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GENETIC AND PHENOTYPIC ANALYSES OF DAYS OPEN AND 305-DAY MILK YIELD IN A COMMERCIAL HOLSTEIN FRIESIAN HERD

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SUMMARY

A total number of 496 lactation records for 298 cows sired by 28 bulls of a commercial herd of Holstein Friesian cows raised in Egypt, belonging to Alexandria Copenhagen Company for Dairy and Meat Production, were used in the present study to analyze factors affecting 305-day milk yield (305-DMY) and days open (DO). Data were collected during 5 years (2006-2010) and analyzed using SAS, XLSTAT and WOMBAT. Parity had a significant (P < 0.05) effect on 305-DMY. Season of calving significantly (P < 0.05) affected DO. Estimates of heritability for 305-DMY and DO were 0.25 and 0.11, respectively. The corresponding estimates of repeatability for 305-DMY and DO were 0.39 and 0.05, respectively. These results reflect a very small contribution of additive genetic variance, and also point out that improvement in such traits could be achieved by improved management and feeding procedures. Coefficients of phenotypic and genetic correlation between the two traits were -0.01 and 0.08, respectively. Results indicate possibility of genetic improvement of milk production and reproduction traits by selection for 305-DMY only, due to its relatively high heritability estimate as well as its negatively favorable phenotypic and positively reasonable genetic correlation coefficients with DO. Although genetic parameters are important tools for improving quantitative traits by selection, still there is room to improve milk production and reproduction traits of Holstein Friesian through the application of improved management procedures.

Keywords: Holstein Friesian, 305-day milk yield, days open, genetic parameters

INTRODUCTION

The Holstein Friesian (HF) is the most popular exotic dairy cattle breed worldwide. The breed is widely used for its outstanding genetic potential for milk production and its attractive capabilities to considerably cover the growing human population needs of milk. For a country like Egypt where the gap between milk demand and supply is not solved yet, due mainly to very limited genetic potentials of the Egyptian native cattle for milk production, introduction of HF seems an effective strategic option. High milk yield has been the primary selection objective in dairy cattle breeding. Nevertheless, high milk yield of Holstein (H) cows makes them more sensitive to heat stress and reproductive failure (Lucy, 2001). Therefore, a great effort has been made to provide suitable and comfortable conditions to exotic animals in large-scale dairy farms in Egypt. During the current and last two decades, many investigators have studied the productive and reproductive performance for various proportions of HF genetic background in Egypt (Abdel-Moez, 2007; Hammoud *et al*., 2010 and Hammoud and Salem, 2013).

Antagonistic relationship between production and reproduction traits has been well documented (VanRaden *et al*., 2004; Gonzáles-Recio *et al*., 2006; Ajili *et al*., 2007 and Riecka and Candrák, 2011). Based on improved milk yields, the trend for poorer reproduction caused by greater milk production will continue and will theoretically worsen as cows achieve greater production (Lucy, 2001). Other changes within the dairy industry; however, probably have equivalent or greater effects on fertility in modern dairy cows. The relative contributions of the different genetic, physiological and environmental factors with regard to the decline in dairy cattle reproduction are not deeply known yet.

Several studies proposed that the influences of milk production on reproduction can only be noticed in the highest producing dairy cows. Such proposal has been previously applied to estimate genetic parameters for milk production traits using field data collected from a highly producing herd composed of HF cows originated from USA and raised under the Egyptian conditions. In the present study, one of our objectives was to study effects of parity and season of calving on both of 305-day milk yield and days open of that herd. Another objective was to estimate heritability and repeatability for the two traits. Additionally, coefficients of genetic and phenotypic correlation between these traits have been estimated.

MATERIALS AND METHODS

The present study was carried out on a Holstein Friesian herd belonging to Alexandria Copenhagen Company for Dairy and Meat Production, located about 45 kilometers south-west Alexandria city, Egypt. The data set was collected by Cattle Information Systems / Egypt (CISE) of Cairo University. The data involved 496 lactation records of 298 cows sired by 28 bulls, throughout the period from 2006 to 2010. The milk production trait considered in this study was 305-day milk yield (305-DMY, kg), while the reproductive trait was days open (DO, day).

