ANALYSES OF THE YIELD OF MILK, MILK COMPONENT, AND ENERGY IN A HOLSTEIN, AYRSHIRE AND HOLSTEIN-AYRSHIRE CROSS DAIRY CATTLE POPULATION

BY

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ABSTRACT

A total of 238 records (101 Holstein, 63 Ayrshire and 74 crossbred) made by cows calving in a two year period from August 1967 to July 1969 inclusive at the Oyster River Research Farm were used to study: a) lactation yields of; milk, milk fat, protein, lactose, total organic solids, and energy; b) lactation average percent; milk fat, protein lactose and total organic solids; c) percent milk energy as; milk fat, protein and lactose; d) the ratio of fat production to protein production, and e) the energy concentration of the milk.

Statistical analyses were by the least squares method of Harvey (16). Constants were fitted for the three breed groups, for the two years included in this study and for the season of lactation start. Constants were also fitted for all interactions. Number of days milked, age in days of the cow at parturition, and number of days open were used as co-variables. A significance level of 5 percent was used throughout.

Breed group and the co-variables of days milked and age were significant for yield traits. The Holsteins and crossbreds did not differ significantly from each other but both groups had significantly higher yields than the Ayrshires. The least squares overall means for yields of; milk, milk fat, protein, lactose, total organic solids and energy were;

14,914 ± 177, 548 ± 7.3, 510.9 ± 6.1, 738.4 ± 9.2, 1,797.6 ± 21.2 lbs., and 4,946 ± 58.9 mcal respectively. The least squares constants for each breed for the above listed traits (in the same order) were: 1) Holstein; 1,239 ± 244, 14.2 ± 10.0, 27.2 ± 8.4 60.2 ± 12.7 lbs., and 238.6 ± 81.2 mcal; 2) crossbred 688 ± 240, 21.6 ± 9.9, 26.2 ± 8.2, 37.2 ± 12.5 lbs., and 225.6 ± 80.1 mcals; and 3) Ayrshire; -1927 ± 256, -35.8 ± 10.5, -53.4 ± 8.8, -97 ± 13.3, -186.5 ± 30.7 lbs., and -464 ± 85.1 mcals.

The partial regression coefficients of all yield traits on number of days milked and on age at parturition were significant and positive.

The overall least squares mean percent protein was 3.44 ± 0.015. The breed least squares constants for Holstein, crossbred and Ayrshire were; -0.11 ± 0.021,).02 ± 0.021, and 0.09 ± 0.022 respectively. Differences between crossbred and Ayrshire means were non significant but both breed group means were significantly higher than the Holstein.

Breed, season, breed by season and year by season were significant sources of variation for percent milk fat and percent total organic solids. Ayrshire means were higher than Holstein for all seasons. For winter calving, crossbred means did not differ significantly from Holstein; for summer calving, crossbred means did not differ significantly from Ayrshire. Differences among Holstein season means were non significant. Crossbreds and Ayrshires calving in the summer tended to have higher percentages than winter or spring calvers. Means of winter calving cows were higher in the second year than in the first year.

Percent lactose increased from 4.88 ± 0.019 in the first year to 5.02 ± 0.017 in the second year.

Significant standard partial regression coefficients for days milked were; percent milk fat 0.27 ± 0.06, percent lactose 0.28 ± 0.06, and percent total organic 0.31 ± 0.06.

Breed, season, breed by season, year by season and days milked were all significant effects on percent milk energy as milk fat, the ratio of milk fat to protein and the energy concentration of the milk. Since percent milk fat is highly correlated with the above traits (correlation coefficients were 0.96, 0.86, and 0.97 respectively) the results were very similar to those obtained for percent milk fat.

Season, year, breed by season and days milked were significant effects on percent milk energy as protein. Higher values were associated with winter calving than summer calving and the effect of season was greater on crossbred than on the other two breed groups. The standard partial regression coefficient for days milked was -0.28 ± 0.07. The means for the first year was 27.8 ± 0.20 and for the second was 27.2 ± 0.25.

Breed, season, year by season and age were significant for percent energy as lactose. Breed means, which were all significantly different from each other were; 27.7 ± 0.22, 26.8 ± 0.20 and 25.6 ± 0.24 for Holstein, crossbred and Ayrshire respectively. Higher values were associated with winter calving and differences were greater in the first year than the second year. The standard partial regression coefficient for age was -.20 ± 0.06.

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INTRODUCTION

The emphasis in animal production today is on the ability of domestic animals to produce high yields of protein. Erb (13) suggested that the dairy cow of the future should produce a maximum amount of protein with a minimum input of energy. This could be achieved by increasing the output of protein relative to milk fat and lactose as well as by increasing lactation protein yields. However the positive genetic correlation of approximately 0.5 (25, 31, 10) between percent milk fat and percent protein would make increasing percent protein while decreasing the percentage of the major milk energy component, milk fat, a relatively slow process.

With the rapid methods of determining protein content now available (7, 11, 20) it is possible to analyse cows and herd milk regularly for protein content. It has also been shown, LeBaron and Brog (23), that input of protein into a manufacturing plant can be accounted for in output and therefore that payment for milk on a protein basis is realistic because dairies can recover the extra costs of high protein milk in the products, although this would be difficult for fluid milk sales. Some milk marketing areas are now paying for milk on protein or solid-not-fat content as well as on milk fat content (22).

Part of the motivation for this thesis was the suggestion, Berry (5), that the dairyman's target should be a cow producing 20,000 pounds of milk testing 3.0% milk fat and 9.0% solids-not-fat. Assuming average values for ash, and lactose of 0.8% and 4.9% respectively, this cow's milk would test 3.3% protein and she would produce 29.3% of her total milk energy as protein.

This thesis is a study of the production of milk, energy and the three major milk components of two breeds of dairy cattle (Holstein and Ayrshire) and crossbreds from these two breeds in the U.B.C. Research Herd at Oyster River, B.C. In addition the composition of the milk produced (with respect to the three major components) and the relationship between protein and energy in milk were considered. The latter trait was studied in order to determine if between breed differences in milk composition and in the ratio of percent milk fat to percent protein were indicative of between breed differences in percent milk energy as protein.

LITERATURE REVIEW

Effect of Season on Performance

Variation in lactation yields of milk are associated with the month in which a cow freshens. Wood (39) suggested that, in the northern hemisphere, lower lactation milk yields are made by summer calving cows than by winter or spring calving cows. However, he found greater seasonal variation in lactational milk yields of cows in the north of Britain than in the southwest of Britain. The highest lactation yields of milk were made by cows calving from October to December in both areas.

In the United States of America, Lee *et al*. (24), in Georgia; and Blanchard *et al*. (8) in the Midwest, also found that the highest lactational milk yields were made by cows calving in the winter, while the lowest yields were made by cows calving in the summer. But Fosgate *et al*. (14) reported that spring freshening cows (Georgia, U.S.A.) produced the most milk. Woodward (40), in the U.S.A., and Bailey (4), in England, showed that the highest milk records were associated with autumn calving cows. Oloufa and Jones (29) in Oregon, found that season of freshening was a non-significant effect on lactational milk production.

Gacula *et al*. (15) reported breed differences in the effect of season of calving on lactational milk yield, however he attributed these apparent breed differences to differences in herd management. Johnstone *et al*.(19) in a study of the effect of season of calving on lactation yields of milk over a ten year period on Jerseys and Holsteins in Louisianna, found that the Jersey breed showed highly significant differences for seasonal effects. The season of calving that gave the highest milk yield for the Jersey breed was January to March and the low was July to September. However, the Holstein breed showed only a highly significant year by season interaction. Johnstone attributed the breed differences to the Holsteins being more sensitive to climate changes between years than the Jerseys.

Thus, in general, most workers reported that cows calving in the summer were lower in lactation milk production than cows calving at other times of the year, but differences were manifest as to which season of freshening resulted in the highest lactation milk yield. In addition there was some evidence that the response to season of calving varied both by breed and by year.

The effect of season of calving on lactation average percent fat was reported (8, 15, 38) to be that late summer calving cows had higher lactational average fat tests. However, Sargent _et al_. (34) found no significant effect of season of freshening on percent fat (North Carolina).

Waite _et al_. (38) studied the effect of season on milk composition, (Ayrshire cattle in Scotland) and found that percent milk fat was maximum in October and fell to a low in June; percent protein, while generally following the pattern of percent milk fat, was high in May - June and again in September with the lowest values reached in the period from January to March. Lactose content was high from January to June, fell to a low level in August and stayed at a relatively low level for the remainder of the year. The variation in lactose percent was less than that for percent protein or milk fat.

Effect of Age of the Cow on Performance

Waite *et al*. (38) showed that increased age of the cow resulted in higher yields of milk with lower percentages of components. The effect on percent lactose due to age was greater than it was for percent milk fat or protein. The drop in percent lactose between the first lactation and grouped ninth and later lactations was 0.35, while the drop in percent milk fat and protein was 0.19 and 0.08 respectively. The finding that the effect of age on the percent composition was small for percent milk fat and protein was supported by the results of other workers (1, 2, 15, 26).

Phenotypic Correlations between Performance Traits

Phenotypic correlations between yield traits have been reported: milk yield and milk fat yield, 0.83 (37) and 0.88 (8); milk yield and solids-not-fat yield, 0.97 (37) and 0.98 (8); and milk fat yield and solids-not-fat yield, 0.90 (8), and are high and positive. The phenotypic correlations between percent component and lactational milk yield have also been reported: milk yield and percent milk fat, -0.21 (12), -0.26 (37) and -0.25 (8); milk yield and percent solids-not-fat, -0.16 (8) and -0.11 (37); and milk yield and percent total solids, -0.24 (8); and are generally low and negative. Other phenotypic correlations between performance traits that have been reported are: percent milk fat and percent protein 0.45 (4) and 0.43 (32); and percent milk fat and percent lactose, zero (8) and slightly negative (32).

Crossbreeding of Dairy Cattle

Robertson *et al*. (33) reviewed the history of experimental crossing of dairy breeds for the first half of this century, and Pearson and McDowell (31) reviewed more recent reports.

Johnson *et al*. (18) studied two and three breed crosses among Jersey, Holstein and Brown Swiss cattle and found that the Brown Swiss by Jersey crosses exceeded the production of the parent breeds; he reported increases of 20% in milk yield, 21% milk fat yield and 15% FCM over the parental mean. However, he reported that crosses with Holsteins essentially equalled the performance of the Holstein.

McDowell and McDaniel (27) studied Holstein, Ayrshire and Brown Swiss with two and three breed crosses, found two distinct groupings for yields of milk, milk fat, protein, SNF, FCM, and energy. The Ayrshire, Brown Swiss, and Swiss by Ayrshire crosses produced less than; the Holstein, the two breed crosses that were half Holstein and the three breed crossbreds. The yields of the two breed crosses, in which Holsteins were one of the breeds, exceeded the mean of the parental breeds. Yields of crossbreds were not greater than Holstein but later analyses (28) showed that in terms of income over feed costs certain crosses were more profitable due to greater efficiency of feed conversion and better milk quality. There was also an indication that first lactation superiority in the crossbreds may not be maintained over their lifetime.

Both the study of Brandt et al. (9) on Guernsey, Holstein and Brown Swiss two and three breed crosses and that of Bereskin and Touchberry (6) showed no statistically significant departure from additive genetic inheritance.

MATERIALS AND METHODS

Source of Data

The animals in this study were from the U.B.C. Research Herd at Oyster River, B.C. This herd of approximately one hundred and twenty cows of milking age was composed of three breed groups; Holstein, Ayrshire and first and second generation crosses between Holstein and Ayrshire. The first generation crosses were the result of mating Holstein sires with Ayrshire females, reciprocal crosses were also made. The first generation females were mated to a bull of the same breed as their own dam to produce the second generation crossbreds.

For this study a lactation record was one in which a cow had milked more than 180 days. All records were terminated at 305 days. These records were made by cows calving over a two year period; from August 1967 to July 1969 inclusive. A total of 238 records were completed in the herd during this period, and consisted of; 101 Holsteins, 63 Ayrshires and 74 crossbred. The crossbred group included both first and second generation crosses and was composed of animals which were 50%, 25% and 75% Holstein. The number of records made by each of these classes of crossbreds was 42, 15 and 17 respectively.

The data was divided on the basis of the season in which lactation started. Six seasons were used; February-

March, April-May, June-July, August-September, October-November and December-January. Table 1 lists the number of records by breed, year and season of freshening.

TABLE 1

NUMBER OF RECORDS CLASSIFIED BY BREED, YEAR AND SEASON

Season	Holstein		Ayrshire		Crossbred		Total by Year		Total by Season
	67-68	68-69	67-68	68-69	67-68	68-69	67-68	68-69	
Feb-Mar	9	7	8	12	5	8	22	27	49
Apr-May	17	20	7	8	10	7	34	35	69
Jun-Jul	10	9	4	4	6	7	20	20	40
Aug-Sep	5	8	1	2	3	2	9	12	21
Oct-Nov	2	4	5	3	7	11	14	18	32
Dec-Jan	4	6	6	3	4	4	14	13	27
TOTAL	47	54	31	32	35	39	113	125	238

Collection and Analyses of the Samples

Milk samples for analyses were taken by the R.O.P. inspector, aided by the farm staff, at the time of his regular visit to the Oyster River Herd. The composite milk sample consisted of two ounces of milk taken in the afternoon and two ounces taken the following morning from the milk of each cow. The weight of milk from each cow on test day was recorded. The dates of sampling (morning milking) are presented in Table 2.

TABLE 2

DATES OF MILK SAMPLING

Month	1967	1968	1969	1970
January	-	29	24	6
February	-	28	-	11
March	-	-	6	26
April	-	8	-	24
May	-	11	15	-
June	-	16	20	-
July	-	16	23	-
August	-	26	-	-
September	10	27	9	-
October	7	-	17	-
November	16	1	15	-
December	19	12	-	-

Mercuric chloride was added to the samples as a preservative and the samples were shipped by freight, in insulated containers with ice packs, to the Provincial Government Branch Laboratory in Vancouver, B.C. The samples were analysed for milk fat, protein and lactose content using an infra-red milk analyser (Grubb-Parsons, Mk II).

Performance Traits Studied

A total of fifteen performance traits were studied. These traits can be divided into three broad groups: 1) lactation yields, 2) lactation average percent composition, and 3) energy relationships.

Lactational yields of milk, milk fat, protein, lactose and total organic solids were computed using the interval between test days as the test period. The yield of total organic solids was calculated as the sum of the yields of the three major components of milk; i.e. the milk fat, protein and lactose (total solid yield could not be calculated because no estimate of mineral content of the milk was made). The yield for the test period was calculated by multiplying the number of days in the test period by the arithmetic mean of the performance traits on the two test days. This procedure had the effect of dividing the test period into two equal sub-periods about a centre date, production credits for the first sub-period coming from the first test day information and production credits for the second sub-period from the second test day information. This method gives a better estimate of lactational yields than does a method that uses a fixed period particularly when the interval between test days varies, as is the case in this study, Sargent *et al.* (34).

Total energy yield was estimated by multiplying the yield in pounds of milk fat, protein and lactose by their standard values, Jenness and Patton (17), for the heats of combustion, (4.132, 2.658 and 1.792 mcal. per pound respectively) and summing the products.

The lactational average composition of the milk was determined for milk fat, protein, lactose and total organic solids by dividing the lactational yield of each component by the lactational yield of milk,(expressed as a percentage).

The distribution of the energy in the milk was calculated by dividing the megacalories of energy in each component by the total energy yield and expressing the result as a percentage of total energy. Another estimate of the relationship between energy and protein was the ratio of milk fat production to protein production. This was calculated by dividing the pounds of fat produced by the pounds of protein; therefore the figures reported show the weight of fat produced per unit weight of protein.

Statistical Methods

A least squares analysis after Harvey (16) was used to estimate the effects of breed, year and season of freshening and all interactions on the performance traits discussed above; i.e. yields of milk, milk fat, protein, lactose, total organic solids and energy; lactational average percent milk fat, protein, lactose and total organic solids; and the distribution of the energy among the three major components of milk.

Number of days open, number of days milked and age of the cow at parturition were all used as co-variables to adjust performance traits studied for differences due to these factors.

Days open were defined as the number of days between lactation start and conception or until the end of the record if conception did not occur, but not to exceed 305 days.

Days milked was defined as the number of days that the cow was milked from the fourth day after calving until completion of the lactation, not to exceed 305 days.

Age was the age of the cow in days at parturition, and since all available lactations were included in this study, this co-variable adjusted performance traits for the effect of parity number as well as for age at parturition. Records of parity greater than one were included because first lactation records of protein production were available for only a small proportion of the herd (analyses of milk for protein were not started until September 1967). This co-variable also adjusted records for the affects of selection, to the extent that it occurred and accounted for differences in performance between age groups. However, as the herd size increased during this period, selection on females was relatively low.

The arithmetic means by breed group, of the three co-variables are reported in Table 3.

TABLE 3

ARITHMETIC MEANS OF THE CO-VARIABLES

	Holstein	Ayrshire	Crossbreds	Overall
Days open	141	154	143	145
Days milked	298	296	299	298
Age - days	1610	1558	1417	1536
- years	(4.41)	(4.27)	(3.88)	(4.21)

The linear mathematical model assumed was:

$y_{ijkl} = \alpha + b_i + s_j + a_k + (bs)_{ij} + (ba)_{ik} + (as)_{jk} + (bsa)_{ijk} + gG_{ijkl} + dD_{ijkl} + aA_{ijkl} + e_{ijkl}$, where:

y_{ijkl} = The observed value of the various performance traits under study of the l^{th} cow of the i^{th} breed calving in the j^{th} season of the k^{th} year.

α = The population mean for the trait under study when equal frequencies exist in all subclasses and G_{ijkl}, D_{ijkl} and A_{ijkl} all equal zero.

b_i = The effect of the i^{th} breed.

s_j = The effect of the j^{th} season of freshening.

a_k = The effect of the k^{th} year of freshening.

$(bs)_{ij}$ = The joint effect of the i^{th} breed in the j^{th} season when the effects of breed and season are held constant.

$(ba)_{ik}$ = The joint effect of the i^{th} breed in the k^{th} year when the effects of breed and year are held constant.

$(sa)_{jk}$ = The joint effect of the j^{th} season in the k^{th} year when the effects of season and year are held constant.

