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R. E. McDowell
Cornell University

J. K. Camoens
Associacion de Criadores Holstein-Friesian de Mexico, Gueretaro

L. Dale Van Vleck
University of Nebraska-Lincoln, dvan-vleck1@unl.edu

E. Christensen
Cornell University

E. Cabello Frias

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R. E. McDOWELL, J. K. CAMOENS[2], L. D. VAN VLECK,
E. CHRISTENSEN, and E. CABELLO FRIAS
Department of Animal Science
Cornell University
Ithaca, NY 14853; and
Associación de Criadores Holstein-Friesian de México,
Queretaro; and Instituto Tecnologico y de Estudios
Superiores de Monterrey, Monterrey

ABSTRACT

Effects of herd, year, age, season, and their interactions on milk yield, lactation length, and reproductive efficiency for purebred and high grade Holsteins were determined by analysis of variance of 17,255 lactation records from 48 herds in Mexico. Herds differed in all traits. Herd average milk yield ranged from 2620 to 7670 kg. Years, ages, and seasons were important for milk yield, but these variables had little influence on lactation length, days open, days dry, and calving interval. Most two-, three-, and four-way interactions for milk yield and days in milk were of importance. Main effects and interactions accounted for 37% of total variance in milk yield. Total variance for milk was 1,344,364 kg^2. From variance component analysis, percentages of total variance in milk yield attributed to herd, sire, cow, and error effects were 23.8, 2.2, 33.9, and 40.0. Phenotypic correlations among milk yield, days dry, days open, lactation length, and calving interval were positive but significant only for milk and lactation length. Lactation length accounted for about 34% of the variation in milk while days dry, days open, and calving interval contributed less than 4%. For milk yield the estimate of heritability within herd was 11.9% and repeatability 45.1%. Effects of herd, year, age, and season on the performance of Holsteins in Mexico do not differ markedly from temperate areas.

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[2] Kluang, Johor, West Malaysia.

INTRODUCTION

Holstein cattle have been imported to Mexico on a large scale to facilitate its rapidly developing dairy industry (21).

As the government of Mexico attempts to develop an AI (artificial insemination) program and progeny testing stations, its concerns are: (a) should the importation of semen and cattle be discouraged because Holsteins from temperate areas are unsuitable for conditions in Mexico; and (b) will the amount of variation needed for selection be in the Holstein population of Mexico? Camoens et al. (3) concluded that factors affecting the performance of Holsteins in Puerto Rico did not differ appreciably from those in temperate areas and that total variation in milk and fat yields was large enough to permit selection for higher yields.

This study deals with the effects of herd, year, age, and season on milk yield of cows classified as Holsteins in herds on Dairy Herd Improvement (DHI) in Mexico; the influence of lactation length, days dry, days open, and calving interval on milk yield; and estimating in several traits components of variance for effects of herds, sires, and cows.

MATERIALS AND METHODS

Source of Data

There were 27,556 records for calvings from 1969 to 1973 in 62 herds. The records were processed routinely at the DHI Regional Center, Provo, UT, and forwarded to USDA. Tapes containing the records were made available by USDA.

The herds had all or portions of their cows registered with the Associación de Criadores Holstein-Friesian de México. Records of grades in a number of herds coded as Holsteins were used, but cows identified other than Holstein were excluded. Records were screened with restrictions. Only lactation records >60 days in length and up to 305 days and coded as terminating normally were considered. Other reasons for rejection were: no birth date, calving age <18 or >200 mo, and milk yield <600 kg. The latter group were deleted because of errors on identification or incomplete records. The edits left 17,255 lactation milk records from 48 herds. Fat tests were not recorded.

The majority of the herds were in the zone 18 to 26 North latitude, ranging in elevation from 1000 to 2200 m. In this region, maximum daily temperatures exceed 25 C 6 to 12 mo per year. Rainfall distribution is such that conditions vary from semi-arid (<30 cm/yr) to wet (>1500 cm/yr).

Methods of Analysis

The model for analysis of variance included the fixed effects of herd, year, season, and age and all two-, three-, and four-way interactions.

Two groupings were used for years (<1971 and ⩾1971), season (April to September and October to March), and ages (<50 and ⩾50 mo). The data were unbalanced with unequal numbers of observations in subclasses; thus, the method of weighted means analysis was used (20).

Effects of days dry, days in milk, days open, and calving interval on milk yield was determined by regression analysis. The independent variables were dropped singly and in pairs to determine their relative importance. The model was:

$$Y = \alpha + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 +$$ residual deviation from regression

where

Y = milk yield; X_1, days dry; X_2, days in milk; X_3, days open; and X_4, calving interval.

