1977) that in order to achieve a 365 day calving interval, it is necessary to start breeding the cows not later than 50 days post partum.

5.3. The relationship between reproduction, production and body weight changes

The dairy herd of the Agriculture Canada Research Station in Agassiz is a high yielding Holstein herd (average production of the 85 cows in this experiment: 8084 kg milk, 7644 kg FCM). Similar studies dated 10 to 20 years ago dealt with production levels which were substantially lower (Smith and Legates, 1962; Wilton et al. 1967). More recent studies, especially from Israel, have involved milk production levels comparable with the production of the Agassiz herd.

Beside the genetic improvement of the herds, nutrition and management have been improved substantially to increase milk production, yet resulting in more stress on the cows. For this reason the results in this study of reproduction-production relationships have been compared to research results from Israel.

Significant correlations in the range of r = .30

between milk production and reproduction traits (number of services per conception, days open, calving interval) have been reported previously (Bar-Anan and Soller, 1979; Francos and Rattner, 1975; Hewett, 1968). These correlations offer an explanation for the higher 305 day milk yield of the late bred group. The fact that early lactation milk yields were not significantly correlated with reproduction traits but the slopes for milk production of the latter part of the current lactation of cows in the late bred group showed a greater persistency indicated that the differences in milk yield between the two groups were mainly due to the differences in the latter part of the lactation. These findings are in agreement with the findings of Erb et al. (1952) and Smith and Legates (1962) who concluded that gestation did not materially affect milk yield until the 5th month after conception. The higher milk production in the late bred group was not accompanied by a greater body weight loss in the early post partum period. The tendency to a higher 305 day milk production of cows calving during the pasture season was accompanied by significantly ($P \leq .01$) higher body weights at calving and body weight changes in the early post partum period as well as with a lower fertility ($P \leq .05$). These situations indicated that high milk yields were not necessarily related to high body weight losses in the early post partum period. However, high body weight losses often were related to high milk yields and with depressed fertility.

Similar findings and the repeatedly reported negative influence of early post partum body weight losses on fertility (Amir and Kali, 1974; Broster, 1973; Youdan and King, 1977) initiated the work of Herz and Graf (1976) and Roberts et al. (1979a) (1979b). Herz and Graf (1976) did not find that blood glucose levels had any influence on fertility. Roberts et al. (1979a) found a significant relationship between fatty liver (due to the mobilization of fatty acids from adipose tissue in the early post partum period) and fertility. The findings of Roberts et al. (1979a) offered an explanation for lower fertility of cows which calved during the pasture season and were still losing weight in the period 60 to 80 days post partum. On the average, the first insemination took place 83 days post partum. Cows which calved during the non-pasture season had a better fertility than cows which calved during the pasture season and were already gaining weight between 60 and 80 days post partum. A positive effect of body weight gain on fertility was reported by Hodges (1976), Huth and Smidt (1979) and Youdan and King (1977). A further explanation for the better fertility of cows calving in the winter months (non-pasture season) is the reported lower progesterone levels during estrus in the winter months which were related to increased conception rates (Rosenberg et al. 1977).

The longer rest period post partum of the late bred group resulted in a longer dry period and therefore in a higher weight gain between calvings, a higher body weight at the subsequent calving, and a heavier calf. The late bred group also gained weight at a higher daily rate (from 60 and 80 days post partum respectively to the subsequent calving) than the early bred group. The weight gain between calvings is especially important for heifers, therefore, several authors recommended a longer rest period for heifers than for cows (Louca and Legates, 1968; Bar-Anan and Soller, 1979).

Calving associated disorders were not significantly related to production traits, the slightly higher ($P \leq .10$) FCM production observed in affected cows can be explained with their longer interval from calving to conception (correlation between days open and 305 day FCM production for all cows in the experiment r = .37).

