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Study of Some Suggested Measures of Milk Yield Persistency and Their Relationships

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ABSTRACT

Phenotypic and genetic parameters were estimated for five persistency criteria of milk yield. The criteria included the maximum production of all test-day records per lactation divided by the related mean, standard deviation of all test-day records of complete lactation, the percentage of daily milk retained from the peak to the end of lactation, the ratio of latest test-day yield record divided by the mean of all test-day yield records and a criterion that was proposed by Wood (1967), which derived from estimated lactation curve factors in incomplete gamma function. Data set comprised 36487 first lactation yields of Holstein dairy cattle of Iran with at least eight recorded test-days per lactation. Heritabilities based on the univariate models were 0.32 for 305-days milk yield and were between 0.0819 to 0.0469 for persistency criteria. Heritabilities based on the multivariate models were changed a little in comparison to univariate models. Genetic correlation between persistency criteria and 305-day milk yield were between 0.6617 to -0.6124. Genetic correlation between persistency criteria were between 0.9988 to -0.9265. Phenotypic correlation had similar trend to genetic correlation. The result showed that genetic correlation between milk yield and some persistency criteria were favorable for selection and breeding programs.

Key Words: Persistency; Milk yield; Dairy cattle; Lactation curve

INTRODUCTION

Milk yield in dairy cattle increases rapidly from calving to peak period of yield in a few weeks, there after decreases gradually until milking is no longer practical (Leon-Velard *et al.,* 1995). The persistency of dairy milk yield, which refers to the degree to which milk yield is maintained from month to month by the cow during her lactation, is an economic trait because lactation curve with flat shape (high persistency) allows cows to be fed according to their requirements, which avoids metabolic disorders and health and fertility problems. The knowledge of persistency is important for herd management and selection strategy. The benefits of selecting for lactations that are more persistent were only speculative, because very little research had been done. As the time goes by, the more is learned about this trait and its relationship with other important traits. The persistency can be influenced genetically and can be affected by such environmental factors as herd management, lactation number, open days, feeding, gestation, year, season and age of calving (Leon-Velard *et al.,* 1995). Studies investigated the genetic aspects of persistency, found heritability estimates to be of moderate size (0.1 to 0.2) and zero to positive genetic correlation with the 305-days milk yield. Analysis of relationship between persistency and other traits shows that genetic improvement for persistency is also possible. The persistency can be defined in several ways, as either ratios of yield in different parts of lactation period, to be derived from factors in lactation curves models as proposed by Wood (1967) or a simple statistical parameter computed from test-day yield records. Some of these criteria cover the entire lactation period and are independent of time and some of them are not. Despite the differences in these criteria, generally high genetic and phenotypic correlation has been found among them (Swalve, 1995).

The incomplete gamma function, which described by Wood (1967) is one of the most popular models used to describe the lactation curve and was shown below:

$y_t = at^b e^{-ct}$

Where y_t = milk yield on day *t*, *a* = a parameter to represent yield at the beginning of lactation, *b* and *c* are factors associated with the inclining and declining slope of the lactation curves, respectively. Typical lactation curve have positive *a*, *b* and c and curve with negative *a*, *b* or *c* is considered atypical. Negative estimates for parameter of *a* implies that yield at the beginning of lactation was less than zero. If *b* and *c* be negative the curve shape will be concave than convex. This model can be linearized with a simple logarithmic transformation as follow:

$Ln(y_t) = Ln(a) + bLn(t) - ct.$

In this study, linear form of this model was used. Wood (1967) also defined $s = -(b + 1)\ ln(c)$ as a measure of persistency of lactation and this definition was used as a criterion of persistency of milk yield.

The objectives of this study were to estimate genetic and phenotypic parameters for different criteria of persistency, finding correlation between them and their relationships with 305-days milk yield, by applying REML under animal models in the Holstein dairy cattle of Iran. Previous studies have showed that persistency was affected by open days; therefore, this factor was added, while applying models as a covariate fixed effect.

