Estimates of Genetic and Phenotypic Parameters for Milk Production in Moroccan Holstein-Friesian Cows

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■ RESSOURCES ANIMALES

Key words

Holstein-Friesian cattle – Dairy cow – Milk yield – Milk fat – Heritability – Genetic correlation – Morocco.

Summary

Heritabilities, repeatabilities and genetic and phenotypic correlations among milk yield, fat yield and fat percentage were estimated using an animal model and 20,140 records of 11,618 Holstein-Friesian cows enrolled in the Moroccan official milk-recording program between 1990 and 1999. Heritabilities for milk yield, fat yield and fat percentage were 0.29, 0.27, and 0.39, respectively, and their repeatabilities were 0.33, 0.32, and 0.39, respectively. Genetic correlations of milk yield with fat yield and with fat percentage were 0.96 and –0.32, respectively, and correlation of fat yield with fat percentage was –0.06. Phenotypic correlations were 0.96 between milk and fat yields, –0.28 between milk yield and fat percentage, and –0.03 between fat yield and percentage. It was concluded that these genetic and phenotypic parameters could be used for the genetic evaluation of dairy cattle in Morocco.

■ INTRODUCTION

To satisfy the growing demand of the human population for milk, the Moroccan government set up a plan in 1975 to increase milk production. The most important genetic strategies were the introduction of improved dairy cattle, the institution of milk recording, and the extension of artificial insemination (AI). Thus, more than 10,000 Holstein and Friesian heifers were purchased annually from Europe and North America. In 1995, the number of improved cows was 288,000 (5). To improve this gene pool, official milk recording was instituted in the early 70's and the progeny test of AI bulls was initiated in 1989 (5). However, development and realization of animal breeding plans require knowledge of genetic parameters of the traits considered.

The objectives of this study were to estimate heritabilities and repeatabilities for milk and fat yields and fat percentage, as well as genetic and phenotypic correlations among them from lactation records of Holstein-Friesian cows enrolled in the Moroccan official milk-recording program. These parameters were needed to plan out future breeding programs as well as to predict breeding values.

■ MATERIALS AND METHODS

Data

The data analyzed were kindly provided by the Livestock Service of the Ministry of Agriculture and concerned Holstein-Friesian cows involved in the official milk-recording program. Test day yields for milk and fat percentage were the basic information used for calculation of yields. Milk recording practiced in Morocco is classified as type A. During lactation, morning and evening milking of each cow was recorded once a month within an interval of 26-35 days. Data were restricted to records for which the first milk recording had occurred between 5 and 73 days and spacing of consecutive sample days was not more than 68 days. Lactation records were standardized to 305 days, except records of cows that went dry with less than 305 days of milk. Data were edited for errors, redundancy, and incomplete observations. Further editing was carried for pedigree checks, consistent lactation number, date of calving, and calving age. The final data file was restricted to

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cows milked twice a day, calving from 1990 to 1999, age at calving from 22 to 120 months, parity from 1 to 5, milk yield range from 845 to 10,104 kg, and over 210-day lactation. Although in Morocco 85% of herds have less than five cows (5), in this study herds that had less than three cows were omitted. Moreover, records with missing values on any of the traits of interest (milk yield, fat yield and fat percentage) were discarded. The remaining records included 20,140 records from 11,618 cows located in 320 herds.

Statistical analyses

The total number of animals in the analysis was 20,220 (11,618 individuals, 1519 sires and 7083 dams). The traits studied were milk yield, fat yield and fat percentage during 305 days of lactation. Data were first analyzed by least-squares analysis of variance in order to identify the fixed effects to include in the model. The statistical model included the age of the cow (≤ 30 months, > 30 to ≤ 42 months, > 42 to ≤ 54 months, > 54 to ≤ 66 months, > 66 to ≤ 78 months, > 78 to ≤ 90 months, and > 90 months), calving season (October through March and April through September), and the herd year of calving. All the effects were significant for all traits and hence were included in the model. First order interactions between effects were not tested and hence were assumed to be negligible.

Variance components for yields and percentage were estimated for each trait separately with derivative-free REML procedures using the MTDFREML program of Boldman *et al.* (4). The basic single-trait repeatability model in matrix notation was:

$$y = Xb + Za + Wpe + e$$

where y is a vector of observations, b is a vector of fixed effects with incidence matrix X, $a \sim N(0, A\sigma^2_a)$ is a vector of random animal effects with incidence matrix Z, $pe \sim N(0, I_c\sigma^2_{pe})$ is a vector of random permanent environmental effects with incidence matrix W, and $e \sim N(0, I_n\sigma^2_e)$ is a vector of random residual effects.