The carryover effects of the current lactation to the subsequent lactation were moderate. The greater persistency of milk production in the first 150 days of the subsequent lactation for the late bred group can be related to the longer dry period of this group. All the cows in the experiment were dried off at 305 days which resulted in a longer dry period for the late bred group. Wood (1977) showed that the dry period influenced the onset of milk production in the following lactation. Due to the longer dry period of the late bred group the average daily milk and FCM yields (calculated over both lactations) were the same for both the early and the late bred group. Economically the average production per day of productive life is more important than the 305 day lactation yields. Therefore, as mentioned before, Israel introduced a system which adjusts lactation milk yields for days open (Bar-Anan and Soller, 1979).

The cows with calving associated reproductive problems (health code group 2) had heavier calves at both calvings. There was no difference in body weights at calvings between the two health code groups. Philipsson (1976) found that the different weights of calves from cows with equal body weights (within the same breed) were due to a) the age of the cow and b) genetics. The incidence of calving associated reproductive problems of the 71 cows calving a second time within this experiment was very low (5 observations); too low to include it into the statistical analysis. This low incidence of calving associated problems might be due to the fact that at the subsequent calvings there were no heifers calving because new cows were not introduced into this experiment. At the current calving there were 10 heifers, which represented 40% of the cows with calving associated problems. Philipsson (1976) showed that the incidence of dystocia was higher in primiparous than in multiparous cows in Swedish dairy breeds. Cows in health code group 2 had a lower fat test in the first 50 days of the subsequent lactation. Their fat test tended to be lower in the current lactation as well; however, the difference was not significant. Whether this difference in the fat test was genetically determined or was related to the reproductive disorders cannot be decided in the context of this study.

Cows which calved during the pasture season at the beginning of the current lactation showed a faster increase of the daily milk yield (slope for milk 0-50 days) and a lower fat test in the first 50 days of the subsequent lactation. Since 90% of the cows calved in the same season at the subsequent calving as at the current calving, these differences can be associated with the calving season. Wood (1969) showed that the production of cows which calved in spring and early summer increased faster than for cows which calved in other seasons. Huber et al. (1964) and Waite et al. (1959) reported that a marked milk fat depression occurred especially during spring pasture. All these workers dealt with spring and early summer calvings. The pasture season in this experiment, however, covered the complete pasture season, May to October. Hence, the findings of Wood (1969), Huber et al. (1964) and Waite et al. (1959) do not conclusively explain the results in this experiment.

The regression equations to predict body weight changes and production in the early subsequent lactation did not reveal any new relationships. Days open was a suitable parameter to predict the weight of the calf of the subsequent calving (R^2 = .57). In other equations, predictions of production traits in the subsequent lactation, with days open as independent variable; the coefficient of determination (R^2) although significant, was very low. The results of the regression analysis showed again that the relationship between reproductive traits of the current lactation and productive traits of the subsequent lactation were not substantial.

6. SUMMARY AND CONCLUSIONS

In a Holstein dairy herd, the influence of early and late breeding post partum on reproduction was investigated. The early post partum reproductive activity was monitored with milk progesterone analysis.

The large variation in the onset of the first estrus, (both progesterone and visually detected ones) could not be explained by age, milk production, body weight losses during the early post partum period, calving associated reproductive disorders, or calving season. The later detection of the first visible heat as compared to the first progesterone detected heat indicated that most cows showed little or no behavioural evidence of first estrus, therefore they were not detected by the herdsmen.

Cows bred early (73 ± 18 days post partum) conceived after fewer services per conception than cows bred late (93 ± 17 days post partum). Within the early bred group cows with calving associated reproductive problems conceived as readily as unaffected cows, while affected cows in the late bred group required significantly more services per conception. A similar situation was found in relation to the calving season: Calving during the pasture season delayed conception in the late bred group but did not influence conception in the early bred group.

The cows in the late bred group produced more FCM in the 305 day lactation and in the beginning of the subsequent lactation. There was no difference in the average daily milk production calculated over the period from the beginning of the current to day 150 of the subsequent lactation. Days open and days dry become important factors if more emphasis is placed on average milk yields per day of productive life rather than on 305 day lactation yields.