MATERIALS AND METHODS

The original data set contained of 465745 yearly records of 133943 Holstein cows in first or later lactations, which collected between 1983 and 2003 by Iranian Animal Breeding Center (IABC). From which 55879 first lactations with at least eight test-day records were extracted. Editions were on the following matters:

1. The length of interval between calving and the first test-day (4 to 45 days).
2. The length of interval between calving and the second test-day (14 to 70 days).
3. The range of test-day yield between 3 to 70 kg.
4. Open days were restricted to be at least 40 days.
5. The age of calving were limited to be between 20 to 40 months.
6. The year of calving was restricted to be aftermath 1991 because of inaccuracy.
7. To enable the application of models considering interaction effects of herd-year-season, the herd size was limited to be more than 70 cows.

The final data set contained 349668 test-day records of 36487 cows that were produced in 157 herds of different climates of Iran.

After estimating lactation curve parameters from 36487 lactations, 6460 (17.7%) were determined to have atypical lactation curves and were excluded from further analysis.

Five criteria of persistency were defined that are described below:

1. The maximum production of all test-day records per lactation divided by the related mean, and denoted by MAME.
2. Standard deviation of all test-day records per lactation denoted by STD.
3. The percentage of daily milk retained from the peak to the end of lactation, calculated as the ratio of the latest test-day yield record divided by the maximum production of all test-day records per lactation timed 100, and denoted by LAMA.
4. The latest test-day record yield divided by the mean of all test-day records yields and denoted by LAME.
5. The criterion that was proposed by Wood (1967) and was calculated from parameters of incomplete gamma function that was fitted to test-day yield records of each cow separately and denoted by WE.

Among these criteria the STD, WE, LAME and the MAME criteria cover the entire lactation period and are independent of time but LAMA. In addition, among them lower values for MAME are favorable whereas for LAMA, LAME and WE higher values are favorable. For STD, however, it is not clear that lower values are favorable or higher values. In order to estimate variance components by applying animal models the DFREML software was used (Meyer, 1993). In addition, to define applied model, the suggested model in literatures was used (Swalve, 1995), but the open days was added to models as a covariate fixed effect.

The model applied is summarized below:

$$y_{ijk} = M + HYS_I + \sum_{i=1}^{4} b_i x_i + a_j + e_{ijk}$$

Where:

y_{ijk} = trait value (persistency criteria & milk yield).
M = overall mean.
HYS_i = fixed effect of herd-year-season of calving.
x_1 = age of calving (days).
x_2 = days in milk at the latest test-day recording.
x_3 = days in milk at the first test-day recording.
x_4 = days between calving and gestation (in all traits except for MAME).
e_{ijk} = residual effect.
b_1, b_2, b_3 & b_4 = regression coefficients.

Under all univariate models var (a) was assumed to be $A\sigma^2_a$ where A is the numerator relationship matrix and var (e) was assumed to be $I\sigma^2_e$.

A program was written by Visual Basic Programming language and was used to estimate lactation curve parameters for each cow.

RESULTS AND DISCUSSION

Linear form of the incomplete gamma function was fitted to individual cow data. Every mean of coefficients in this model were 2.54 ± 0.80 for *ln (a)*, 0.247 ± 0.22 for *b* and 0.00324 ± 0.0022 for *c* parameters. Multiple coefficient of determination, (R^2), varied from cow to cow and mean of this criterion was0.6116 ± 0.248. Of 36487 lactations, 6460 (17.7%) were determined to have atypical lactation curves. Among them 277 lactations for parameter of a, 5940 lactations for parameter of b and 2963 lactations for parameter of c had negative estimated and in some cases a lactation had more than one negative parameters. Tekerli *et al.* (2000) reported 26.3% of atypical curves on a total 1278 lactations. Rekik *et al.* (2003) reported 15 to 42% atypical curves in different types of herds in Tunisia.

The Mean, standard deviation and extremes values of milk yield and persistency criteria were showed in Table I. The mean of persistency criteria showed that the persistency of milk yield is not approximately very low.

The residual distribution of all persistency criteria and milk yield were normal or did not differ significantly from a normal distribution.