$(bsa)_{ijk}$ = The joint effect of the i^{th} breed in the j^{th} season and the k^{th} year when the effects of breed, season and year are held constant.

g = The partial regression coefficient of y_{ijkl} on G_{ijkl}.

G_{ijkl} = The number of days open associated with the l^{th} cow of the i^{th} breed freshening in the j^{th} season and the k^{th} year.

d = The partial regression coefficient of y_{ijkl} on D_{ijkl}.

D_{ijkl} = The number of days milked of the l^{th} cow of the i^{th} breed freshening in the j^{th} season and the k^{th} year.

a = The partial regression coefficient of y_{ijkl} on A_{ijkl}.

A_{ijkl} = The age in days at parturition of the l^{th} cow of i^{th} breed freshening in the j^{th} season and the k^{th} year.

e_{ijkl} = The random effect associated with the l^{th} cow of the i^{th} breed freshening in the j^{th} season and k^{th}

year, which is assumed to be independent and normally distributed with mean equal zero and variance σ^2.

All effects in the model except e_{ijkl} were regarded as fixed.

The level of significance was 0.05.

All significant effects were tested by Duncan's new multiple range test, as modified by Kramer (20) or by the t-test (16).

Phenotypic correlation coefficients between all performance traits studied were computed.

The proportion of the total sums of squares that was accounted for by fitting; the statistical model, and each effect in the model were calculated.

During the period covered by this study some cows completed two lactations. As no rational basis existed for using one of these records and discarding the other, both records were used as independent estimates of performance traits. Thus the unit of observation in this study was an individual lactation record rather than the performance of an individual cow. Use of both records in this way would tend to improve estimates of year and season effects. However use of two records for some cows and one record for others would result in giving too much weight to the performance of the cow with two records as compared to the cow with only one.

If the fact that a cow had two records was related to her performance in the first record; i.e. cows with high production were retained in the herd and those with low production were sold, and if any breed group had more duplicate records than another, then breed estimates for this breed group would tend to be biased upwards.

Table 4 shows that the proportion of duplicate records is approximately the same for each breed group, and that the main reason for cows having only one record is that these cows freshened for the first time during the second year of the study and thus had the opportunity to produce only one record. Another reason for a cow having only one record was that she was relatively fresh when the study started and was not included in the first year but subsequently completed a record in the second year.

For the above reasons it is the opinion of the author that whether a cow had one or two records was mainly a random process and therefore little or no bias was introduced in breed estimates by using both lactation records.

TABLE 4. NUMBER OF COWS AND NUMBER OF RECORDS BY BREED AND AGE AT PARTURITION

AGE	HOLSTEIN		CROSSBRED		AYRSHIRE		TOTALS	
Yrs.	#Rec.	#Single[a]	#Rec.	#Single[a]	#Rec.	#Single[a]	#Rec.	#Single[a]
1	1	-	-	-	-	-	1	-
2	25	18	20	13	17	9	62	40
3	18	3	22	3	18	3	58	9
4	25	3	21	2	10	2	56	7
5	16	1	5	1	5	-	26	2
6	6	3	5	1	8	4	19	8
7	4	2	1	-	3	1	8	3
8	3	2	-	-	1	-	4	2
9+	3	3	-	-	1	-	4	3
Totals	101	35	74	20	63	19	238	74
No. Cows	68		47		41		156	

a The number of cows in each age group that completed only one lactation during the period covered by this study.

LACTATION YIELDS: RESULTS AND DISCUSSION

A summary of the results of the analyses of variance of yields of milk, milk fat, protein, lactose, total organic solids (TOS) and energy is presented in Table 5. This table shows the value of R^2 for the statistical model; i.e. the proportion of the total variation in each yield trait that was accounted for by fitting: the main effects of breed, season and year; all interactions between and among the main effects; and the three co-variables of; days open, days milked, and age. The value of R^2 for each effect in the model (i.e. the proportion of the total variation that was accounted for by that effect) is also shown. For lactation yields of; milk, milk fat, protein, lactose, total organic solids, and energy the statistical model accounted for; 60, 51, 58, 58, 58, and 57 percent respectively of the total variation. For these traits the effect of breed group and the co-variables of; days milked, and age at parturition were the only categories in the analyses of variance that were significant.

Breed Group

The overall yield means, with standard error, and the breed group least squares constants, with their standard errors are reported in Table 6. The lactation production of milk and energy for each breed group are shown graphically in Figure 1. Figure 2 shows the relationship between breed

TABLE 5. SUMMARY OF THE ANALYSES OF VARIANCE: LACTATION YIELDS.

Yield	Total Fitted[1]	Total C.S.S.[2]	Main Effects[3]			Interactions[3]				Co-variables[3]		
			Br.	Sn.	Yr.	Br.XSn.	Br.XYr.	Yr.XSn.	BXSXY	Open	Milked	Age
Milk	0.60	$2.28x10^9$	0.12*	0.01	-	0.01	-	0.01	0.03	-	0.12*	.14*
Fat	.51	$3.13x10^6$	.03*	.02	-	.03	-	.02	.02	-	.18*	.14*
Protein	.58	$2.53x10^6$	.08*	.02	-	.01	-	.02	.03	-	.13*	.16*
Lactose	.58	$5.86x10^6$	.11*	.01	-	.01	-	.01	.03	-	.13*	.09*
Total Org. Sol.	.58	$3.09x10^7$	.08*	.01	-	.02	-	.01	.03	-	.16*	.14*
Energy	.57	$2.32x10^8$	.06*	.01	-	.02	-	-	.03	-	.17*	.15*
Deg. of Freedom	38	237	2	5	1	10	2	5	10	1	1	1

1 Fraction of the total sums of squares accounted for by fitting the effects in the statistical model (R^2).

2 Total corrected sums of squares ($lbs.^2$ except energy which is $mcal^2$)

3 Fraction of the total sums of squares accounted for by each effect in the statistical model (values less than 0.01 are not shown).

* Significant source of variation.

TABLE 6

OVERALL MEANS AND BREED GROUP LEAST SQUARES CONSTANTS:
LACTATION YIELDS[1]

	Overall Means ± S.E.	Least Squares Constants ± S.E. Holstein	Crossbred	Ayrshire
Milk	14,914.0 ± 177.0	1239.0 ± 244.0[a]	688.0 ±240.0[a]	-1927.0 ± 256.0[b]
Fat	548.2 ± 7.3	14.2 ± 10.0[a]	21.6 ± 9.9[a]	- 35.8 ± 10.5[b]
Protein	510.9 ± 6.1	27.2 ± 8.4[a]	26.2 ± 8.2[a]	- 53.4 ± 8.8[b]
Lactose	738.4 ± 9.2	60.2 ± 12.7[a]	37.2 ± 12.5[a]	- 97.4 ± 13.3[b]
T.O.S.	1,797.6 ± 21.2	101.6 ± 29.2[a]	84.9 ± 28.9[a]	- 186.5 ± 30.7[b]
Energy	4,946.5 ± 58.9	238.6 ± 81.2[a]	225.6 ± 80.1[a]	- 464.2 ± 85.1[b]

1 Units are pounds except energy which is in megacalories.

a,b Constants superscripted by the same letter are not significantly different from each other by Duncan's test.

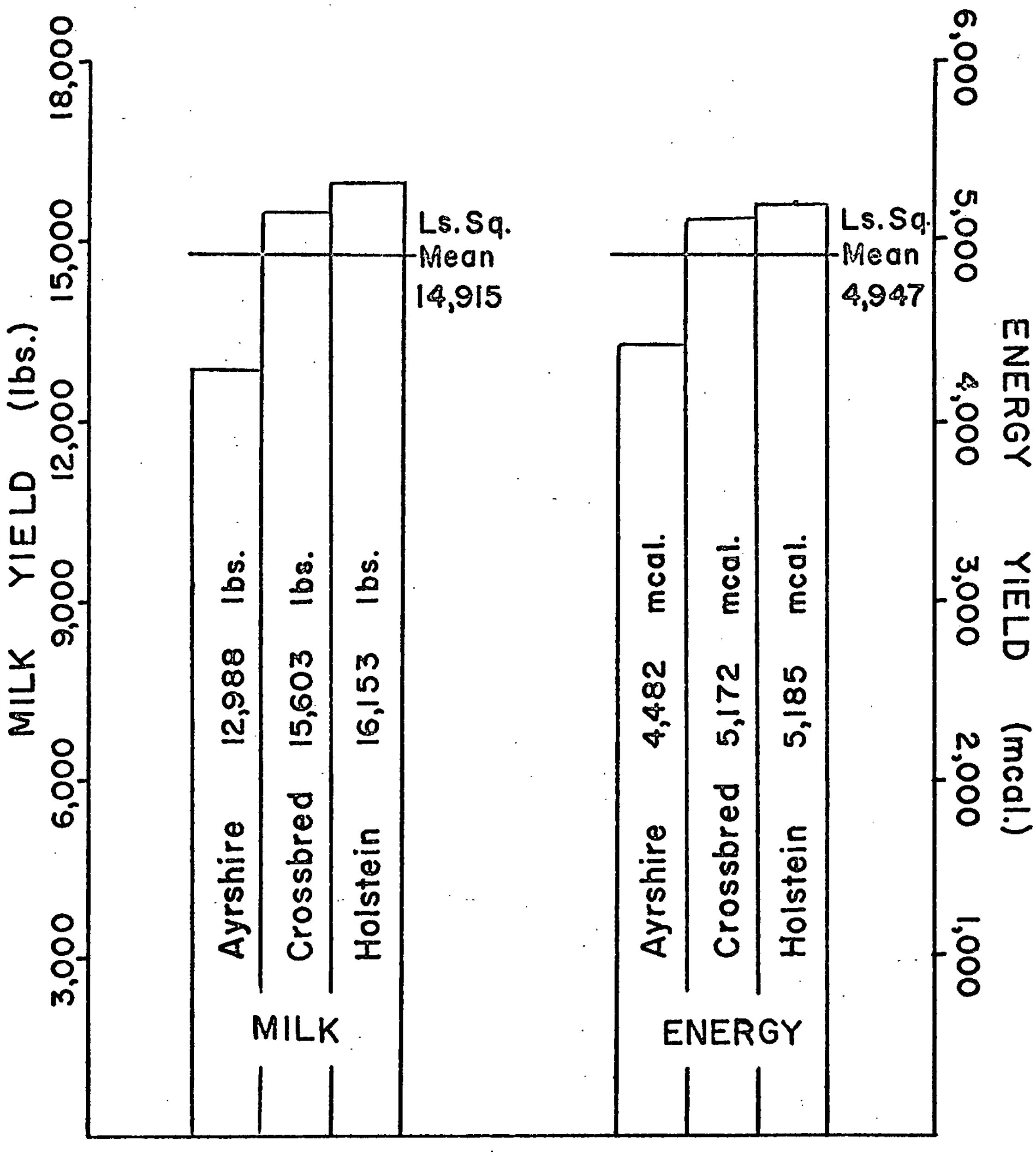

FIGURE 1. Lactation milk and energy yields of the three breed groups.

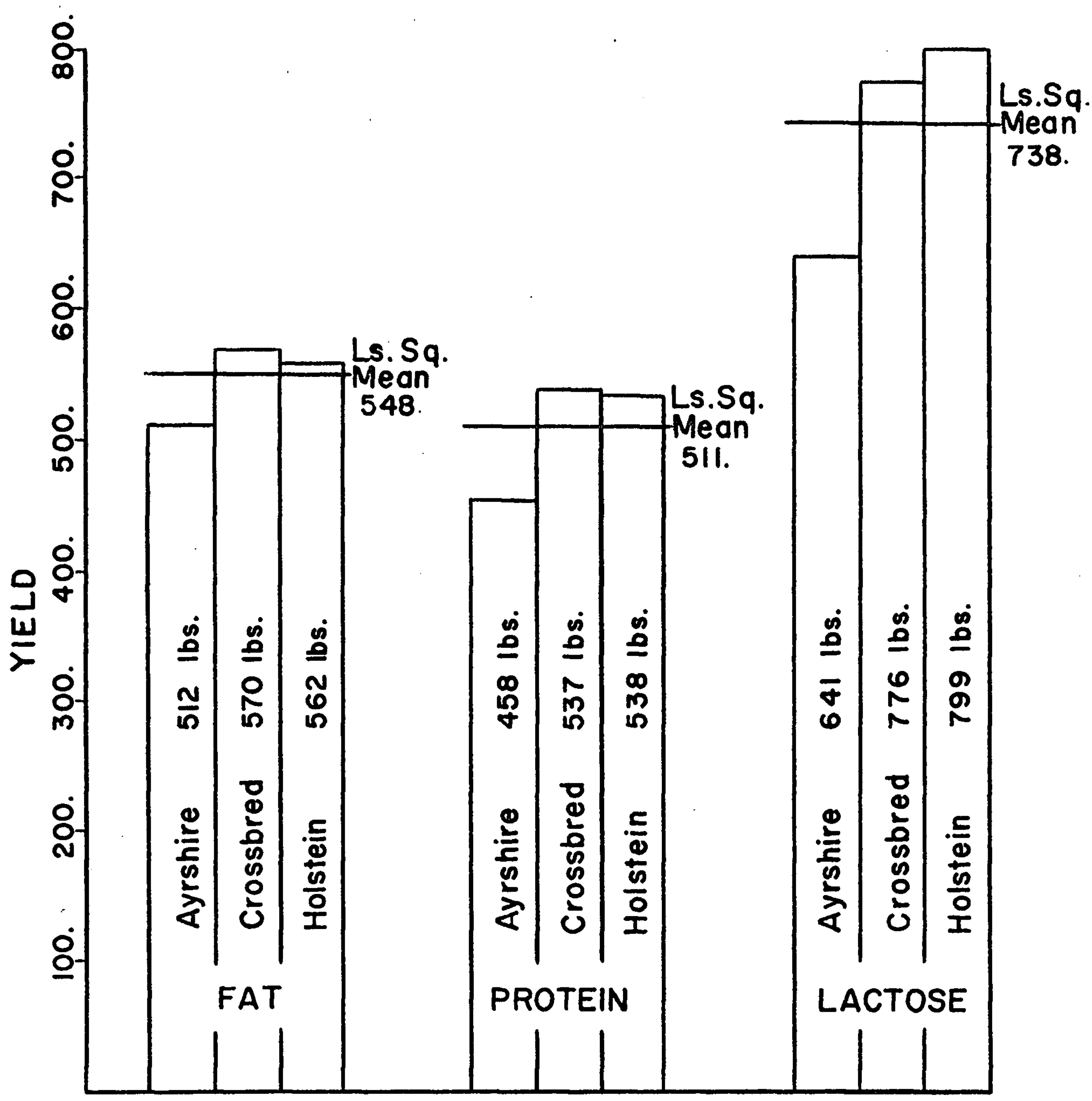

FIGURE 2. Lactation yields of; milk fat, protein and lactose of the three breed groups.

groups for lactational yields of milk fat, protein and lactose.

Duncan's test showed that the Holstein and crossbred groups did not differ significantly in lactational production of milk, milk fat, protein, lactose, total organic solids, and energy (Table 6). However, both breed groups produced at a significantly higher level than the Ayrshires for all the above traits.

The effect of breed accounted for 12% of the total variation in lactation milk yield. The least squares mean lactational milk yields for the three breed groups of Holstein, crossbred and Ayrshire were: 16,153 ± 299; 15,603 ± 273; and 12,988 ± 336 pounds respectively. Thus the Holsteins produced 3,166 pounds more milk per lactation than the Ayrshires and 551 pounds more than the crossbreds (non-significant). The overall least squares mean was 14,914 ± 177 pounds.

For lactational yields of milk fat the effect of breed group accounted for 3% of the total variation. The lactation production of milk fat for Holsteins, crossbreds and Ayrshires was 562.4 ±12.3; 569.8 ± 11.2; and 512.4 ± 13.8 pounds respectively. The crossbred group produced the most milk fat per lactation. The lactation fat yield of this breed group was 7.4 lbs. more than the Holsteins (non-significant) and 57.4 lbs. higher than the Ayrshires. The overall mean lactation yield of milk fat was 548.2 ± 7.3 lbs.

The effect of breed group accounted for 8% of the total variation in lactation production of protein. The least squares mean for Holstein, crossbred and Ayrshire were 538.1 ± 10.2; 537.1 ± 9.4; and 458.3 ± 11.5 pounds respectively. The overall least squares mean was 510.9 ± 6.1 pounds. There was a difference of only one pound in lactational yield of protein between the Holstein and crossbred but these two groups produced significantly more protein (70 lbs.) per lactation than the Ayrshires.

For lactational yields of lactose the effect of breed group accounted for 11% of the total variation. The least squares mean for the three breed groups was 798.6 ± 15.5; 775.6 ± 14.2; and 641.1 ± 17.5 pounds of lactose per lactation of Holstein, crossbred and Ayrshire respectively. The overall mean was 738.4 ± 9.2 pounds.

The effect of breed group accounted for 8% of the total variation in lactation yield of total organic solids. The yields of total organic solids (the sum of the above yields of milk fat, protein and lactose) for the three breed groups were 1899.2 ± 35.9; 1882.5 ± 32.8; and 1611.1 ± 40.3 pounds per lactation for Holstein, crossbred and Ayrshire respectively. The overall least squares mean was 1797.6 ± 21.2 lbs. Thus the difference (non-significant) between Holstein and crossbred for total yield of the major nutrients in milk was only 16.7 lbs., while that between the two parental breeds was 288.1 lbs. in favour of the Holsteins.

For lactational yields of energy the effect of breed group accounted for 6% of the total variation. The energy yields of the three breed groups were 5185.1 ± 99.5; 5172.1 ± 90.9; and 4482.7 ± 111.8 mcal. milk energy per lactation for Holstein, crossbred and Ayrshire respectively, with an overall least squares mean of 4946.5 ± 58.9 mcal.

Season of Calving

While the effect of season of calving on lactational yields did not account for a significant amount of the total variation, the trend was for cows that freshened in the autumn and winter to produce more milk, milk fat, protein, lactose, total organic solids and energy per lactation than those that freshened in the spring and summer. The least squares constants and standard errors for season of freshening effects are shown in Table 7 and are graphed in Figure 3.

Year

Year was not a significant source of variation of lactation yields. The year least squares constants with their standard errors, for lactation yields are shown in Table 8.