Animals included in this study were housed in well-ventilated sheds and were fed a total mixed ration all year around. Nutrient requirements of dairy cattle recommended by the National Research Council (NRC, 2001) were offered according to cow's body weight, milk yield and stage of lactation. Fresh water was available at all the time. Doses of frozen semen, from the top 100 Total Performance Index (TPI) Holstein bulls in USA and Canada, were imported to artificially inseminate cows and heifers in order to maintain the genetic properties and purity of the breed. Heifers were served for the first time when reached 375 kg of weight. All lactating animals were machine milked three times daily at eight-hour intervals and were dried off about two months prior to their expected calving date. A central recording system, operated by CISE, was practiced by a monthly visit to the farm to collect data in the respective testing periods. The animals were routinely vaccinated against common bacterial and viral diseases.

The dataset consisted of 305-day milk yield, twice daily milking and mature equivalent yields for milk in the first, second and third parity. All cows were mandatory required to have a first lactation milk yield, and additional lactations were utilized only if the first one was available.

Statistical analysis system (SAS, 2004) and XLSTAT (2013) were utilized to test the significance of the fixed effects (parity, season of calving and interaction between parity and season of calving) on 305-DMY and DO traits using mixed model procedure. Preliminary least squares analyses using the PROC GLM option of SAS showed for 305-DMY and DO traits that fixed effect of the year of calving and the interaction effect between season of calving and year of calving were not significant ($P > 0.05$); therefore, they were excluded from the final analysis using the mixed models. The final linear model used was as follows:

$$Y_{ijklm} = \mu + a_i + pe_j + P_k + S_l + (PS)_{kl} + e_{ijklm},$$

Where,

Y = the phenotype,

μ = overall population mean,

a_i = random animal additive genetic effect i, $a_i \sim N(0, \sigma^2_a)$,

pe_j = random effect of permanent environment i on the animal j, $pe_j \sim N(0, \sigma^2_{pe})$,

P_k = fixed effect of parity k, (k = 1, 2, 3),

S_l = fixed effect of season of calving l, (l = 1, 2, 3, 4), where 1 = Winter (December, January, February), 2 = Spring (March, April, May), 3 = Summer (June, July, August) and 4 = Autumn (September, October, November),

$(PS)_{kl}$ = interaction effect between parity and season of calving,

e_{ijklm} = random residual ~ $N(0, \sigma^2_e)$.

Genetic parameters including heritability and repeatability as well as genetic and phenotypic correlation coefficients were estimated by using WOMBAT, a software package for quantitative genetic analyses of continuous variation traits, fitting a linear, mixed model; estimates of covariance components and the genetic parameters were obtained by restricted maximum likelihood (Meyer, 2012). Covariances were assumed zero between genetic and environmental effects and between all environmental effects for records not on the same animal.

RESULTS AND DISCUSSION

Analyses of variance (ANOVA) of 305-day milk yield and days open are presented in Table (1). The least squares means and standard deviations for the two traits as affected by parity, season of calving and interaction between parity and season of calving are shown in Table (2).

Milk yield was, still and also will be the first breeding objective in dairy cattle industry worldwide. In regards to 305-day milk yield, parity had a significant ($P < 0.05$) effect on the trait. Adjustment of total milk yield (TMY) in the actual lactation period (LP) to the standardized 305-day period seems to be responsible for this significant effect, compared to total milk yield which was not significantly affected by parity (unpublished data). Our result is in consistency with that obtained by Dematawewa and Berger (1998) and Abdel-Moez (2007).

The mean of 305-DMY obtained in this study (8805 kg) was extremely superior to that published by Abdel-Moez (2007, 6118 kg). Within the parity subclasses, the highest 305-DMY estimate was obtained early in the cow's career, during the second lactation (9556.79 kg). This estimate was 1259.16 and 320.41 kg ahead of the first and third lactation, while the third parity exceeded the first one by 938.75 kg. The amount of 305-DMY in the first parity was significantly ($P < 0.05$) lower than that obtained in the second and third parity; however, the last two lactations did not differ significantly from each other (Table 2). The decline of 305-DMY observed after the second lactation may be attributed to loss of adaptability of the high yielding cows to the prevailing environmental conditions. The fluctuation shown in 305-DMY among successive lactations has been previously revealed by Albuquerque *et al*. (1996) and Dematawewa and Berger (1998). Abdel-Moez (2007) reported that the highest 305-DMY of H and HF cows in Egypt was recorded in the 2^{nd} parity and then decreased progressively. This decline supports the need for further studies to investigate and identify the cause(s) of this rapid decline. None of the other sources of variation revealed significant effect on 305-DMY.

