THE EFFECT OF GENOTYPE X NUTRITION INTERACTION AND NUTRIENT INTAKE ON REPRODUCTIVE PERFORMANCE IN EARLY LACTATION OF HOLSTEINS

by

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Dedicated to:

- My dear husband, Raj, whose moral support was invaluable.

- Our darling girls, Maynika and Vandena, particularly Maynika who suffered the pains of separation from her mummy at the tender age of 15 months.

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ABSTRACT

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THE EFFECT OF GENOTYPE X NUTRITION INTERACTION AND NUTRIENT INTAKE ON REPRODUCTIVE PERFORMANCE IN EARLY LACTATION IN HOLSTEIN

This study was based on 23,195 lactation records of Holstein cows in 799 herds from the Quebec Dairy Herd Analysis Service. They represented lactations initiated over the period of October 1979 to December 1980. The data were analyzed to study the effects of level of net energy (1), protein, calcium and phosphorus intake in the first 90 days postpartum on days to first service, days to final service and number of services per cow. Heritabilities of the reproductive traits and the sire by nutrient components of variance were estimated by Minimum Norm Quadratic Unbiased Estimators (MINQUE). Genetic correlation coefficients for sires on different nutrient levels were calculated by intra-class methods. Age and month of calving included in the least squares model had a significant effect on the reproductive traits. None of the nutrient measures, expressed as a percent of requirement, showed any significant trend on reproductive measures. The possible exception was calcium, where intake 20 percent above requirement, tended to improve the level of reproductive performance. An increase of 100 kg of 90 day FCM was associated with an increase of 0.32±0.11, 1.67±0.26 and 0.03±0.00 days to first service, days to final service and number of services per cow respectively. Heritabilities of reproductive traits were 0.01 to 0.02. Based on analysis of variance and genetic correlation analysis, sire x nutrient interaction with respect to the reproductive measures were absent.

RESUME

L'EFFET DE L'INTERACTION GENOTYPE-NUTRITION ET DE LA CONSOMMATION DE NUTRIMENTS SUR LA PERFORMANCE REPRODUCTIVE AU DEBUT DE LA LACTATION CHEZ DES VACHES HOLSTEIN

Cette étude a été faite sur 23,195 lactations de vaches Holstein dans 799 troupeaux inscrits au Programme D'Analyse des Troupeaux Laitiers du Québec (P.A.T.L.Q. - D.H.A.S.). Ces données représantaient des lactations ayant commencées dans la période comprise entre le mois d'octobre, 1979, et le mois de décembre, 1980. Les données ont été analysées pour étudier les effets des niveaux d'énergie nette, protéine, calcium et phosphate consommé dans les premiers 90 jours après vêlage, sur les jours au premier service, jours au dernier service, et nombre de services par vache. Les composants de la variance et les heritabilités des caractères reproductifs ont été obtenus par la méthode MINQUE (Minimum Norm Quadratic Unbiased Estimation). Les corrélations génétiques ont été calculées pour les taureaux en differents niveaux de nutrition utilisant les méthodes d'intra-classes. L'âge de la vache et le mois de vêlage analysés par la méthode des Moindres Carrés n'ont pas eu un effet significatif sur les caractères reproductifs. De la même façon, l'effet des nutriments, exprimés comme pourcentages des besoins nutritifs, n'a pas été significatif. Cependant, une consommation de calcium 20% au-dessus des besoins nutritifs a eu tendance à améliorer le niveau de la performance reproductive. Une augmentation de 100 kg de lait (L.C.G.) au 90 jours a été associée à une augmentation de 0.32$\pm$0.11 jours au premier service, de 1.67$\pm$0.26 jours au dernier

service, et de 0.03 ± 0.00 services par vache. Les heritabilités des caractères reproductifs ont variées entre 0.01 et 0.02. Les résultats obtenus de l'analyse de variance et les corrélations génétiques n'ont pas indiquées l'effet d'une intéraction taureau-nutrition sur les mesures de la performance reproductif.

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I. INTRODUCTION

The success of a dairy enterprise depends on cows calving regularly and producing large quantities of good quality milk. Most official milk recording programs in North America have calving intervals in excess of 13 months where the ideal is considered to be 12 months. Wellington (1980) reported a range of calving interval values for Holsteins and Holstein crosses in the Caribbean countries of 12.5 to 17.5 months. In U.S. studies, 16% of dairy cow disposals were attributed to reproductive problems (White et al., 1965; Miller et al., 1966). The causes of reproductive problems are complex and can be attributed to genetic and environmental factors including nutrition, climate, health and management factors.

The effects of level of nutrition and body condition on the reproductive efficiency of cows have been investigated and documented in the literature. The practice of flushing in sheep is based on creating a positive energy balance at the time of mating. The dairy cow represents a particular problem in that the optimal time of breeding coincides with a period of peak production. This may frequently result in a negative energy, protein or mineral balance. Experimental results of underfeeding on reproductive efficiency have been variable. Most studies have normally been based on a small number of animals and considered one nutrient at a time.

Most estimates of the heritability of reproductive measures are low. In spite of this, sires in artificial insemination (AI) units are known to differ in their ability to cause conception. AI units regularly report sires as having a high, average or low conception rate. These conception rate rankings may be temporary or permanent. Semen is a logical method of transferring genetic material to other countries. The question arises as to whether the order of merit remains the same with respect to reproductive traits from one country to another where environmental conditions may differ.

There are suggestions of possible genotype by environment interaction with respect to reproductive traits. The variation in reproductive performance for Holsteins in Caribbean countries as reported by Wellington (1980) is a possible example. This variation could be attributed to a variety of environmental factors including nutritional conditions. Data are not available to study or estimate genotype by nutritional environment interactions in the caribbean area.

It is of interest to establish whether or not genotype by nutritional environmental interactions with respect to reproduction are of significant importance to be considered in dairy cattle breeding.

Since September 1979, the Quebec Dairy Herd Analysis Service has been collecting laboratory feed analysis data on the energy, protein, calcium and phosphorus content of forages and concentrates fed to herds on the program. The field supervisor is present on the monthly test day to take milk samples and to check and record milk weights, feed inputs and reproduction data. This represents a unique set of field data which could be used to determine whether or not genotype by nutrition interactions are important for reproductive traits.

This study was undertaken to:

1. Investigate the effects of energy, protein, calcium and phosphorus intake levels in early lactation on dairy cow reproductive measures.

2. Estimate the heritability of reproductive measures such as days to first service, days to final service and number of services per conception.

3. Investigate the importance of sire x nutrition interaction on dairy cow reproductive traits.

II LITERATURE REVIEW

1. Effects of energy intake on reproductive efficiency

The high producing dairy cow is usually in negative energy balance during early lactation since energy intake is insufficient to meet its requirements for maintenance and lactation.

Both pre- and postpartum levels of energy intake have been observed to affect reproductive performance of beef cows as measured by conception rate and percentage of cows pregnant (Wiltbank et al., 1962, 1964). Dunn et al. (1969) fed 240 Hereford and Angus heifers postpartum with three levels of energy intake (high, moderate and low). After 120 days on trial, percent pregnancy rate was significantly in favour of the high energy group (87, 72 and 64, percent respectively). Israeli Fresians maintained on a high energy diet (6 kg hay and concentrate *ad libitum*) were found to have fewer inseminations per conception and earlier conceptions than those fed a standard diet of 6 kg hay and concentrate for production (Folman et al., 1973).

The effect of lactation and 3 levels of energy intake (133%, 100% and 66% N.R.C. req.) on ovarian activity of 27 Holstein cows were investigated (Oxenreider et al., 1971). Results indicated that low levels of energy intake (66%) significantly delayed post partum follicular growth and ovulation particularly in animals that were lactating. In a combined group of Holstein and Hereford heifers, high energy diets (66.4%, 63.0%, 54.3% TDN) resulted in significantly shorter intervals to 1st oestrus and to conception over 2 postpartum periods (Hansen et al., 1982).

On the other hand, Gardner (1969) reported that neither production level nor prepartum (115% and 160% D.E. required for maintenance) and postpartum (high and low) levels of energy intake had a significant effect on a number of measures of reproductive performance in 64 Holstein cows. Carstairs et al. (1980) used 48 Holstein heifers in a 2 x 2 factorial experiment. They employed two levels each of energy (135 and 85% N.R.C.), and of phosphorus (138 and 98% N.R.C.). Neither main effects nor the interaction had any significant effect on days to first ovulation, services per conception and days postpartum to reach 3 ng/ml serum progesterone level.

It appears from the above studies that the effect of level of energy intake on reproductive efficiency of cows is inconclusive.

2. Effects of protein intake on reproductive efficiency

There are conflicting literature reports on the effect of protein levels in the diet on reproductive efficiency of cows.

Bedrake et al. (1964) fed a group of 500 lb. yearling beef heifers rations containing 1.06, 0.60, 0.28 and 0.08 lbs. of crude protein (CP)/day for 6½ mos. The 1.06 lb. C.P. / day group showed 50 days to 1st oestrus compared to 90 days and no oestrus from the 0.28 and 0.08 lbs. C.P. / day groups. In the same trial, results from another group of 675 lb. 2-year old heifers fed the highest level (1.34 lb. C.P. / day), came in oestrus 8 days earlier than a group fed 0.62 lb. C.P. / day.

In Australia, using a group of 8 cows fed native pasture hay, it was found that phosphorus supplementation (25.83 g. P. / day) had no significant effect on reproductive efficiency, however when protein was supplemented (400 g. cotton seed meal / day) oestrus activity was markedly increased (Teleni et al., 1977).

Reports from dairy cattle studies indicate that increased crude protein had a negative influence on reproductive parameters. Sonderegger et al. (1977) reported that surplus dietary protein exceeding 250-300 g. / cow / day lengthened the interval between parturition and first service in dairy cows. Jordan and Swanson (1979) fed three groups of 15 dairy cows 12.7, 16.3 and 19.3% crude protein starting at 4 days postpartum and continuing for 91 days. Results indicated that the 19.3% group had 2.4 services / conception compared to 1.67 in the other groups. Treacher et al. (1976) concluded that feeding 75% A.R.C. requirements for protein probably had no significant effect on fertility.

On the other hand, Edwards et al. (1980) reported that differing levels of dietary protein (13, 15 and 17%) did not have a significant effect on number of services per conception or on days open.

3. Effects of phosphorus on reproductive efficiency

Phosphorus deficiencies have been reported to produce various types of ovary dysfunction resulting in oestrus irregularities (Hignett and Hignett, 1951). In a review, McDowell, (1976), concluded that large economic losses have resulted due to phosphorus deficiency and resulting infertility.

Phosphorus supplementation resulted in increased fertility levels in cows raised in areas naturally deficient in phosphorus. Soluble phosphate administered in the drinking water resulted in improved liveweight gain and fertility, but only in lactating cows (Hart and Mitchell, 1965). Services per conception in dairy heifers decreased from 3.7 before phosphorus supplementation to 1.3 after supplementation with dicalcium phosphate offered free choice over 4 years (Morrow, 1969).

Work of Hart and Mitchell (1965) and Teleni et al. (1977) indicated that adequate levels of both phosphorus and protein together were desirable for good fertility.

The above studies refer to effects of long term under-feeding of phosphorus; however, different results were obtained in other experiments of shorter duration. Thus, several workers have reported either inconclusive or insignificant effects of dietary phosphorus levels (N.R.C. level or higher) on reproductive efficiency of dairy or beef cows (Hecht et al., 1977; Noller et al., 1977; Call et al., 1978; Carstairs et al., 1980).

It appears that long term under feeding of phosphorus may hamper reproduction; however, supplementation above N.R.C. requirements does not necessarily optimize reproductive efficiency.

4. Effects of calcium on reproductive efficiency

Calcium and phosphorus are often considered together since these are closely related with vitamin D in bone metabolism. A range of Ca:P ratios of 1:1, 4:1 and 8:1 in rations were reported as having no significant differences when fed to lactating cows

(N.R.C., 1978). However, N.R.C.(1978), also reports a better absorption of both elements at a ratio of 2:1 than 1:1 for pregnant heifers and poor growth and feed utilization by Holstein steers on a ratio of 8:1. It appears therefore that the suggested range of ratios are from 1:1 to 8:1 with better absorption at a 2:1 ratio. While the effects of phosphorus on reproductive performance of cows have been studied in detail, the effects of calcium have received much less attention.

A relationship between Ca:P intakes and fertility was demonstrated by Hignett and Hignett (1951). Any significant deviation from optimum Ca:P intakes resulted in lower conception rates to first service. Ward et al. (1971) investigated the effects of two levels of calcium to phosphorus (approx. 1.1:1 and 2.3:1) with or without vitamin D supplementation on bovine fertility. They found that involution of the uterus was complete eight days sooner in the group fed higher levels of calcium and supplemented with vitamin D. First ovulation postpartum occured six days earlier in the higher calcium group but was not affected by vitamin D supplementation. Cows supplemented with vitamin D exhibited earlier postpartum oestrus and conception. Services per pregnancy was not affected by calcium or vitamin D. In another study of 68 herds in British Columbia, Peterson and Waldern (1977) identified low intakes of calcium and phosphorus in silage as contributing to a reproductive problem.