Variance components for estimates of heritability and repeatability were from the model:

$$Y_{ijkl} = \mu + H_i + S_{ij} + C_{ijk} + E_{ijkl}$$

where

Y_{ijkl} = measurement of trait;

μ = population mean common to all records;

H_i = random effect associated with i^{th} herd, with mean zero and variance σ_h^2;

S_{ij} = random effect of the j^{th} sire of the i^{th} herd, with mean zero and variance σ_s^2;

C_{ijk} = random effect of the k^{th} cow nested within the j^{th} sire and the i^{th} herd, with mean zero and variance σ_c^2; and

E_{ijkl} = random error with mean zero and variance σ_e^2.

Henderson's Method 1 (10) was used to estimate the variance components.

Estimates of components of variance were denoted $\hat{\sigma}_h^2$, $\hat{\sigma}_s^2$, $\hat{\sigma}_c^2$, and $\hat{\sigma}_e^2$. $\hat{\sigma}_p^2$ total variance was the sum of these. Heritabilities were estimated within herd as $4\ \hat{\sigma}_s^2/(\hat{\sigma}_p^2 - \hat{\sigma}_h^2)$. Repeatabilities were estimated within herd as $(\hat{\sigma}_s^2 + \hat{\sigma}_c^2)/(\hat{\sigma}_p^2 - \hat{\sigma}_h^2)$.

RESULTS AND DISCUSSION

Herd, Year, Age, and Season Effects

Herd effects were significant (P<.05) for milk yield, days in milk, days open, days dry, and calving interval (Table 1). Herd averages for milk yield ranged from 2620 to 7670 kg. Coefficients of variation indicated a high variability among cows within herd for these traits. Differences among herds can be explained partially on quality of sires (15) and on forage quantity and quality. Herds where corn or sorghum silages were fed all or most of the year had higher average yields than herds using green chopped forages and some grazing (unpublished). Herd size and intensity of culling also may have contributed to herd differences in performance. Size of herd varied from about 40 to over 200 cows. Culling rate varied from 8 to 28%/yr.

Year effects were significant for all traits except calving interval (Table 1). For herds on test continuously, yearly average milk yield showed an upward trend from 4271 kg in 1969 to 4750 kg in 1973. In the same period, average lactation length increased 19 days and days open increased about 2 days per year.

Age effects were significant except for days in milk. Highest yields were from cows calving at 70 to 80 mo. Lactation yields began to decline for cows calving past 90 mo (13, 14). Cows calving from 70 to 80 mo averaged 18% higher in production than cows in first lactation (average 31.4 mo) which corresponds to the difference in areas of the US (16). Cows in first lactation averaged 22 days longer in days open

TABLE 1. F-ratios and tests of significance for the effects of herd, year, age, season, and the interactions.

Effects	d.f.	Milk	Days			Calving interval
			In milk	Open	Dry	
Herd (H)	10-27[a]	82.8*	59.8*	36.9*	18.4*	8.4*
Year (Y)	1	48.6*	49.8*	107.4*	6.7*	.0
Age (A)	1	199.9*	3.3	8.6*	19.1*	2.6*
Season (S)	1	42.6*	31.0*	10.1*	1.9	1.0
H × Y	10-27	15.0*	50.2*	4.3*	5.1*	1.1
Y × A	1	8.5*	2.6	2.8	.4	.1
A × S	1	2.9*	1.5	.3	.8	.0
S × H	10-27	5.0*	7.9*	3.7	2.4*	1.0
H × A	10-27	2.7*	2.1*	1.3	3.1*	1.1
Y × S	1	1.5	4.1*	9.7*	1.4	.3
H × Y × A	10-27	3.1*	1.6*	1.3	1.7	2.2*
Y × A × S	1	.4	.2	.1	.0	.2
A × S × H	10-27	1.2	.9	.9	1.2	.4
S × H × Y	10-27	3.5*	9.6*	3.4	1.4	.7
H × Y × A × S	10-27	9.4*	5.9*	5.3*	6.9*	6.2*
Error[b]	1310-16236	14705	934	5559	1247	5195

[a]Range of degrees of freedom.

[b]Error mean squares.

*P<.05.

than cows in second and later lactation.

Effects of season of calving were significant (P<.05) for milk yield, days in milk, and days open (Table 1). In general, season effects accounted for more than twice as much variation as for most studies in the temperate zone and for Puerto Rico (3). For milk yield, the influence of month of calving was bimodal. Cows calving July to September were well above average, and the same was true for cows calving in January while lactation length and days open tended to have single peaks (Table 2). There also was a seasonal trend in number of calvings, but there was no seasonal pattern for days dry.

The two-, three-, and four-way interactions were significant in most instances for milk yield and days in milk. Those interactions which included herd were more often significant (Table 1). Herd, year, age, season, and their interactions accounted for 37% of the total variance (R^2) in milk yield. This was lower than the 39% reported for herds in Puerto Rico (3) but greater than the 32% reported by Gacula et al. (9).