Co-variables

The number of days milked and the age of the cow at parturition were significant effects on all yield traits studied. The partial regression coefficients are reported in Table 9. The partial regression coefficients are the pooled within subclass regressions of yield in pounds (or mcal. in the case of energy yield) on the days milked and on the age of the cow, in days, at parturition. The coefficients are thus

TABLE 7. SEASON LEAST SQUARES CONSTANTS: LACTATION YIELDS[1].

Yield[2]	Least Squares Constants ± S.E.					
	Feb - Mar	Apr - May	Jun - Jul	Aug - Sep	Oct - Nov	Dec - Jan
Milk	446.0 ± 316.0	- 11.0 ± 295.0	-815.0 ± 359.0	116.0 ± 507.0	-60.0 ± 457.0	323.0 ± 469.0
Fat	- 9.3 ± 13.0	- 26.3 ± 12.1	- 20.3 ± 14.8	43.3 ± 20.8	15.1 ± 18.8	- 2.5 ± 19.2
Protein	13.8 ± 10.8	0.0 ± 10.1	- 30.3 ± 12.3	17.2 ± 17.4	- 5.0 ± 15.7	4.3 ± 16.1
Lactose	21.3 ± 16.4	- 1.4 ± 15.3	- 36.3 ± 18.7	5.4 ± 26.4	- 8.4 ± 23.8	19.4 ± 24.4
TOS	25.9 ± 37.9	- 27.7 ± 35.4	- 86.9 ± 43.1	65.9 ± 60.9	1.7 ± 54.8	21.2 ± 56.2
Energy	36.6 ± 105.2	-111.3 ± 98.1	-229.5 ± 119.5	234.2 ± 170.0	34.0 ± 152.2	36.0 ± 155.9

1 Season of calving was not a significant source of variation for lactation yields.

2 Units are pounds, except energy which is in megacalories.

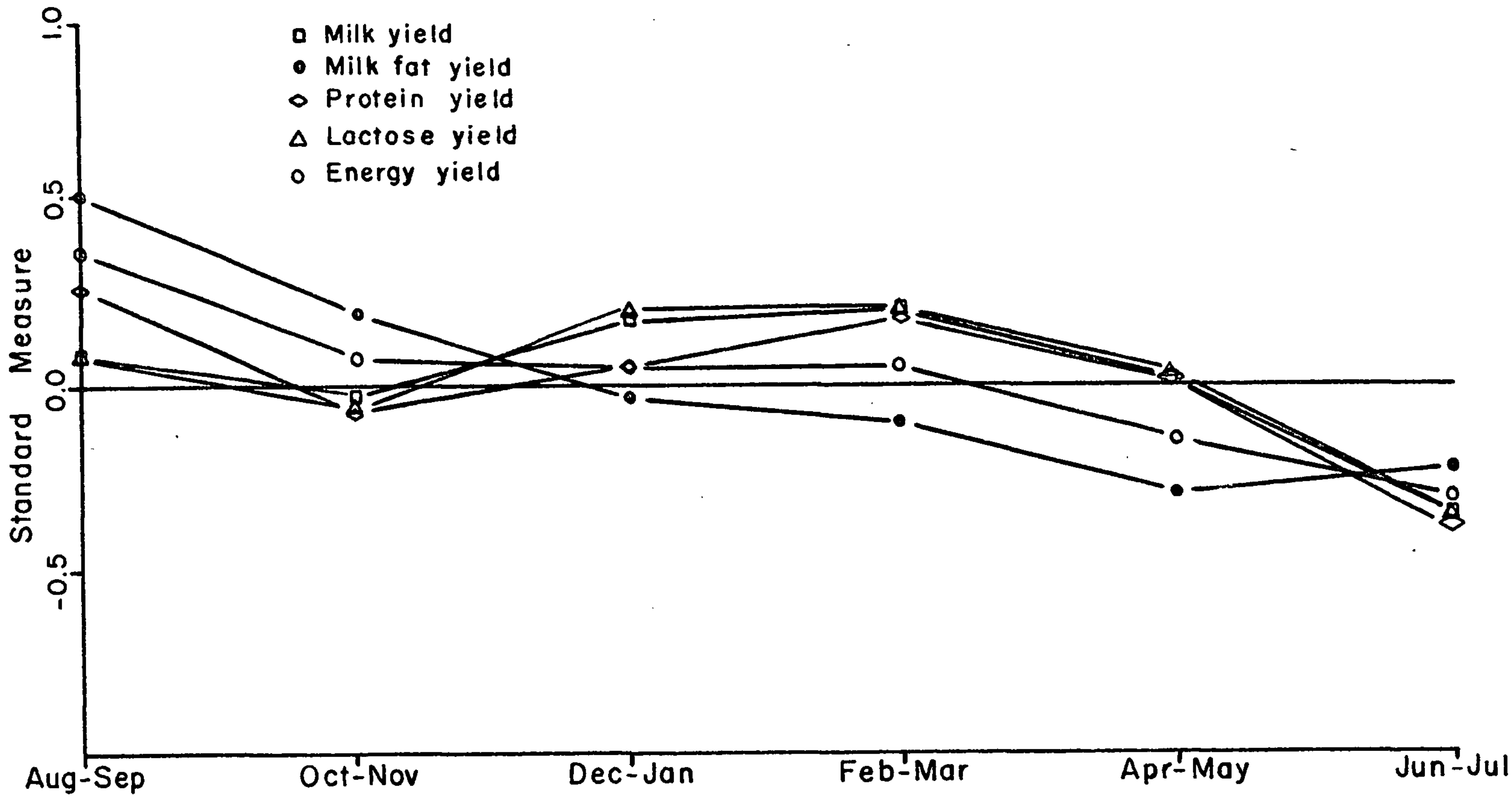

FIGURE 3. The effect of season of freshening on lactation yields of; milk, milk fat, protein, lactose and energy (plotted in standard measure as deviations from the mean). Season of freshening was not a significant source of variation for yield traits.

TABLE 8

YEAR LEAST SQUARES CONSTANTS:
LACTATION YIELDS[1]

Yield[2]	1967-68 ± S.E.	1968-69 ± S.E.
Milk	-71.5 ± 177.6	71.5 ± 177.6
Fat	- 4.3 ± 7.3	4.3 ± 7.3
Protein	1.1 ± 6.1	- 1.1 ± 6.1
Lactose	-13.5 ± 9.2	13.5 ± 9.2
T.O.S.	-16.6 ± 21.3	16.6 ± 21.3
Energy	-38.7 ± 59.1	38.7 ± 59.1

1 Year was not a significant source of variation for lactation yields.

2 All yields in pounds except energy which is in mega calories.

TABLE 9

PARTIAL AND STANDARD PARTIAL REGRESSION COEFFICIENTS[1]: LACTATION YIELDS ON DAYS MILKED AND AGE AT PARTURITION

Yield	DAYS MILKED		AGE	
	Units[2] of Yld. ± S.E.	Stan. Meas. ± S.E.	Units[2] of Yld. ± S.E.	Stan. Meas. ± S.E.
Milk	58.8 ± 7.7	0.39 ± 0.05	2.12 ± 0.25	0.43 ± 0.05
Fat	2.74 ± 0.32	.50 ± 0.06	0.079 ± 0.010	.43 ± 0.06
Protein	2.08 ± 0.26	.42 ± 0.05	0.075 ± 0.008	.46 ± 0.05
Lactose	3.15 ± 0.40	.42 ± 0.05	0.089 ± 0.013	.35 ± 0.05
T.O.S.	7.97 ± 0.93	.46 ± 0.05	0.243 ± 0.030	.42 ± 0.05
Energy	22.5 ± 2.6	.48 ± 0.05	0.686 ± 0.084	.43 ± 0.05

1 All coefficients are significant

2 Units are pounds except energy which is in megacalories

the increase in yield per day milked and per day of age above the intercept where days milked and age both equal zero. The partial regression coefficients are also listed in standard measure in Table 9; these values estimate the change in yield, as a fraction of a standard deviation of yield, associated with one standard deviation change in the independent variable -- days milked and age in days in this case.

The co-variable of days milked accounted for 12, 18, 13, 13, 16 and 17 percent of the total variation of lactation yields of milk, milk fat, protein, lactose, total organic solids and total energy respectively. The partial regression coefficients were: 58.8 ± 7.7 (0.39 ± 0.05); 2.74 ± 0.32 (0.50 ± 0.06); 2.08 ± 0.26 (0.42 ± 0.05); 3.15 ± 0.40 (0.42 ± 0.05); 7.97 ± 0.93 (0.46 ± 0.05) and 22.5 ± 2.6 (0.48 ± 0.05) for the above listed yield traits in the same order. The figures in parentheses are the values of the partial regression coefficients in standard measure. The values for yield of milk fat and for yield of energy are slightly higher than for other yield traits, this was due to the increase in fat percent with advancing lactation.

The co-variable of age at parturition accounted for: 14, 14, 16, 9, 14 and 15 percent of the total variation in yields of milk, milk fat, protein, lactose, total organic solids and energy respectively. The partial regression coefficients (standard measure in parentheses) for the above listed yield traits were: 2.12 ± 0.25 (0.43 ±0.05); 0.079 ± 0.010

(0.43 ± 0.06); 0.075 ±0.008 (0.46 ± 0.05); 0.089 ± 0.013 (0.35 ± 0.05); 0.243 ± 0.030 (0.42 ± 0.05) and 0.686 ± 0.084 (0.43 ± 0.05) respectively. The regression of yields on age are all positive and are approximately the same magnitude for all yield traits in standard measure except for yield of lactose which was slightly lower than the others. This result was due to the drop in lactose percent in the milk of older cows.

Summary of Yield Traits

In summary, the Holstein and crossbred did not differ significantly in any of the yield traits studied. However, both groups produced at a significantly higher level than the Ayrshires for all yield traits.

Differences in lactation yield between Holstein and Ayrshire were 3166 lbs. of milk, 288.1 lbs. total organic solids and 702.8 mcal energy; while those between crossbred and Ayrshire were: 2615 lbs. milk, 271.4 lbs. total organic solids and 689.8 mcal energy. The partial regression coefficients of all yield traits studied on number of days milked and on age at parturition were significant and positive.

MILK COMPOSITION: RESULTS AND DISCUSSION

A summary of the results of the analyses of variance of lactation average percent milk fat, protein, lactose, and total organic solids is presented in Table 10. For the above listed traits, the statistical model accounted for 43, 28, 39, and 41 percent respectively of the total variation. The overall means, with their standard erros, and the breed group least squares constants, with their standard erros, for lactation average percent milk fat, protein, lactose, and total organic solids are presented in Table 11.

Breed Group

The effect of breed group was a significant source of variation for lactation average percent milk fat, protein, and total organic solids but not for lactation average percent lactose (Table 10). Breed group differences in lactation average percent composition are shown graphically in Figure 4.

Breed group accounted for 12% of the total variation in lactation average percent milk fat. As the interaction of breed by season was also a significant source of variation for this trait, differences among breed means were related to the season in which lactation started. The least squares means for Holstein, crossbred and Ayrshire groups were: 3.48 ± 0.05; 3.68 ± 0.04 and 3.94 ± 0.06 percent respectively. Thus the crossbred group mean was slightly below the overall mean of 3.70 ± 0.03 percent.

TABLE 10. SUMMARY OF THE ANALYSES OF VARIANCE: LACTATION AVERAGE MILK COMPOSITION.

Component	Total Fitted[1]	Total C.S.S.[2]	Main Effects[3]			Interactions[3]				Co-variables[3]		
			Br.	Sn.	Yr.	Br.XSn.	Br.XYr.	Yr.XSn.	BXSXY	Open	Milked	Age
% Fat	0.43	42.99	.12*	.09*	-	.07*	-	.07*	.03	-	0.05*	-
% Protein	.28	9.31	.10*	.02	.01	.03	-	.03	.06	-	-	-
% Lactose	.39	7.79	-	-	.09*	.04	-	.02	.02	-	.06*	.11*
% TOS	.41	78.83	.12*	.07*	-	.06*	-	.07*	.04	-	.07*	-
Deg. of Freedom	38	237	2	5	1	10	2	5	10	1	1	1

1 Fraction of the total sums of squares accounted for by fitting the effects in the statistical model (R^2).

2 Total corrected sums of squares.

3 Fraction of the total sums of squares accounted for by each effect in the statistical model (values less than 0.01 are not shown).

* Significant source of variation.

TABLE 11

OVERALL MEANS AND BREED GROUP LEAST SQUARES CONSTANTS:
LACTATION AVERAGE PERCENT MILK COMPOSITION

Component	Overall Mean ± S.E.	Least Squares Constants ± S.E.		
		Holstein	Crossbred	Ayrshire
% Fat *	3.70 ± 0.029	- 0.22 ± 0.040	- 0.02 ± 0.40	0.24 ± 0.042
% Protein	3.44 ± .015	- .11 ± .021[b]	.02 ± .021[a]	.09 ± .022[a]
% Lactose[n.s.]	4.95 ± .013	.00 ± .018	.01 ± .017	- .01 ± .018
% T.O.S.*	12.09 ± .040	- .33 ± .055	.01 ± .054	.31 ± .058

* Breed group was a significant source of variation but Duncan's test was not used to test the breed means because the breed by season interaction was also significant.

a,b Constants superscripted by the same letter are not significantly different from each other by Duncan's test.

n.s. Differences among breed means not significant by the analysis of variance.

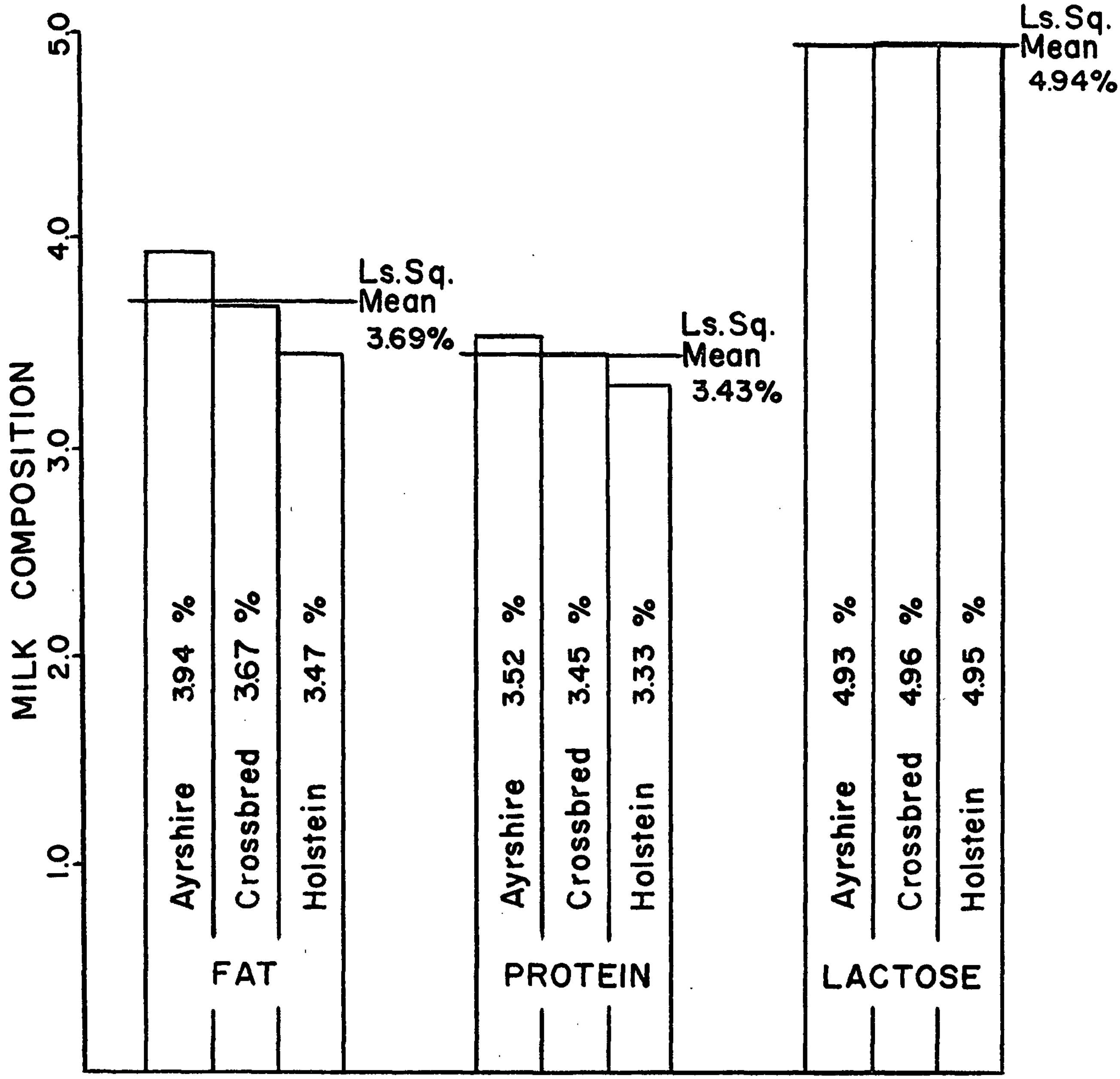

FIGURE 4. Lactation average percent milk fat, protein and lactose for the three breed groups.

For lactation average percent protein, breed group was the only category in the statistical model that was significant. This effect accounted for 10% of the total variation (Table 10) in percent protein. Duncan's test showed that the crossbred and Ayrshire breed groups did not differ significantly in lactation average percent protein, but both groups were significantly higher for this trait than the Holsteins. The least squares means for the Holstein, crossbred and Ayrshire groups were: 3.33 ± 0.026; 3.46 ± 0.023; and 3.53 ± 0.029 percent respectively. The overall least squares mean was 3.44 ± 0.015 percent (Table 11).

Breed group accounted for 12% of the variation of lactation average total organic solids. The breed season interaction was also a significant source of variation, as it was in the case of percent milk fat. The breed group least squares means for Holstein, crossbred and Ayrshire were: 11.76 ± 0.07, 12.10 ± 0.06 and 12.40 ± 0.08 percent respectively. The overall mean was 12.04 ± 0.04 percent.

<u>Season of Calving</u>

Season of calving was a significant source of variation for lactation average percent milk fat, and total organic solids but not for lactation average percent protein or lactose (Table 10). The season of calving least squares constants for lactation average milk composition are reported in Table 12.