Table 1. Analysis of variance of 305-day milk yield and days open as affected by different factors*

Source of variation	Df	305-day milk yield		Days open	
		MS	*P*	MS	*P*
Parity	2	4511498	0.0001	12550	0.4017
Season of calving	3	54771	0.9970	45365	0.0212
Parity x Season	6	2029208	0.7115	19357	0.2112
Residual	489	7252278		32078	

* $P < 0.05$

Table 2. Least squares means* and standard deviations (LSM±SD) of 305-day milk yield (kg) and days open (day) as affected by parity and season of calving

Classification	No. of Records	305-day milk yield LSM ± SD	Days open LSM ± SD
Parity			
1	298	8297.63[a] ± 114.1	213.96 ± 7.6
2	150	9556.79[b] ± 223.9	191.72 ± 14.9
3	48	9236.38[b] ± 399.7	205.70 ± 26.4
Season of calving			
Winter	176	9181.08 ± 187.7	177.02[a] ± 12.6
Spring	71	8824.98 ± 521.5	281.11[b] ± 34.6
Summer	88	8769.84 ± 259.0	189.34[a] ± 17.2
Autumn	161	9345.17 ± 182.4	167.70[a] ± 12.2

*Within each column, means followed by different letters differ significantly from each other at $P < 0.05$

Considering days open, season of calving had significant effect ($P < 0.05$) on DO (Table 1). These results are consistent with that reported by Melendez and Pinedo (2007) and Hammoud *et al.* (2010). As shown in Table (2), spring calvers had significantly ($P < 0.05$) longer DO than cows calved in the other seasons of the year. Not surprisingly, the shortest DO in this study was recorded for autumn-calving cows. Cows calved in this season are expected to enjoy feeding on high-quality green feed (Egyptian clover) rich in vitamins and minerals for about six months, which results in shorter DO, in specific, and improved reproductive performance, in general, compared to their counterparts calved in spring season that suffer from shortage of green feeds during forthcoming summer. VanRaden *et al*. (2004) found that fertility measures were best following autumn calvings and poorest following spring calvings. These results were expected because fewer cows express estrus or conceive during hot summer months, in addition to a negatively larger effect of heat stress with higher production. Antagonism between production and reproduction traits has been previously reported by Dematawewa and Berger (1998), Gonzáles-Recio *et al*. (2006) and Riecka and Candrák (2011). Interestingly, Lucy (2001) found that cows calved in spring had significantly ($P < 0.05$) longer calving interval (CI) than those calved in all other seasons. These results could be due to the coincidence of green feeds with spring season causing improvement in milk production traits (higher TMY and longer LP) and subsequently, weakness in reproductive performance traits (longer DO and longer CI). Deteriorations in reproductive performance over time have been documented in dairy populations in many countries (Roman *et al.*, 2000; Gonzáles-Recio *et al.*, 2006; Melendez and Pinedo, 2007; Norman *et al.*, 2007 and Hammoud *et al.*, 2010). Selection for high milk yield in dairy cattle is generally accompanied by a decline in fertility.

As shown in Table (1), neither parity nor parity by season of calving interaction affected significantly DO. The mean of DO obtained in this study (193 days) was fitted inside the range of estimates reported by Abdel-Moez (2007; 112 day) and Goshu *et al.* (2014; 250 day). The fluctuation in DO from parity to another in this study was also mentioned by Norman *et al*. (2007) and Hammoud *et al*. (2010). In contrast, Abdel-Moez (2007) mentioned that DO decreased gradually from the 1st to the 5th lactation. Contradictory to this finding, Dematawewa and Berger (1998) and Ajili *et al*. (2007) recorded a gradual increase in DO with the advance in lactation number, indicating that measures of fertility tended to get poorer according to parity number with slight decreases from the first to second to third parity.