High milk production had a negative influence on reproduction only when related to substantial body weight losses in the same time period. There was no marked effect of calving associated problems or calving season on production in the current or the beginning of the subsequent lactation.

In short, the conclusions from this study are:

- The onset of estrus showed a large inexplainable individual variation.
- Early breeding versus late breeding resulted in less services per conception for the early bred cows.
- Cows with reproductive problems conceived readily when bred early but required more services per conception when bred late.
- The influence of calving associated disorders and the calving season was more distinct in the late bred group than in the early bred group.
- Late bred cows produced more milk and FCM in the 305 day lactation and first 150 days of the subsequent lactation.

- The average daily milk yield (calculated over both lactations, including the dry period) was the same for both the early and the late bred group.
- Calving associated disorders and the calving season were moderately related to production during the current and subsequent lactation.

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8. APPENDIX

Table 1: Means and standard deviations of the covariables milk production 0-50 days post partum, body weight changes (BWC) 0-60 days post partum in the current lactation and age of calving at the beginning of the current lactation.

Cows in:	Milk Production 0-50 d.p.p. (kg)		Body Weight Changes 0-60 d.p.p. (kg)		Age (mo.)	
	$\bar{x}$	s.d.	$\bar{x}$	s.d.	$\bar{x}$	s.d.
Early bred group	1520	326	-40.8	37.1	44.9	20.0
Late bred group	1653	380	-54.4	40.9	46.2	22.7
Health code 1	1619	360	-40.8	37.1	45.1	17.3
Health code 2	1511	351	-54.4	40.8	46.6	29.2
Pasture season	1649	336	-53.3	31.2	47.3	20.9
Non-pasture season	1543	374	-43.9	44.9	44.4	21.5
Total	1587	358	-47.6	39.4	45.5	21.3

Table 2: Means and standard deviations of reproductive traits in the current lactation

a) Early and late bred groups, health status group and groups according to the calving season

b) Interactions and covariables

a)

Trait	Groups (G) early bred x̄	s.d.	late bred x̄	s.d.	Sign.	Health status (H) normal x̄	s.d.	abnormal x̄	s.d.	Sign.	Calving season (S) pasture x̄	s.d.	non-pasture x̄	s.d.	Sign.
1st visible heat (d.p.p.)	50	28.5	47	25.2	n.s.	49	27.6	47	25.0	n.s.	49	28.3	48	25.8	n.s.
1st prog. det. heat (d.p.p.)	34	10.0	33	10.5	n.s.	34	11.1	34	8.2	n.s.	32	8.6	35	11.4	n.s.
Number of visible heats	2.2	1.0	3.0	1.7	**	2.5	1.2	2.8	2.0	n.s.	2.5	1.1	2.7	1.7	n.s.
Number of prog. det. heats	3.1	1.4	4.2	1.3	**	3.7	1.4	3.7	1.6	n.s.	3.7	1.3	3.7	1.6	n.s.
1st cycle length (days)	18.4	8.6	16.6	6.2	n.s.	18.1	8.3	15.9	4.7	n.s.	17.4	4.5	17.6	9.2	n.s.
Days to 1st. service	72	18.2	93	17.3	**	82	21.5	83	18.9	n.s.	83	22.8	82	18.9	n.s.
Number of services	1.50		1.95		*	1.63		1.96		*	1.74		1.72		n.s.
Days from 1st service to conception	16.40	25.0	26.2	39.8	**	18.7	29.9	27.9	40.9	**	23.0	36.5	20.1	31.2	*
Days open	88	33.0	121	40.6	**	100	38	113	46	**	106	42	103	39	*
Calving interval (days)	373	34.1	404	38.0	**	385	35	400	47	**	387	40	391	39	*

b)

Trait[1]	Interactions G x H	G x S	H x S	G x H x S	Covariables age (mo.)	milk 0-50 d.p.p.(kg)	BWC 0-60 d.p.p.(kg)
Number of prog. det. heats	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	-.00451
1st cycle length (days)	n.s.	n.s.	n.s.	n.s.	n.s.	.01011	n.s.
Number of services	*	*	n.s.	n.s.	n.s.	n.s.	n.s.
Days from 1st service to conception	**	**	*	*	n.s.	n.s.	n.s.
Days open	**	*	n.s.	n.s.	n.s.	n.s.	n.s.
Calving interval (days)	**	n.s.	**	n.s.	n.s.	n.s.	n.s.