Season of calving accounted for 9% of the total

TABLE 12. SEASON LEAST SQUARES CONSTANTS: LACTATION AVERAGE PERCENT MILK COMPOSITION

Component	Least Squares Constants ± S.E.					
	Feb-Mar	Apr-May	Jun-Jul	Aug-Sep	Oct-Nov	Dec-Jan
% Milk fat*	-0.18 ± .05	-0.18 ± .05	0.05 ± .05	0.27 ± .08	0.12 ± .08	-0.08 ± .08
% Protein[n.s.]	-0.01 ± .03	0.0 ± .03	-0.02 ± .03	0.10 ± .04	-0.02 ± .04	-0.05 ± .04
% Lactose[n.s.]	-0.01 ± .02	-0.01 ± .02	0.02 ± .03	0.0 ± .04	0.03 ± .03	0.03 ± .03
% TOS*	-0.21 ± .07	-0.20 ± .07	0.05 ± .08	0.37 ± .11	0.08 ± .10	-0.09 ± .10

* Season by calving was a significant source of variation but Duncan's test was not used to test season means because year by season and breed by season interactions were significant.

n.s. Differences among season means not significant by the analyses of variance.

variation of lactation average percent milk fat. Cows calving in the summer and autumn had higher lactation average percent fat than cows calving in the winter and spring. However, the first order interactions of breed by season and year by season were both significant sources of variation. Therefore the effect of season of calving on this trait differed among the three breed groups and between the two years considered in this study.

Season of freshening accounted for 7% of the variation of lactation average percent total organic solids. The seasonal affect was similar to that for percent milk fat and the first order interactions of breed by season and year by season were significant sources of variation (as was the case for percent milk fat).

Season of freshening was not a significant source of variation for lactation average percent milk protein. However, the trend was for cows calving in August-September to have the highest percent protein (this was also the high season for percent milk fat). The second highest season for percent protein was April-May which was the lowest for percent fat. This result may be indicative of a trend for spring grazing to increase percent protein but to lower percent milk fat (while increasing milk yields) as reported by Waite (38).

Year

Year least squares constants, with their standard errors, for lactation average milk composition are presented in Table 13. Year was a significant source of variation for lactation average percent lactose and accounted for 9% of the total variation. Lactation average percent lactose increased from 4.88 $\pm$ 0.019 in the first year to 5.02 $\pm$ 0.017 in the second year. Year was not a significant source of variation of lactation average percent milk fat, protein or total organic solids.

Breed by Season Interaction

Breed by season interaction was a significant source of variation for lactation average percent milk fat and total organic solids, and accounted for 7 and 6% respectively of the total variation of these two traits.

The breed season interaction constants and the subclass means (as deviations from the overall mean) for lactation average percent milk fat are shown in Table 14 and the subclass means are graphed in Figure 5. The subclass means (as deviations from the overall mean) were computed by summing the appropriate constants for the effects of; breed, season, and breed by season interaction.

Three of the breed season interaction constants were significantly different from zero by a t-test (Table 14). These were the constants associated with; 1) Holsteins calving in April-May, 2) Holsteins calving in August-September, and 3) crossbreds calving in February-March. The interaction constants associated; with crossbreds calving in December-January and in August-September and with Ayrshires calving

TABLE 13

YEAR LEAST SQUARES CONSTANTS:
LACTATION AVERAGE PERCENT MILK COMPOSITION

Component	1967-68 ± S.E.	1968-69 ± S.E.
% Fat n.s.	-0.015 ± 0.029	0.015 ± 0.029
% Protein n.s.	0.026 ± 0.015	-0.026 ± 0.015
% Lactose *	-0.068 ± 0.013	0.068 ± 0.013
% T.O.S. n.s.	-0.057 ± 0.040	0.057 ± 0.040

n.s. Differences between years not significant by the analysis of variance.

* Differences between years were significant by the analysis of variance.

TABLE 14. BREED BY SEASON INTERACTION LEAST SQUARES CONSTANTS AND SUBCLASS MEANS, AS DEVIATIONS FROM THE OVERALL MEAN: LACTATION AVERAGE PERCENT MILK FAT.

Season	A. Least Squares Constant ± S.E.			B. Subclass means[1] ± S.E.		
	Holstein	Crossbred	Ayrshire	Holstein[n.s.]	Crossbred	Ayrshire
Feb - Mar	.07 ± .07	-.17 ± .07*	.10 ± .07	-.33 ± .09	-.37 ± .10[b]	.15 ± .08[ab]
Apr - May	.16 ± .06*	-.08 ± .07	-.08 ± .07	-.25 ± .06	-.28 ± .08[b]	-.02 ± .09[b]
Jun - Jul	.01 ± .07	.12 ± .08	-.13 ± .08	-.17 ± .09	.13 ± .10[a]	.17 ± .12[ab]
Aug - Sep	-.22 ± .10*	.19 ± .12	.03 ± .14	-.17 ± .10	.44 ± .15[a]	.55 ± .20[a]
Oct - Nov	.00 ± .12	.13 ± .09	-.13 ± .10	-.10 ± .19	.24 ± .12[a]	.23 ± .13[ab]
Dec - Jan	-.02 ± .10	-.19 ± .12	.21 ± .11	-.32 ± .11	-.29 ± .17[b]	.37 ± .14[a]

1 As deviations from the overall mean.

* Constant differed significantly from zero by a t-test.

n.s. Means in this column are not significantly different from each other by Duncan's test.

a,b, Means in the same column superscripted by the same letter are not significantly different from each other by Duncan's test.

Means in the same row underlined by the same line are not significantly different from each other by Duncan's test.

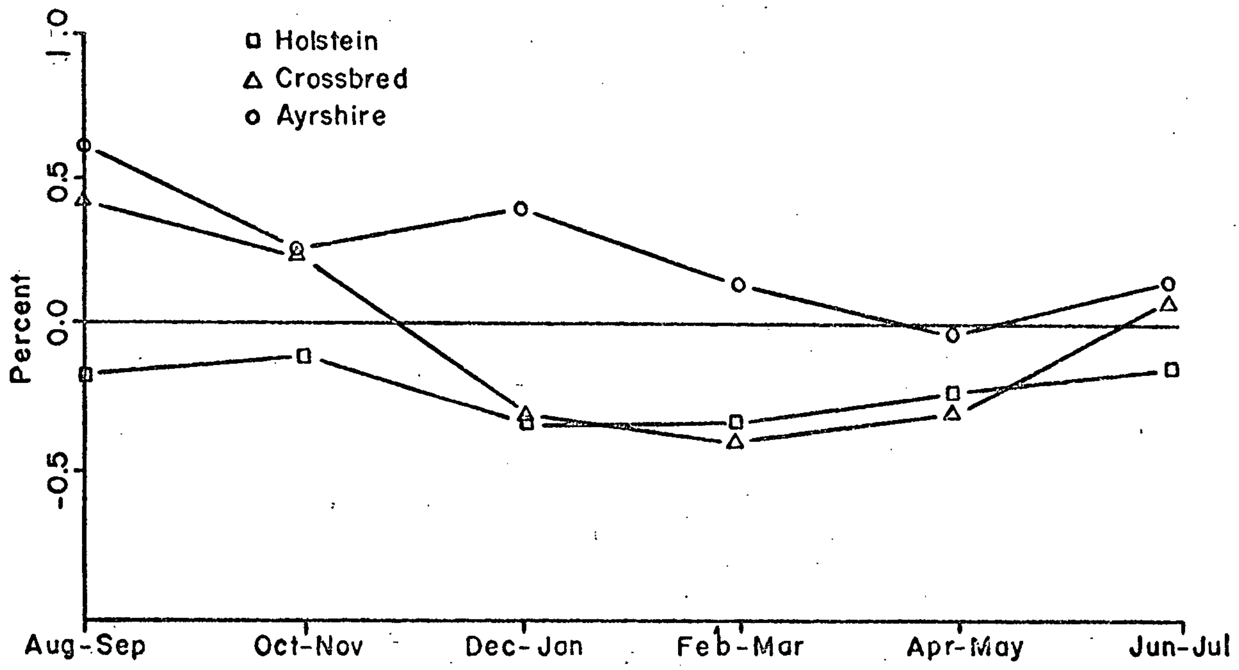

FIGURE 5. Breed-season subclass means, as deviations from the overall mean, for lactation average percent milk fat.

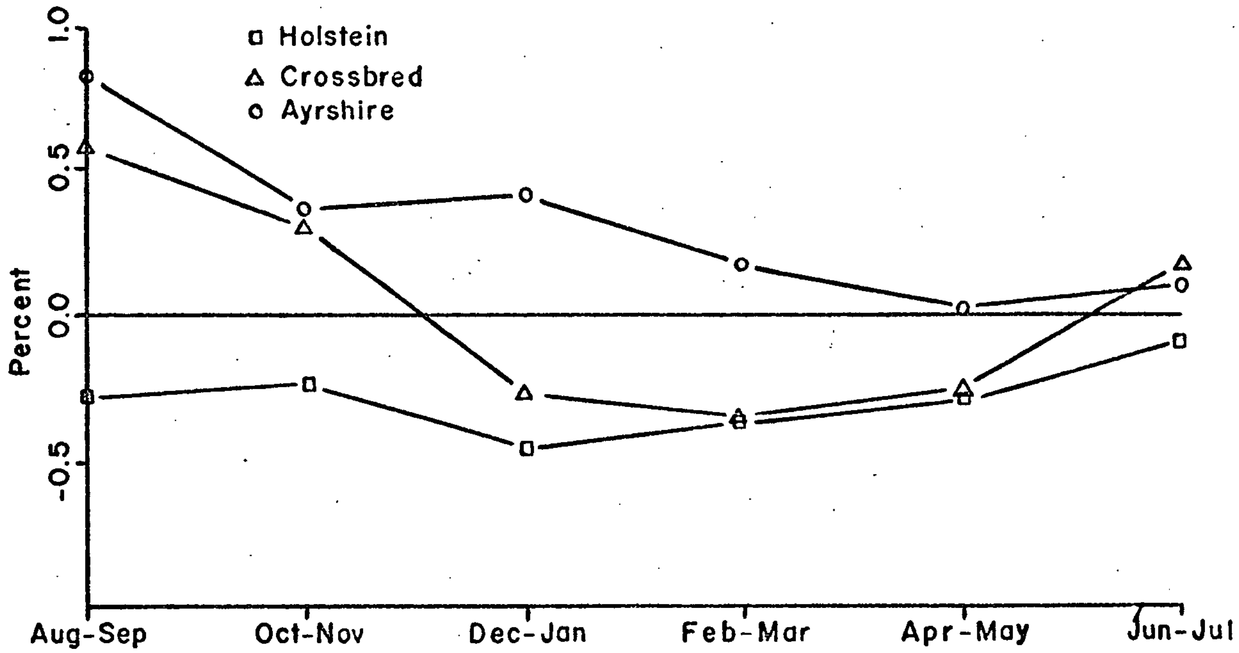

FIGURE 6. Breed-season subclass means, as deviations from the overall mean, for lactation average percent total organic solids.

in December-January, while not significantly different from zero were relatively large (in absolute value).

In order to determine the effect of season of calving on lactation average percent milk fat for each breed group, Duncan's test was applied to the season subclass means of each breed separately (Table 14). The Holstein seasonal means were not significantly different from each other. For crossbreds, summer and autumn (June to November inclusive) calving was associated with significantly higher percent milk fat levels than winter and spring (December to May inclusive) calving. Differences among Ayrshire seasonal means, within each of the following groups of means, were not significant: 1) August-September, December-January, October-November, June-July, and February-March; 2) October-November, June-July, February-March, and April-May. Significantly higher lactation average percent milk fat was associated with Ayrshires calving in August-September and December-January than in April-May (Table 14).

Duncan's test on the breed group means, for each season, showed that: 1) in June-July and August-September, differences between crossbred and Ayrshire means were not significant but both means were significantly higher than the Holstein; 2) in December-January, February-March, and April-May differences between Holstein and crossbred means were not significant, but both means were significantly lower than the Ayrshire; 3) in October-November differences among means of the three breed groups were not significant (Table 14).

The breed season interaction constants and subclass means (as deviations from the overall mean) for lactation average percent total organic solids are shown in Table 15 and graphed in Figure 6. The constants associated with Holsteins calving in April-May and in August-September and with Ayrshires in June-July were significantly different from zero by a t-test.

Holstein seasonal means (percent total organic solids) were not significantly different from each other. Differences among crossbred seasonal means, within each of the following groups of means, were not significant: 1) August-September, October-November and June-July; 2) June-July and December-January; 3) December-January, April-May and February-March. The following comparisons of crossbred seasonal means were significant: 1) August-September and October-November higher than December-January, April-May, and February-March; 2) June-July higher than April-May and February-March.

Differences among Ayrshire seasonal means, within each of the following groups of means, were not significant: 1) August-September, December-January, and October-November; 2) December-January, October-November, February-March, June-July, and April-May. The Ayrshire mean (percent total organic solid) for August-September calving was significantly

TABLE 15. BREED BY SEASON INTERACTION LEAST SQUARES CONSTANTS AND SUBCLASS MEANS, AS DEVIATIONS FROM THE OVERALL MEAN: LACTATION AVERAGE PERCENT TOTAL ORGANIC SOLIDS.

Season	A. Least Squares Constant ± S.E.			B. Subclass means[1] ± S.E.		
	Holstein	Crossbred	Ayrshire	Holstein[n.s.]	Crossbred	Ayrshire
Feb - Mar	.14 ± .10	-.19 ± .10	.05 ± .09	-.40 ± .12	-.39 ± .14[c]	.16 ± .11[b]
Apr - May	.21 ± .08*	-.10 ± .10	.11 ± .09	-.31 ± .09	-.29 ± .12[c]	.00 ± .13[b]
Jun - Jul	.16 ± .10	.10 ± .11	-.26 ± .12*	-.11 ± .12	.17 ± .13[ab]	.10 ± .17[b]
Aug - Sep	-.33 ± .14*	.17 ± .16	.16 ± .18	-.29 ± .14	.56 ± .21[a]	.84 ± .28[a]
Oct - Nov	-.16 ± .17	.20 ± .12	-.04 ± .14	-.24 ± .26	.29 ± .12[a]	.34 ± .17[ab]
Dec - Jan	-.02 ± .14	-.18 ± .16	.20 ± .15	-.44 ± .16	-.26 ± .23[bc]	.42 ± .20[ab]

1 As deviations from the overall mean.

* Constant differed significantly from zero by a t-test.

n.s. Means in this column are not significantly different from each other by Duncan's test.

a,b,c Means in the same column superscripted by the same letter are not significantly different from each other by Duncan's test.

Means in the same row underlined by the same line are not significantly different from each other by Duncan's test.

greater than the Ayrshire means for: February-March, June-July, and April-May (Table 15).

Duncan's test on the breed group means (percent total organic solids) for each season showed that: 1) in August-September and October-November, crossbred and Ayrshire means did not differ significantly but were significantly higher than Holstein; 2) in December-January, February-March, and April-May, Holstein and crossbred means did not differ significantly but were significantly lower than Ayrshire; 3) in June-July, differences among the means of the three breed groups were not significant.

Year by Season Interaction

Year by season interaction was a significant source of variation of lactation average milk fat and total organic solids, and accounted for 7% of the total variation in each of these traits.

The year season interaction constants and subclass means (as deviations from the overall mean) for lactation average percent milk fat are shown in Table 16 and graphed in Figure 7. The interaction constants in the two seasons of December-January and February-March were significantly different from zero by a t-test (Table 16). Thus differences in response to season of freshening between the two years occurred in the winter months.

For the first year (August 1967 to July 1968) the effect of season of calving on lactation average per cent

TABLE 16. YEAR BY SEASON INTERACTION LEAST SQUARES CONSTANTS AND SUBCLASS MEANS, AS DEVIATIONS FROM THE OVERALL MEAN: LACTATION AVERAGE PERCENT MILK FAT.

Season	A. Least Squares Constant ± S.E.		B. Subclass Means[1] ± S.E.	
	1967 - 68	1968 - 69	1967 - 68	1968 - 69
Feb - Mar	-.18 ± .05*	.18 ± .05*	-.38 ± .08[c]	.02 ± .08[a]
Apr - May	.07 ± .05	-.07 ± .05	-.13 ± .07[b]	-.26 ± .08[b]
Jun - Jul	.08 ± .06	-.08 ± .06	.11 ± .08[a]	-.01 ± .09[a]
Aug - Sep	.13 ± .18	-.13 ± .18	.39 ± .13[a]	.16 ± .11[a]
Oct - Nov	.08 ± .07	-.08 ± .07	.19 ± .13[a]	.02 ± .09[a]
Dec - Jan	-.18 ± .08*	.18 ± .08*	-.27 ± .11[bc]	.11 ± .12[a]

1 As deviations from the overall mean.

* Constant differed significantly from zero by a t-test.

a,b,c. Means in the same column superscripted by the same letter are not significantly different from each other by Duncan's test.

Means (in the same row) that are not underlined are significantly different by a t-test.

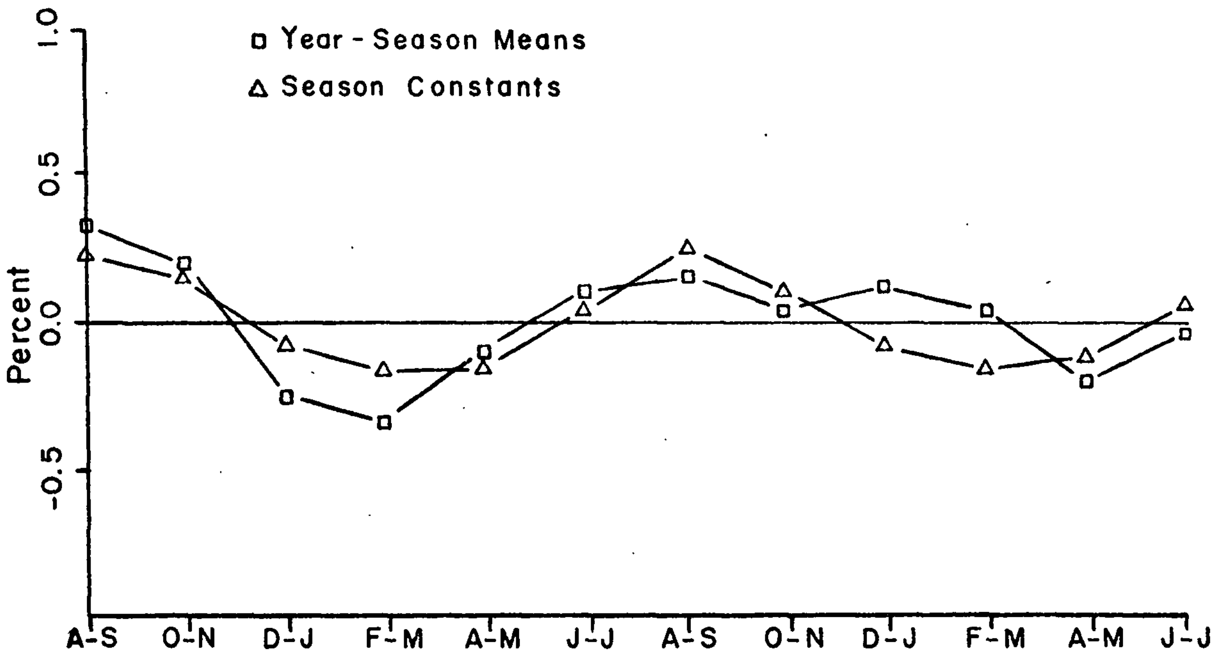

FIGURE 7. Year-season subclass means, as deviations from the overall mean, for lactation average percent milk fat. Season of freshening constants are also plotted.