In order to determine suitable model, Proc GLM of the SAS software (1990) was used. Results of primary analysis by SAS showed, 305-days milk yield and all criteria of persistency except MAME, were affected by open days. There were positive and significant linear relationship between open days and milk yield indicating that, the more days exist between calving and gestation, the more milk yield is produced at the complete period of lactation. Relationship between open days and LAMA was positive and significant suggesting that by increasing interval between calving and gestation, persistency of milk yield was

Table I. Means, standard deviations, maximum and minimum values of traits

Trait	Mean	Standard deviation	Maximum	Minimum
305-days milk yield	6456.23	1198.15	11188	2213
STD[1]	4.12017	1.52285	16.66	0.2
MAME[2]	1.23850	0.113756	3.16	1.03
LAMA[3]	60.2528	12.7842	94	9
LAME[4]	0.735	0.116987	0.97	0.13
WE	7.29544	0.607403	15.51	5.44

1. Standard deviation of all test-day records per lactation, 2. The maximum production of all test-day records per lactation divided by the related mean, 3. The percentage of daily milk retained from the peak to the end of lactation timed by 100, 4. The latest test-day record yield divided by the mean of all test-day records, 5. The criterion that was proposed by Wood (1976) and was calculated as, s=-(b+1) ln (c) which b and c are parameters of incomplete gamma function.

increased. The major reason of this effect is probably effect of gestation i.e. that as gestation advanced, daily milk yield decreased and therefore 305-day milk yield and persistency were decreased. However, for STD these relationships are complicated and confusable. As will be showed later, genetic and phenotypic correlation between milk yield and STD is positive and relationship between STD and open days was negative. On the other hand open days have had positive relationship with milk yield therefore it seems that, at least in this study, STD is not a suitable definition of persistency of milk yield. A significantly linear Relationship between 305-days milk yield and age of calving was found demonstrating that milk yield was increased by increasing age of calving. The reason of this is probably development of udder system or reduction of growth rate. The more is the age of calving, the more development of udder system and the less growth rate will be, and hence milk yield was increased. Relationship between age of calving and MAME and STD were positive but negative for others. The resultant development of udder system through increasing of age, raised milk yield at peak period, consequently, increasing of MAME and STD and decreasing of other persistency criteria.

Relationship between days in milk at latest test-day recording and 305-days milk yield was significant and positive. Test-day records per lactation varied between at least eight to ten and therefore, days in milk at latest test day recording varied between 260 to 310 days. It is obvious that by increasing period of lactation, 305-day milk yield is increased. Relationship between LAME, LAMA and days in milk at latest test-day recording was negative but positive for others criteria of persistency. After stage of peak yield, as period of milking was longer, daily milk yield was reduced, therefore, milk yield at latest test-day was reduced and MAME and STD were increased but other criteria were reduced.

Estimates of variance components of 305-days milk yield and persistency criteria by univariate models were given in Table II. Estimates of heritability for 305-days milk yield was approximately high (0.3177) and in close agreement with former studies using data from Iran (Montazer Torbiti *et al.,* 2003). The estimates of heritabilities for persistency criteria were approximately low (0.0469 to 0.0819) but in close agreement with pervious study using data from Iran (Montazer Torbiti *et al.,* 2003). Shanks *et al.* (1981) reported 0.02 heritability for persistency, which was calculated by incomplete gamma function, but Batra *et al.* (1987) reported 0.21 heritability for this criterion of persistency. Among all persistency criteria, the highest heritability was estimated for STD and the lowest was estimated for *LAME*. The estimates for the heritabilities in this study were slightly lower than pervious studies. The heritability of STD criteria was higher than MAME, which is in agreement with the literature (Swalve, 1995). Also in this study phenotypic and residual variance for persistency traits were higher and additive variance were lower than previous study (Swalve, 1995) probably because of difference in recording system or climate factors.

Estimates of phenotypic and genetic correlation between 305-days milk yield and persistency criteria were given in Table III. As were shown in this Table, genetic correlation between persistency and milk yield ranged between 66.17% to - 0.61.24% and were in good agreement with pervious studies (Swalve, 1995). Correlation between 305-days milk yield and LAMA criteria of persistency was about 0.42, indicating that, it is possible to improve persistency by selecting animals based on 305-days milk yield. Genetic correlation between MAME and milk yield was around -0.612 and therefore suitable for selecting animals based on 305-days milk yield and to improve persistency similar to WE and LAMA criteria. However, for STD, there was low positive genetic correlation with 305-days milk yield and probably not suitable for selection. However, positive correlation between STD and milk yield indicating that higher yield were associated with higher standard deviation of test-day yields (Swalve, 1995). Heritabilities of milk yield based on multivariate models in comparison to univariate models changed a little but in case of STD, heritability of milk yield was decreased sharply (result not shown).