In a review, Morrow (1980) concluded that there was no relationship between fertility and dietary Ca:P ratio and that the level of intake of these minerals was more important than their ratio.

Palissier (1972) hypothesized that there was probably an indirect relation between calcium intake and reproduction through the effect of calcium on milk fever and associated dystocia and retained placenta.

5. <u>Effects of environment on reproductive efficiency</u>

Herd, season and age of calving effects are important factors affecting reproductive efficiency of dairy cows.

Variation in reproductive efficiency due to differences in herd size has been well established. Results of a study on New York dairy herds indicated that conception rate declined as herd size increased (Spalding <u>et al</u>., 1975). Tong <u>et al</u>. (1979) reported similar results from Quebec dairy herds. Seykora <u>et al</u>. (1980) reported that services per conception increased from 1.7 to 1.9 as herd size increased from 50 to 200 cows. Differences in management practices between herds accounted for most of the variance in reproductive efficiency. Heat detection, time allocated to observing oestrus and time of 1st insemination all contribute to herd differences in reproductive performance. Cows bred before 50 days required an average of 0.7 more services compared to cows which were bred later (Britt, 1975; Britt <u>et al</u>., 1976).

Type of housing also influences reproductive performance Gwazdauskas and Lineweaver (1981) found a higher conception rate of 10.7 percent for cows or heifers out on pasture than for those kept in the barn.

Seasonal variation in fertility occurs in both dairy and beef cows. Fertility was reported to be lowest during winter months (Vincent, 1972). Tong <u>et al</u>. (1979) reported that in Quebec dairy herds, cows calving in spring had better reproductive performance compared to those calving at other times of the year. Des Marchais (1982) reported similar findings. Year of calving was observed as having a small, but significant, effect on source of variation in reproductive performance (Fielden et al. (1980).

Fertility increases with age, reaching a peak, and then declines as the cows get older (Tong et al., 1979). However, other reports indicate no change in breeding efficiency as cows get older (Berger et al., 1981; Hansen et al., 1981). Spalding et al. (1975) reported a decline in fertility with increasing age. Differences in selection and culling practices in the populations studied could account for some of these inconsistancies.

6. Genetic aspects of reproductive efficiency

Any successful dairy producer is interested in having his cows breeding regularly and producing a calf every 12-13 months. Since most heritability estimates of various measures of reproductive efficiency are rather low, there is controversy as to the importance that should be attached to dairy cow fertility. Table 1 presents average heritability estimates for various measures of reproductive efficiency as summarized by Maijala (1976) from several literature reports. The heritability estimates for a few measures of fertility in Holstein cows are presented in Table 2. These low estimates indicate that direct selection to improve fertility would not be effective.

In a review, Maijala (1976) reported that fertility at

TABLE 1. Heritability estimates for various measures of reproductive efficiency

Trait	Studies	Number cows		Heritability, %	Own Studies	
		Liter.	Own	Liter.	Finl.	Swed.
Length of calving interval	4	5683		1.7		
% long calving intervals			19560		3.3	
No. services/conception	5	3239	22240	3.2	2.5	
Conception rate after 1 service	4	7789	9728	5.1	1.7	
NR % after 1st service	1	1015	219396	0.0	1.3	2.5
Conception rate after 2 services	1	554	9728	-0.4	1.6	
Days from calving to heat	2	973		2.3		
% short heat periods	1	2832		11.0		
Regularity of heat periods	1	834		5.0		
Strength of heat	1	554	8537	21.0	3.5	
Days from 1st serv. to concep.	2	1597		3.7		
Days from calving to concep.	1	1314		(9.0)		
% fertility disturbances			30204		1.0	
% sterility treatments			158261		1.6	
Culling for sterility	1	4009	166983	10.2	2.1	1.7
Final conception rate in A.I.			158262			2.7
% cystic ovaries	3	12111	185418	13.5	3.5	1.3
% multiple births	2	13864	493000	5.8	3.1	
% abortions	1	2832	91330	5.0		0.5
% stillbirths	1	2832	91330	5.0		0.4
Oestrus after conception	1	2832		4.0		

Source: Maijala (1976)

TABLE 2. Heritability estimates of some reproductive traits in Holstein cattle

Traits	$h^2 \pm SE$	Study
Days to first service	0.03 ± 0.01	Hansen et al. (1981)
	0.04 ± 0.01	Berger et al. (1981)
	0.04 ± 0.02	Des Marchais (1982)
	0.03 ± 0.04	Gasteiger (1980)
No. of services	0.02 ± 0.01	Hansen et al. (1981)
	0.01 ± 0.01	Berger et al. (1981)
Days to final service	0.04 ± 0.01	Berger et al. (1981)

the herd level can be improved through individual selection in bulls. The average estimate of h^2 for the annual % Non Return Rate of bulls on the basis of progeny groups of over 1500 bulls from New Zealand, Sweden, the DDR and Finland was 25%. The heritability estimates for the annual averages of semen quality range from 20-40% and of semen quantity from 10-20%.

Genetic correlations between milk yield and reproductive performance have been observed (Berger et al., 1981). They indicated that high producing cows were bred later, took longer to conceive, and required more services per conception than low producing cows. Janson and Andreasson (1981) and Hansen et al., (1983) reported positive genetic correlation between milk yield and fertility measures. That is time to first service, conception and services per conception would increase with milk yield.

6.1 Genotype x environment interaction

Genotype x environment (GE) interaction is best defined as changes in phenotypic expression of a given genotype in differing environments. Falconer (1981) suggested that when there is a GE interaction the phenotypic value P is not $P=G+E$ but $P=G+E+I_{GE}$ where I is the interaction component. Further, GE interaction can arise because a specific difference of environment may have a greater effect on some genotypes than on others (Falconer, 1981). For example limited feeding may diminish genetic differences in comparison to *ad libitum* feeding (Pirchner 1969).

GE interaction also occurs when temperate animals are imported into the tropics or vice versa. That is there is a change in the ranking of the genotype from one environment to another. For example genotype A may be superior to genotype B in environment X; but inferior in environment Y (Falconer, 1981). The term environment is used here in the broadest sense including levels of nutrition, herd management, climate, etc. McDowell et al. (1976) estimated small sire x location interactions (genetic correlations 0.81 and 0.71) for sires used in Mexico, U.S.A. and Canada.

John Hammond's (1947, 1951) sustained interest in optimising environment, both for full expression of animal genotypes and for selective breeding, did much to arouse the interest of livestock breeders in the role and effects of GE interactions and, thus contributed a lot to better understanding of the concept.

Falconer and Latyszewski (1952) found a genotype x nutrition interaction for increased growth in mice in a high and low nutrition line. Additional supporting evidence has come from the work of Park et al. (1966) with rats, Korkman (1961) with mice and Fowler and Ensminger (1960) with swine. All of the above research compared satisfactory vs. restricted nutrition levels and measured growth rate which is normally reduced by restricted nutrition levels. Fowler and Ensminger (1960) indicated that selection for increased rate of gain under the two nutritional environments (restricted and normal) were for different characters: feed efficiency and greater appetite respectively.

More recently, evidence for the existance of GE interactions, ie. sire x ration interaction in Holsteins for fat yield, fat corrected milk yield and efficiency of feed utilization was reported by Lamb et al. (1977). Vagi and Torok (1976) reported a genotype x nutrition interaction for milk production from a state farm in Hungary.

The work done by Mao and Burnside (1969) is particularly relevant to our study. They examined the importance of interaction between estimates of breeding values of dairy sires (sire proofs) and several contrasting herd environments in which their daughters made records. No interactions of practical importance between sire proofs and most herd environments were found, however, a highly significant interaction involving sire proofs and level of grain feeding in summer was found;it was insignificant in winter. The interaction component of variance accounted for 17% of the total variance in sire proofs. Genetic correlations between proofs of the same sires based on their daughters in herds with different levels of grain feeding in summer ranged from 0.54 to 0.79.

Fimland (1973) in Syrstad (1976) grouped his data into three groups based on per cent of net energy supplied in concentrates (<35%, 35-42% and >42% respectively). The genetic correlation coefficients between milk yields in the three groups ranged from approx. 0.8 to 1.0, thus indicating the presence of insignificant amounts of sire x energy level interaction.

The interaction between dietary regimen and breed on postpartum reproduction was investigated by Kress et al. (1971). He reported inconclusive results due to a high incidence of uterine prolapseia cows fed the high energy diet. Hansen et al. (1982)

used 31 twins of Hereford and Holsteins on high diets of 66.4, 63.0 and 54.3% T.D.N. fed from 210-449 days and low diets of 52.4, 52.2 and 50.3% T.D.N. fed over the same period, to study the effects of breed and diet on postpartum reproduction. Days to first oestrus and days to conception over two postpartum periods were shorter on the high energy diets. A significant breed x diet interaction was noted. The Holsteins responded with a shorter period to first oestrus on the high level diet than did the Herefords.

6.2 Statistical approach to estimating genotype x environment interaction

Two methods to estimate genotype x environmental interactions have been used.

6.2.1 Analysis of variance method

This method is quite convenient and is based on conventional two-way, cross-classified analysis of variance, using for example, sire and herd, or sire and nutrition levels as sources of variation (Dickerson, 1962; Falconer, 1981; Syrstad, 1976). Dickerson (1962) concludes that this method is a satisfactory tool provided "(1) the interaction component of variance is adjusted for important variation between environments in the scale of genetic effects and (2) the variance component for the average effect of genetic groups is recognised as equivalent to the average covariance of the same genetic group in different environments, (ie. $\sigma_G^2 = \sigma_{Gij}^2$) to include the real possibility of negative genetic correlation."

6.2.2 Genetic correlation method

The same genotype (animals of a breed, for example) expressed in two different environments can be considered as two separate characters (phenotypes) and the genetic correlation between the two characters can be estimated using appropriate analysis of covariance. This concept was introduced by Falconer (1952). This method is useful when small numbers of environments are involved and it is desirable to quantify the degree of interaction. Thus, a genetic correlation of unity means that no GE interaction exists. Any deviation from unity indicates the existence and the degree of interaction, (Pirchner, 1969). Dickerson (1962), extended this method to include more than 2 environments.

III. SOURCE AND PROCESSING OF DATA

1. Source

Test day data for cows enrolled in the Quebec Dairy Herd Analysis Service (Q.D.H.A.S.) official program were obtained for the period from October, 1979 to August, 1981. These records served as the base from which the data set for this study was created.

These test day records contained all the cow identification, production, milk composition and reproduction data. They also included herd and cow feed reports and feed composition.

Relevant Q.D.H.A.S. forms are included in Appendix A where further details can be found.

2. Creation of data set

2.1 The test day data for the official Q.D.H.A.S. herds were extracted from D.H.A.S. tape files. Approximately 43,000 records per month were retrieved.

2.2 The test day data were sorted so that the complete test day file for each cow was in sequence by date.

2.3 The sorted test day data files were then used to create a record for each lactation for each cow contained in the period under study.

2.4 Ninety and 305 day lactation records for each lactation were completed for each cow according to the Canadian Milk Recording Board procedure. Feed intakes and requirements were computed and expressed in terms of intake and requirement per day within the respective 90 day and 305 day or complete lactations, if less than

305 days. The variables contained in the lactation record are presented in Table 3.

2.5 The genetic analysis was based on first lactations initiated after October, 1979. The lactation records were sorted by sire. Sires with less than 50 daughters with records were excluded from the data set. This represented the data set that was used for genetic analysis.

3. Editing restrictions

The present study was restricted to Holstein identified cows. The data were edited to ensure the presence of the following information: the cow, sire and dam identification, birth and calving dates, complete test day data with a minimum of 150 days in milk complete with feed and forage analysis, individual meal intake, dates of service, with service sire and date dry.

The 150 minimum days in milk from calving was to ensure that an adequate post-calving period was available for a recording of reproduction data.

For the sire x nutrition interaction study, only sires with at least 50 daughters and a minimum of 10 daughters per feeding group were included.

4. Description of the lactation record

The variables contained in the lactation record are listed in Table 3. Most variables are self explanatory. Variables date bred

TABLE 3. Description of variables in a lactation record

No.	Variable Name	Comments
1	Herd number	
2	Cow number	
3	Calving date	
4	Cow breed	
5	Cow registration	
6	Cow nip letter	
7	Sire breed	
8	Sire registration	
9	Dam breed	
10	Dam registration	
11	Dam nip letter	
12	Birth date	
13	Date bred previous calving	
14	Service sire	
15	Calving codes sex/size/calving ease/ alive or dead last calving	
16	Date dry	
17	Date bred No. 1	
18	Service sire identification	
19	Date bred No. 2	
20	Service sire identification	
21	Date bred No. 3	
22	Service sire identification	
23	Date bred final	May be 4th or any later breeding
24	Service sire identification	
25	Final service sequence	Total no. of services reported
26	Next calving date	

continued .....