Total variance for milk yield has tended to vary according to the sample examined. The total variance for milk yield within herd, year, age, and season was 1,344,364 kg^2 which is close to the 1,405,711 kg^2 variance in milk yield reported by Van Vleck et al. (24). Similar to the findings for temperate regions, it appears the amount of variation required for selection to be effective is among Holsteins in Mexico.

Phenotypic Correlations

Phenotypic correlations, estimated across herds, years, ages, and seasons, among milk yield, days dry, days open, lactation length, and calving interval were positive (Table 3), but the only one significantly correlated with milk yield was lactation length. The correlation between milk yield and lactation length is lower than for Holsteins (.66) in Puerto Rico (4) but is similar to temperate areas (2). Correlations for measures of reproduction with milk yield fall within the range generally accepted for temperate areas (17).

The correlation between days open and calving interval is similar to that for Puerto Rico (4) but much lower than in temperate areas. The low correlation in this study is attributed to the high variability in both traits

TABLE 2. Unadjusted means and standard deviations for milk yield, lactation length, days open, and days dry by month of calving.

				Days					
	No.	Milk (kg)		Lact.		Open		Dry	
Mo	rec.	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Jan.	1791	5020	1449	285	41	130	79	73	41
Feb.	1158	4784	1447	278	54	136	82	69	34
Mar.	1194	4624	1314	281	49	139	83	70	41
Apr.	1065	4509	1278	282	49	148	86	66	35
May	1130	4305	1259	277	61	151	84	72	37
June	1044	4700	1413	284	48	150	83	75	50
July	1460	5192	1636	287	44	154	83	72	34
Aug.	1660	4943	1592	287	44	151	85	74	42
Sept.	1620	5014	1691	288	42	140	83	71	34
Oct.	1541	4875	1580	287	43	141	80	76	42
Nov.	1710	4533	1445	288	39	140	82	72	38
Dec.	1882	4795	1485	290	35	139	82	72	43
All	17255	4750	1482	285	44	143	82	72	39

TABLE 3. Phenotypic correlations and tests of significance between various traits.

Trait	Days Dry	Days Open	Lact. length	Calving interval
Milk yield	.09	.16	.58*	.12
Days dry		.04	.38	.33*
Days open			.33*	.18*
Lact. length				.11

*P<.05.

within cow, within herd, and among herds. The correlation between days open and previous dry period was near zero (Table 3).

Regression Coefficients

All regression coefficients with four, three, and two independent variables (lactation length, days dry, days open, and calving interval) were significant (P<.05) for milk yield (Table 4). The variations in R^2 between combinations indicate the relative importance of the independent variables on milk yield. Combinations with lactation length gave the highest F-ratios and highest R^2 values, about 34%. Days dry, days open, and calving interval together accounted for only 3.8% of the variation in milk yield. The R^2 for days dry and days open was 3.2% and that for days open plus calving interval was 1.7%. Exclusion of days open from the regression lowered R^2 only .2% which suggests that days open had little influence on milk yield not explained by the other variables. Similarly, exclusion of either days dry or calving interval from the regressions reduced R^2 by less than 1%. Lactation length was the most important factor. Quantitatively, the regression equations can be interpreted that an increase of 1 day in lactation length is equivalent to adding about 20 kg of milk whereas 1-day change in the other independent variables will have little effect on lactation yields.

The R^2 for all independent variables was about 10% lower than for Puerto Rico (4) and appears intermediate to those in the literature. In part the lower coefficient for Mexico may have arisen because lactation length was a joint variable, not so in others. Some authors, such as Ripley et al. (18) and Schaeffer et al. (19), have recommended that days open should be considered in evaluating dairy records, but this does not appear warranted for Mexico herds. The difference may be that days open averaged 10 to 30 days longer than usually reported; therefore, pregnancy did not have a measureable effect on milk yield. Although the regression coefficients for days dry and calving interval were significant in all combinations, the β's were too small to warrant consideration in evaluation of records in Mexico.

Components of Variance

Variance in milk yield attributed to herd was less than the 30 to 40% for most studies in temperate areas (Table 5). However, it does agree with data from Puerto Rico (5) and at least one other study (7).

The herd variance for lactation length and days open was higher than generally reported. Nevertheless, the values seem reasonable in view of the wide variability among herds for these traits.

The sire component (σ_s^2) for milk yield of 2.2% is in the low range of estimates generally reported. However, Lytton and Legates (11) obtained the same value for sires in the southern US versus 4.9% σ_s^2 for sires in northern US. They presumed the difference reflected an inferior environment in the south. On the other hand, Camoens et al. (5) found a sire component of 4.9% for Holstein sires in Puerto Rico in unadjusted records, but the sire component was reduced to 2.0% after age-season adjustment. The overall herd average milk yield in Puerto Rico was about 950 kg below that of Mexico (15). The negative values of σ_s^2 for lactation length and days open were interpreted as zero for sire variance. This implies that genotype contributed no detectable role in accounting for variation of these traits in Mexico herds. Similar results were reported by

TABLE 4. Regression coefficients (β) for milk yield as dependent variable and various combinations of lactation length, days dry, days open, and calving interval as independent variables.

