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Research Article

Estimation of Breeding Values for Dairy Cattle Using Test-Day Milk Yields

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Abstract: The objectives of this study were to estimate genetic parameters and breeding values for test-day (TD) and 305-day milk yields, and to compare the results from TD and 305-day analyses. The data comprised 10,822 TD records from 1103 first lactations of Holstein cows from state farms in the western part of Turkey. Additive genetic, residual and permanent environmental variances, heritabilities and breeding values for 305-day and TD milk yields were estimated by the REML method using animal models. The heritability estimate (0.11) of TD milk yields was lower than the corresponding estimate (0.25) for 305-day milk yields. The product-moment correlations (≥ 0.97) show that estimated breeding values (EBVs) for TD milk yields are closely correlated with EBVs for 305-day milk yields. Spearman and Kendall rank correlations between rankings of animals for EBVs for TD and 305-day milk yields were also high (≥ 0.97 and ≥ 0.86, respectively). Shifts in rank for various top lists of cows and sires ranked by their EBVs for 305-day and TD milk yields show that more extreme changes in ranks occurred in cows than in sires. TD milk yields could be used instead of 305-day milk yield for the genetic evaluation of dairy cattle. Furthermore, using TD yields for genetic evaluations offers more advantages.

Key Words: dairy cattle, breeding value, test-day milk yields, test-day model

Süt Sığırlarında Denetim Günü Süt Verimlerini Kullanarak Damızlık Değerin Tahminlenmesi

Özet: Bu çalışmanın amacı, denetim günü ve 305 günlük süt verimlerine ilişkin genetik parametreler ile damızlık değerlerini tahminlemek ve bu analizlerden elde edilen sonuçları karşılaştırmaktır. Çalışmada, Türkiye'nin batısındaki kamuya ait çiftliklerde yetiştirilen 1103 adet Siyah Alaca ineğin ilk laktasyonlarına ilişkin 10822 adet denetim günü süt verimi kullanılmıştır. Denetim günü ve 305 günlük süt verimlerinin eklemeli genetik, hata ve kalıcı çevre varyansları, kalıtım dereceleri ile damızlık değerleri REML yöntemiyle birey modeli kullanılarak tahminlenmiştir. Denetim günü süt verimlerinin kalıtım derecesi (0.11), 305 günlük süt veriminin kalıtım derecesinden (0.25) daha düşük bulunmuştur. Denetim günü verimlerinden tahminlenen damızlık değerleri ile 305 günlük süt verimlerine ait damızlık değer tahminleri arasındaki korelasyonlar (≥ 0.97) yüksek bulunmuştur. Denetim günü ve 305 günlük süt verimlerine ait damızlık değer tahminlerine göre bireylerin sıralanışları arasındaki Spearman ve Kendall sıra korelasyonları da yüksek bulunmuştur (sırasıyla ≥ 0.97 ve ≥ 0.86). Denetim günü ve 305 günlük süt verimlerine ait damızlık değerlerine göre sıralanan inek ve boğalar için oluşturulan çeşitli en iyiler listelerindeki sıralanmada saptanan yer değişiklikleri, ineklerin sıralanmasındaki değişimin boğalara göre daha fazla olduğunu göstermiştir. Süt sığırlarının genetik değerlendirilmesinde, denetim günü süt verimleri 305 günlük süt verimi yerine kullanılabilir. Ayrıca, genetik değerlendirmelerde denetim günü verimlerinin kullanılması birçok avantaj da sağlamaktadır.

Anahtar Sözcükler: Süt sığırı, damızlık değer, denetim günü süt verimi, denetim günü modeli

Introduction

Selection for milk yield in dairy cattle is generally based on the analysis of 305-day lactation records. In order to estimate 305-day lactation yields, test-day (TD) yields are generally recorded at monthly intervals. Incomplete lactation records are usually extended to 305-day records. The accuracy of 305-day yields depends on the number of TDs, the number of days between tests and the methods of estimating 305-day yields.

Recently, attempts have been made to use TD yields instead of 305-day yields for the genetic evaluation of dairy cattle (1-3). The use of TD yields mainly depends on the relative amount of genetic variation during a lactation. The heritability estimates for TD yields for mid-lactation have been either the same or slightly lower than those for 305-day yields, although estimates were lower for the beginning and end of lactation (2,4,5).