* significant ($P \leq .05$)
** significant ($P \leq .01$)
n.s. not significant

BWC = body weight changes, d.p.p. = days post partum

1 Traits listed in Table 2a without any significant interactions and covariables were not listed in Table 2b.

Table 3: Means and standard deviations of productive traits in the current lactation

a) Early and late bred groups, health status group and groups according to the calving season

b) Covariables[1]

Trait	Groups (G)					Health status (H)					Calving season (S)				
	early bred		late bred			normal		abnormal			pasture		non-pasture		
	$\bar{x}$	s.d.	$\bar{x}$	s.d.	Sign.	$\bar{x}$	s.d.	$\bar{x}$	s.d.	Sign.	$\bar{x}$	s.d.	$\bar{x}$	s.d.	Sign.
FCM 0-50 days (kg)	1401	310	1509	416	n.s.	1495	364	1362	371	n.s.	1532	335	1404	385	n.s.
FCM 50-100 days (kg)	1386	285	1412	612	n.s.	1453	331	1269	709	n.s.	1458	335	1361	565	n.s.
FCM 100-150 days (kg)	1284	233	1313	303	n.s.	1302	274	1293	265	n.s.	1322	292	1288	251	n.s.
FCM 305 days (kg)	7276	1565	7995	2304	*	7708	1974	7492	2089	*	7880	2012	7506	1992	*
Milk 305 days (kg)	7595	1659	8550	2484	*	8084	2058	8084	2438	n.s.	8202	2082	8039	2250	n.s.
Fat % 305 days	3.71	.47	3.57	.38	n.s.	3.68	.42	3.55	.44	n.s.	3.74	.46	3.57	.40	n.s.
Slope milk 0-150 days	-.0271	.0366	-.0372	.0639	n.s.	-.0383	.0410	-.0175	.0712	n.s.	-.0411	.0379	-.0249	.0609	n.s.
Slope fat % 0-150 days	-.0013	.0034	-.0016	.0036	n.s.	-.0013	.0032	-.0019	.0041	n.s.	-.0012	.0035	-.0019	.0035	n.s.
Slope FCM 0-150 days	-.0290	.0420	-.0405	.0648	n.s.	-.0398	.0446	-.0230	.0733	n.s.	-.1433	.0413	-.0287	.0632	n.s.
Slope milk 150-305 days	-.1178	.0487	-.0955	.0448	**	-.1073	.0490	-.1052	.0457	n.s.	-.1045	.0547	-.1079	.0419	n.s.
Slope fat % 150-305 days	.0009	.0008	.0010	.0119	n.s.	-.0010	.0011	-.0010	.0009	n.s.	-.0009	.0011	.0010	.0010	n.s.
Slope FCM 150-305 days	-.1059	.0430	-.0825	.0419	**	-.0956	.0447	-.0907	.0419	n.s.	-.0948	.0521	-.0362	.0362	n.s.

b)

Trait[2]	Covariables		
	Age (mo.)	Milk 0-50 d.p.p. (kg)	BWC 0-60 d.p.p. (kg)
FCM 0-50 days (kg)	2.09701	.79563	n.s.
FCM 50-100 days (kg)	n.s.	.58840	n.s.
FCM 100-150 days (kg)	n.s.	.40013	n.s.
FCM 305 days (kg)	n.s.	3.68808	n.s.
Milk 305 days (kg)	n.s.	4.35779	n.s.
Slope milk 0-150 days	n.s.	-.00006	.00017
Slope FCM 0-150 days	n.s.	-.00007	n.s.
Slope milk 150-305 days	-.00071	n.s.	n.s.
Slope fat % 150-305 days	-.00002	n.s.	n.s.
Slope FCM 150-305 days	-.00077	n.s.	n.s.