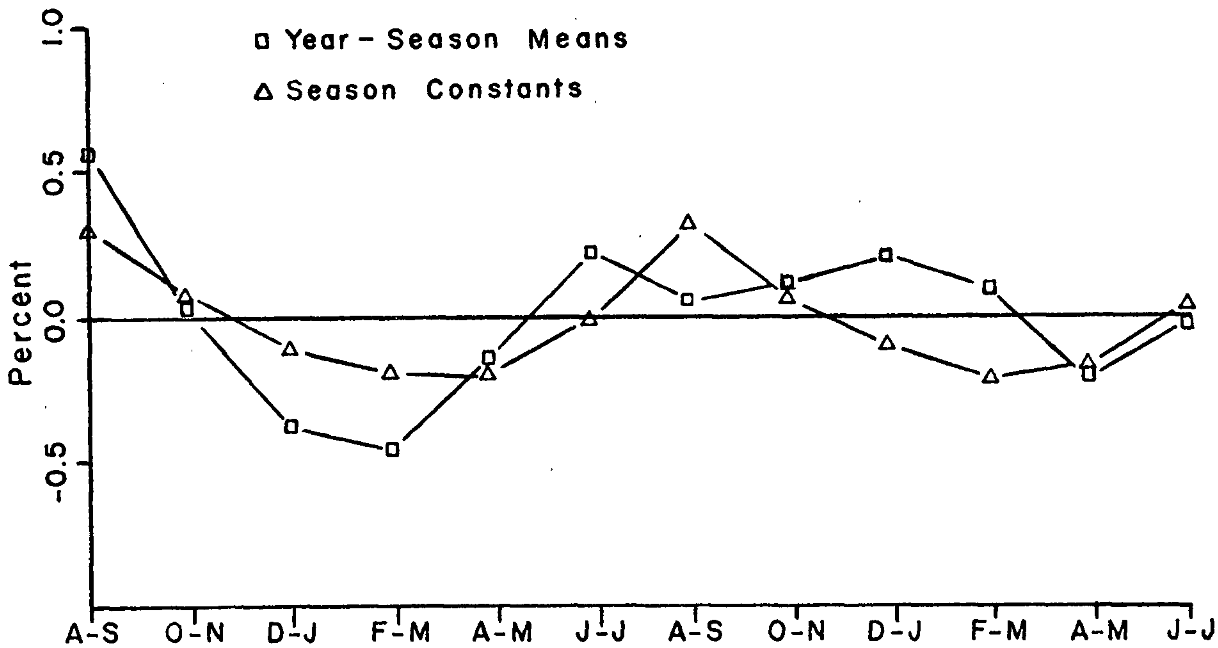

FIGURE 8. Year-season subclass means, as deviations from the overall mean, for lactation average percent total organic solids. Season of freshening constants are also plotted.

milk fat was: 1) cows calving from June to November inclusive did not differ significantly, but were higher in percent milk fat than cows calving at other times of the year; 2) cows calving in April-May did not differ significantly from cows calving in December-January but were significantly higher in percent milk fat than cows calving in February-March; and 3) cows calving in December-January did not differ significantly in percent milk fat from cows calving in February-March. For the second year (August 1968 to July 1969) cows calving in April-May were significantly lower in percent milk fat than cows calving at other times of the year; cows calving at other seasons of this year did not differ significantly in average percent fat (Table 16).

A t-test was used to test differences between corresponding seasons in the two years for significance. Cows calving in February-March and December-January of the second year were significantly higher in average percent milk fat than cows calving in these two seasons in the first year. The differences between years for each of the other four seasons were not significant (Table 16). However, the trend was for slightly lower percent milk fat in each of these seasons in the second year, than in the corresponding seasons of the first year. As the second order interaction was not a significant source of variation, breed response to season of freshening was relatively consistent across both years.

The year season interaction constants and subclass means (as deviations from the overall mean) for lactation average percent total organic solids are shown in Table 17 and graphed in Figure 8.

For the first year (August 1967 to July 1968 inclusive) Duncan's test (Table 17) showed that: 1) cows calving August-September did not differ significantly in percent total organic solids from cows calving in June-July and in October-November but were significantly higher than cows calving at other times of the year; 2) cows calving June-July and October-November did not differ significantly in percent total organic solids from cows calving in April-May but were significantly higher than cows calving December-January and February-March; 3) cows calving April-May did not differ significantly in percent total organic solids from cows calving in December-January but were significantly higher than cows calving in February-March and 4) cows calving December-January did not differ significantly in percent total organic solids from cows calving in February-March. For the second year in this study (August 1968 to July 1969 inclusive) season of calving did not have a significant effect on lactational average percent total organic solids.

The t-test indicated that cows calving in February-March and in December-January of the second year were significantly higher in lactation average percent total organic solids than cows calving in these two seasons in the first year.

TABLE 17. YEAR BY SEASON INTERACTION LEAST SQUARES CONSTANTS AND SUBCLASS MEANS, AS DEVIATIONS FROM THE OVERALL MEAN: LACTATION AVERAGE PERCENT TOTAL ORGANIC SOLIDS.

Season	A. Least Squares Constant ± S.E.		B. Subclass Means[1] ± S.E.	
	1967 - 68	1968 - 69	1967 - 68	1968 - 69[n.s.]
Feb - Mar	-.24 ± .07*	.24 ± .07*	-.51 ± .11[d]	.09 ± .11
Apr - May	.09 ± .07	-.09 ± .07	-.17 ± .09[bc]	-.23 ± .11
Jun - Jul	.12 ± .08	-.12 ± .08	.24 ± .09[ab]	-.01 ± .12
Aug - Sep	.26 ± .12	-.26 ± .12	.58 ± .18[a]	.06 ± .15
Oct - Nov	.01 ± .10	-.01 ± .10	.03 ± .18[ab]	.12 ± .12
Dec - Jan	-.24 ± .11*	.24 ± .11*	-.39 ± .15[cd]	.21 ± .16

1 As deviations from the overall mean.

* Constant differed significantly from zero by a t-test.

n.s. Means in this column are not significantly different from each other by Duncan's test.

a,b,c,d. Means in the same column superscripted by the same letter are not significantly different from each other by Duncan's test.

Means (in the same row) that are not underlined are significantly different by a t-test.

The differences between years for each of the other four seasons were not significant (Table 17).

Days Milked and Age at Parturition

The co-variable of days milked was a significant source of variation for lactation average percent milk fat, lactose, and total organic solids. Age at parturition was a significant source of variation for lactation average percent lactose. The significant partial and standard partial regression coefficients are shown in Table 18.

Days milked accounted for 5% of the total variation in lactation average percent fat. The partial regression coefficient was positive and the value was 0.27 ± 0.06 in standard measure and 0.0055 ± 0.0013 in percent; indicating an increase in lactation average milk fat percent with an increase in lactation length.

Days milked and age at parturition were both significant effects on lactation average percent lactose and accounted for 6% and 11% respectively of the total variation in this trait. The partial regression coefficient of lactation average percent lactose on number of days milked was positive; 0.28 ± 0.06 in standard measure and 0.0024 ± 0.0006 in percent; indicating an increase of percent lactose with advancing lactation. This finding does not agree with reports in the literature; Robertson *et al*. (32) showed that, within a lactation, lactose tends to rise from parturition until approximately the 45th day of lactation after which time it

TABLE 18

PARTIAL AND STANDARD PARTIAL REGRESSION COEFFICIENTS[1]: LACTATION AVERAGE PERCENT COMPOSITION ON DAYS MILKED AND AGE AT PARTURITION

Component	DAYS MILKED		AGE	
	Percent (x 10^{-3}) ± S.E.	Stan. Meas. ± S.E.	Percent (x 10^{-3}) ± S.E.	Stan. Meas. ± S.E.
% Fat	5.5 ± 1.5	0.27 ± 0.06	-	-
% Lactose	2.4 ± 0.6	0.28 ± 0.06	-0.11 ± 0.02	-0.37 ± 0.06
% T.O.S.	8.5 ± 1.7	0.31 ± 0.06	-	-

1 Only significant regression coefficients are shown.

slowly declines until late lactation when further drops can be fairly steep. The discrepancy between the findings in this study and those reported in the literature could be explained if year effects were gradual and continuous across time due to changing environment or management (for example lower levels of mastitis) and these influences tended to alter normal lactational changes.

The regression of lactation average percent lactose on age of the cow at parturition was significant and negative; indicating a decline in percent lactose in milk produced by older cows. The partial regression coefficient was -0.37 ± 0.006 in standard measure and -0.00011 ± 0.00002 in percent. Reports in the literature indicate that percent lactose declines as the age of the cow increases. (2,15,38).

Days milked was a significant source of variation for lactation average total organic solids and accounted for 7% of the total variation. The partial regression coefficient was 0.31 ± 0.06 in standard measure and 0.0085 ± 0.0017 in percent (Table 18).

The co-variable of days milked was not a significant source of variation of lactation average percent protein. Reports in the literature (3, 38) indicated that percent protein increased in late lactation in a manner similar to the lactation trend for percent milk fat, in which case the expected result would be that days milked would have a significant effect on lactation average percent protein (as was the case with percent fat). However Bailey (3) reported that the increase in percent protein usually observed after 180-200 days in lactation was associated with pregnancy, and this increase did not occur in barren cows. Cows in the present study were open for an unusually long period of time (Table 3), which may explain the non significant effect of days milked on lactation average percent protein.

<u>Summary of Milk Composition</u>

Breed group was a significant source of variation for lactation average percent milk fat, protein, and total organic solids, but not for percent lactose.

For percent protein, Ayrshire and crossbred means did not differ significantly, but both breed group means were significantly higher than the Holstein. Breed group was the only significant affect on lactation average percent protein.

Differences in lactational average percent milk fat and total organic solids among the breed groups were related to the season in which lactation started. In general, Ayrshire means were higher than Holstein for all seasons; crossbred means (winter calving) did not differ significantly from Holstein, and crossbred means (summer calving) did not differ significantly from Ayrshire.

Season, breed by season, and year by season were significant sources of variation for percent milk fat and percent total organic solids. Differences among Holstein seasonal means were not significant. Crossbreds and Ayrshires (with the exception of Ayrshires calving in December-January) calving in the summer tended to have higher percentages than winter and spring calvers. Differences between summer and winter calving was greater for crossbreds than for Ayrshires.

Less variation was associated with season of calving in the second year than in the first year. Means of cows calving in the winter of the second year were higher in percent milk fat and percent organic solids than cows calving in the winter of the first year.

An increase in the number of days milked was associated with a significant increase in lactation average percent milk fat, lactose and total organic solids. A significant decline in lactation average percent lactose was associated with increased age of the cow.

ENERGY RELATIONSHIPS: RESULTS AND DISCUSSION

A summary of the results of the analyses of variance of 1) percent milk energy as; milk fat, protein and lactose; 2) ratio of milk fat to protein; and 3) energy concentration of milk (in kcal. per pound) is presented in Table 19. For the above listed traits the statistical model accounted for 39, 35, 40, 36, and 43 percent respectively of the total variation of each trait. The overall means, with their standard errors, and the breed group least squares constants, with their standard errors are presented in Table 20.

Breed Group

Breed group was a significant source of variation for percent milk energy as; milk fat and lactose, but not for percent energy as protein. Breed group means of these three traits are shown graphically in Figure 9. Breed group was also a significant source of variation for the ratio of milk fat to protein and for the energy concentration of milk.

Nine percent of the total variation of percent energy as milk fat was accounted for by breed group. Since the interaction of breed by season was also a significant source of variation for this trait, differences among breed means were related to the season in which lactation started. The least squares means for Holstein, crossbred and Ayrshire groups were; 44.7 ± 0.32, 45.5 ± 0.30 and 47.2 ± 0.36 percent energy as fat respectively. The overall mean was 45.8 ± 0.19 percent.

TABLE 19. SUMMARY OF THE ANALYSES OF VARIANCE: ENERGY RELATIONSHIPS

Trait	Total Fitted[1]	Total C.S.S.[2]	Main Effects[3] Br.	Sn.	Yr.	Br.XSn.	Interactions[3] Br.XYr.	Yr.XSn.	BXSXY	Co-variables[3] Open	Milked	Age
Percent of energy as:												
a. Fat	0.39	1.76×10^3	0.09*	0.09*	-	0.07*	-	0.06*	0.03	-	0.04*	-
b. Protein	.35	5.39×10^2	.01	.07*	.03*	.07*	-	.04	.04	-	.05*	-
c. Lactose	.40	7.90×10^2	.12*	.06*	.01	.04	-	.05*	.03	-	.01	.03*
Fat/Prot. ratio	.36	2.95	.05*	.09*	.01	.08*	-	.05*	.04	-	.05*	-
Energy/lb. milk	.43	1.03×10^5	.13*	.08*	-	.06*	-	.07*	.04	-	.06*	-
Deg. of Freedom	38	237	2	5	1	10	2	5	10	1	1	1

1 Fraction of the total sums of squares accounted for by fitting the effects in the statistical model (R^2).

2 Total corrected sums of squares.

3 Fraction of the total sums of squares accounted for by each effect in the statistical model (values less than 0.01 are not shown).

* Significant source of variation.

TABLE 20

OVERALL MEANS AND BREED GROUP LEAST SQUARES CONSTANTS: ENERGY RELATIONSHIPS

Trait	Overall Mean ± S.E.	Least Squares Constants ± S.E.		
		Holstein	Crossbred	Ayrshire
Percent Energy as:				
a. Fat *	45.8 ± 0.19	-1.12 ± 0.26	-0.26 ± 0.26	1.38 ± 0.28
b. Protein [n.s.]	27.5 ± .11	0.15 ± 0.15	0.17 ± 0.15	-0.33 ± 0.16
c. Lactose	26.7 ± .13	0.97 ± 0.17[a]	0.08 ± 0.17[b]	-1.05 ± 0.18[c]
Fat/Protein ratio*	1.08 ± .008	-0.030 ± 0.011	-0.013 ± 0.011	0.043 ± 0.012
Energy (kcal)/ lb. milk*	332.9 ± 1.4	-11.9 ± 2.0	-0.10 ± 1.9	12.0 ± 2.1

* Breed group was a significant source of variation but Duncan's test was not used to test breed means because the breed by season interaction was also significant.

a,b,c Constants superscripted by the same letter are not significantly different from each other by Duncan's test.

n.s. Differences among breeds not significant by the analysis of variance.

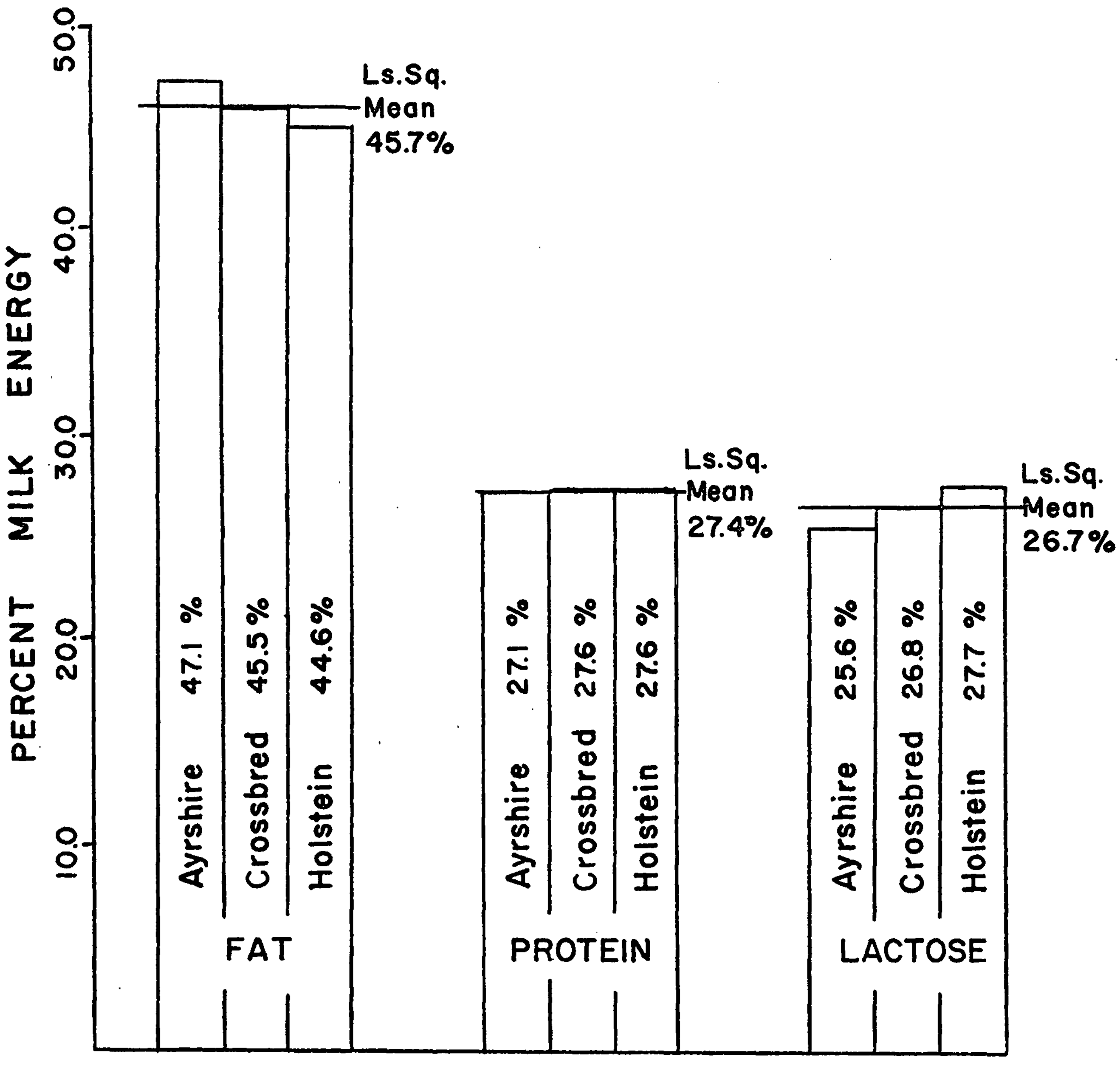

FIGURE 9. Lactation average percent milk energy as; milk fat, protein and lactose for the three breed groups.