Estimates of phenotypic and genetic correlation between persistency criteria were given in Table III. As were shown by this Table, genetic correlation between persistency traits were suitable and were ranged between 0.9988 to -0.9265. Phenotypic correlation had similar trend to genetic Correlation for all cases but in some cases, phenotypic correlation is very lower than genetic correlation. The results for the relationship between persistency traits confirmed pervious studies (Swalve, 1995). Additive variance of all persistency criteria that were considered here in multivariate approach in comparison to univariate models were increased slightly and therefore heritabilities were increased a little too, but result not shown.

Table II. Estimates variance components and heritabilities along with their standard errors (se (h^2)) for305-days milk yield and persistency criteria

Parameter	305-days milk yield	STD[1]	MAME[2]	LAMA[3]	LAME[4]	W E[5]
σ^2_p	905922.3	1.967280621	0.0113	143.4052382	0.0123937	0.3267545
σ^2_a	287832.7	0.1610406106	0.00079	9.480624614	0.00058	.02532744
σ^2_e	618089.6	1.806240010	0.0105	133.9246136	0.0118129	0.301427
h^2	0.3177	0.0819	0.07	0.066	0.0469	0.0775
se(h^2)	0.0167	0.0093	0.0088	0.008	0.00785	0.0112

1. Standard deviation of all test-day records per lactation
2. The maximum production of all test-day records per lactation divided by the related mean.
3. The percentage of daily milk retained from the peak to the end of lactation timed by 100.
4. The latest test-day record yield divided by the mean of all test-day records
5. The criterion that was proposed by Wood (1976) and was calculated as, s=-(b+1) ln (c) which b and c are parameters of incomplete gamma function.

Table III. Estimates of correlation between persistency criteria and milk yield (figure above dashes are genetic correlation and below dashes are phenotypic correlation)

Trait	305-days milk yield	STD[1]	MAME[2]	LAMA[3]	LAME[4]	W E[5]
305-days milk yield	------------	0.3432	-0.6124	0.4171	0.292	0.6617
STD[1]	0.0662	----------	0.5437	-0.7061	-0.7606	-0.3503
MAME[2]	-0.3589	0.6601	------------	-0.9265	-0.85	-0.8134
LAMA[3]	0.3177	-0.8262	-0.7140	---------	0.9988	0.7195
LAME[4]	0.2415	-0.7509	-0.4788	-9481	------------	-0.6208
W E[5]	0.1403	-0.0851	-0.2013	0.0736	-0.0028	------------

1. Standard deviation of all test-day records per lactation
2. The maximum production of all test-day records per lactation divided by the related mean.
3. The percentage of daily milk retained from the peak to the end of lactation timed by 100.
4. The latest test-day record yield divided by the mean of all test-day records
5. The criterion that was proposed by Wood (1976) and was calculated as, s=-(b+1) ln (c) which b and c are parameters of incomplete gamma function.

CONCLUSION

Genetic and phenotypic parameters were estimated for different criteria of persistency of milk yield. Results showed heritability of this trait was low to medium. Results of multivariate analysis showed there were medium to high absolute genetic correlation between some of them and 305-days milk yield trait and high absolute genetic correlation between them. Among all criteria that were considered, WE and MAME had highest absolute genetic correlation with milk yield and seemed to be favorable for breeding programs and selection strategy. Also a similar situation but to a smaller extent power were for LAMA criteria. However, it seemed that STD is not a suitable criterion for persistency of milk yield. Therefore, in order to improve persistency in populations without any reduce in 305 milk yield it is possible to select animals based on the MAME or WE and by this way not only persistency but also milk yield can be improved. However, more research is needed to apply this trait in selection index.

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