* significant ($P \leq .05$)
** significant ($P \leq .01$)
n.s. not significant
BWC = body weight changes, d.p.p. = days post partum

1 No interactions of traits listed in Table 3a were significant.

2 Traits listed in Table 3a without any significant covariables were not listed in Table 3b.

Table 4: Means and standard deviations of body weights and body weight changes (BWC) in the current lactation and at the subsequent calving.

a) Early and late bred groups, health status group and groups according to the calving season

b) Interactions and covariables

a)

Trait	Group (G)							Health status (H)							Calving season (S)						
	early bred			late bred				normal			abnormal				pasture			non-pasture			
	$\bar{x}$	n	s.d.	$\bar{x}$	n	s.d.	Sign.	$\bar{x}$	n	s.d.	$\bar{x}$	n	s.d.	Sign.	$\bar{x}$	n	s.d.	$\bar{x}$	n	s.d.	Sign
Wt. at calving-(1)	611	42	97.0	625	43	100.7	n.s.	630	60	94.8	588	25	102.1	n.s.	648	38	90.7	595	47	98.9	*
BWC 0-60 d.p.p.	-41	42	37.1	-54	43	40.9	n.s.	-51	59	38.3	-39	25	41.4	n.s.	-53	38	31.2	-43	47	45.1	n.s.
BWC 0-80 d.p.p.	-31	42	40.1	-50	42	41.6	n.s.	-46	59	39.8	-25	24	43.3	n.s.	-56	37	26.8	-28	47	47.1	**
BWC 60-80 d.p.p.	10	40	23.0	6	40	22.5	n.s.	6	56	21.0	14	24	26.1	n.s.	- 2	35	21.3	16	45	20.7	**
BWC/day (kg/day):																					
60 d.p.p. to calving-(2)	.28	33	.16	.35	38	.14	*	.30	49	.14	.35	22	.18	n.s.	.25	33	.14	.37	38	.15	*
80 d.p.p. to calving-(2)	.27	33	.17	.35	38	.16	*	.30	49	.15	.33	22	.18	n.s.	.26	33	.16	.34	38	.17	n.s.
Wt. at calving-(2)	657	31	60.9	689	38	59.0	*	674	48	60.8	674	21	64.9	n.s.	683	32	55.8	667	37	66.2	n.s.
BWC calving-(1) to calving-(2)	45	31	66.5	67	37	70.2	**	44	47	60.5	86	21	78.5	*	26	31	61.2	80	37	65.8	**
Wt. of calf (1)	42.0	33	4.9	43.2	36	5.8	n.s.	42.1	47	4.9	43.8	22	5.9	*	44	31	5.8	41	38	4.6	*

b)

Trait[1]	Interactions				Covariables		
	G x H	G x S	H x S	G x H x S	Age (mo.)	Milk 0-50 d.p.p.(kg)	BWC 0-60 d.p.p.(kg)
Wt. at calving-(1)	n.s.	n.s.	n.s.	n.s.	3.64819	.24916	-.53863
BWC 0-80 d.p.p.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	.70976
BWC 60-80 d.p.p.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	-.28215
60 d.p.p.-calving -(2)	n.s.	n.s.	n.s.	n.s.	-.00998	n.s.	n.s.
80 d.p.p.-calving -(2)	n.s.	n.s.	n.s.	n.s.	0.01001	n.s.	n.s.
Wt. at calving-(2)	n.s.	n.s.	n.s.	n.s.	n.s.	.26688	n.s.
BWC calving-(1) to calving-(2)	n.s.	n.s.	n.s.	n.s.	-3.59641	.04057	.79207
Wt. of calf (1)	n.s.	*	n.s.	n.s.	n.s.	n.s.	.01140

* significant ($P \leq .05$)
** significant ($P \leq .01$)
n.s. not significant

BWC = body weight changes, d.p.p. = days post partum

1 Traits listed in Table 4a without any significant interactions and covariables were not listed in Table 4b.

Table 5: Means and standard deviations for traits in the subsequent lactation.