There are various advantages of using TD records, such as the fact that they do not have to be extended using a number of factors, and there is better modelling with TD records than 305-day ones, and more accurate genetic evaluation (1,2,6).

Breeding values have been estimated for 305-day and TD yields by several researchers (1,2,3,7). Swalve (2) reported that a comparison of both sets of breeding values indicated only minor changes in sire rank, but more drastic reranking for individual cows. Correlations between estimated breeding values (EBVs) for TD and 305-day yields ranged from 0.87 to 0.97 in the Ptak and Schaeffer study (1) and from 0.88 to 0.96 in that by Swalve (2).

The objectives of this study were to estimate genetic parameters and breeding values for TD and 305-day milk yields, and to compare the results from TD and 305-day analyses.

Materials and Methods

The data came from the Tahirova, Dalaman, Türkgeldi and Sarmısaklı state farms in the western part of Turkey for Holstein cows calving from 1980 to 1992. The original data comprised 1557 first lactations, from which lactations with no TD record, and incomplete lactations were excluded. Furthermore, the age of calving was restricted to 20 to 41 months, and only lactations lasting at least 270 days were included. The final data file contained 1103 first lactations with at least nine TD yields: 305-day lactation milk yields for the same 1103 lactations were calculated using the centering date method (8). In the TD analysis, the first 10 TD yields were used because the number of TD records for TD $\geq$ 11 was limited. The final data file contained 10,822 TD records. Years of calving were incorporated into three periods (1980 to 1983 = period 1, 1984 to 1987 = period 2 and 1988 to 1992 = period 3) because the data extended over a period of 13 years. Four calving seasons were distinguished: winter (December to February), spring (March to May), summer (June to August) and autumn (September to November). The structure of the final data file is given in Table 1.

Variance components (additive genetic, residual, and permanent environmental variances), heritabilities and breeding values for 305-day and TD milk yields were estimated by the REML method using animal models with a DFREML 3.0 program (9). The models used were as follows:

For 305-day lactation records,

$$Y_{ijk} = HPS_i + b_1x_{1ijk} + b_2x_{2ijk} + a_j + e_{ijk} \quad [1]$$

where

Y_{ijk} = 305-day milk yield record,

HPS_i = fixed effect of herd-period-season of calving,

X_1 = age of calving, as a covariable,

X_2 = days in milk (DIM) at first TD, as a covariable,

a_j = animal's random additive genetic effect,

e_{ijk} = random residual effect.

For TD records (repeatability model),

$$Y_{ijk} = HPS_i + b_1x_{1ijk} + b_2x_{2ijk} + b_3x_{3ijk} + b_4x_{4ijk} + b_5x_{5ijk} + a_j + pe_j + e_{ijk} \quad [2]$$

where

Y_{ijk} = milk yield record from a single TD,

HPS_i = fixed effect of herd-period-season of calving,

X_1 = age of calving, as a covariable,

X_2 = DIM / c, as a covariable, where c is a constant set to 305 (1),

X_3 = $(DIM / c)^2$, as a covariable,

X_4 = ln(c / DIM), as a covariable,

X_5 = $(\ln(c / DIM))^2$, as a covariable,

a_j = animal's random additive genetic effect,

pe_j = effect of random permanent environment of the cow during lactation,

e_{ijk} = random residual effect.

The repeatability model is analogous to the model TY1 of Ptak and Schaeffer (1). In the model, TD yields

Table 1. The structure of the final data.

Item	No.
First lactations with ≥ 9 TD records	1103
TD records (unlimited)	11,611
TD records (limited to first 10 TD)	10,822
Herds	4
Periods	3
Seasons	4
Herd-period-seasons	43
Sires	154
Mean TD records per cow (limited to first 10 TD)	9.81
Mean TD records per herd (limited to first 10 TD)	2705.5

were taken as repeated measurements, and the model included four covariates to account for the shape of the lactation curve.

Results

Phenotypic means and standard deviations for 305-day and TD milk yields and DIM for the first 10 TD are given in Table 2. Milk yield peaked at around 45 DIM and then declined as lactation progressed.