Breed group accounted for 12 percent of the total variation in percent milk energy as lactose. The least squares breed group means were; 27.7 ± 0.22, 26.8 ± 0.20 and 25.6 ± 0.24 percent for Holstein, crossbred and Ayrshire respectively. The overall least squares mean was 26.7 ± 0.13 percent. Duncan's test showed that all the three breed group means differed significantly from each other.

The effect of breed group accounted for 5 percent of the total variation of the ratio of milk fat to protein. The breed by season interaction was also a significant source of variation. The least squares means for Holstein, crossbred and Ayrshire groups were; 1.05 ± 0.014, 1.07 ± 0.012 and 1.12 ± 0.15 respectively. The overall least squares mean was 1.08 ± 0.008.

Breed group accounted for 13 percent of the total variation of energy concentration of milk. Breed by season interaction was also a significant source of variation. The least squares means for Holstein, crossbred and Ayrshire groups were; 321.0 ± 2.41, 332.8 ± 2.21 and 344.9 ± 2.72 kilocalories per pound of milk. The overall least squares mean was 332.9 ± 1.4 kilocalories per pound of milk.

Season of Calving

Season of calving was a significant source of variation of: 1) percent milk energy as; milk fat, protein, and lactose; 2) ratio of milk fat to protein; and 3) energy concentration of milk. For these traits season of calving accounted for: 9, 7, 6, 9, and 8 percent respectively of the total variation. Since breed by season or year by season (or both) interactions were also significant sources of variation for each of the above listed traits, season responses varied both by breed and by year. The season least squares constants are shown in Table 21.

<u>Year of Calving</u>

Year least squares constants, with their standard errors, for energy relationships are shown in Table 22.

Year of lactation start was a significant source of variation for percent milk energy as protein and accounted for 3 percent of the total variation. The least squares mean for the first year (August 1967 to July 1968) was 27.8 $\pm$ 0.20 percent, but in the second year it declined to 27.2 $\pm$ 0.25 percent. This decline was attributed to an increase (non sig.) from the first year to the second year in lactation average percent milk fat and lactose; and a decrease (non sig.) in percent protein.

<u>Breed by Season Interaction</u>

The interaction of breed by season was a significant source of variation for: 1) percent milk energy as; milk fat, and protein; 2) ratio of milk fat to protein; and 3) energy concentration of milk.

Breed by season interaction accounted for 7 percent of the total variation of percent milk energy as milk fat. The least squares constants and subclass means (as deviations from the overall mean) are shown in Table 23 and the subclass means are graphed in Figure 10.

TABLE 21. SEASON LEAST SQUARES CONSTANTS: ENERGY RELATIONSHIPS

Trait	Least Squares Constants ± S.E.					
	Feb-Mar	Apr-May	Jun-Jul	Aug-Sep	Oct-Nov	Dec-Jan
% Energy as:						
a. Milk fat*	-1.20 ± .34	-1.15 ± .32	0.37 ± .39	1.44 ± .55	0.95 ± .50	-0.41 ± .51
b. Protein*	0.61 ± .20	0.62 ± .18	-0.32 ± .22	-0.37 ± .32	-0.46 ± .28	-0.08 ± .29
c. Lactose*	0.59 ± .23	0.52 ± .21	-0.05 ± .26	-1.06 ± .37	-0.48 ± .33	0.48 ± .34
Fat/Prot. ratio*	-0.050± .014	-0.051± .013	.018± .016	.047± .023	.041± .021	-0.006± .021
Energy (kcal)/ lb. Milk*	-8.10 ±2.56	-7.89 ±2.38	1.99 ±2.90	13.94 ±4.10	4.06 ±3.70	-4.01 ±3.70

* Season of calving was a significant source of variation but Duncan's test was not used to test season means because year by season and/or breed by season interactions were significant.

TABLE 22

YEAR LEAST SQUARES CONSTANTS:
ENERGY RELATIONSHIPS

Trait	1967-68 ± S.E.		1968-69 ± S.E.	
Percent Energy as:				
a. Fat n.s.	-0.080	± 0.192	0.080	± 0.192
b. Protein *	0.324	± 0.110	-0.324	± 0.110
c. Lactose n.s.	-0.244	± 0.128	0.244	± 0.128
Fat/Protein ratio n.s.	-0.0132	± 0.0081	0.0132	± 0.0081
Energy (kcal) lb. Milk n.s.	-1.15	± 1.44	1.15	± 1.44

n.s. Differences between years not significant by the analysis of variance.

* Differences between years significant by the analysis of variance.

TABLE 23. BREED BY SEASON INTERACTION LEAST SQUARES CONSTANTS AND SUBCLASS MEANS, AS DEVIATIONS FROM THE OVERALL MEAN: PERCENT ENERGY AS MILK FAT.

Season	A. Least Squares Constant ± S.E.			B. Subclass means[1] ± S.E.		
	Holstein	Crossbred	Ayrshire	Holstein$^{n.s.}$	Crossbred	Ayrshire$^{n.s.}$
Feb - Mar	.23 ± .48	-1.07 ± .50*	.84 ± .48	-2.09 ± .58	-2.52 ± .66^{b}	1.02 ± .54
Apr - May	.90 ± .41*	- .54 ± .46	-.35 ± .48	-1.34 ± .41	-1.95 ± .58^{b}	- .12 ± .60
Jun - Jul	-.48 ± .49	.85 ± .52	-.37 ± .58	-1.01 ± .56	.96 ± .64^{a}	1.38 ± .80
Aug - Sep	-1.00 ± .67	1.37 ± .77	-.37 ± .89	-1.08 ± .66	2.55 ±1.01^{a}	2.44 ±1.34
Oct - Nov	.50 ± .81	.72 ± .60	-1.22 ± .67	.33 ±1.26	1.41 ± .57^{a}	1.10 ± .82
Dec - Jan	- .14 ± .66	-1.34 ± .77	1.48 ± .73*	-1.67 ± .74	-2.00 ±1.09^{b}	2.45 ± .95

1 As deviations from the overall mean.

* Constant differed significantly from zero by a t-test.

n.s. Means in this column are not significantly different from each other by Duncan's test.

a,b. Means in the same column superscripted by the same letter are not significantly different from each other by Duncan's test.

Means in the same row underlined by the same line are not significantly different from each other by Duncan's test.

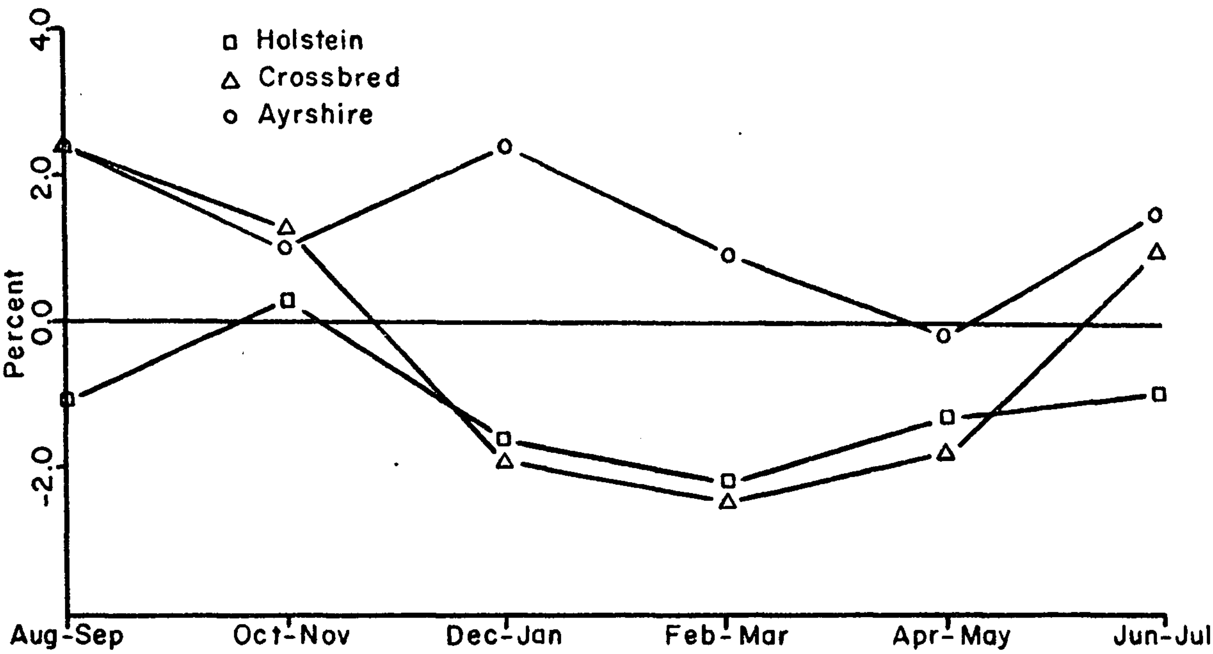

FIGURE 10. Breed-season least squares means, as deviations from the overall mean, for percent milk energy as milk fat.

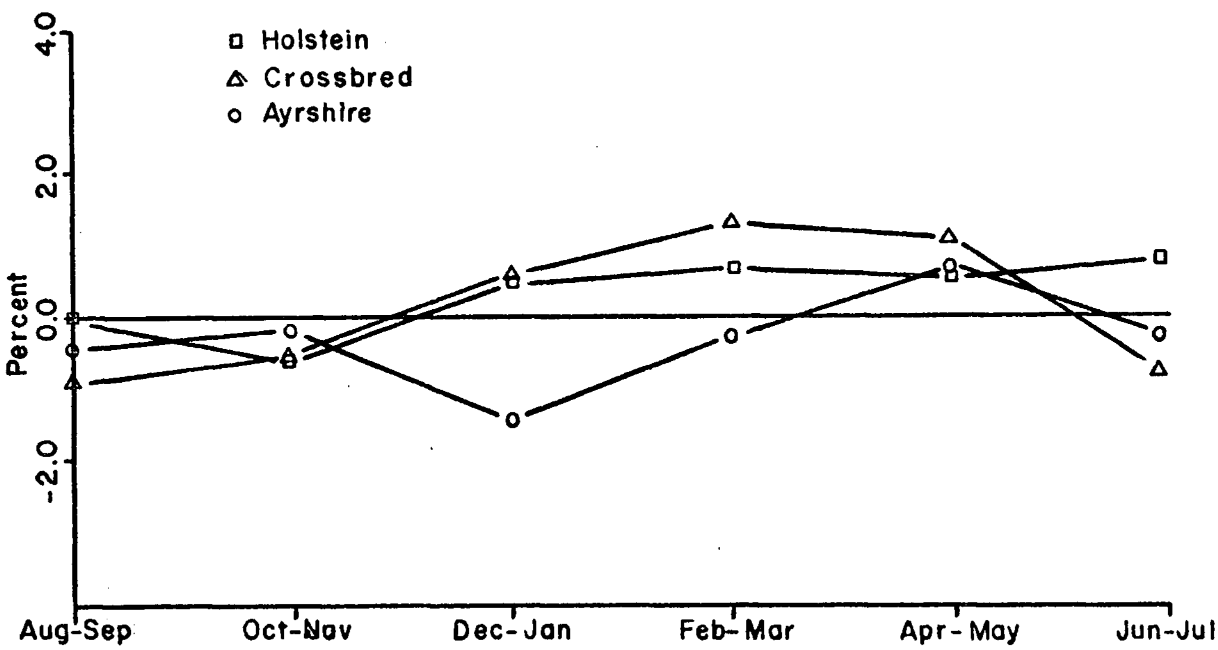

FIGURE 11. Breed-season least squares means, as deviations from the overall mean, for percent milk energy as protein.

The interaction constants associated with; 1) Holsteins calving in April-May, 2) crossbreds calving in February-March, and 3) Ayrshires calving in December-January were significantly different from zero by a t-test.

Duncan's test on effect of season of calving for each breed group showed that the seasonal means of the; 1) Holsteins were not significantly different from each other; 2) Ayrshires were not significantly different from each other; and 3) crossbreds calving June to November inclusive were significantly higher than the seasonal means of the crossbreds calving December to May inclusive (Table 23).

Duncan's test on the breed group means, for each season showed that; 1) in June-July and August-September differences between Ayrshire and crossbred means were non significant but both were significantly higher than Holstein; 2) in December-January and February-March differences between Holstein and crossbred means were non significant but both were significantly lower than Ayrshire; 3) in April-May differences between Holstein and both the crossbred and Ayrshire were non significant, but differences between crossbred and Ayrshire were significant; 4) in October-November differences among means of the three breed groups were non significant (Table 23).

Breed by season interaction accounted for 7 percent of the total variation of percent milk energy as protein. The least squares constants and subclass means (as deviations from the overall mean) are shown in Table 24 and the subclass means are graphed in Figure 11.

The interaction constants associated with; 1) Holsteins calving in April-May; 2) crossbreds calving in June-July, and 3) Ayrshires calving in December-January were significantly different from zero by a t-test.

The results of Duncan's test on the seasonal means for each breed group are presented in Table 24. Holstein seasonal means were not significantly different from each other. For both the crossbred and Ayrshire winter calving was associated with higher percent energy as protein values than winter calving; although differences between summer and winter were greater for the crossbred than for the Ayrshire.

Duncan's test on the breed group means for each season showed that; 1) in February-March differences between Holstein and Ayrshire means were not significant but means of both groups were significantly higher than the crossbred, 2) in December-January differences between Holstein and crossbred means were not significant but the means of both groups were significantly lower than the Ayrshire, 3) in the four seasons from April to November inclusive differences among means of the three breed groups were not significant (Table 24).

The breed by season interaction accounted for 8 percent of the total variation of the ratio of milk fat to protein. Least squares constants and subclass means (as

TABLE 24. BREED BY SEASON INTERACTION LEAST SQUARES CONSTANTS AND SUBCLASS MEANS, AS DEVIATIONS FROM THE OVERALL MEAN: PERCENT ENERGY AS PROTEIN.

Season	A. Least Squares Constant ± S.E.			B. Subclass means[1] ± S.E.		
	Holstein	Crossbred	Ayrshire	Holstein[n.s.]	Crossbred	Ayrshire
Feb - Mar	-.11 ± .27	.57 ± .29	.46 ± .27	.66 ± .34	1.36 ± .38[a]	-.18 ± .31[ab]
Apr - May	-.46 ± .22*	.30 ± .27	.16 ± .27	.31 ± .24	1.10 ± .33[a]	.46 ± .34[a]
Jun - Jul	.25 ± .28	-.62 ± .30*	.37 ± .33	.08 ± .24	- .76 ± .37[b]	-.28 ± .46[ab]
Aug - Sep	.18 ± .38	-.56 ± .44	.38 ± .51	-.04 ± .38	- .75 ± .58[b]	-.31 ± .77[ab]
Oct - Nov	-.31 ± .47	-.29 ± .34	.60 ± .39	-.62 ± .72	- .59 ± .33[b]	-.19 ± .47[ab]
Dec - Jan	.45 ± .38	.61 ± .44	-1.06 ± .42*	.52 ± .43	.70 ± .63[ab]	-1.47 ± .54[b]

1 As deviations from the overall mean.

* Constant differed significantly from zero by a t-test.

n.s. Means in this column are not significantly different from each other by Duncan's test.

a,b. Means in the same column superscripted by the same letter are not significantly different from each other by Duncan's test.

Means in the same row underlined by the same line are not significantly different from each other by Duncan's test.

deviation from the overall mean) are shown in Table 25 and the subclass means are graphed in Figure 12.

The results of Duncan's test on the seasonal means for each breed group and on the breed group means for each season are presented in Table 25. The results are similar to those obtained for percent energy as milk fat (Table 23).

The breed by season interaction accounted for 6 percent of the total variation of energy concentration of the milk. Least squares constants and subclass means (as deviations from the overall mean) are presented in Table 26 and are graphed in Figure 13.

The results of Duncan's test on the seasonal means for each breed group and on the breed group means for each season are similar to those obtained for lactation average percent milk fat as can be seen by comparing Table 14 with Table 26.

<u>Year by Season Interaction</u>

The interaction of year by season was a significant source of variation for; 1) percent milk energy as: milk fat and lactose, 2) ratio of milk fat to protein, and 3) energy concentration of the milk.

Year by season interaction accounted for 6 percent of the total variation of percent energy as milk fat. Least squares constants and subclass means (as deviations from the overall mean) are shown in Table 27 and are graphed in Figure 14. The least squares constant in February-March

TABLE 25. BREED BY SEASON INTERACTION LEAST SQUARES CONSTANTS AND SUBCLASS MEANS, AS DEVIATIONS FROM THE OVERALL MEAN: RATIO OF MILK FAT TO PROTEIN.