TABLE 3 continued

No.		Variable Name	Comments
90 day	305 day		
27	43	Milk yield (kg)	computed from test day milk weights
28	44	Fat yield (kg)	computed from milk and fat % test day data
29	45	Protein yield (kg)	computed from milk and protein % test day data
30	46	Milk value ($)	
31	47	Feed cost ($)	
32	48	Energy fed (Mcal)	
33	49	Energy required (Mcal)	
34	50	Protein fed (kg)	
35	51	Protein required (kg)	
36	52	Calcium fed (g)	
37	53	Calcium required (g)	
38	54	Phosphorus fed (g)	
39	55	Phosphorus required (g)	
40	56	BCA milk	
41	57	BCA fat	
42	58	Cow rating	
59		Energy from corn silage (%)	
60		Energy from hay silage (%)	
61		Energy from hay (%)	
62		Energy from pasture (%)	
63		Date culled	

no. 1, 2, 3 and final together with service sire identification were included to allow for calculation of the reproductive measures as days to first service, number of services and days to final service. Date bred no. 4 included either the 4th or final bred date. Four breeding dates were considered an appropriate number of records to maintain on the file.

Ninety day and 305 day milk, fat and protein yields were computed from test day data, milk weights, fat % and protein % and were expressed as cumulative yields over 90 and 305 days.

Net energy fed, protein, calcium and phosphorus fed were computed as the average daily intake over 90 and 305 day periods. They were based on nutrients present in meal, protein supplement and forages as supplied from the analysis of feeds given in test day data records. Net energy , protein, calcium and phosphorus required were based on 1978 N.R.C. standards for dairy cattle and were calculated as part of the recommendations to the farmer.

5. Classification of the lactation data

There were 23,195 lactation records distributed over 799 Holstein herds. The data were classified based on 90 day production and nutrient intake records. Table 4 provides the distribution of observations by classification of the variables considered in the analysis.

5.1 Age and month of calving

Age classification was simply by age in years at calving with those calving under three years of age classed as 2 year olds. Those over 5 years of age were also grouped as one class.

The records were grouped by month of calving from October 1979 to December 1980.

5.2 Nutrient intake

The nutrient intake of net energy of lactation, protein, calcium, and phosphorus were expressed as intakes as a percent of requirements (N.R.C., 1978). The net energy and protein values were divided into 5 classifications with a range of 10% each. The mid classification contained approximately one third of the observations. The calcium and phosphorus data consisted of a greater range of values and were classified into 7 subgroups. The calcium subgroups each covered a range of 20% and the phosphorus subgroups a range of 15% intakes as a percent of requirements.

5.3 Genotype by nutrition interaction studies

Table 5 presents the division of the nutrient intake as a percent of requirement for the interaction studies. The nutrition levels were each classified into 3 groups. The data used in the interaction studies were restricted to the first 90 day record of each cow and only for sires with 50 or more daughters. There were 66 sires in all represented by 23,743 daughters. This would explain the difference in the classification for calcium and phosphorus groupings in tables 4 and 5.

TABLE 4. Classification of data for the nutrition status study

Classification	No. of observations
Total	23195
Age	
≤ 2 (yrs)	7082
3	4907
4	3606
5	2572
> 5	5028
Year - month of calving	
1979	
October	722
November	1013
December	1389
1980	
January	1599
February	1664
March	1453
April	1727
May	1426
June	1085
July	929
August	890
September	1336
October	2028
November	2280
December	3654
90 day Energy % (I/R)	
≤ 80	3130
81 - 90	5172
91 - 100	7520
101 - 110	4871
> 110	2502
90 day Protein % (I/R)	
≤ 75	3182
76 - 85	5316
86 - 95	7131
96 - 105	4777
> 105	2789

continued .....

TABLE 4. continued

Classification	No. of observations
90 day	
Calcium % (I/R)	
≤ 90	1454
91 - 110	3476
111 - 120	5091
121 - 140	5183
141 - 160	3601
161 - 180	2231
> 180	2159
90 day	
Phosphorus % (I/R)	
≤ 90	786
91 - 115	1627
116 - 130	3720
131 - 145	5284
146 - 160	5518
161 - 175	3496
> 175	2764

(I/R) intake/requirement

TABLE 5. Levels of nutrient intake in the sire x nutrient interaction analysis

Nutrient	Groups in relation to NRC requirements: below average	average	above average
90 day Energy % (I/R)	< 92	92 - 107	> 107
90 day Protein % (I/R)	< 90	90 - 105	> 105
90 day Calcium % (I/R)	< 155	155 - 175	> 175
90 day Phosphorus % (I/R)	< 155	155 - 175	> 175

(I/R) intake/requirement

IV. METHODS OF ANALYSIS

The data were analysed on an IBM 370 Model 148 computer utilising available FORTRAN programs. Given below is a brief description of various models used and their underlying assumptions.

1. Least squares analysis

The data on the three dependent variables (days to first service, days to final service and number of services) was subjected to least squares analysis in order to test the statistical significance of various fixed effects including levels of different nutrients. The following general model was used:

$$
\begin{aligned}
Y_{ijklmnop} = \mu &+ H_i + A_j + D_k + E_l + P_m + C_n + F_o \\
&+ (EP)_{lm} + (EC)_{ln} + (EF)_{lo} + (PC)_{mn} \\
&+ (PF)_{mo} + (CF)_{no} + b_o\,NE + b_1 M \\
&+ b_2 CS + b_3\,HS + b_4\,HY + b_5\,PS \\
&+ e_{ijklmnop}
\end{aligned}
$$

where:

$Y_{ijklmnop}$ = An observation for the respective dependent variable

μ = population mean

H_i = an effect common to all cows in the i^{th} herd

A_j = an effect common to all cows of j^{th} age ($j = 1, ..., 5$)

D_k = an effect common to all cows calving during k^{th} year-month ($k = 1, ..., 15$)

E_l = an effect common to all cows receiving l^{th} level of energy intake/requirement ($l = 1, ..., 5$)

P_m = an effect common to all cows receiving m^{th} level of protein intake/requirement ($m = 1, ..., 5$)

C_n = an effect common to all cows receiving n^{th} level of calcium intake/requirement ($n = 1, ..., 7$)

F_o = an effect common to all cows receiving o^{th} level of phosphorus intake/requirement ($o = 1, ..., 7$)

$(EP)_{lm}$ = an interaction effect of $(lm)^{th}$ energy-protein subclass

$(EC)_{ln}$ = an interaction effect of $(ln)^{th}$ energy-calcium subclass

$(EF)_{lo}$ = an interaction effect of $(lo)^{th}$ energy-phosphorus subclass

$(PC)_{mn}$ = an interaction effect of $(mn)^{th}$ protein-calcium subclass

$(PF)_{mo}$ = an interaction effect of $(mo)^{th}$ protein-phosphorus subclass

$(CF)_{no}$ = an interaction effect of $(no)^{th}$ calcium-phosphorus subclass

b_o, ..., b_5 = partial regression of dependent variable on the independent and continuous variable holding all other discrete variables constant

NE = net energy intake per day

M = 100 kg 4% Fat Corrected Milk 90 days

CS = per cent net energy from corn silage

HS = " " " " " hay silage

HY = " " " " " hay

PS = " " " " " pasture

$e_{ijklmnop}$ = random error, assumed to be NID (0, σ_e^2)

The equations for herd effects were absorbed. Further details on various classes in each main effect can be found in Section III, sub-section 5.1 and Table 4.

In addition to the three dependent variables mentioned above, it was also possible to analyse calving interval, days to and services per conception but for a much reduced set of those cows which had a subsequent calving during the period of this study. The general model described above was used except that the interactions were not included.

The analyses of variance for all traits are given in Appendix B - Tables 1B, 2B and 3B.

2. Estimation of variance components

Henderson's (1973) mixed model equations were used to obtain MINQUE (Minimum Norm Quadratic Unbiased Estimation) of sire and sire x nutrient interaction components of variance employing the following mixed model.

2.1 Mixed Model

$$Y_{ijklmo} = \mu + H_i + A_j + D_k + N_l + S_m + (SN)_{lm} + e_{ijklmo} \quad \text{.....................(i)}$$

where:

Y_{ijklmo} = an observation for the respective dependent variable (i.e., days to 1st service, number of services and, days to final service)

N_l = an effect common to all cows in the l^{th} feeding group within the respective nutrient (i.e., energy, protein, Ca and P; l = 1, ..., 3)

S_m = an effect common to all cows sired by the m^{th} sire $\sim (0, \sigma_e^2)$

$(SN)_{lm}$ = an interaction effect common to all cows in the l^{th} feeding group within the respective nutrient and sired by the m^{th} sire after main effects of S and N have been removed $\sim (0, \sigma^2_{sn})$

e_{ijklmo} = random error, assumed to be NID $(0, \sigma_e^2)$

The symbols H_i, A_j and D_k are as defined in sub-section IV.1

However, computer programs were not available to run the above described mixed model since it included two random effects in addition to error. Thus in order to facilitate analysis, the above model was reduced into two, each including only one random effect, as follows:

$$Y_{ijklmo} = \mu + H_i + A_j + D_k + N_l + S_m + e_{ijklmo} \quad \ldots\ldots \text{(ii)}$$

$$Y_{ijklmo} = \mu + H_i + A_j + D_k + (SN)_{lm} + e_{ijklmo} \quad \ldots\ldots \text{(iii)}$$

where $(SN)_{lm}$ in model (iii) is the effect of the lm^{th} SN sub-class.

In addition to estimating sire and sire x nutrition interaction components of variance, genetic standard deviations for sire effects were also estimated for each nutrient x feeding group subclass in order to calculate the correction factor for, σ^2_{sn}. To achieve this, model (ii) above was further reduced as follows:

$$Y_{ijkmo} = \mu + H_i + A_j + D_k + S_m + e_{ijkmo}$$

This model was then run separately for each nutrient x feeding group subclass, thus making a total of three analyses per nutrient or 12 analyses per trait.

2.2 General Mixed Linear Model

The mixed model (i) in subsection 2.1 can be written in the following general form:

$$Y = Xb + Zu + e$$

where:

y = a vector of observation of order nx1, for n = total number of observations

X = a fixed and known matrix of order n x p

b = a vector of unknown fixed effects of order p x 1

Z = a fixed and known matrix of order n x q

u = a vector of random variables of order q x 1 ∿ (0, G)

e = a vector of random errors of order n x 1

Additionally, u and e are uncorrelated.

The mixed model equations (Henderson, 1973) are:

$$\begin{pmatrix} X'X & X'Z \\ Z'X & Z'Z+D \end{pmatrix} \begin{pmatrix} \hat{b} \\ \hat{u} \end{pmatrix} = \begin{pmatrix} X'y \\ Z'y \end{pmatrix}$$

where:

$$D = \begin{pmatrix} I\sigma_e^2/\sigma_s^2 & \\ & I\sigma_e^2/\sigma_{sn}^2 \end{pmatrix} = G^{-1}\sigma_e^2$$

assumingG is non-singular, and σ_e^2, σ_{sn}^2 , ..., σ_s^2 known.

2.3 Procedure: MINQUE

In partitioned form, the mixed model equations are:

$$\begin{pmatrix} X'X & X'Z_1 & X'Z_2 \\ Z_1'X & Z_1'Z_1+I\hat{\sigma}_e^2/\hat{\sigma}_s^2 & Z_1'Z_2 \\ Z_2'X & Z_2'Z_1 & Z_2'Z_2+I\hat{\sigma}_e^2/\hat{\sigma}_{sn}^2 \end{pmatrix} \begin{pmatrix} \hat{b} \\ \hat{u}_1 \\ \hat{u}_2 \end{pmatrix} = \begin{pmatrix} X'y \\ Z_1'y \\ Z_2'y \end{pmatrix}$$

where $\hat{\sigma}_e^2$, $\hat{\sigma}_s^2$, $\hat{\sigma}_{sn}^2$, are prior estimates of σ_e^2, σ_s^2, σ_{sn}^2.