a) Early and late bred groups, health status group and groups according to the calving season

b) Interactions and covariables

a)

Trait	Groups (G)					Health status (H)					Calving season (S)				
	early bred		late bred			normal		abnormal			Pasture		Non-Pasture		
	x	s.d.	x	s.d.	Sign.	x	s.d.	x	s.d.	Sign.	x̄	s.d.	x̄	s.d.	Sign.
Calving weight (kg)	657	97.0	689	100.7	*	675	60.8	675	64.9	n.s.	683	55.8	667	64.4	n.s.
Weight of calf (kg)	47	5.3	45	5.8	n.s.	45	7.2	48	6.4	*	47	8.3	46	6.0	n.s.
BWC 0-60 d.p.p. (kg)	-55	33.0	-66	39.4	n.s.	-56	33.1	-71	42.6	n.s.	-55	31.8	-64	40.5	n.s.
BWC 0-80 d.p.p. (kg)	-32	45.9	-54	43.9	n.s.	-36	47.5	-63	35.2	n.s.	-40	45.7	-49	47.0	n.s.
BWC 60-80 d.p.p.(kg)	18	22.5	8	27.9	n.s.	20	26.3	8	22.2	n.s.	13	23.1	14	30.1	n.s.
Milk 0-50 days (kg)	1620	409	1803	250	n.s.	1701	360	1739	322	n.s.	1756	290	1672	385	n.s.
Fat % 0-50 days	3.73	.64	3.80	.48	n.s.	3.84	.56	3.62	.54	*	3.69	.63	3.84	.47	*
FCM 0-50 days (kg)	1540	40.6	1745	253	n.s.	1648	367	1636	315	n.s.	1663	260	1624	410	n.s.
Slope milk 0-50 days	.1444	.1701	.1702	.1702	n.s.	.1399	.1771	.1945	.1472	n.s.	.2125	.1108	.1115	.1921	**
Slope fat 0-50 days	-.0059	.0113	-.0069	.0069	n.s.	-.0064	.0125	-.0063	.0106	n.s.	-.0090	.0136	.0042	.0100	n.s.
Slope FCM 0-50 days	.1170	.1589	.1376	.1376	n.s.	.1111	.1720	.1617	.1316	n.s.	.1679	.1187	.0939	.1813	*
Slope milk 0-150 da.	-.0640	.0353	-.0318	.0361	**	-.0467	.0317	-.0522	.0421	n.s.	-.0508	.0364	-.0468	.0404	n.s.
Slope fat % 0-150 da.	-.0025	.0055	-.0036	.0054	n.s.	-.0026	.0048	-.0039	.0067	n.s.	-.0026	.0057	-.0032	.0053	n.s.
Slope FCM 0-150 days	-.0709	.0302	-.0492	.0390	*	-.0570	.0373	-.0672	.0338	n.s.	-.0585	.0342	-.0607	.0378	n.s.

b)

Trait[1]	Interactions				Covariables		
	G x H	G x S	S x H	G x H x S	Age (mo.)	Milk 0-50 d.p.p.(kg)	BWC 0-60 d.p.p.(kg)
Calving weight (kg)	n.s.	n.s.	n.s.	n.s.	n.s.	.26688	n.s.
BWC 0-60 d.p.p. (kg)	n.s.	n.s.	n.s.	n.s.	2.22134	-.10406	n.s.
BWC 0-80 d.p.p. (kg)	*	n.s.	n.s.	n.s.	n.s.	-.12510	n.s.
Milk 0-50 days (kg)	n.s.	n.s.	n.s.	n.s.	n.s.	.60117	n.s.
FCM 0-50 days (kg)	n.s.	n.s.	n.s.	n.s.	n.s.	.42136	n.s.
Slope milk 0-50 days	n.s.	n.s.	n.s.	n.s.	n.s.	-.00018	-.00072
Slope FCM 0-50 days	n.s.	n.s.	n.s.	n.s.	n.s.	-.00019	-.00067
Slope milk 0-150 da.	n.s.	n.s.	n.s.	n.s.	n.s.	-.00005	n.s.
Slope FCM 0-150 days	n.s.	n.s.	n.s.	n.s.	n.s.	-.00005	n.s.