Estimates of variance components, heritabilities and the relative portion of permanent environment variance to total variance (PE) for TD and 305-day milk yields are presented in Table 3. The heritability estimates for 305-day and TD milk yields were 0.25 and 0.11, respectively. The heritability estimate of milk yield under the TD model is lower than the corresponding estimate for 305-day milk yield. The relative portion of permanent environmental variance to total variance of TD was estimated as 0.34.

The product-moment, Spearman rank and Kendall rank correlations between EBVs for 305-day and TD milk yields for cows, and sires with different numbers of daughters are given in Table 4. The product-moment correlations (≥ 0.97) show that EBVs for TD milk yields are closely correlated with EBVs for 305-day milk yields. The Spearman rank correlations (≥ 0.97) indicate that the rankings of animals for EBVs for TD and 305-day milk yields are also closely correlated with each other. Among sires, the Spearman rank correlations either did not change or rose slightly as the number of daughters per sire increased. All Kendall rank correlations were ≥ 0.86. Among sires, these correlations rose as the number of daughters per sire increased.

To show the changes in the rankings of cows and sires ranked by their 305-day milk yield EBVs and their TD milk yield EBVs, shifts in rank for the various top lists were determined. The results are presented in Table 5. When only the first 10 cows are considered, there are eight animals on both lists. For the various top lists of cows, ≥ 80% of the cows appear on both lists. When the first five sires are considered, 60% (three sires) were on both lists. However, when the first 10, 25 and 50 sires are considered, the number of sires on both lists was

Table 2. Phenotypic means and standard deviations for 305-day milk yield and test-day milk yields.

		DIM		Milk (kg)	
	No.	$\bar{x}$	SD	$\bar{x}$	SD
305-day	1103	-	-	4486	1354
TD 1	1103	15.59	7.84	16.79	4.01
TD 2	1103	45.00	8.22	18.34	5.55
TD 3	1103	75.10	8.94	17.63	5.71
TD 4	1103	104.50	9.50	16.76	5.70
TD 5	1103	134.60	10.43	15.87	5.43
TD 6	1103	163.99	11.10	15.17	5.34
TD 7	1103	193.39	11.81	14.19	5.04
TD 8	1103	223.49	12.92	13.21	4.90
TD 9	1103	252.89	13.68	12.15	4.78
TD 10	895	279.93	14.43	11.54	4.93

Table 3. Estimates of variance components[1], heritabilities and PE[2] for 305-day milk yield (Model 1) and test-day (TD 1 to TD 10) milk yields (Model 2).

	σ^2_A	σ^2_E	σ^2_{PE}	h^2	PE
305-day	111295	337879	-	0.25 ± 0.10	-
TD	1.01	5.08	3.19	0.11 ± 0.06	0.34 ± 0.05

[1] σ^2_A = Additive genetic variance, σ^2_E = residual variance, σ^2_{PE} = variance of permanent environment

[2] PE = Relative portion of permanent environment to total variance

Table 4. Correlations[1] between estimated breeding values for 305-day milk yield (Model 1) and test-day milk yields (Model 2).

	No.	r	r_s	T
Cows	1103	0.977	0.973	0.863
Sires with				
≥ 2 daughters	132	0.975	0.974	0.872
≥ 5 daughters	75	0.976	0.976	0.878
≥ 10 daughters	41	0.969	0.975	0.883
≥ 15 daughters	21	0.982	0.982	0.914
≥ 20 daughters	10	0.978	0.988	0.956

[1] r = Pearson product-moment correlation, r_s = Spearman rank correlation, T = Kendall rank correlation

Table 5. Shifts in rank of cows and sires by 305-day milk yield EBVs compared with ranking by test -day milk yield EBVs.