Let T be a symmetric generalized inverse of the coefficient matrix:

$$\begin{pmatrix} X'X & X'Z \\ Z'X & Z'Z+D \end{pmatrix}^{-} = T = \begin{pmatrix} T_{bb} & T_{bu} \\ T_{bu}' & T_{uu} \end{pmatrix} \quad \text{which,}$$

in partitioned form,

$$T = \begin{pmatrix} T_{bb} & T_{b1} & T_{b2} \\ T_{b1}' & T_{ss} & T_{ssn} \\ T_{b2}' & T_{sns}' & T_{snsn} \end{pmatrix},$$

then sums of squares are computed:

$$t_o = y'y - \hat{b}'X'y - \hat{u}'Z'y - \sum_{i=1}^{2} \hat{u}_i' \hat{u}_i \hat{\sigma}_e^2/\hat{\sigma}_i^2$$

$$t_i = \hat{u}_i'\hat{u}_i(\hat{\sigma}_e^2/\hat{\sigma}_i^2)^2, \text{ for } i = 1,2$$

and coefficients:

$$P_{oo} = n - r - q + \sum_{i=1}^{2}\sum_{j=1}^{2} \text{tr } T_{ij} T_{ij}' \frac{\hat{\sigma}_e^2}{\hat{\sigma}_i^2} \frac{\hat{\sigma}_e^2}{\hat{\sigma}_j^2}, \text{ where } r = \text{rank of } X$$

$$P_{oi} = \left(\frac{\hat{\sigma}_e^2}{\hat{\sigma}_i^2}\right)^2 \left(\text{tr } T_{ii} - \sum_{j=1}^{2} \text{tr } T_{ij}T'_{ij} \frac{\hat{\sigma}_e^2}{\hat{\sigma}_j^2}\right), \text{ for } i = 1, 2$$

$$P_{ii} = \left(\frac{\hat{\sigma}_e^2}{\hat{\sigma}_i^2}\right)^2 \left(q_i - 2\text{tr } T_{ii} \frac{\hat{\sigma}_e^2}{\hat{\sigma}_i^2} + \text{tr } (T_{ii})^2 \left(\frac{\hat{\sigma}_e^2}{\hat{\sigma}_i^2}\right)^2 \right), \text{ for } i = 1, 2$$

$$P_{ij} = \left(\frac{\hat{\sigma}_e^2}{\hat{\sigma}_i^2}\right)^2 \text{ tr } T_{ij}T'_{ij} \left(\frac{\hat{\sigma}_e^2}{\hat{\sigma}_j^2}\right)^2 , \text{ for } i,j = 1,2 \text{ and } i \neq j$$

Defining

$$P = \begin{pmatrix} P_{oo} & P_{o1} & P_{os} \\ P'_{o1} & P_{11} & P_{12} \\ P'_{os} & P'_{12} & P_{22} \end{pmatrix}, \qquad t = \begin{pmatrix} t_o \\ t_1 \\ t_2 \end{pmatrix} \text{ and } \hat{\sigma}^2 = \begin{pmatrix} \hat{\sigma}_e^2 \\ \hat{\sigma}_s^2 \\ \hat{\sigma}_{sn}^2 \end{pmatrix}$$

the MINQUE of σ^2 is

$$\hat{\sigma}^2 = P^{-1}t$$

2.4 Iteration

Prior estimate of σ_e^2/σ_i^2 ratio is needed for this procedure and serves as the starting point for repeated iterations until convergence is achieved.

3. Mixed Model Analysis

This procedure was used to obtain the analysis of variance with the random effect of sires included in the model (see model (ii) in subsection 2.1). Estimates of σ_e^2 and σ_s^2 from the MINQUE analyses were assumed as known populations parameters.

The mixed model equations were:

$$\begin{pmatrix} X'X & X'Z \\ Z'X & Z'Z+KI \end{pmatrix} \begin{pmatrix} \hat{b} \\ \hat{u} \end{pmatrix} = \begin{pmatrix} X'y \\ Z'y \end{pmatrix}$$

where $K = \sigma_e^2/\sigma_s^2$ (from MINQUE)

Solutions were obtained for b and u. The ANOVA is given in Appendix B, Table 4B.

4. <u>Definition and Estimation of Heritability</u>

Heritability of a trait is defined as that portion if its total phenotypic variance (σ_p^2) which is due to variance of additive gene effects (σ_A^2). That is

$$h^2 = \frac{\sigma_A^2}{\sigma_p^2}$$

It was estimated using paternal half-sib method as follows:

$$h^2 = \frac{4\ \sigma_s^2}{\sigma_s^2 + \sigma_e^2}$$

where:

σ_s^2 = estimate of sire component of variance

σ_e^2 = estimate of error component of variance

These components of variance were calculated by MINQUE procedure as already described.

5. <u>Estimation of Genotype x Environment Interaction</u>

Two methods were used.

5.1 Analysis of variance method

This has been described already in subsection 3 above and the ANOVA is given in Appendix B, Table 4B.

5.2 Genetic correlation (r_G) method

The average degree of genetic correlation was computed from the components of variance for sires (σ_s^2, across feeding groups) and for interaction (σ_{sn}^2) by the intra-class method as

$$r_G = \frac{\sigma_s^2}{\sigma_s^2 + \sigma_{sn'}^2} \quad \text{(Dickerson, 1962)}$$

where

$$\sigma_{sn'}^2 = \sigma_{sn}^2 \text{ corrected}$$

$$= \sigma_{sn}^2 - \tfrac{1}{2}\,[\{(\sigma_{s1}-\sigma_{s2})^2 + (\sigma_{s1}-\sigma_{s3})^2 + (\sigma_{s2}-\sigma_{s3})^2\}]/3$$

and σ_{s1}, σ_{s2}, σ_{s3} are the genetic standard deviations for sire effects within each of the three environments (feeding groups).

The elements necessary to compute r_G are given in Appendix B, Table 5B.

V. RESULTS AND DISCUSSION

The total data set of 23,195 lactation records were analysed. The results are presented in Table 7 and Appendix B, Table 1B. Due to differences in feed sources between summer and winter (outdoor grazing vs indoor hay) and more uniform feeding during winter, the fall and winter months data were analysed in a second analysis separately. A total of 15,685 cow records were available (Table 8) for this analysis.

A third set of data including 4,226 cows calving a second time during the 23 month period of this study represented a third analysis. This facilitated the study of three different, but more precise, measures of fertility, namely, calving interval, days to conception and services per conception (Table 9). However, the results of this analysis must be viewed within the restrictions of the sample, in terms of inclusion of only cows with a subsequent calving within the data collection period.

1. Means of reproductive traits, 90 day 4% fat corrected milk (FCM) and source of energy

The means and standard errors of the reproductive traits, 90 day 4% FCM and sources of energy are presented in Table 6. The average figure for days to first service was 81.4 days. Similar results were reported for Quebec Holsteins by Tong et al. (1979). Des Marchais (1982) reported a slightly lower average of 79.8 days for Holstein cows in Quebec. This trait is influenced by management descisions. It is generally recommended that cows should be bred the first oestrus after 60 days postpartum, however some dairymen will breed cows earlier while others will delay breeding high producing cows.

The average number of days to final service was 120.3 days. Tong <u>et</u> <u>al</u>. (1979) reported 121 days open for Quebec herds. This trait is dependant upon days to first breeding. Genetic and phenotypic correlations of 0.79 and 0.40 for days to first breeding and days open have been reported (Berger <u>et</u> <u>al</u>., 1981; Everett <u>et</u> <u>al</u>., 1966). A final service in the D.H.A.S. data collection is confirmed only after a calving for that service is recorded. The days to final service reported is not necessarily a final date. Some cows may return to service several months after the final service while others may have not been in calf and culled late in lactation.

The average number of services per cow was 1.8. Similar results (1.9) were reported for Quebec dairy herds by Tong <u>et</u> <u>al</u>. (1979) and Des Marchais (1982) for services per conception. As already discussed, the final service in this study was not confirmed, therefore this value may be an under estimation. The average number of services per conception for 4,226 cows with a subsequent calving during the 23 month period of this study was 1.5. This is lower that 1.8 reported by Des Marchais (1982). This estimate is biased downward as cows with long calving intervals and repeat services would not have calved again within the data collection period and would have been excluded from this third analysis.

The average calving interval for 4,226 cows was 380 days. This is lower that the average of 396 days reported for the D.H.A.S. official population of Holsteins (P.A.T.L.Q. summary, 1980). This can be attributed to limitations of the data set as discussed in the preceeding paragraph.

The mean net energy (1) intake per day was 27.8 Mcal for the 1st 90 days of lactation in this study compared to the lower value of 20 Mcal for Quebec cows reported by Cassali (1979). The change in the method of estimating net energy intake from Morrison net energy values to NRC net energy (1) standards in 1979 and increase in milk production since may explain this difference.

The roughage intakes are expressed as a percent of total net energy intake. Corn silage, grass silage, hay and pasture accounted for 10.5, 7.0, 23.8 and 6.6%, respectively of the daily net energy intake so that 47.8% of the net energy intake per day came from roughages and 52.2% from concentrates. Cassali (1979) reported that 51.1% of the estimated net energy intake over 90 days in lactation came from concentrate for Holstein cows in Quebec.

The mean 90 day 4% FCM was 2258.8 kg. Cassali (1979) reported a 90 day milk yield for some Quebec herds of 1648.1 kg. However, average production per cow in Quebec has increased since that study was done, as demonstrated by the value from the present study.

2. <u>Effect of age, year-month of calving and 90 day 4% FCM on reproductive traits</u>

The analysis of variance for days to first and final service and number of services are presented in Appendix B, Table 1B, 2B. Age of cow, year-month of calving and 90 day 4% FCM had significant effects on the three reproductive measures.

In the third model which was restricted to cows that had calved, age had a significant effect on services per conception and days to conception; year-month of calving had a significant effect on calving interval, services per conception and days to conception while 90 day 4% FCM yield had significant effects on the calving interval (Appendix B, Table 3B).

Two year old and 5 year old or older cows required more days to first and final service as well as more services than cows of intermediate age (Table 7, 8). Similar results were reported by Tong et al. (1979) for Quebec herds. Des Marchais (1982) reported that older cows required more services to conceive and had 27.5 more days open compared to 2 year olds. Selection of cows for high production may account for the fact that older cows show more reproductive problems. A dairy farmer may be reluctant to cull a good producer even if she had reproductive problems.

In Table 11, days to conception rather than final service was measured. Older cows had least days to conception and services per conception, in contrast to results reported in Tables 7 and 10. This could be explained by restrictions of the data set.

Least squares estimates of differences of year-month of calving and distribution of observations are presented in Table 7. The smallest number of calvings occured in October 1979, June, July and August 1980, with the largest number occurring in October, November and December 1980. The small number of October 1979 calvings was due to the start of data collection at that time.

Cows calving in March to September tended to have more days to first service. Des Marchais (1982) reported that cows calving in March and April had fewer days to first service. Days to first service is a trait which is influenced by the dairyman's decision rather than the oestrus cycle, hence the inconsistencies.

Cows calving during spring (March - June) required less days to final service and less number of services. These results are in close agreement with those of Des Marchais (1982) and Tong et al. (1982) who postulated that environmental change from indoors to outdoors and the access to fresh pasture have favourable effects on reproductive performance. Spring calvers are due to be bred when they are out on pasture. It is therefore easier for the dairyman to detect his cows in heat by mounting (Des Marchais et al., 1980). Cows in Quebec are kept in tie stall barns during winter, making heat detection more difficult. This is partly responsible for the lower reproductive efficiency of the winter calvers (Des Marchais, 1982).

Cows calving in October and November 1979 had longer calving intervals and had more days to conception and services per conception (Table 11). These results should be ignored as they are affected by the restrictions of the data set. Cows calving in December, January and February 1980, would have had a shorter period of time to reach a subsequent calving.

The effect of 90 day 4% FCM was chosen as it covers the lactation period in which it is normally desired to achieve conception. In Tables 7, 10 and 11, 90 day 4% FCM is expressed in 100 kg units. For the complete data set (Table 7) an increase of 100 kg of 90 day milk yield was associated with an addition of .32 days to first service, an addition of 1.67 days to final service and an increase of 0.03 services per conception. These effects were all slightly increased in Table 10 where the data for previous calvings between March and August were excluded. Antagonism between milk yield and fertility has been reported by Hansen et al. (1981), Hansen et al. (1983) and Janson and Andreasson (1981).

Clark and Davis (1980) indicated that high producing cows are normally in a state of negative energy balance during early lactation due to their inability to eat enough and this, in part may explain their low fertility. Further, our data may be biased as high producing cows with fertility problems are more likely to be retained in the breeding herd than low producing cows with little or no reproductive problems.

3. Effect of nutrient intake on reproductive traits

The nutrient intakes for the 90 day postpartum period was expressed as percent of requirements based on N.R.C. standards. Of the various nutrients only calcium intake had a significant effect on days to first service. Of the first order interactions among the nutrients, only the effects of energy x protein on number of days to first service were significant. Of the covariables, net energy intake per day had significant effects on days to first and final service (Appendix B, Table 1B). For the fall and winter data, protein intake had significant effects on days to first service (Appendix B, Table 2B).