* significant ($P \leq .05$)
** significant ($P \leq .01$)
n.s. not significant

BWC = body weight changes, d.p.p. = days post partum

[1] Traits listed in Table 5a without any significant interactions and covariables were not listed in Table 5b.

Table 6: Correlations between body weight and body weight changes (BWC) in the current lactation.

Trait	Calving weight (1)	Weight of calf(1)	BWC 0-60 dpp	BWC 0-80 dpp	BWC 60-80 dpp	BWC calv.(1)-calv.(2)
Calving weight (1)	1.00					
Weight of calf (1)	.33**	1.00				
BWC 0-60 d.p.p.	-.63**	-.18	1.00			
BWC 0-80 d.p.p.	-.65**	-.23	.84**	1.00		
BWC 60-80 d.p.p.	-.13	-.14	-.17	.37**	1.00	
BWC calving (1) - calving (2)	-.78**	-.09	.67**	.67**	.10	1.00
Calving weight (2)	.72**	.72**	-.27*	-.29*	-.08	-.10

(1) = current lactation (2) = subsequent lactation
Significant correlations * P ≤ .05, ** P ≤ .01

d.p.p. = days post partum

Table 7: Correlations between body weight and body weight changes (BWC) in the subsequent lactation.

Trait	BWC calv.(1) -calv.(2)	Calving weight (2)	Weight of calf(2)	BWC 0-60 dpp(2)	BWC 0-80 dpp(2)
BWC calving (1) - calving (2)	1.00				
Calving weight (2)	-.10	1.00			
Weight of calf (2)	-.06	.33**	1.00		
BWC 0-60 d.p.p.(2)	-.25	-.19	.11	1.00	
BWC 0-80 d.p.p.(2)	-.25	-.17	.03	.76**	1.00
BWC 60-80 d.p.p.(2)	-.17	.00	.10	-.02	.45**

(1) = current lactation, (2) = subsequent lactation
** Significant correlation: P ≤ .01

d.p.p. = days post partum

Table 8: Correlations between body weights and body weight changes (BWC) and milk production in the current lactation.

Trait	Calving weight (1)	BWC 0-60 dpp	BWC 0-80 dpp	BWC calving (1) - calving (2)
FCM 0-50 days	.83**	-.66**	-.66**	-.64**
FCM 50-100 days	.44**	-.29*	-.30*	-.56**
FCM 100-150 days	.65**	-.45**	-.45**	-.51**
FCM 305 days	.58**	-.45**	-.45**	-.50**
Fat % 305 days	.03	-.08	-.06	-.05
Milk 305 days	.56**	-.42**	-.43**	-.46**
Slope FCM 0-150	-.45**	.46**	.48**	.41**
Slope FCM 150-305	.01	-.26	.00	.29*
Slope FCM 0-305	.34**	-.54**	.36**	.47**

(1) = current lactation, (2) = subsequent lactation
Significant correlations: * P ≤ .05, ** P ≤ .01

d.p.p. = days post partum

Table 9: Correlations between body weight and body weight changes (BWC) and milk production in the subsequent lactation.

Trait	BWC calv.(1) -calv.(2)	Calving weight (2)	BWC 0-60 dpp(2)	BWC 0-80 dpp(2)
FCM 0-50 days	-.10	.13	-.06	-.16
FCM 50-100 days	-.01	.40**	-.23	-.32*
FCM 100-150 days	-.30*	.37**	-.00	-.07
Fat % 0-150 days	.09	-.19	.05	.17
Slope Milk 0-150 days	-.23	-.07	-.03	.04
Slope Fat % 0-150 da.	.16	.00	.24	.13
Slope FCM 0-150 days	-.12	-.10	.21	.20

(1) = current lactation, (2) = subsequent lactation
Significant correlations: * P ≤ .05, ** P ≤ .01

d.p.p. = days post partum