σ^2_a is the additive genetic variance, σ^2_{pe} is the permanent environmental variance, σ^2_e is the residual variance, A is the additive genetic relationship matrix, and I_c and I_n are identity matrices of order equal to the number of cows and the number of records, respectively.

Convergence of the derivative-free iterative process was considered reached when the variance of simplex values (–2 log-likelihood) was less than 10^{-8}. To ensure a global maximum, each analysis was restarted with previous converged values until the estimated value of the –2 log-likelihood function did not differ in its first three decimal places. Solutions for fixed and random effects were from the last round of iteration in which the global maximum was achieved.

Similar derivative-free REML procedures were used for bivariate analyses to estimate correlations between traits. The model included the same fixed effects and the animal effects only. Estimates from single-trait analyses were used to obtain starting values for bivariate analyses. Convergence was first obtained when the simplex variance was less than 10^{-3} and then when the simplex variance was less than 10^{-8}.

■ RESULTS AND DISCUSSION

Fixed effects

Unadjusted means, standard deviations, and coefficients of variation for milk yield, fat yield and fat percentage are presented in Table I. Means of yields of milk and fat, and fat percentage were 5353.4 kg, 192.8 kg, and 3.63%, respectively. Performance levels for yields were higher than earlier estimates by Boujenane and Ba (6) in Black and White cows enrolled in the official milk record-keeping program from 1975 to 1982, indicating a positive trend in the interval between the two studies. Moreover, coefficients of variation for yields (28.6 and 26.5%) were larger than that for fat percentage (7.16%).

The estimates for age at calving indicated that milk and fat yields were highest for calving at 78 to 90 months, whereas fat percentage was highest for calving at less than 30 months (Table II). Milk and fat yields increased with the increasing age at calving until 78 to 90 months, and declined slightly thereafter. Differences between the highest and lowest age classes for milk and fat yields were 759.7 and 25.6 kg, respectively. For fat percentage, there was a lack of trend with age. The difference between the extreme classes was 0.03%. The influence of age at calving on milk yield and composition was consistent with published results (7, 13, 20).

Yields of milk and fat were highest for cows calving from October through March, and lowest for those calving from April through September. Conversely, fat percentage was highest for cows calving from April through September and lowest for those calving from October through March. Differences between seasons of calving for milk yield, fat yield, and fat percentage were –132.5 kg, –4.66 kg, and 0.001%, respectively. The influence of season of calving on lactation is well recognized (7, 13). Seasonal variation in cow performance was expected to be primarily a manifestation of variation in feed quantity and quality.

Single-trait analyses

Table III shows heritability and repeatability estimates derived from the variance component estimates with single-trait analyses. The heritability estimates were 0.29 for milk yield, 0.27 for fat yield, and 0.39 for fat percentage. The heritability estimate for milk yield agrees with those given by many authors (2, 3, 8, 10, 18, 24), was slightly lower than those from other studies (9, 12, 22) and was slightly higher than those from yet other studies (11, 17, 19). The heritability of fat yield was comparable to those of Chauhan and Hayes (8), deJager and Kennedy (10) and Van Vleck *et al.* (23). The estimate of heritability for fat percentage was similar to that of Meyer (19), but markedly smaller than those previously mentioned (8, 9, 10, 18). These heritabilities indicated that there was a considerable amount of variation in milk yield similar to that found for fat that would be used for selection. The heritability was higher for fat percentage than those for milk and fat yields. This is in agreement with results reported in the literature (8, 10, 15, 24). The estimate of heritability for milk yield was higher than that for fat yield. This result is similar to those of Boichard and Bonaiti (3), Dematawewa and Berger (11), and Van Vleck and Dong (22), but contrary to other reports (8, 15, 18).

Table I

Number of records, unadjusted means, standard deviations and coefficients of variation for milk yield, fat yield and fat percentage of Holstein-Friesian cows

Trait	Num. of records	X	SD	CV (%)
Milk yield (kg)	20,140	5353.4	1533.9	28.6
Fat yield (kg)	20,140	192.8	51.2	26.5
Fat (%)	20,140	3.63	0.26	7.16

Table II

Number of records and effects of age and season of calving on milk yield, fat yield and fat percentage of Holstein-Friesian cows