None of the nutrients had a significant effect on the reproductive traits in the data set of subsequent calvers (Appendix B, Table 3B).

3.1 Net energy

Least squares estimated differences (L.S.E.) of net energy are presented in Table 7. One third of the cows were fed 91-100% of the requirement. In all, 80% of the cows were fed 81-110% of the requirements. Net energy intake as a percent of requirement did not have a significant effect on any of the reproductive traits. The only trends suggested were that below optimum energy intakes reduced days to first service and increased days to final service. In a study of Quebec herds, Tong et al. (1979) reported that herds with low levels of net energy intakes had fewest days from calving to first service.

3.2 Protein

Protein intake as a percent of requirement appeared to be similarly distributed as energy intake except at an approximately 5% lower level. Protein as a percent of requirement had no significant effect on reproductive measures (Table 7, 9). The analysis of the fall and winter data (Table 8) indicated that protein intake had a significant effect on days to first service only. No trends could be identified from the data. The range of protein intakes is not very great and this may partially explain the lack of significance. There are conflicting literature reports on the effects of protein intake on reproductive traits. Edwards et al. (1980) reported that differing levels of dietary protein did not have a significant effect on number of services per conception or on days open in Holsteins.

3.3 Calcium and phosphorus

Least squares estimates of differences of the effects of calcium and phosphorus are presented in Tables 7, 8 and 9. Approximately 90% of the cows in the Quebec population are fed above N.R.C. requirements for calcium and phosphorus. Approximately 45% of the population receive about 111-140% of their N.R.C. requirements for calcium and about 63% receive 116-160% of their N.R.C. requirements for phosphorus. Latest recommendations for calcium and phosphorus are above N.R.C. 1978 requirements (Quebec C.B.L., 1982).

Cows whose intake of calcium was between 90-120% of N.R.C. requirements, needed more days to first service than others. Although differences were not significant, the same group of cows also needed more days to final service (Table 7). Ward et al. (1971) reported that uterine involution was completed 8 days sooner and first ovulation occured 6 days earlier in 37 Holstein cows fed 200 g calcium daily compared to a 100 g group. However, their work showed that differences in calcium intake did not significantly effect first postpartum oestrus.

The effect of phosphorus intakes on reproductive traits was not significant. The only trend was fewer days to first service with lower levels of phosphorus intake. McDowell (1976) refers to increased fertility levels in grazing cows after phosphorus supplementation. This is related to long term under feeding of phosphorus. Other reports have indicated that phosphorus fed at minimum daily requirement or supplemented did not affect postpartum reproductive performance (Hecht et al., 1977;Carstairs et al., 1980).

3.4 Two-way nutrient interactions

All two-way nutrient interactions were tested for significance. The protein x energy interaction was significant for number of services ($P<.05$). The protein x calcium interaction for days to first service was also significant ($P<.01$). The least squares estimates are presented in Tables 10 and 11. There were no apparent trends indicated in the two-way classification of the least squares estimates.

3.5 Regression of reproductive traits on net energy (1) intake

In tables 7, 8 and 9 daily net energy (1) intake for the 90 day period was treated as a covariate. In all cases daily net energy intake did not have a significant effect on reproductive traits. This is not inconsistent with other studies (Carstairs et al., 1980).

Ninety day 4% FCM yield as a measure of output and net energy intake are complementary measures of animal function. Cassali (1979) suggests that the same set of genes contribute in part to the genetic variance of both traits and that feed intake is a function of the cow's genetic capacity for milk production. In this study, 4% FCM yield as well as net energy intake/day were included in the model as covariates. However, it appears that 4% FCM yield alone is a good enough measure of the ability of the animal to utilize energy for reproductive functions. Changes in body weight would compensate for any under or over net energy intake.

3.6 Percent of net energy from different roughage sources

The percent of energy from corn silage, grass silage, hay and pasture were included as covariates in the analysis (Tables 7, 8 and 9). Of all the sources of net energy only hay had a significant effect on days to first and final service. As percent net energy contribution from hay increased, days to first service and to final service increased by 0.15 and 0.21 days, respectively.

Hay was the major source of net energy from roughage. In 90 day intakes, 47.8% of the net energy intake came from roughage of which approximately 50% was from hay. In some herds, particularly for cows calving in late fall and early winter (a period of poor reproductive performance), hay may represent the entire source of net energy from roughage. Thus, there is some suggestion that multiple sources of roughage is more favourable for reproduction than a single roughage source of hay.

3.7 The effect of population studied on reproductive measures

Tables 7 and 8 represent a study of days to first service, days to final service and number of services for cows without a subsequent calving. Hence the days to final service and number of services may be underestimated. Table 9 required that the cow calved before being included in the study.

Comparing the number of cows calving between October 1979 and February 1980, it is apparent that a large number of cows in the full data set were either culled before calving or still had not calved by August 1981. This means that some of the cows with a final service may not have been in calf. Any study of field data is subject to culling.

The limitations in Table 9 are evident in the effects of month of calving on reproductive measures where the values of calving interval, days to conception and services per conception are much greater for cows calving in the earlier months.

Most of the reports quoted in this study were based on experimental data. There are certain limitations of field data with respect to its use for nutrient intakes. Nutrient intakes are frequently estimated. Pasture intakes are variable and difficult to estimate. However comparison of results from Tables 7 and 8 revealed no difference due to the exclusion of pasture fed cows. Field data however has the advantage of the use of large volume of data, under which commercial production operates.

4. Heritability estimates of reproductive traits

Heritability estimates are presented in Table 12. The heritability of days to first service was 0.02. This is comparable to heritability estimates of 0.03 to 0.04 from the literature (Des Marchais, 1982; Hansen et al., 1981; Berger et al., 1981). Heritability of the number of services per cow was 0.01. Hansen et al. (1981) and Berger et al. (1981) reported heritabilities of 0.02 and 0.01 respectively for this trait for North American herds. Heritability of days to final service was 0.02. Berger et al. (1981) reported a slightly higher heritability of 0.04 for North American herds. As expected for reproductive traits, the estimates are low.

5. Sire x Nutrition interaction

5.1 Analysis of variance

None of the sire x nutrient (energy, protein, Ca and P) interactions had a significant effect on any of the three reproductive measures analysed (Appendix B, Table 4B). Existence of negative interaction sums of squares may be due to the fact that these were calculated as the difference between error sums of squares for the complete and reduced model and not directly (see section IV. 3).

Syrstad (1976) cautioned that there may be statistical interactions which could give misleading results from the use of the cross classified two-way model. However, this does not apply in this case as the interactions were not significant.

5.2 Genetic correlations (r_G)

The genetic correlations are presented in Table 13 and were calculated from different sire components of variance and covariance as given in Appendix B, Table 5B. No estimates are presented for days to final service in either table since components of variance and covariance were either negative or zero. This can be explained perhaps by the fact that they were calculated from full and reduced models by subtraction.

Six of the eight estimates of r_G in Table 13 were equal to 1.0. The r_G of sire x protein interaction and sire x energy interaction with respect to days to first service were 0.85 and 0.93 respectively. Genetic correlations close or equal to 1.0 indicate the absence of sire x energy, sire x protein, sire x calcium and sire x phosphorus interactions on both days to first service and number of services. Kress et al. (1971) found that a genotype x diet interaction was not significant for a number of reproductive traits studied but accounted for approximately 23% of the variance of the reproductive traits from first standing heat to first calving.

The genetic correlation results were not in agreement with those of Hansen et al. (1982). They found a significant genotype (breed) x diet interaction for interval to first oestrus and to conception; that is, the differences caused due to high and low energy intake in the interval from calving to first oestrus were greater for Holsteins than Herefords. This was probably due to a number of factors including the diversity of the genotypes. Genotypes in the current study were represented by progeny groups (half sibs) where as breeds were used in the study by Hansen et al. (1982). According to Syrstad (1976), use of different breeds usually results in a larger genetic variation which increases the chances of obtaining a significant interaction compared to the use of half sibs groups.

Hansen's study also employed the use of twins under experimental conditions, which enabled the testing of identical genotypes in the different environments but restricted the number of environments to 2. Syrstad (1976) suggests that milk recording data (as in this study) was not particularly suited to estimating genotype x nutrition interactions because of the lack of precision in estimating feed intakes and the limited variability with respect to levels of nutrition in different herds. The differences between the feeding groups in this study were not very dramatic (Table 5). As explained previously the days to first service is a trait which is influenced more by management decisions than by genetic effects and the number of services as measured may not have been final for that calving.

There are certain advantages however to the use of field data; a large number of observations, a ready and available supply of data from progeny tests without employing extra resources and data collected under prevailing farm conditions where research results have potential application.

These results suggest that ranking of sires, on the basis of their daughters' reproductive performance in Quebec dairy herds with differing levels of nutrition, remained unaltered. The implication of this conclusion for dairy sire selection is that dairy cattle breeders may continue to select sires without being concerned with the nutritional status of herds in which their daughters are expected to perform.

It should be pointed out that the above conclusion was not unexpected in view of the limited variability with respect to levels of nutrition in different Quebec dairy herds, i.e., most D.H.A.S. enrolled herds tend to feed levels approaching N.R.C. nutrient requirements.

TABLE 6. Means and standard errors for reproductive traits, 90 day 4 % FCM and sources of energy.

Trait	Mean ± S.E.
Days to first service	81.35±0.18
Days to final service	120.32±0.43
Number of services	1.81±0.01
Calving interval	379.98±0.58
Services per conception	1.54±0.01
Net energy intake/day (Mcal)	27.77±0.03
90 day 4 % FCM (kg)	2258.83±3.34
Energy from corn silage (%)	10.46±0.08
Energy from grass silage (%)	6.99±0.07
Energy from hay (%)	23.75±0.09
Energy from pasture (%)	6.62±0.08

TABLE 7. Least squares estimated differences from zero subclass, standard errors and tests of significance for age, year-month of calving and nutrient intakes on reproductive traits'

Classification	No. of obs.	Days to: 1st Service	Days to: Final Service	No. of Services
General mean	23195	81.35±0.18	120.32±0.43	1.81±0.01
Age		*	**	**
≤2 yrs	7082	- 0.25±0.67	1.40±1.64	0.00±0.03
3	4907	- 0.79±0.58	- 7.27±1.41	- 0.14±0.02
4	3606	- 1.80±0.59	- 8.62±1.45	- 0.14±0.02
5	2572	- 0.50±0.65	- 8.58±1.60	- 0.17±0.03
>5	5028	0.00±0.00	0.00±0.00	0.00±0.00
Year-month of calving		**	**	**
October 79	722	- 0.48±1.18	14.14±2.90	0.16±0.05
November 79	1013	1.83±1.01	10.25±2.47	0.08±0.04
December 79	1389	- 1.20±0.88	5.87±2.16	0.04±0.04
January 80	1599	0.09±0.83	4.06±2.04	- 0.03±0.03
February 80	1664	- 0.19±0.81	2.46±2.00	- 0.05±0.03
March 80	1453	2.59±0.85	1.67±2.10	- 0.10±0.03
April 80	1727	5.23±0.83	0.02±2.04	- 0.23±0.03
May 80	1426	1.10±0.97	- 4.71±2.38	- 0.23±0.04
June 80	1085	1.30±1.16	- 2.76±2.85	- 0.15±0.05
July 80	929	1.86±1.20	7.19±2.93	- 0.03±0.05
August 80	890	4.76±1.14	10.55±2.81	0.00±0.05
September 80	1336	3.87±0.95	9.90±2.23	0.07±0.04
October 80	2028	0.10±0.77	5.47±1.89	0.06±0.03
November 80	2280	0.28±0.72	4.82±1.77	0.07±0.03
December 80	3654	0.00±0.00	0.00±0.00	0.00±0.00

continued.....