Combination	Intercept (α)	Regression coefficients Lact. length	Days open	Days dry	Calving interval	F-ratio	R^2 (%)
			(kg)				
1	-1119*	20.36*	2.64*	-1.04*	1.11*	468.5*	34.8
2	-782*	20.45*	3.51*	-.87*	. . .	619.1*	34.6
3	3656*	. . .	2.89*	3.42*	1.77*	46.3*	3.8
4	-1057*	19.88*	2.69*	. . .	1.00*	620.1*	34.7
5	-1070*	20.38*	. . .	-1.07*	1.47*	619.1*	34.6
6	4228*	. . .	4.29*	3.72*	. . .	59.3*	3.2
7	-768*	20.03*	2.00*	. . .	. . .	924.0*	34.5
8	3846*	. . .	2.74*	. . .	2.37*	31.1*	1.7
9	-543*	20.51*	. . .	-.82*	. . .	911.8*	34.2
10	3711*	. . .	. . .	3.39*	2.18*	64.7*	3.6
11	-1007*	19.88*	. . .	. . .	1.32*	921.4*	34.4

*$P < .05$; df 3507 to 3509.

TABLE 5. Percentages of variance for herd, sire, cow, and error and the total variance for several traits with unadjusted records.

Trait	Herd	Sire	Cow	Error	Total
	(%)				
Milk yield	23.8	2.2	33.9	40.0	1,344,364 (kg^2)
Lact. length	22.6	-4.2	37.4	44.2	1550 ($days^2$)
Days open	12.4	-1.3	43.6	45.3	6772 ($days^2$)

Camoens et al. for Puerto Rico (5) and from the US (6).

From 34 to 44% of the total variance in milk yield, lactation length, and days open was due to variance among cows (σ_c^2), Table 5. The magnitude of the estimates show potential for cow selection, changes in herd management, or both for improvement of yield and breeding efficiency.

Herds, sires, and cows accounted for 55 to 60% of the variation in milk yield, lactation length, and days open. These results are similar to those for Holsteins in Puerto Rico (5). The error variance (40 to 45%) is lower than the estimates of about 50% reported by Van Vleck and Henderson (23). The difference may be partially due to the more extensive model of this study.

Heritability and Repeatability

Estimates of heritability derived from components of variance for lactation length and days open are similar to those for Holsteins in temperate areas (1, 7), but those for milk yield are considerably lower than usually reported for Holsteins (Table 6). The Mexico records were unadjusted for differences in age which may have contributed to the lower values. Nevertheless, the h^2 for milk falls within the range reported by McDowell (12) for unselected native cattle in tropical areas.

TABLE 6. Heritability and repeatability within herd for various traits from unadjusted records.

Trait	Heritability	Repeatability
Milk yield	11.9	45.1
Lact. length	0	48.2
Days open	0	50.4

Estimates of repeatability for milk yield (Table 6) are on the low side; however, they are within the range of accepted values (17). Conversely, repeatabilities for lactation length and days open are considerably higher than from most studies in temperate areas. High repeatability for traits like lactation length and days open may be associated with general conditions in tropical areas. Camoens et al. (5) obtained similar repeatabilities for these traits with Holsteins in Puerto Rico. McDowell (13) reported repeatability for lactation length ranged from .42 to .46 in cattle native to tropical areas.

A number of cows had been imported as bred heifers from Canada or the US. An even larger number were sired by bulls from AI studs in the two countries or were progeny of sires imported to Mexico. Often, it has been assumed that much of the genetic variation would be overshadowed by a tropical environment (8), but the hypothesis is not supported. The total variation in milk yield (Table 5) is well within the range accepted for temperate areas. Van Vleck (22) indicated genetic variability could differ between environments and concluded that higher performance was associated with higher genetic variability. Lower estimates of genetic variability, therefore, could be a function of lower production. On these premises, if high production could be obtained in tropical areas, highesr estimates of genetic variability may ensue. Although feeding and management in Mexico are insufficient for full expression of genetic potential of Holsteins originating in part or whole from temperate areas for milk production, the use of good genetic stock is warranted (15).

The general conclusion is that factors affecting the performance of Holsteins in Mexico do not differ markedly from those in temperate areas. Total variation in milk yield appears sufficient to permit selection for higher yields. Similar to temperate areas, lactation length and reproductive efficiency seem influenced largely by decisions of herd owners. The close similarity of findings from this study and those on Holsteins in Puerto Rico (3, 4, 5) supports this conclusion.

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