Effect	Number	Milk yield (kg)		Fat yield (kg)		Fat (%)	
		Difference[a]	Row mean	Difference[a]	Row mean	Difference[a]	Row mean
Age (months)							
[Age ≤ 30][b]	4944	0.0	5055.4	0.0	183.5	0.000	3.65
30 < age ≤ 42	1786	170.3	5013.7	5.9	182.7	–0.002	3.67
42 < age ≤ 54	2448	368.6	5417.5	12.0	195.8	–0.017	3.64
54 < age ≤ 66	3650	554.1	5489.4	18.0	197.0	–0.028	3.62
66 < age ≤ 78	2601	754.8	5661.3	25.2	202.6	–0.030	3.61
78 < age ≤ 90	1951	759.7	5627.2	25.6	201.2	–0.028	3.61
Age > 90	2760	666.7	5386.5	22.1	192.7	–0.031	3.62
Calving season							
[Oct.-March][b]	10,364	0.0	5453.2	0.00	196.3	0.000	3.63
April-Sept.	9776	–132.5	5247.5	–4.66	189.2	0.001	3.64

[a] Estimates of deviation from reference class

[b] The reference class from which deviations were taken is in brackets

The low heritabilities found in the present study may be explained by the low mean performance of the Moroccan cows. Hill *et al.* (16) showed that heritability estimates of milk yield and composition may increase as the production level of herds increases.

Permanent environmental variance as a proportion of phenotypic variance was low and varied from almost zero for fat percentage to 0.05 for milk yield. The repeatability estimates for milk and fat yields and fat percentage were 0.33, 0.32 and 0.39, respectively. The estimates for yields were higher than their corresponding heritabilities, but that of fat percentage was similar.

Table III

Variance components, heritability and repeatability estimates for milk yield, fat yield and fat percentage from single-trait analyses

Parameter[a]	Milk yield	Fat yield	Fat %
σ_p^2	846,641.5	984.1	0.026
σ_a^2	241,588.2	268.7	0.010
σ_{ep}^2	40,744.2	42.5	0.000
σ_e^2	564,310.1	672.9	0.016
h^2	0.29	0.27	0.39
c^2	0.05	0.04	0.00
e^2	0.67	0.68	0.61
t	0.33	0.32	0.39

[a] σ_p^2 = phenotypic variance; σ_a^2 = additive genetic variance; σ_{ep}^2 = permanent environment variance; σ_e^2 = residual variance; $h^2 = \frac{\sigma_a^2}{\sigma_p^2}$ = heritability; $c^2 = \frac{\sigma_{ep}^2}{\sigma_p^2}$ = permanent environmental variance as a proportion of phenotypic variance; $e^2 = \frac{\sigma_e^2}{\sigma_p^2}$ = residual variance as a proportion of phenotypic variance; $t = \frac{\sigma_a^2 + \sigma_{ep}^2}{\sigma_p^2}$ = repeatability

The repeatability estimates of the present study were lower than those reported by other workers (1, 11, 14, 21, 24). The medium repeatabilities indicated that temporary environmental factors contributed appreciably to the variation in milk traits among parities, hence, culling of cows on single performance should be avoided.

Two-trait analyses

Table IV shows estimates of genetic correlations, phenotypic correlations, and average for heritabilities from all bivariate analyses. The heritability estimates for milk and fat yields (0.33 and 0.32, respectively) were higher than those obtained from single-trait analyses, but those for fat percentage were similar (0.39).

There was a very high positive genetic correlation of 0.96 between milk and fat yields suggesting that selection for milk yield would increase fat yield. Reported estimates of genetic correlations between milk and fat yields ranged from 0.40 to 0.95 (2, 8, 10, 11, 15, 17, 21, 24).

Table IV

Heritabilities, genetic and phenotypic correlations from bivariate analyses among milk yield, fat yield and fat percentage of Holstein-Friesian cows[a]

Trait	Trait		
	Milk yield	Fat yield	Fat %
Milk yield	0.33	0.96	–0.32
Fat yield	0.96	0.32	–0.06
Fat %	–0.28	–0.03	0.39

[a] Heritabilities, on the diagonal, are the average values from all bivariate analyses. Genetic and phenotypic correlations are shown above and below the diagonal, respectively

Milk yield had a negative genetic correlation of –0.32 with fat percentage. This correlation was in the range of those reported in the literature (8, 9, 10, 15, 18, 21, 24), falling between –0.20 and –0.56. The negative correlation between milk yield and fat percentage indicated that selection for the former would decline fat percentage.