TABLE 7. continued

Classification	No. of obs.	Days to: 1st Service	Days to: Final Service	No. of Services
90 Day Energy % (I/R)		NS	NS	NS
≤80	3130	- 0.03±1.54	4.30±3.78	0.04±0.06
81-90	5172	- 0.74±1.18	0.92±2.91	0.00±0.05
91-100	7520	- 0.83±0.95	3.08±2.33	0.05±0.04
101-110	4871	- 0.78±0.79	1.97±1.95	0.05±0.03
>110	2502	0.00±0.00	0.00±0.00	0.00±0.00
90 Day Protein % (I/R)		NS	NS	NS
≤75	3182	- 0.09±1.22	- 0.05±2.99	- 0.01±0.05
76-85	5316	0.54±0.97	- 1.65±2.39	- 0.04±0.04
86-95	7131	- 0.08±0.83	- 0.59±2.04	- 0.01±0.03
96-105	4777	- 0.45±0.74	- 1.06±1.81	- 0.01±0.33
>105	2789	0.00±0.00	0.00±0.00	0.00±0.00
90 Day Calcium % (I/R)		*	NS	NS
≤90	1454	3.40±1.52	5.62±3.73	- 0.01±0.06
91-110	3476	0.63±1.22	0.12±2.99	- 0.01±0.05
111-120	5091	0.42±1.05	1.70±2.57	0.00±0.04
121-140	5183	- 0.63±0.92	- 1.81±2.27	- 0.04±0.04
141-160	3601	- 0.34±0.86	- 0.53±2.12	- 0.03±0.04
161-180	2231	- 0.85±0.86	- 2.08±2.11	- 0.05±0.04
>180	2159	0.00±0.00	0.00±0.00	0.00±0.00
90 Day Phosphorus % (I/R)		NS	NS	NS
≤90	786	- 2.02±1.80	1.11±4.42	0.06±0.08
91-115	1627	- 1.88±1.39	- 0.82±3.42	0.04±0.06
116-130	3720	- 0.08±1.11	1.98±2.73	0.07±0.05
131-145	5284	0.75±0.93	1.10±2.29	0.03±0.04
146-160	5518	0.67±0.81	1.21±1.99	0.04±0.03
161-175	3496	0.40±0.76	1.29±1.86	0.03±0.03
>175	2764	0.00±0.00	0.00±0.00	0.00±0.00

continued.....

TABLE 7. continued

Classification	No. of obs.	Days to: 1st Service	Days to: Final Service	No. of Services
Covariables				
Regr. on 90 Day net energy intake/day (Mcal.)		NS - 0.08±0.12	NS 0.38±0.29	NS 0.00±0.00
Regr. on 90 Day 4% FCM (100Kg)		** 0.32±0.11	** 1.67±0.26	** 0.03±0.00
Regr. on % net energy from corn silage		NS 0.01±0.04	NS 0.04±0.10	NS 0.00±0.00
Regr. on % net energy from grass silage		NS - 0.01±0.05	NS 0.09±0.12	NS 0.00±0.00
Regr. on % net energy from hay		** 0.15±0.04	* 0.21±0.10	NS 0.00±0.00
Regr. on % net energy from pasture		NS - 0.03±0.04	NS 0.05±0.09	NS 0.00±0.00

*P < .05 **P < .01 NS P>.05 (I/R) intake/requirement

TABLE 8. **Least square estimated differences from zero subclass, standard errors and tests of significance for age, year-month of calving, and nutrient intakes on reproductive traits (Fall and Winter data)**

Classification	No. of obs.	Days to: 1st Service	Days to: Final Service	No. of Services
General Mean	15686	80.95±0.21	120.42±0.51	1.85±01
Age		*	**	**
≤2 yrs	5632	0.93±0.80	1.55±2.00	- 0.03±0.04
3	3685	- 0.25±0.70	- 7.41±1.74	- 0.18±0.03
4	2369	- 1.62±0.74	- 8.15±1.85	- 0.17±0.03
5	1497	0.39±0.84	- 8.35±2.10	- 0.19±0.04
>5	2502	0.00±0.00	0.00±0.00	0.00±0.00
Year-Month of Calving		**	**	**
October 79	722	- 1.38±1.17	12.34±2.92	0.15±0.05
November 79	1013	1.49±0.98	9.59±2.45	0.08±0.04
December 79	1389	- 1.39±0.85	5.16±2.14	0.04±0.04
January 80	1599	- 0.07±0.81	3.61±2.01	0.04±0.04
February 80	1664	- 0.61±0.79	2.08±1.98	- 0.05±0.04
September 80	1336	3.05±1.07	7.96±2.68	0.06±0.05
October 80	2028	- 0.16±0.77	4.54±1.94	0.06±0.03
November 80	2280	0.17±0.69	4.75±1.73	0.08±0.03
December 80	3654	0.00±0.00	0.00±0.00	0.00±0.00
90 Day Energy % (I/R)		NS	NS	NS
≤80	1967	- 0.26±1.82	1.31±4.54	- 0.06±0.08
81 - 90	3426	- 1.04±1.34	- 1.29±3.48	- 0.07±0.06
91 - 100	5187	- 1.10±1.11	2.16±2.78	0.01±0.05
101 - 110	3337	- 0.73±0.92	2.22±2.30	0.03±0.04
>110	1768	0.00±0.00	0.00±0.00	0.00±0.00

continued ....

TABLE 8. continued

Classification	No. of obs.	Days to: 1st Service	Days to: Final Service	No. of Services
90 Day Protein % (I/R)		*	NS	NS
≤75	1654	- 1.03±1.46	- 1.24±3.65	- 0.03±0.07
76 - 85	3293	1.46±1.31	- 0.02±2.83	- 0.00±0.05
86 - 95	5036	0.47±0.94	0.23±2.35	0.02±0.04
96 - 105	3523	- 0.35±0.82	- 0.58±2.06	0.02±0.04
>105	2179	0.00±0.00	0.00±0.00	0.00±0.00
90 Day Calcium % (I/R)		NS	NS	NS
≤90	939	2.77±1.85	1.92±4.64	- 0.03±0.08
91 - 110	2203	0.27±1.46	0.14±3.65	0.02±0.07
111 - 120	3443	0.29±1.24	1.39±3.11	0.02±0.06
121 - 140	3556	- 0.86±1.08	- 0.84±2.73	- 0.01±0.05
141 - 160	2452	- 0.69±1.01	1.44±2.53	0.04±0.05
161 - 180	1541	- 0.92±0.99	- 3.53±2.49	- 0.05±0.04
>180	1551	0.00±0.00	0.00±0.00	0.00±0.00
90 Day Phosphorus % (I/R)		NS	NS	NS
≤90	409	- 1.18±2.21	5.07±5.52	0.10±0.10
91 - 115	927	- 1.53±1.67	- 0.17±4.18	0.07±0.07
116 - 130	2357	- 0.37±1.31	2.20±3.29	0.07±0.06
131 - 145	3604	- 0.25±1.09	- 0.22±2.75	0.03±0.05
146 - 160	4014	- 0.01±0.95	- 0.01±2.37	0.03±0.04
161 - 175	2418	- 0.05±0.88	- 0.06±2.20	0.04±0.04
>175	1956	0.00±0.00	0.00±0.00	0.00±0.00

continued ....

TABLE 8. continued

Classification	No. of obs.	Days to: 1st Service	Days to: Final Service	No. of Services
Covariables				
Regr. on 90 Day net energy intake/day (Mcal)		NS - 0.10±0.14	NS - 0.04±0.34	NS - 0.00±0.01
Regr. on 90 Day 4% FCM (100 Kg)		** 0.41±0.12	** 2.01±0.31	** 0.04±0.01
Regr. on % net energy from corn silage		NS 0.07±0.05	NS 0.16±0.13	NS 0.00±0.00
Regr. on % net energy from grass silage		NS - 0.01±0.06	NS 0.07±0.15	NS 0.00±0.00
Regr. on % net energy from hay		** 0.13±0.04	NS 0.13±0.12	NS - 0.00±0.00
Regr. on % net energy from pasture		NS 0.05±0.06	NS 0.15±0.14	NS 0.00±0.00

*p < .05 **p < .01 NS P > .05 (I/R) intake/requirement

TABLE 9. Least squares estimated differences from zero subclass, standard errors and tests of significance for age, year-month of calving and nutrient intakes on reproductive traits (subsequent calvings)

Classification	No. of obs.	Calving interval	Days to conception	Services per conception
General Mean	4226	379.98±0.58	98.60±0.58	1.54±0.01
Age		NS	*	**
≤2 yrs	1594	2.72±2.55	- 1.00±2.58	- 0.06±0.06
3	1026	- 1.65±2.15	- 4.51±2.17	- 0.15±0.07
4	638	- 1.56±2.27	- 5.08±2.30	- 0.11±0.05
5	388	- 4.94±2.58	- 6.57±2.61	- 0.15±0.06
>5	580	0.00±0.00	0.00±0.00	0.00±0.00
Year-Month of calving		**	**	**
October 79	526	23.16±2.74	20.05±2.78	0.33±0.06
November '79	714	19.23±2.17	16.93±2.20	0.28±0.05
December 79	950	11.20±1.90	10.45±1.93	0.21±0.04
January 80	1037	11.32±1.79	9.95±1.81	0.14±0.04
February 80	999	0.00±0.00	0.00±0.00	0.00±0.00
90 Day Energy % (I/R)		NS	NS	NS
≤80	653	5.34±5.81	4.10±5.89	0.05±0.13
81-90	1021	3.61±4.48	2.86±4.54	0.03±0.10
91-100	1419	4.35±3.59	3.00±3.64	0.06±0.08
101-110	756	- 1.74±3.02	- 2.08±3.06	- 0.08±0.07
>110	377	0.00±0.00	0.00±0.00	0.00±0.00

continued ....

TABLE 9. continued

Classification	No. of obs.	Calving interval	Days to conception	Services per conception
90 Day Protein % (I/R)		NS	NS	NS
≤75	545	- 3.41±4.81	1.02±4.87	0.08±0.10
76-85	1044	0.01±3.76	2.60±3.81	0.05±0.08
86-95	1350	- 0.24±3.17	1.37±3.21	0.02±0.07
96-105	851	3.65±2.76	3.76±2.80	0.12±0.06
>105	436	0.00±0.00	0.00±0.00	0.00±0.00
90 Day Calcium % (I/R)		NS	NS	NS
≤90	281	- 1.73±7.10	1.23±7.19	0.03±0.15
91-110	705	- 0.56±5.62	- 1.26±5.69	0.06±0.12
111-120	907	2.79±4.73	0.08±4.79	0.07±0.10
121-140	912	2.31±4.09	1.21±4.14	0.09±0.09
141-160	610	4.90±3.64	4.60±3.69	0.12±0.08
161-180	384	- 1.58±3.20	- 2.13±3.24	- 0.02±0.07
>180	427	0.00±0.00	0.00±0.00	0.00±0.00
90 Day Phosphorus % (I/R)		NS	NS	NS
≤90	139	3.10±7.38	0.01±7.48	0.06±0.16
91-115	325	2.04±5.75	0.45±5.83	0.02±0.12
116-130	738	0.57±4.68	0.67±4.74	0.02±0.10
131-145	964	1.70±3.91	2.12±3.96	0.01±0.09
146-160	968	1.54±3.26	1.24±3.30	0.00±0.07
161-175	602	1.78±2.88	0.23±2.91	0.03±0.06
>175	490	0.00±0.00	0.00±0.00	0.00±0.00

continued ....

TABLE 9. continued

Classification	No. of obs.	Calving interval	Days to conception	Services per conception
Covariables				
Regr. on 90 Day net energy intake/day (Mcal)		NS 0.26±0.47	NS 0.31±0.47	NS 0.01±0.01
Regr. on 90 Day 4% FCM (100 kg)		* 0.86±0.42	NS 0.69±0.42	NS 0.00±0.01
Regr. on % net energy from corn silage		NS 0.45±0.24	NS 0.31±0.25	NS 0.01±0.01
Regr. on % net energy from grass silage		NS 0.24±0.30	NS 0.24±0.30	NS 0.01±0.01
Regr. on % net energy from hay		** 0.58±0.20	NS 0.40±0.21	NS 0.00±0.00
Regr. on % net energy from pasture		NS 0.20±0.28	NS 0.10±0.28	NS 0.00±0.00

*P<.05 **P<.01 NS P>.05 (I/R) intake/requirement

TABLE 10. Least squares estimated differences from zero subclass and standard errors for energy-protein subclasses for numbers of services

90 day Energy % (I/R)	90 day Protein % (I/R) ≤ 75	76-85	86-95	96-105	> 105
≤ 80	0.05±0.07	-0.00±0.07	0.16±0.10	-0.04±0.12	-0.27±0.17
81 - 90	-0.03±0.07	-0.02±0.06	-0.01±0.06	0.13±0.08	-0.28±0.13
91 - 100	0.14±0.09	-0.01±0.05	0.04±0.05	0.03±0.05	0.13±0.07
101 - 110	-0.04±0.16	0.10±0.07	0.02±0.05	0.03±0.04	0.09±0.05
> 110	-0.09±0.41	-0.03±0.16	-0.02±0.08	0.02±0.09	0.00±0.00

(I/R) intake/requirement

TABLE 11. Least squares estimated differences from zero subclass and standard errors for protein-calcium subclasses for days to first service

90 day Protein % (I/R)	90 day Calcium % (I/R)						
	≤ 90	90-110	111-120	121-140	141-160	161-180	> 180
≤75	1.92±1.70	0.33±1.77	0.03±1.68	1.90±1.89	5.45±2.44	-3.00±3.76	3.09±3.85
76-85	4.21±1.96	0.81±1.52	1.32±1.39	0.27±1.39	-0.07±1.57	-2.62±1.84	2.44±2.49
86-95	3.49±2.14	1.21±1.46	-0.77±1.30	-0.19±1.23	-0.99±1.30	-1.10±1.45	1.04±1.70
96-105	-1.03±2.21	-0.23±1.70	0.85±1.34	-2.10±1.26	-0.08±1.26	-0.58±1.40	-1.92±1.65
>105	1.51±2.09	-2.92±2.11	2.83±1.88	0.47±1.57	-3.73±1.59	2.34±1.74	0.00±0.00

(I/R) intake/requirement

TABLE 12. Heritability estimates for reproductive traits studied

Trait	h^2
Days to first service	0.02 ± 0.007
No. of services	0.01 ± 0.005
Days to final service	0.02 ± 0.007

TABLE 13. Genetic correlations between days to first service or number of services for sires on different nutrient levels.