Season	A. Least Squares Constant ± S.E.			B. Subclass means[1] ± S.E.		
	Holstein	Crossbred	Ayrshire	Holstein[n.s.]	Crossbred	Ayrshire
Feb - Mar	.009 ± .020	-.045 ± .021*	.035 ± .020	-.070 ± .025	-.107 ± .028[b]	.029 ± .023[ab]
Apr - May	.036 ± .017*	-.022 ± .019	-.014 ± .020	-.045 ± .017	-.086 ± .024[b]	-.022 ± .025[b]
Jun - Jul	-.019 ± .020	.042 ± .022	-.023 ± .024	-.030 ± .024	.048 ± .027[a]	.039 ± .034[ab]
Aug - Sep	-.029 ± .028	.051 ± .033	-.023 ± .037	-.012 ± .028	.085 ± .042[a]	.067 ± .056[ab]
Oct - Nov	.024 ± .034	.027 ± .025	-.051 ± .028	.035 ± .053	.056 ± .024[a]	.033 ± .035[ab]
Dec - Jan	-.022 ± .028	-.054 ± .032	.076 ± .030*	-.058 ± .031	-.073 ± .046[b]	.113 ± .040[a]

1 As deviations from the overall mean.

* Constant differed significantly from zero by a t-test.

n.s. Means in this column are not significantly different from each other by Duncan's test.

a,b. Means in the same column superscripted by the same letter are not significantly different from each other by Duncan's test.

Means in the same row underlined by the same line are not significantly different from each other by Duncan's test.

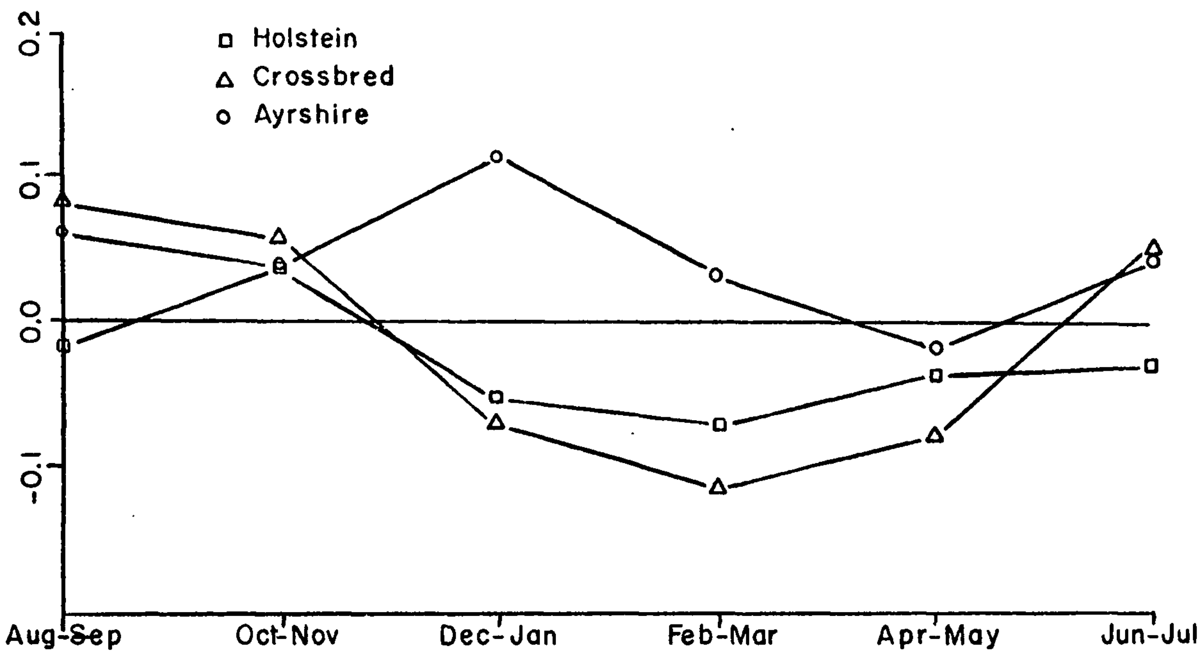

FIGURE 12. Breed-season subclass means, as deviations from the overall mean, for the ratio of milk fat to protein.

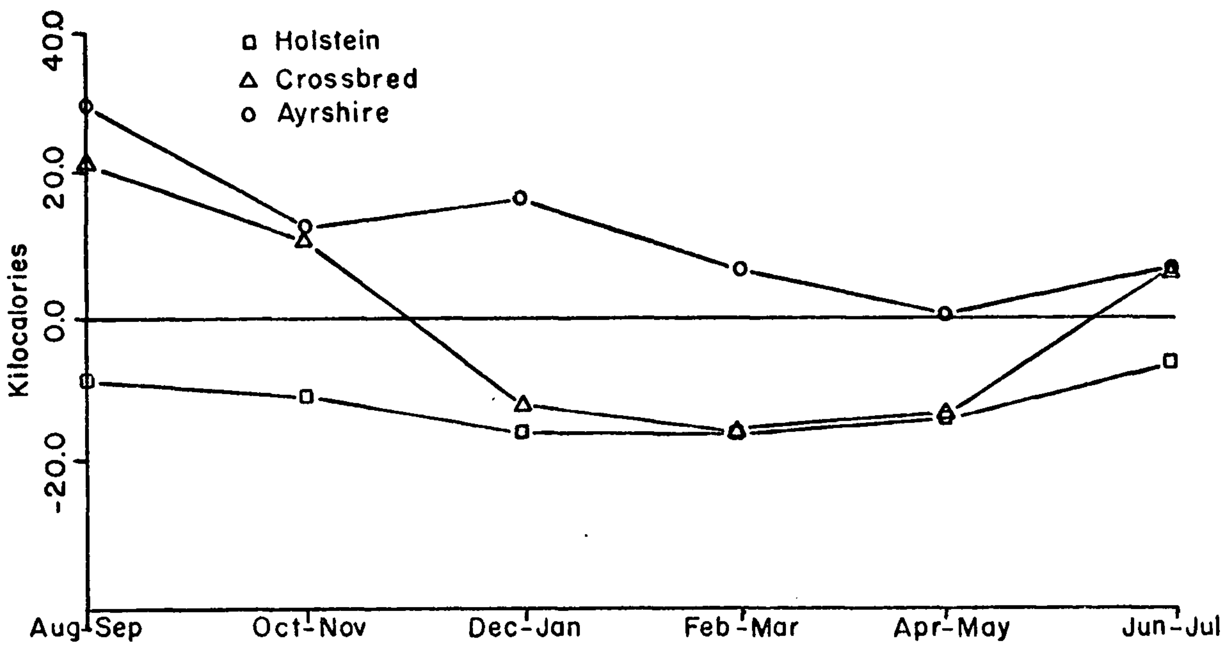

FIGURE 13. Breed-season subclass means, as deviations from the overall mean, for the energy concentration of the milk (kilocalories per pound).

TABLE 26. BREED BY SEASON INTERACTION LEAST SQUARES CONSTANTS AND SUBCLASS MEANS, AS DEVIATIONS FROM THE OVERALL MEAN: ENERGY (KCAL) PER POUND OF MILK.

Season	A. Least Squares Constant ± S.E.			B. Subclass means[1] ± S.E.		
	Holstein	Crossbred	Ayrshire	Holstein[n.s.]	Crossbred	Ayrshire
Feb - Mar	4.5 ± 3.6	-7.4 ± 3.6*	3.0 ± 3.5	-15.6 ± 4.4	-15.6 ± 4.9[b]	6.9 ± 4.0[ab]
Apr - May	7.8 ± 3.0*	-3.9 ± 3.5	-3.9 ± 3.6	-12.1 ± 3.1	-11.8 ± 4.3[b]	0.2 ± 4.5[b]
Jun - Jul	3.6 ± 3.6	4.3 ± 3.9	-7.9 ± 4.3	- 6.4 ± 4.2	6.2 ± 4.8[a]	6.1 ± 6.0[ab]
Aug - Sep	-12.0 ± 5.0*	7.7 ± 5.8	4.4 ± 6.7	-10.1 ± 4.9	21.5 ± 7.5[a]	30.3 ± 9.9[a]
Oct - Nov	- 3.5 ± 6.1	7.2 ± 4.5	-3.7 ± 5.0	-11.4 ± 9.4	11.2 ± 4.3[a]	12.4 ± 6.2[ab]
Dec - Jan	- 0.3 ± 5.0	-7.9 ± 5.7	8.2 ± 5.4	-16.3 ± 5.6	-11.9 ± 8.2[b]	16.2 ± 7.1[ab]

1 As deviations from the overall mean.

* Constant differed significantly from zero by a t-test.

n.s. Means in this column are not significantly different from each other by Duncan's test.

a,b. Means in the same column superscripted by the same letter are not significantly different from each other by Duncan's test.

Means in the same row underlined by the same line are not significantly different from each other by Duncan's test.

TABLE 27. YEAR BY SEASON INTERACTION LEAST SQUARES CONSTANTS AND SUBCLASS MEANS, AS DEVIATIONS FROM THE OVERALL MEAN: PERCENT MILK ENERGY AS MILK FAT.

Season	A. Least Squares Constant ± S.E.		B. Subclass Means[1] ± S.E.	
	1967 - 68	1968 - 69	1967 - 68	1968 - 69
Feb - Mar	-1.13 ± .34*	1.13 ± .34*	-2.25 ± .51[d]	0.15 ± .54[a]
Apr - May	.48 ± .33	- .48 ± .33	-0.74 ± .45[bc]	-1.55 ± .51[b]
Jun - Jul	.40 ± .38	- .40 ± .38	0.68 ± .56[ab]	0.06 ± .59[a]
Aug - Sep	.43 ± .56	- .43 ± .56	1.78 ± .87[a]	1.09 ± .71[a]
Oct - Nov	.84 ± .49	- .84 ± .49	1.71 ± .85[a]	0.19 ± .57[a]
Dec - Jan	-1.00 ± .51	1.00 ± .51	-1.49 ± .71[cd]	0.68 ± .78[a]

1 As deviations from the overall mean.

* Constant differed significantly from zero by a t-test.

a,b,c,d. Means in the same column superscripted by the same letter are not significantly different from each other by Duncan's test.

Means (in the same row) that are not underlined are significantly different by a t-test.

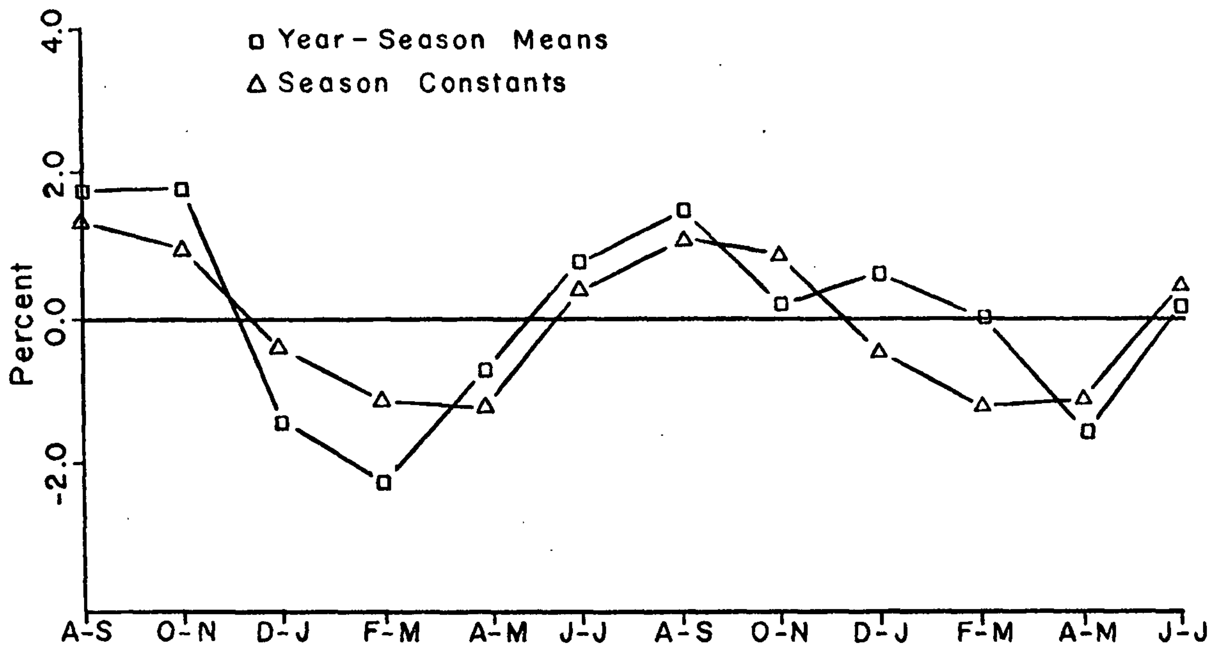

FIGURE 14. Year-season subclass means, as deviations from the overall mean, for percent milk energy as milk fat. Season of freshening constants are also plotted.

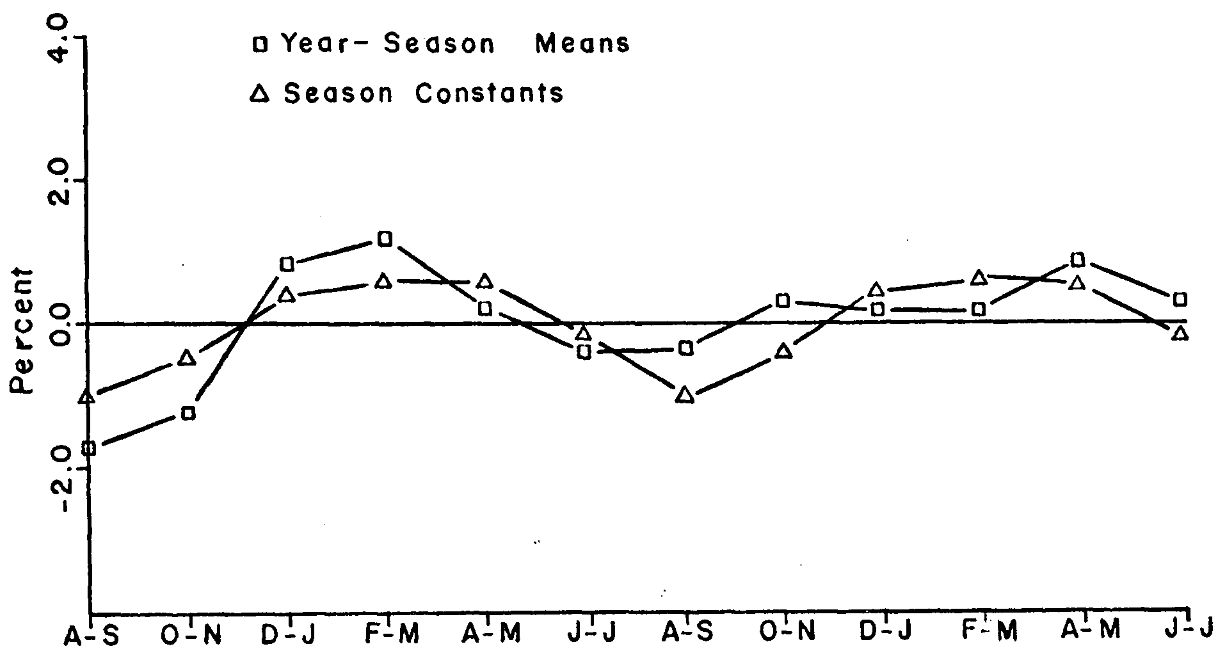

FIGURE 15. Year-season subclass means, as deviations from the overall mean, for percent milk energy as lactose. Season of freshening constants are also plotted.

season was significantly different from zero by a t-test.

Duncan's test showed that differences among first year seasonal means, within each of the following groups of means (ranked in descending order both within and between groups) were non significant; 1) August-September, October-November, and June-July, 2) June-July and April-May, 3) April-May and December-January, and 4) December-January and February-March. In the second year the April-May season mean was significantly lower than all others (Table 27).

A t-test showed that the February-March mean percent energy as milk fat was significantly lower in the first year than in the second year. Differences between years for each of the other five seasons were not significant. Except for the seasons of December-January and February-March, values in the second tended to be slightly lower than in the first year.

The year by season interaction accounted for 5 percent of the total variation in percent energy as lactose. Least squares constants and subclass means are presented in Table 28 and graphed in Figure 15.

Duncan's test showed that differences among first year seasonal means, within each of the following groups of means (ranked in descending order both within and between groups) were not significant; 1) February-March and December-January, 2) December-January, April-May and June-July, 3) April-May, June-July and October-November, 4) June-July, October-November and August-September. Differences among the

TABLE 28. YEAR BY SEASON INTERACTION LEAST SQUARES CONSTANTS AND SUBCLASS MEANS, AS DEVIATIONS FROM THE OVERALL MEAN: PERCENT MILK ENERGY AS LACTOSE.

Season	A. Least Squares Constant ± S.E.		B. Subclass Means[1] ± S.E.	
	1967 - 68	1968 - 69	1967 - 68	1968 - 69[n.s.]
Feb - Mar	.73 ± .23*	-.73 ± .23*	1.08 ± .34[a]	0.10 ± .36
Apr - May	-.21 ± .22	.21 ± .22	0.07 ± .30[bc]	0.97 ± .34
Jun - Jul	-.14 ± .25	.14 ± .25	-0.43 ± .37[bcd]	0.33 ± .39
Aug - Sep	-.43 ± .37	.43 ± .37	-1.74 ± .58[d]	-0.39 ± .47
Oct - Nov	-.50 ± .32	.50 ± .32	-1.23 ± .57[cd]	0.26 ± .38
Dec - Jan	.54 ± .34	-.54 ± .34	0.78 ± .47[ab]	0.19 ± .52

1 As deviations from the overall mean.

* Constant differed significantly from zero by a t-test.

n.s. Means in this column are not significantly different from each other by Duncan's test.

a,b,c,d. Means in the same column superscripted by the same letter are not significantly different from each other by Duncan's test.

Means (in the same row) that are not underlined are significantly different by a t-test.

second year seasonal means were not significant (Table 28).

The first year February-March mean was significantly higher than the mean of this season in the second year; the first year April-May mean was significantly lower than the mean of this season in the second year, by a t-test. Differences between years for each of the other four seasons were not significant.

The year season interaction accounted for 5 percent of the total variation in the ratio of milk fat to protein. Least squares constants and subclass means (as deviations from the overall mean) are presented in Table 29 and are graphed in Figure 16.

The results of Duncan's test on the seasonal means for each year and on year means for each season are presented in Table 29. The results are similar to those for percent energy as milk fat (Table 27).

The interaction of year by season accounted for 7 percent of the total variation in the energy concentration of the milk (kcal. per lb.). Least squares constants and subclass means (as deviations from the overall mean) are presented in Table 30 and are graphed in Figure 17.