Heritability and repeatability for the studied traits estimated across parities are presented in Table (3). The heritability estimates for 305-DMY was similar to previous studies (Albuquerque *et al.*, 1996; Abdel-Moez, 2007 and Zavadilová and Zink, 2013). Van Tassell *et al*. (1999) reported that the mean heritability estimates increased with standard deviations, and estimates ranged from 0.18 to 0.51 across six specialized dairy cattle breeds (Holstein, Ayrshire, Brown Swiss, Guernsey, Jersey and Shorthorn). The heritability estimates for 305-DMY obtained in the present study indicated medium genetic to environmental variance ratio, reflecting differences in the response of cows to the existing environmental conditions. Therefore, good management can play a major role in improvement of animal performance in milk production traits. According to Falconer and Mackay (1996), heritability can't be estimated easily with great precision, and most estimates have rather large standard errors. Different estimates of the same character on the same organism show wide range of variation, some of which may reflect real differences between populations and/or the conditions under which they are studied.

In general, the heritability for DO estimated in the current study is consistent with literature estimates (Abdel-Moez, 2007 and Hammoud and Salem, 2013). Zavadilová and Zink (2013) found that heritability estimates for fertility traits ranged from 0.02 to 0.06, where that of DO was 0.05. All estimates of heritability for fertility traits in the second lactation were lower than those in the first lactation. The authors added that culling in the first lactation probably reduced genetic and herd-year variances for the second parity cows leading to lower estimates of heritability. This reduces the scope for selection for female fertility in the second parity cows.

The relative importance of environmental differences is considerably higher for reproductive traits than for milk yield (Roman *et al*., 2000). Therefore, even with selection, the changes in these traits would be expected to be small and that efforts should be devoted to improving management practices. Good management can play a major role in improvement of animal performance in reproductive traits (Lucy, 2001 and Goshu *et al*., 2014). While developing a national genetic evaluation for cow fertility in USA, VanRaden *et al*. (2004) reported that heritability of DO increased steadily as the upper limit was decreased from 305 to 150 days. Estimates were 0.030 at 305 days, 0.033 at 250 days, 0.036 at 200 days, and 0.041 at 150 days, averaging 0.037. Economic benefits of very early pregnancy are not as great as the costs of delayed pregnancy. Decreasing the upper limit would increase heritability but reduces the penalty for severe infertility. Nevertheless, the rate of genetic change depends mainly on the accuracy of selection, which is subsequently related to heritability estimates. Therefore, accurate estimation of genetic parameters would help in designing efficient breeding programs for objective traits that are to be improved in the next generations through selection.

Repeatability estimates of the two studied traits are shown in Table (3). Estimate of repeatability for 305-DMY was 0.39. Current result is; however, concurrent with other recent research. Van Tassell *et al*. (1999) reported that the repeatability estimate for milk yield of H cows was approximately 0.55 and did not change with standard deviation.

The repeatability estimate for DO in the present study (0.05) is considerably lower than the estimate of 0.12 reported by Dematawewa and Berger (1998) using 122,715 lactation records, and also that of 0.13 obtained by VanRaden *et al*. (2004) analyzing 2,195,643 lactation records, both of H cows. This finding would encourage the possibility of reducing DO through adoption of better management approach, because of DO seem to be affected more by temporary environmental factors, rather than genetic and permanent environmental ones. Therefore, it would thus be possible to shorten the length of DO by improving reproductive management strategies commonly practiced in dairy herds. Repeatability differs very much according to the nature of the character, the genetic properties of the population, and the environmental conditions under which the individuals are kept (Falconer and Mackay, 1996). High estimates of repeatability allow culling of cows based on single records from a genetic standpoint and assessment of several records is not required before selecting cows for lactation.

Estimates of genetic and phenotypic correlation between the two studied traits are illustrated in Table (4). The coefficient of phenotypic correlation between 305-DMY and DO was negative (-0.01). However, VanRaden *et al*. (2004) analyzing 2,195,643 lactation records of H cows in USA, indicated that the phenotypic correlation coefficient between 305-DMY and DO was positive (0.11).