Sire x Nutrient	r_G Days to first service	No. of services
Sire x energy	0.93	1.00
Sire x protein	0.85	1.00
Sire x calcium	1.00	1.00
Sire x phosphorus	1.00	1.00

VI. SUMMARY AND CONCLUSIONS

A total of 23,195 lactation records of Holstein cows, enrolled on the Q.D.H.A.S. official program were computed from monthly test day data collected over a 23 month period (October, 1979 to August, 1981).

The data were used to study the effects of (1) level of nutrition and, (2) sire x nutrition interaction on reproductive measures. The nutrients studied were energy, protein, calcium and phosphorus intakes expressed as percent of requirements in the first 90 day postpartum period. The reproductive measures studied were: days to first service, days to final service and number of services per cow. A study with a subpopulation of 4,226 cows with a subsequent calving was used to study the effects of the nutrients on calving interval, days to conception and services per conception.

The least squares models used to estimate the effects of nutrient intakes included age and month of calving. Both factors had a significant effect on reproductive traits. The reproductive performance, as measured by the reproductive traits, was best for the postpartum period following calving for 3 to 5 year old cows. Cows calving in the February to July period required fewer services to conceive again following calving. Cows calving in October and November had the poorest reproductive record.

The analysis of the complete set of data indicated that calcium, expressed as percent of requirement, was the only nutrient that had a significant effect on days to first service. There was a trend for cows with calcium levels below 120 percent of N.R.C. requirements to have more days to first service than cows consumming over 120 percent of calcium requirements. While not significant, this trend carried over to final service.

The least squares models also contained covariates as to source of roughage energy, net energy intake and 90 day milk yield. The effect of total net energy on reproductive measures was not significant. The percent of energy intake from hay was highly significant for days to first service and significant for days to first service in the full model. The number of days increased with increases of hay intake. This may be attributed to herds with hay as a single source of roughage during the winter months. In all models, the days to first service and final service and the number of services per cow increased: 0.32±0.11, 1.67±0.26 and 0.03±0.00 respectively, with an increase of 100 kilograms of 90 day (4 % FCM) milk yield in the full model.

The two-way interactions between the nutrient intake, measured as percent of requirements, were tested. The only interactions found significant were for number of services on energy x protein and for days to first service on protein x calcium. The two-way least squares estimates indicated no particular trends. There was some suggestion of combined levels of high protein and calcium intakes favouring reproductive performance.

Heritability of the reproductive measures: days to first service, days to final service and services per cow were all low, 0.02, 0.02 and 0.01, respectively.

The sire x nutrient interaction effects were found to be negligible. The average degree of sire x nutrition interaction for each nutrient was estimated by calculating genetic correlations by the intra-class method. The r_G values were either unity or close to unity. This is not unexpected with the low heritability and lack of significance of the nutrient intake effects.

Within the Quebec D.H.A.S. population, where feed quality and intakes are measured and feed recommendations are provided, genotype x nutrient interactions do not exist or are not of significant importance.

The 90 day postpartum milk yield has a closer relationship with reproductive measures than nutrient intakes. This is probably because milk yields are better estimated than nutrient intakes. It is also probably because cows can compensate for nutrient intakes by body weight changes.

Based on this study, there is no evidence to indicate that sire x nutrition interaction interferes with the ranking of sires with regard to reproductive performance. It would appear that if genotype x nutrition interactions affect reproduction they only do so under a more extreme range of nutrient intakes than exist in the population studied.

VII. LITERATURE CITED

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APPENDIX A

00	03	

NURTON
KINGS
N.B.

D.H.A.S.

A JOINT PROGRAM OF
NEW BRUNSWICK
DEPARTMENT OF AGRICULTURE AND MACDONALD COLLEGE

05-APR-[illegible]	11-[illegible]	[illegible]	14-[illegible]	[illegible]-10	80	

FORM 1 HERD SUMMARY

PRODUCTION SUMMARY

DESCRIPTION	This test	12 months				ANNUAL TOTAL
No. COWS	36	34.2				
No. DAYS IN MILK		312				
COWS IN MILK No.	31	29.2				
" " " %	86.1	85.5				
MILK PRODUCED (kg)	14.1	5259				181000
4% FAT CORRECTED MILK	19.5	18.4				
% FAT	4.3	3.9				7100
% PROTEIN	3.4					
BCA MILK	114	115				
" FAT	123	121				
MILK VALUE	3.79	1361				[illegible]
MILK VALUE LESS FEED COST	2.07	697				[illegible]
FEED COST / LITER OF MILK	12.24	9.03				
HOURS / TONNE OF MILK	11.6	11.6				
AVE HERD WEIGHT (kg)	510	510				
AVE HEIFER WEIGHT (kg)	453					
AVE AGE OF HERD Yr mo.	4.04					
AVE. AGE OF HEIFERS Mo.	28					
COWS ENTERING HERD	1					3
% COWS ENTERING HERD	3					8
COWS OUT OF HERD						3
% COWS OUT OF HERD						8
CALVING INTERVAL ACTUAL	360	384				30
PROJECTED	374					
NO BREEDINGS / COW / YEAR	10					
DAYS DRY	37	53				
DAYS OPEN	78	102				

FEEDING

DESCRIPTION	This test	12 months		ANNUAL TOTAL	1	2	3	4
AMOUNT FED (kg)								
CORN SILAGE	8.0	73[illegible]		25	8.0			
HAY SILAGE								
OTHER SUCCULENTS		[illegible]		[illegible]				
DRY HAY	8.0	[illegible]		[illegible]	8.0			
PASTURE		[illegible]		[illegible]				
MEAL	4.3	[illegible]		[illegible]	4.3			
PROTEIN SUPPLEMENT	9.0	[illegible]		20	9.0			
PERCENT ENERGY								
CORN SILAGE	12	3			12			
HAY SILAGE								
OTHER SUCCULENTS		12						
DRY HAY	27	[illegible]			27			
PASTURE		[illegible]						
MEAL	48	43			48			
PROTEIN SUPPLEMENT	13	3			13			
MILK PRODUCTION (kg)	18.4	5295			18.4			
4% FAT CORRECTED MILK	17.0				17.0			
% FAT	4.35	3.90			[illegible]			
AVE COW WEIGHT	510	510			510			
FEEDING RATE (kg / 100 kg b. wt.)								
ROUGHAGE HAY EQUIV	1.4	1.4			1.[illegible]			
DRY MAT BASE	1.15				1.[illegible]			
TOTAL RATION	3.2				3.2			
FEEDING INDEX (BASE 100)								
ENERGY	103	13			103			
PROTEIN								
CALCIUM								
PHOSPHORUS								
MAGNESIUM								

REPRODUCTION EFFICIENCY SUMMARY

MINIMUM DAYS OPEN		NO. OF COWS WITHOUT BREEDING DATES	COWS BRED FROM 6/ 1/78 TO 3/ 2/78: NO. OF COWS	AVERAGE NO. OF BREEDINGS / CONCEPTION
NUMBER OF DAYS	< 80	6	1	1.0
	80 – 100	2	0	.0
	100 +	0	0	.0
		AVERAGE 41.3 DAYS	TOTAL 1	AVERAGE 1.0

FOR COWS BRED SINCE	3/ 2/78	No. 10
MINIMUM DAYS OPEN	112	
NO. OF COWS OPEN FOR MORE THAN 85 DAYS	5	
COW BRED 3 TIMES OR MORE	4	
NON-RETURN RATE	.0	
ANNUAL AVERAGE	.0	

BREEDINGS PER CONCEPTION	NON-RETURN RATE
1.4	70
1.6	[illegible]
1.7	[illegible]
1.8	[illegible]
2.0	[illegible]
2.2	46
2.8	46

NUMBER OF COWS PROJECTED

FOR THE MONTH OF	MAY	JUN	JUL	AUG	SEP	OCT
IN MILK	32	30	31	31	33	34
DRY	4	6	5	5	3	2
TO CALVE	1	4	2	3	2	1

MANAGEMENT DECISIONS COWS ELIGIBLE

TO CULL	TO DRY	TO CALVE	TO BREED	PREGNANCY CHECK
[illegible] 75	[illegible] 21/03	[illegible] 06/03	[illegible] 18/01	25 31/03
[illegible] 83	[illegible] 13/04	[illegible] 10/04	[illegible] 22/01	[illegible] 21/03
[illegible] 84	16 25/04	14 10/04	[illegible] 26/02	19 01/03
[illegible] 86	[illegible] 01/05	23 06/05	[illegible] 01/03	34 01/03
[illegible] 87	2 13/05		35 03/03	
[illegible] 90	11 26/05		28 06/03	
16 91			[illegible]	
			14 27/03	

Region	County	Herd Code	
00	03		NURTON
			KINGS
			N.B.

D.H.A.S.

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NEW BRUNSWICK

DEPARTMENT OF AGRICULTURE AND MACDONALD COLLEGE

Dates							
05-APR -74	11-04	00	00	12-04	02-10	06	1

OPTIONS ... 42 33

FORM 2 PERFORMANCE RECORD

TEST DAY DATA FOR / CUMULATIVE REPORT TO 05-APR -74

Breed	Reg No / HIP No / Eartag	Control No	Milk kg	Fat %	Prot %	Given kg	Code	Barn Name	Milk Values $ Total	Over Feed Cost	Projection (Milk / Age / Calving / BCA)	Days Dry	Days Open	Days Preg	Days in Milk	Milk kg	Fat %	Prot %	Milk Values $ Total	Over Feed Cost	
H	165182U	141	23.3	4.1	3.4	10 9	1	1	9.08	3.66	711 11281 7 1 464 P 5284 106-103	40	81	2	83	2194	5.21	3.4	540	358	92
H	2701109	192	8.9	5.2	3.4	3 3	1	2	2.60	1.38	4: 6 12506 2 1 550	50	101	185	285	5130	3.67	3.0	1265	698	98
H	2516816	182	0.0	0.0	0.0	1	1	3	0.00	-0.94	6: 7 11505 5 1 584	55	54	277	281	5648	3.92	2.7	1451	836 -98	100
H	201439A 38579	189	24.8	4.4	3.5	12 11	1	4	6.69	4.15	4: 3 10103 3 1 440	50			35	808	4.94	3.5	214	166	
H	2905081 41047	195	24.3	4.5	3.5	12 11	1	5	6.62	4.02	3: 2 12004 2 1 524 P 6727 130-144	52			16	389	4.50	3.5	106	22	
H	2529562 33033	160	18.9	4.8	3.5	7 7	1	6	5.30	3.33	6: 7 11105 5 1 640 5658 116-121	110	95	161	206 303	5355 5658	3.53 3.53	3.3 3.3	1511 1454	838 878	118
H	2711741 37698	181	11.5	4.2	3.4	5 4	1	7	3.03	1.62	4: 4 11005 3 1 500	58	114	196	310	5217	3.91	3.1	1410	478	103
H	391189A	204	14.0	3.3	3.4	8 7	1	8	3.34	1.59	130 10602 1 1 430 P 4358 107-128				58	1056	3.98	3.4	276	208	
H	2992537	201	15.0	4.6	3.4	8 8	1	9	4.14	2.20	2: 0 12112 1 1 500 P 6698 135-139		62	43	105	1766	4.35	3.4	549	321	100
H	2657133 30607	171	16.0	4.5	3.4	8 6	1	10	4.37	2.37	5: 1 13107 5 1 244 P 5492 129-138	68	101	147	248	5988	3.76	2.9	1512	896	115
B	165183X 018199	151	10.5	4.8	3.4	3 3	1	11	2.94	1.67	9: 6 13108 8 1 594	62	[illegible]	171	217	4429	4.11	2.7	1160	613	98
H	2843163 41844	196	11.4	4.3	3.4	3 4	1	12	3.05	1.95	2: 0 11001 1 1 460		347	95	442	7459	4.01	3.1	1801	1129	105
H	3018386 45883	203	18.7	4.0	3.4	9 10	1	13	4.82	2.83	2: 0 12201 1 1 420				73	1562	4.01	3.4	387	278	
H	165190A 37118	180	24.5	4.3	3.5	12 10	1	14	6.54	4.00	4: 0 12703 4 1 440	55			9	221	4.10	3.5	59	-21	
H	201437A 41041	197	20.2	3.8	3.4	9 9	1	15	5.09	2.99	3: 1 10602 2 1 500 P 5293	63	58	0	58	1225	3.43	3.4	319	218	
B		194	17.0	4.2	3.4	7 7	1	16	4.48	2.74	3: 9 10111 2 1 470 P 5505	83	147	8	155	3247	3.90	3.3	834	585	98
H	165188U 24123	158	4.0	4.0	3.4	1 1	1	17	1.04	0.27	8: 2 10107 6 1 450 P 4611 118-131	44	74	204	278	5243	3.55	2.5	1295	704	88
H	2983912	198	13.0	4.8	3.5	5 7	1	18	3.45	2.18	2: 0 11709 1 1 500		179	21	200	3341	4.20	3.3	895	526	103
H	2757195	190	5.5	5.1	3.5	1 1	1	19	1.59	0.76	3: 1 10307 1 1 500		439	202	641	8788	3.98	3.1	2221	1301	94
H	165190U 24142	155	23.5	4.8	3.6	12 10	1	20	6.59	3.98	8 10 11008 7 1 534	55			77	1852	4.59	3.6	550	329	
B	165171X	170	12.4	4.9	3.4	4 5	1	21	3.50	2.12	5: 4 12704 4 1 550 P 5252	72	319	24	343	6704	4.43	2.8	1731	1035	105
H	201438U	199	15.0	4.2	3.4	6 3	1	22	4.11	2.43	110 12710 1 1 540		30	130	160	3155	4.30	3.2	821	526	116
H	165173U 32590	167	0.0	0.0	0.0	0	1	23	0.00	-0.68	5: 6 12004 4 1 500	21	99	231	329	5805	3.81	2.8	1470	909 -15	93

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978

D.H.A.S.