The genetic correlation between fat yield and fat percentage was slightly negative (–0.06), but lower than the correlation between milk yield and fat percentage. The estimates of correlation for fat yield and fat percentage differed from the positive relationships reported in the literature (8, 10, 15, 18, 19, 24). This antagonism between fat yield and percentage occurs mainly because the former depends more on milk yield than on fat content.

The phenotypic correlation was positive and high between milk and fat yields (0.96), negative and medium between milk yield and fat percentage (–0.28), and close to zero between fat yield and fat percentage (–0.03). The phenotypic correlation between yields was similar to its corresponding genetic correlation and nearly in agreement with previous works (8, 9, 10, 11, 18, 19, 22, 24). The phenotypic correlation of fat percentage with milk yield was comparable to those reported by Chauhan and Hayes (8), Cue *et al.* (9), deJager and Kennedy (10), and Welper and Freeman (24), ranging from –0.26 to –0.34. However, the phenotypic correlation between fat yield and fat percentage close to zero was different from the positive and medium relationship reported in the literature (8, 10, 18, 19, 24).

■ CONCLUSION

This report is the first documentation of genetic and phenotypic parameters in Moroccan dairy cattle. The estimates of genetic parameters obtained in Holstein-Friesian cows were very similar to those reported in the literature. Heritabilities indicated that there was a considerable amount of variation in milk yield, similar to that found for fat. The genetic correlation between yields was shown to be high. However, the negative correlation between milk and fat percentage will not permit a rapid genetic change under divergent selection. In Morocco, where milk, butter and other derived products are partly imported in order to satisfy the human population's demand, the desired breeding goal would seem to be the increase in milk yield, while holding the fat percentage constant.

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Résumé

Boujenane I. Estimation des paramètres génétiques et phénotypiques de la production laitière des vaches de race Frisonnes Holstein au Maroc

L'héritabilité et la répétabilité du rendement laitier, de la quantité de matières grasses et du taux butyreux, ainsi que leurs corrélations génétiques et phénotypiques, ont été estimées en utilisant un modèle animal à partir de 20 140 données relevées sur 11 618 vaches Frisonnes Holstein soumises au contrôle laitier officiel au Maroc, entre 1990 et 1999. Les héritabilités du rendement laitier, de la quantité de matières grasses et du taux butyreux ont été respectivement de 0,29, 0,27 et 0,39, leurs répétabilités ont été respectivement de 0,33, 0,32 et 0,39. Les corrélations génétiques du rendement laitier avec la quantité de matières grasses et le taux butyreux ont été respectivement de 0,96 et –0,32, et celle de la quantité de matières grasses avec le taux butyreux a été de –0,06. Les corrélations phénotypiques ont été de 0,96 entre les rendements en lait et en matières grasses, de –0,28 entre le rendement en lait et le taux butyreux, et de –0,03 entre le rendement en matières grasses et le taux butyreux. Il a été conclu que ces paramètres génétiques et phénotypiques pourraient être utilisés pour l'estimation des valeurs génétiques des bovins laitiers au Maroc.

Mots-clés : Bovin Frison Holstein – Vache laitière – Rendement laitier – Matières grasses du lait – Héritabilité – Corrélation génétique – Maroc.

Resumen

Boujenane I. Estimaciones de los parámetros genéticos y fenotípicos para la producción de leche en vacas Holstein-Friesian en Marruecos

Se estimaron heredabilidades, repetibilidades y correlaciones genéticas y fenotípicas con la producción de leche, la cantidad de grasa y el porcentaje de grasa, utilizando un modelo animal y 20 140 registros pertenecientes a 11 618 vacas Holstein-Friesian, registradas en el programa oficial de registros de leche de Marruecos, entre 1990 y 1999. La heredabilidad para la producción de leche, cantidad de grasa y porcentaje de grasa fue de 0,29, 0,27 y 0,39, respectivamente y la repetibilidad fue de 0,33, 0,32 y 0,39, respectivamente. Las correlaciones genéticas para producción de leche con cantidad de grasa y porcentaje de grasa fueron de 0,96 y –0,32, respectivamente y la correlación de la cantidad de grasa con el porcentaje de grasa fue de –0,06. La correlación fenotípica fue de 0,96 entre la cantidad de leche y de grasa, –0,28 entre porcentaje de grasa y producción de leche y –0,03 entre cantidad y porcentaje de grasa. Se concluye que estos parámetros genéticos y fenotípicos podrían utilizarse para la evaluación genética del ganado de leche en Marruecos.

Palabras clave: Ganado bovino Holstein Friesian – Vaca lechera – Rendimiento lechero – Grasa de la leche – Heredabilidad – Correlación genética – Marruecos.