The results of Duncan's test on the seasonal means for each year and on the year means for each season are similar to those obtained for lactation average percent milk fat as can be seen by comparing Table 16 with Table 30 and Figure 7 with Figure 17. The similarity in the results for these two traits was attributed to the high positive correlation

TABLE 29. YEAR BY SEASON INTERACTION LEAST SQUARES CONSTANTS AND SUBCLASS MEANS, AS DEVIATIONS FROM THE OVERALL MEAN: RATIO OF MILK FAT TO PROTEIN.

Season	A. Least Squares Constant ± S.E.		B. Subclass Means[1] ± S.E.	
	1967 - 68	1968 - 69	1967 - 68	1968 - 69
Feb - Mar	-.039 ± .014*	.039 ± .014*	-.101 ± .021[c]	.002 ± .023[a]
Apr - May	.020 ± .014	-.020 ± .014	-.045 ± .018[bc]	-.058 ± .022[b]
Jun - Jul	.020 ± .016	-.020 ± .016	.026 ± .023[ab]	.012 ± .025[a]
Aug - Sep	.008 ± .023	-.008 ± .023	.041 ± .037[ab]	.052 ± .030[a]
Oct - Nov	.031 ± .021	-.031 ± .021	.059 ± .036[a]	.023 ± .024[a]
Dec - Jan	-.040 ± .021	.040 ± .021	-.060 ± .030[bc]	.048 ± .033[a]

1 As deviations from the overall mean.

* Constant differed significantly from zero by a t-test.

a,b,c. Means in the same column superscripted by the same letter are not significantly different from each other by Duncan's test.

Means (in the same row) that are not underlined are significantly different by a t-test.

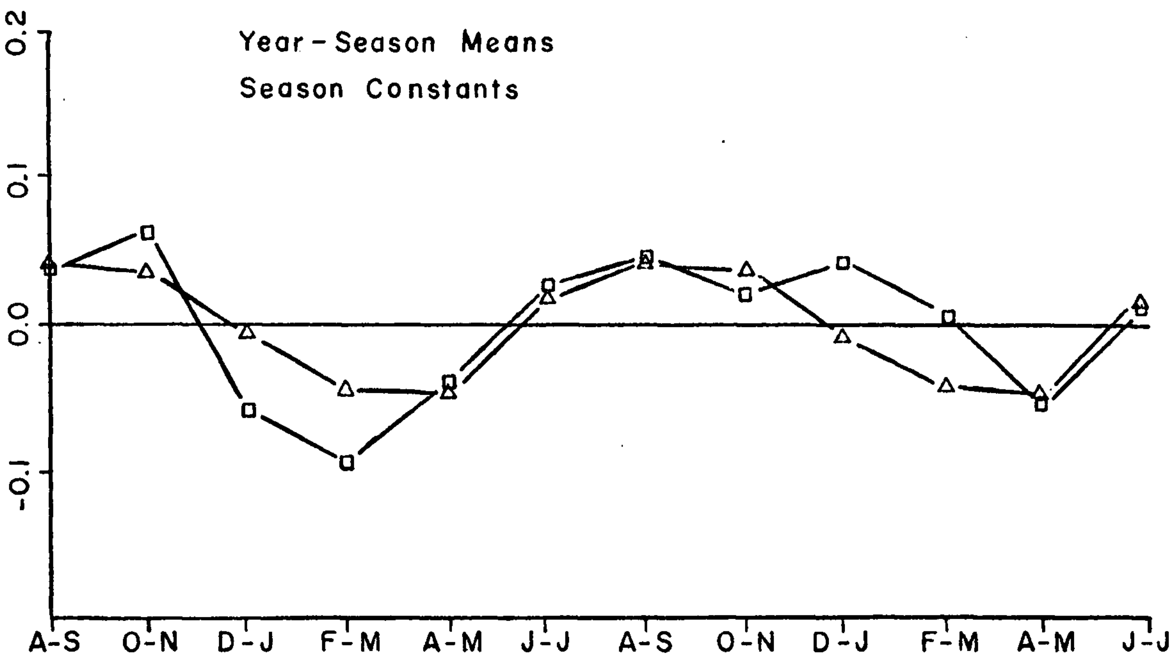

FIGURE 16. Year-season subclass means, as deviations from the overall mean, for the ratio of milk fat to protein. Season of freshening constants are also plotted.

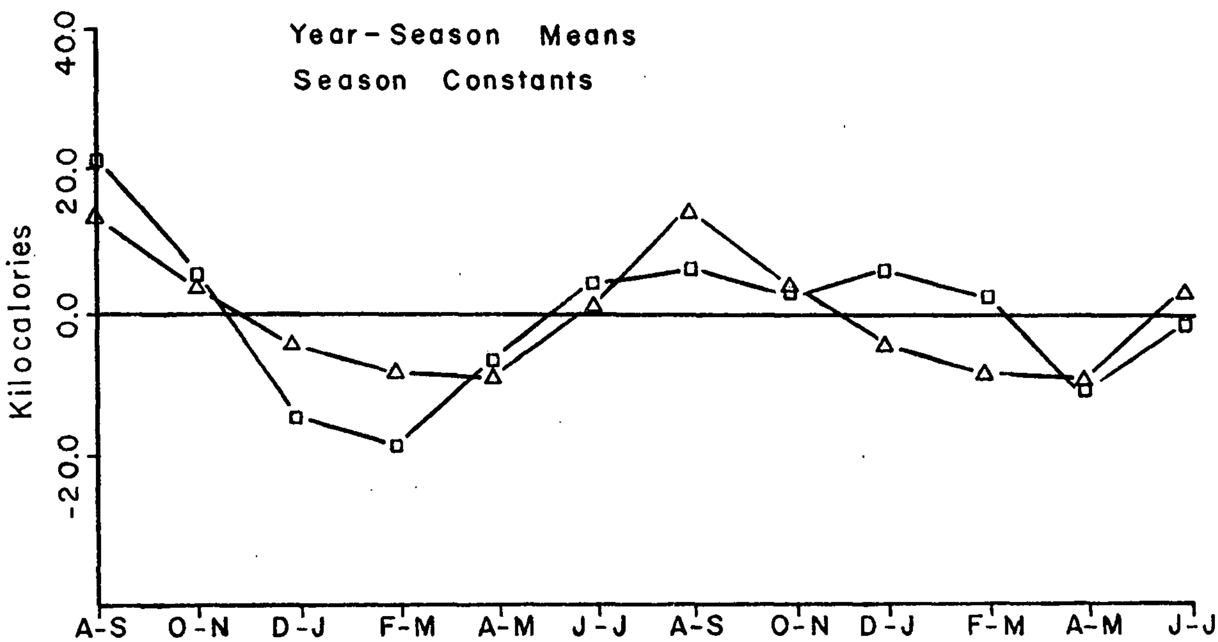

FIGURE 17. Year-season subclass means, as deviations from the overall mean, for the energy concentration of the milk. Season of freshening constants are also plotted.

TABLE 30. YEAR BY SEASON INTERACTION LEAST SQUARES CONSTANTS AND SUBCLASS MEANS, AS DEVIATIONS FROM THE OVERALL MEAN: ENERGY (KCAL) PER POUND MILK.

Season	A. Least Squares Constant ± S.E.		B. Subclass Means[1] ± S.E.	
	1967 - 68	1968 - 69	1967 - 68	1968 - 69
Feb - Mar	-9.1 ± 2.6*	9.1 ± 2.6*	-18.3 ± 3.8^{d}	2.2 ± 4.0^{a}
Apr - May	3.2 ± 2.5	-3.2 ± 2.5	- 5.8 ± 3.3^{bc}	-9.9 ± 3.8^{b}
Jun - Jul	4.1 ± 2.8	-4.1 ± 2.8	4.9 ± 4.2^{ab}	-1.0 ± 4.4^{ab}
Aug - Sep	8.6 ± 4.2*	-8.6 ± 4.2*	21.4 ± 6.5^{a}	6.5 ± 5.3^{a}
Oct - Nov	2.1 ± 3.7	-2.1 ± 3.7	5.0 ± 6.4^{ab}	3.2 ± 4.2^{a}
Dec - Jan	-8.9 ± 3.8*	8.9 ± 3.8*	-14.1 ± 5.3^{cd}	6.1 ± 5.8^{a}

1 As deviations from the overall mean.

* Constant differed significantly from zero by a t-test.

a,b,c,d. Means in the same column superscripted by the same letter are not significantly different from each other by Duncan's test.

Means (in the same row) that are not underlined are significantly different by a t-test.

between percent milk fat and energy concentration of milk.

Days milked and Age at Parturition

Days milked was a significant source of variation for; 1) percent milk energy as; milk fat and protein, 2) ratio of milk fat to protein, and 3) energy concentration of the milk. This co-variable accounted for 4, 6, 5, and 6 percent of the total variation of the above listed traits respectively. Age at parturition was significant for percent energy as lactose and accounted for 3 percent of the total variation of this trait. Significant partial regression coefficients are shown in Table 31.

The partial regression coefficient associated with the regression of percent energy as fat on days milked was; 0.031 ± 0.008 in percent and 0.24 ± 0.06 in standard measure. The regressions of; the ratio of milk fat to protein and energy concentration of the milk were also significant and positive. The partial regression coefficients (standard measure in parentheses) were 0.0014 ± 0.0004 (.26 ± .07) and 0.29 ± 0.06 (0.29 ± 0.06) respectively. The partial regression coefficients associated with the regression of percent energy as protein on days milked was -0.020 ± 0.05 in percent and -0.28 ± 0.07 in standard measure.

The partial regression coefficient associated with the regression of percent energy as lactose on age at parturition was -0.00058 ± 0.00018 in percent and -0.20 ± 0.06 in standard measure. This decline in percent energy as lactose associated with increased age was attributed to the decline in percent lactose associated with increased age (Table 18).

Summary of Energy Relationships

Breed, season, breed by season, year by season and days milked were significant for percent milk energy as milk fat, the ratio of milk fat to protein and the energy concentration of the milk. Ayrshire means were higher than Holstein for all seasons. For winter calving, crossbred means did not differ significantly from Holstein; but for summer calving, crossbred means did not differ significantly from Ayrshire. Differences among Holstein seasonal means were non significant. Crossbreds and Ayrshires calving in the summer tended to have higher values than winter or spring calvers (except Ayrshires in December-January). Means of winter calving cows were higher in the second year than in the first year.

Season, year, breed by season and days milked were significant for percent milk energy as protein. Higher values were associated with winter calving than summer calving and the effect of season was greater on the crossbreds than on the other two breed groups.

Breed, season, year by season and age were significant for percent energy as lactose. Breed means were all significantly different from each other. Higher values were associated with winter calving and the differences were greater in the first year than in the second year.

TABLE 31

PARTIAL AND STANDARD PARTIAL REGRESSION COEFFICIENTS[1]: ENERGY RELATIONSHIPS ON DAYS MILKED AND AGE AT PARTURITION

Trait	DAYS MILKED		AGE	
	Meas. Units[2] ± S.E.	Stan. Meas. ± S.E.	Meas. Units[2] ± S.E.	Stan. Meas. ± S.E.
Percent energy as:				
a. Fat	0.031 ± 0.008	0.24 ± 0.06	-	-
b. Protein	-0.020 ± 0.005	-0.28 ± 0.07	-	-
c. Lactose	-	-	-0.00058 ± 0.00018	-.20 ± 0.06
Fat/Protein ratio	0.0014 ± 0.0004	0.26 ± 0.07	-	-
Energy (kcal)/ lb. milk	0.29 ± 0.06	0.29 ± 0.06	-	-

1 Only significant regression coefficients are shown.

2 Units in which the trait was measured.

CORRELATIONS BETWEEN PERFORMANCE TRAITS

Phenotypic correlations between all performance traits studied were calculated and are present in Table 32.

The correlation between all yield traits were high and positive, ranging from .84 between yields of fat and milk to .99 between yields of lactose and milk.

The correlation between percent fat and yields of both milk and lactose were low and negative and the coefficients were -.21 and -.20 respectively. Percent fat was positively correlated with yield of fat (.33).

Percent protein also showed a low negative correlation of yields of milk and lactose and the coefficient was -.25 in both cases. The correlation between percent protein and yield of protein was not significantly different from zero; but percent protein was significantly correlated with percent fat (.45).

Percent lactose was not significantly correlated with yields of milk, fat or protein but was with yields of lactose (.27), total organic solids (.18) and total energy (.16). Percent lactose was not significantly correlated with the percent of fat or the percent of protein.

Percent energy as fat showed a high positive correlation (.96) with percent fat and a low positive correlation with percent protein (.23). Percent energy as protein was negatively correlated with both percent fat (-.66) and percent lactose (-.33) and also with percent energy as fat

TABLE 32

PHENOTYPIC CORRELATIONS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.Milk yld.	1.00														
2.Fat yld.	.84*	1.00													
3.Prot.yld.	.96*	.87*	1.00												
4.Lact.yld.	.99*	.84*	.94*	1.00											
5.TOS yld.	.97*	.93*	.97*	.97*	1.00										
6.Energy yld.	.95*	.96*	.96*	.95*	.99*	1.00									
7.% Fat	-.21*	.33*	-.09	-.20*	-.01	.08	1.00								
8.% Protein	-.25*	.00	.03	-.25*	-.10	-.07	.45*	1.00							
9.% Lactose	.11	.13	-.09	.27*	.18*	.16*	.06	-.10	1.00						
10.% TOS	-.21*	.29*	-.03	-.15*	.02	.09	.91*	.65*	.33*	1.00					
11.% En. fat	-.17*	.36*	-.11	-.18*	.01	.09	.96*	.23*	-.06	.77*	1.00				
12.% En. prot.	-.01	-.37*	-.09	-.06	-.12	-.17*	-.66*	.34*	-.33*	-.48*	-.77*	1.00			
13.% En. lact.	.25*	-.23*	.09	.31*	.09	.01	-.88*	-.63*	.37*	-.75*	-.85*	.33*	1.00		
14.Fat/prot.	-.10	.38*	-.12	-.08	.05	.13	.86*	-.05	.12	.66*	.94*	-.93*	-.64*	1.00	
15.Kcal/lb.milk	-.22*	.30*	-.06	-.19*	.00	.08	.97*	.62*	.18*	.98*	.85*	-.52*	.84*	.74*	1.00
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

(-.77). Percent energy as protein was positively correlated with percent protein (.34). Percent energy as lactose was also negatively correlated with the percent in the milk of the other two components; the correlations were: -.88 with percent fat and -.63 with percent protein. Percent energy as lactose was positively correlated with percent lactose (.37), yield of milk (.25) and with percent energy as protein (.33). The fat protein ratio was positively correlated with percent fat (.86) and with percent energy as fat (.94) but was negatively correlated with percent energy as protein (-.93) and percent energy as lactose (-.64).

CONCLUSIONS AND SUMMARY

The Holstein-Ayrshire crossbreds at Oyster River produced slightly, but not significantly, less milk per lactation than the higher yielding parental breed, the Holsteins, and significantly more (2615 pounds) than the lower yielding parental breed, the Ayrshires. The percentage of milk fat and protein in the milk of the crossbreds was approximately mid-way between that of the two parental breeds.

Differences in lactation yields of milk fat and protein between crossbreds and Holsteins were very small; seven pounds of milk fat in favour of the crossbreds, and one pound of protein in favour of the Holsteins. Thus this crossbred group was able to equal the production of the higher yielding parental breed in pounds of milk, milk fat, protein and in mega-calories of energy per lactation. This result agrees with reports (18, 27, 31, 33) in the literature that crossbreds in which one of the parental breed is Holstein, frequently equal but seldom surpass the yields of the Holsteins.

Statistical analysis of the breed by season interaction for lactation average milk fat percentage indicated that; 1) summer and autumn freshening Ayrshires and crossbreds were not significantly different but these two groups were significantly higher testing than Holsteins freshening at this time of year; 2) winter and spring calving crossbreds were not significantly different from winter and spring calving Holsteins but these two breed groups were significantly lower in lactational average milk fat content than the Ayrshires calving at this time of year. Because milk fat is the major energy component of milk, it follows that the significant breed by season interactions that were apparent in the energy relationships among the major milk components can be attributed, at least in part, to the breed by season interactions in lactation average milk fat percentage. If this apparent genotype-environment interaction is a general phenomena in dairy cattle, then care should be taken in choosing appropriate mature equivalent correction factors for the calculation of mature equivalent records for crossbred cattle: and breed should be taken into account in adjusting calving distributions in mixed herds.

The division of energy among the three major milk components indicated that: slightly less than one-half the total milk energy was in the milk fat and the remainder of the milk energy was divided almost equally between protein and lactose. The three breed groups did not differ significantly in percentage of milk energy as protein. The overall mean was 27.5 $\pm$ .11 percent, or expressed in terms of milk energy per pound of protein the value was 9.69 $\pm$ .038 megacalories per pound of protein. The three breed groups did differ significantly in the proportion of the total milk energy accounted for by both milk fat and lactose. The results were that the breed with the highest milk fat test, Ayrshires, had a higher proportion of total milk energy in the milk fat and a lower proportion in lactose than the breed with the lowest milk fat test -- Holsteins.

The three breed groups included in this study differed significantly in the ratio of milk fat to protein. The Ayrshire breed had a significantly wider ratio than the crossbreds and Holsteins. Breed differences in milk fat to protein relationships were shown by Overman (30) who found that regression equations predicting protein percentages from milk fat percentage were different for each breed. The result that protein to energy relationships did not differ significantly among the three breeds, while the relationship of milk fat to protein did, would indicate that caution should be used in interpreting fat to protein ratios as indicators of energy to protein relationships for between breed comparisons, if the results in this study are generally true.

Season of freshening did not account for a significant portion of variation in any of the yield traits under study. However, the trend was for fall and winter freshening cows to have higher yields than cows freshening in the spring and early summer.

Season of freshening was a significant source of variation for percent milk fat, for percent total organic solids and for performance traits involving energy relationships. However, year by season interactions were also significant sources of variation for these traits. The main reason for this significant year by season interaction was that cows that calved from December to March inclusive in the first year of the study were well below the overall average for lactational average milk fat percentage, while those that calved during this period in the second year were above the overall average. As management in both years was essentially the same, the reason for the differential season response by year is not readily apparent but may be due to differences in weather conditions.

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