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REGION	COUNTY	HERD CODE
00	03	

NORTON
KINGS
N.B.

05-APR-78 | 11-04 | 00 00 | 12-04

FORM 3 MANAGEMENT DATA

DATES / 24 HR PROD.

TEST DATE	ARRIVED	LAB	E-P	BULK TANK	EVALUATED		
05/04/78	11/04	00 00	12/04		508	6	

MILK PRICE / MILKING TIME

$/LITER	BASE FAT	DIFF.			START	END	START	END
27.24	4.2	2.82	6	1.5				

OPTIONS

K3 OPTION CHOSEN — CODE NO. 1: IS ON 0: DISCONTINUE

OPTION CHOSEN	CODE NO.	
DHAS OFFICIAL	12	
MILK WEIGHT IN KG	31	
NECK CHAIN FORM2	42	
NECKCHAIN WITHIN GP FM4	53	

FEED IDENTIFICATION/ANALYSIS

	CODE	ID		DM %	NE (MCAL/KG)	PRICE $/T	% PROT			
1	230	S CORN	2	24.0	1.34	15				
2	460	HR BREE	2	20.0	1.52	25				
3	113	H GRAT	2	88.0	.60	44				
4	350	HEALMIX	2	88.0	1.83	158				
5										
6										
7										
8										
9										

MAILING ADDRESS

ULISS D JOHNSON
NORTON
KINGS
N.B.

BASE RATION COMPOSITION BY GROUP

GROUP	ID	AMOUNT kg	ID	AMOUNT kg	ID	AMOUNT kg									
1	1	8.0	2	9.0	3	8.0						4	0	99	0.00 / 1.
2															1.
3															1.
4															1.

00	03	

NORTON
KINGS
N.B.

D. H. A. S.

A JOINT PROGRAM OF
NEW BRUNSWICK
DEPARTMENT OF AGRICULTURE AND MACDONALD COLLEGE

FORM 4 MONTHLY HERD TEST

05-APR -7[illegible]	11-04	03 04	12-04	02-12	06

LEE K. 62 33

Breed	ID / Sire / Dam nos.	Dates	Control no.	Barn name	P.M.	A.M.	Rec.	Rec.	Condition 1	Condition 2	Weight	Fat %	Prot. %	Calf code	Projected	Comments
H n H	1651320	050270 120178 031578	151	1	10.3	13.0	9	0.01	4 3 4	1	620	4.1	3.6	1 2 1 1		
H n H	2701109 297250 2475665	161272 240277 031077	192	2	4.5	4.6	3	0.01	1		550	5.2	3.4		P 5704 108-108	335-250
n H H	2516818 206165 2219262	230970 150577 020777	182	3	0.0	0.0	0	0.01	3		580					CALVIN
H H H	2014553A 320776 1651730	141173 010378 030677	169	4	12.2	12.6	11	0.01	2 1 3		460	4.4	3.5			TO CALF
H H H	2565061 300429 2520338	261274 200378 200677	195	5	10.7	13.6	11	0.01	2 20 3		520	4.5	3.5			TO CALF
H H H	2529502 300428 2441127	210171 110977 201077	160	6	9.5	9.4	7	0.01	1		640	4.8	3.5		P 6767 130-144	
n H H	2711741 293081 2529563	070173 300577 210777	161	7	5.3	6.2	4	0.01	1		462	4.2	3.4		5658 114-121	
n n H	3411057A 323231 1651900	220376 060278	204	8	7.0	7.0	7	0.01	1		430	3.3	3.6			WEIGHT TO CALF
n H H	2552537 300428 2520338	061273 211277 210278	201	9	7.0	8.0	8	0.01	1		500	4.6	3.4		P 6356 107-124	
n n n	2657133 300428 2146057	050272 310777 051177	171	10	6.0	8.0	6	0.01	1		540	4.3	3.4		P 8678 135-139	
o d A	1651535A	100266 310677 161077	151	11	5.0	5.5	3	0.01	1		590	4.8	3.4		P 3992 124-135	
n H H	2643163 320170 2387723	050574 160177 311277	150	12	5.4	6.0	4	0.01	1		460	4.3	3.4			
n H H	3010386 293681 2651134	040376 220176	203	13	9.3	5.4	10	0.01	1		420	4.0	3.4	1 2 1 1		BRED
n H H	1651804A 320670 1651690	240773 270378 230677	180	14	11.2	13.3	10	0.01	2 27 3		48[illegible]	[illegible]	3.3			TO CALF
n H H	2311137A 323670 1651620	261274 060278 280378	197	15	10.0	10.2	9	0.01	4 28 3	1	530	3.8	3.4			TO CALF
5 d d		300174 011177 280378	194	16	7.5	9.5	7	0.01	4 28 3	1	470	4.2	3.4		P 3293	CCF TO
H H H	1651880	100469 010777 130977	158	17	2.0	2.0	1	0.01	1		452	4.0	3.4		P 3363	[illegible] DRY DATE
H H H	2583312 297280 2657133	260275 170977 150378	156	18	4.0	7.0	7	0.01	4 15 3	1	500	4.8	3.3		P 4811 116-134	
H H H	2757195 284451 1931145	010673 010776 150577	190	19	2.5	3.0	1	0.01	1		500	5.1	3.3			DRY DATE
H H H	1651930	100327 100178 060477	155	20	10.5	13.0	10	0.01	1		550	4.8	3.6	2 1 1 1		BRED
o o A	1651771X 9124 1651431X	221271 270477 120378	170	21	6.0	6.4	5	0.01	4 12 3	1	550	4.9	3.4			
n n H	2014330	201275 271077 261177	157	22	6.0	9.0	8	0.01	1		540	4.2	3.4		P 3232	
H n H	1651730	051071 200477 210777	167	23	0.0	0.0	0	0.01	3 15 3		500					CALVIN

APPENDIX B

TABLE 1B. Analyses of variance of age, year-month of calving and nutrient intakes on reproductive traits

Source of variation	d.f.	Mean Squares: Days to: 1st Service	Final Service	No. of Services
Age	4	1836.80*	89082.00**	26.20**
Year-month of calving	14	4373.00**	27640.50**	13.40**
Energy (E)	4	404.70	6656.30	2.00
Protein (Pr)	4	473.10	1576.00	0.50
Calcium (C)	6	1704.30*	8608.70	1.00
Phosphorus (P)	6	1122.20	1691.40	0.60
E x Pr	16	791.70	6178.20	2.20*
E x C	24	651.90	2378.60	0.70
E x P	24	528.70	4689.70	1.20
Pr x C	24	1145.46**	3216.17	0.80
Pr x P	24	783.06	4985.73	1.22
C x P	36	322.06	5083.66	1.53
Regr. on net E intake/day (Mcal)	1	356.00	7009.00	1.00
Regr. on 90 day 4% FCM (100 kg)	1	6544.80**	173041.50**	48.10**
Regr. on % net E from corn silage	1	57.90	540.60	0.00
Regr. on % net E from grass silage	1	12.90	2189.40	2.50
Regr. on % net E from hay	1	8961.40**	18238.00*	0.00
Regr. on % net E from pasture	1	494.40	1348.80	0.00
Error	22204	683.60	4040.56	1.22

NOTE: All nutrients were measured as per cent (intake/requirement)

*P<.05 **P<.01

TABLE 2B. Analyses of variance of age, year-month of calving and nutrient intakes on reproductive traits (fall and winter data)

Source	d.f.	Mean Squares 1st Service	Mean Squares Final Service	No. of Services
Age	4	1992.41*	56010.60**	20.63**
Year-month of calving	8	1708.18**	14546.23**	4.22**
Energy (E)	4	341.00	6124.87	2.32
Protein	4	1627.54*	568.07	0.27
Calcium	6	932.54	4750.03	1.62
Phosphorus	6	150.99	2045.48	0.53
Regr. on net E intake/day (Mcal)	1	325.63	49.49	0.37
Regr. on 90 day 4% FCM (100kg)	1	7095.98**	166822.37**	51.40**
Regr. on % net E from corn silage	1	1133.09	5501.80	0.36
Regr. on % net E from grass silage	1	14.71	787.40	1.56
Regr. on % net E from hay	1	4533.72**	4706.64	0.22
Regr. on % net E from pasture	1	522.72	4693.23	0.04
Error	14857	616.89	3860.61	1.22

*P<.05 **P<.01

TABLE 3B. Analyses of variance of age, year-month of calving and nutrient intakes on reproductive traits (Subsequent calvings)

Source	d.f.	Mean Squares: calving interval	Services per conception	Days to conception
Age	4	2930.41	2.19**	3556.73*
Year-month of calving	4	32215.17**	6.99**	24661.92**
Energy (E)	4	2594.43	1.34	1810.68
Protein	4	1971.53	1.26	1051.64
Calcium	6	1747.58	0.64	1720.62
Phosphorus	6	603.60	0.05	215.71
Regr. on 90 day net E intake/day (Mcal)	1	397.31	0.82	544.37
Regr. on 90 day 4% FCM (100 kg)	1	5441.67*	0.01	3477.38
Regr. on % net E from corn silage	1	4448.93	0.52	2008.38
Regr. on % net E from grass silage	1	818.99	1.74	814.32
Regr. on % net E from hay	1	10124.12**	0.09	4986.34
Regr. on % net E from pasture	1	651.32	0.31	1637.93
Error	3562	1270.60	0.60	1303.16

*P<.05 **P<.01

TABLE 4B. Analyses of variance for sire x nutrition interactions on reproductive traits

		Mean Squares		
Source of variation	d.f.	Days to 1st Service	Number of Services	Days to Final Service
Sire x energy	130	37.83[NS]	0.00[a]	0.00[a]
Error	22661	66.69	1.16	3928.01
Sire x protein	130	63.97[NS]	0.00[a]	0.00[a]
Error	19057	661.22	1.14	3710.50
Sire x Calcium	130	34.80[NS]	0.05[NS]	0.00[a]
Error	17586	66.35	1.17	3759.02
Sire x Phosphorus	130	0.00[a]	0.00[a]	0.00[a]
Error	17586	659.44	1.15	3714.54

[NS] $P>.05$

[a] Sums of squares were negative and assumed to be zero

TABLE 5B. Sire (σ_s^2) and sire x nutrition (σ_{sn}^2) components of variance and genetic standard deviations (σ_s, σ_{s2}, and σ_{s3}) of sires for feeding groups 1, 2 and 3

Nutrient	Days to 1st Service					Number of Services				
	σ_s^2	σ_{sn}^2	σ_{s1}	σ_{s2}	σ_{s3}	σ_s^2	σ_{sn}^2	σ_{s1}	σ_{s2}	σ_{s3}
Energy	3.406	0.270	1.895	2.217	1.978	.005	.000	.094	.685	0.00
Protein	2.962	.493	.930	1.996	2.042	.004	0.00[a]	.109	.004	0.00
Calcium	3.069	.327	1.692	2.627	1.526	.004	.001	.065	0.00	.080
Phosphorus	3.104	0.00[a]	1.246	2.084	1.513	0.004	0.00	.685	.082	0.00

[a]Negative variance, assumed to be 0