			Largest rank shift		
Animals considered	Number of animals on both lists	Percentage of animals on both lists	From 305-day list	To TD list	Absolute difference
Cows					
First 10	8	80	7	11	4
First 25	20	80	25	45	20
First 50	42	84	47	127	80
First 75	65	87	67	169	102
First 100	83	83	67	169	102
Sires (≥ 5 daughters)					
First 5	3	60	4	9	5
First 10	9	90	4	9	5
First 25	24	96	12	4	8
First 50	48	96	28	46	18

≥ 90%. The largest shifts in rank for the first 10, 25, 50, 75 and 100 cows, and for the first 5, 10, 25 and 50 sires are presented based on the ranking for 305-day milk yield EBVs. As shown in Table 5, when the first 10 cows are considered, the cow in 7^{th} position on the 305-day list appeared in 11^{th} position on the TD list, which was the largest rank shift in this group.

Discussion

Although studies focusing on 305-day milk yield analysis in dairy cattle are available, studies analysing TD records as repeated measurements are new in Turkey.

In this study, milk yield peaked at around 45 DIM and then declined as lactation progressed, as reported by Swalve (2) and Stanton et al. (10).

The heritability estimate of 305-day milk yield in this study is lower than the estimates reported by Swalve (2) and Meyer et al. (11), similar to that of Visscher and Goddard (12), and higher than the estimate of Strabel and Szwaczkowski (13). The heritability estimate of milk yield under the TD model is lower than those estimated by Swalve (2), Strabel and Szwaczkowski (13) and Reents et al. (14).

The heritability estimate of milk yield under the TD model was lower than the corresponding estimate for 305-day milk yield. This result is in agreement with the result reported by Swalve (2), but disagrees with the study by Strabel and Szwaczkowski (13).

The estimation of the relative portion of permanent environmental variance to total variance of TD in this study is similar to the estimate of Swalve (2) and smaller than that by Strabel and Szwaczkowski (13). The level of PE could change depending on the number of TDs included and the model used in the analysis of TD records (2).

The magnitude of the product-moment and Spearman rank correlations between sire EBVs from 305-day and TD milk yields in this study are similar to the correlations obtained by Ptak and Schaeffer (1) with models (TY1 and TY2) including herd-year-season effects.

In this study, Kendall rank correlations between the EBVs were also calculated. This correlation is suitable as a measure of correlation with the same sort of data for which the Spearman rank correlation is useful (15). The interpretation of the Kendall rank correlation, however, is different from that of the Spearman rank correlation. For our results, the Kendall rank correlation is the difference between the probability that EBVs for TD and 305-day milk yields are in the same order and the probability that EBVs for TD and 305-day milk yields are in different orders. Among sires, Kendall rank correlations rose as the number of daughters per sire increased. This increment is higher than the increment in the Spearman rank correlation.

When shifts in rank for various top lists of cows and sires ranked by their 305-day milk yield EBVs and their TD milk yield EBVs are considered, the percentage of cows and sires on both lists obtained in this study were greater than those from the Swalve study (2). The largest shifts in rank for the first 10, 25, 50, 75 and 100 cows, and for the first five, 10, 25 and 50 sires were investigated based on the ranking for 305-day milk yield EBVs. When the largest shifts in rank, based on 305-day lists compared with TD lists, are considered, all the shifts were downward. In the sire lists, however, one upward shift was observed (Table 5). When the absolute difference of the largest rank shifts is examined, it can be seen that more extreme changes in ranks occurred in cows than for sires with ≥ 5 daughters because of lower accuracies. This result is in agreement with the result from the study by Swalve (2), who explained that drastic changes in rank for cows seemed to be associated with lactation curves that deviated greatly from the standard lactation curve.

The correlations between EBVs for 305-day and TD milk yields for cows and sires are very high. This suggests that TD milk yields could be used instead of 305-day milk yield for the genetic evaluation of dairy cattle. The ranking of sires will be affected less than the ranking of cows when the TD model is used to estimate breeding values.

The heritability estimate of TD milk yields was lower than the corresponding estimate for 305-day milk yield. However, it was lower than expected. The magnitude of the heritability estimate of TD milk yields was expected to be closer to the corresponding estimate for 305-day milk yield (1,2). The lower estimate in this study could be explained by the small number of observations and the model used for TD milk yield analysis. It was reported that when the herd-test-date effect is included in the model instead of the herd-year-season effect, higher heritabilities were estimated (2,11). Furthermore, due to the many advantages of using TD yields (1,16), TD models should be used in genetic evaluations.

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