Table 3. Across-parity estimates of heritability, repeatability and standard errors (SE) for 305-day milk yield and days open

Trait	Heritability ± SE	Repeatability ± SE
305-day milk yield	0.25 ± 0.001	0.39 ± 0.001
Days open	0.11 ± 0.25	0.05 ± 0.047

Table 4. Phenotypic correlation (above the diagonal) and genetic correlation (below the diagonal) between 305-day milk yield (305-DMY) and days open (DO)

Trait	305-DMY	DO
305-DMY	-	-0.01
Days Open	0.08	-

The estimate of genetic correlation between 305-DMY and DO averaged 0.08 in the current study as compared with 0.28 from the previous study carried out by Abdel-Moez (2007). Such positive and unfavorable genetic correlation between 305-DMY and DO can be justified on the basis of the influence of high milk yield on prolonged CI, in general, and DO, in specific. Similar results were also reported previously in HF cattle by Dematawewa and Berger (1998) and Riecka and Candrák (2011). VanRaden *et* *al*. (2004) reported that selection for high yield over several generations has contributed to longer CI because of an unfavorable genetic correlation between yield and DO of about 0.38. On the other hand, Hammoud and Salem (2013) found negative genetic correlation between 305-DMY and DO in H cows raised in Egypt. Also, Goshu *et al*. (2014) reported significantly negative genetic and phenotypic correlation coefficients between first CI with 305-DMY, indicating that higher 305-DMY was associated with shorter CI, on phenotypic scale due to genetic reasons. These correlations as expected were in accordance with the observed correlations of 305-DMY with first service period (FSP) in HF cows. Length of first CI is determined by the length of FSP and so relationships with both traits also behave in similar way.

The economic value of the increased milk yield greatly exceeds the economic value of the decreased fertility as measured by increased DO and subsequently CI, as concluded by Dong and Van Vleck (1989), reporting expected genetic increase of 2.1 days of CI for a genetic increase of 450 kg of milk. Similar findings were obtained by Gonzáles-Recio *et al*. (2006) indicating that high yielding cows tend to be less fertile and have extended CI and DO. The authors also observed high genetic correlations between DO with different milk production traits, ranging between 0.63 and 0.76. These results suggest that more highly productive cows tend to have longer DO and CI likely due to physiological competition between high milk production and reproduction cycle of the cow. Including breeding values for milk production, instead of phenotypic values, in fertility evaluation seems more sustainable for better and more accurately illustration of relationship between production and reproduction traits (Riecka and Candrák, 2011).

Zavadilová and Zink (2013) reported that genetic correlations between reproduction traits and milk production traits were moderate to high (0.48 to 0.65) and unfavorable, indicating that cows genetically predisposed to yield high amount of milk are also more likely to be less fertile (correlation between 305-DMY and DO was 0.65). The same authors mentioned that the correlation between fertility and milk production traits may be affected by individual decisions made by farmer if, for example, high-yielding cows are inseminated later than moderate- or low-yielding cows. This concept seems to be a common practice in Egypt with high-yielding exotic cows. Although the coefficient of genetic correlations between milk production and fertility traits are generally unfavorable, they are not unity; it is not inevitable that fertility will decrease as genetic merit for milk yield increases. Good management can encourage high fertility and high yield in dairy cows, but it will become increasingly difficult in the long term to maintain the current standards if fertility is not included in the breeding objective, as supported earlier by findings of Dematawewa and Berger (1998).

Several studies reported that reproductive efficiency in dairy cows is decreasing worldwide, mainly because the primary selection objective in dairy cattle breeding is oriented towards milk production traits. However, many other equally important factors may be involved, such as increasing herd size, greater use of confinement housing, labor shortages, higher inbreeding percentages and changing global environment causing heat stress to dairy cows (Lucy, 2001). Clearly defined breeding goals associated with better management (culling on low production, selection on traits other than milk yields, varied feed resources, etc.) and incorporation of marker-assisted selection (MAS) into traditional breeding schemes in Egypt would improve the performance of HF cows and reduce production costs.

CONCLUSION

Heritability estimates for 305-day milk yield and days open, in the current study, were in consistency with literature. Also, correlation coefficients between the two traits were in agreement with those reported in previous studies. Genetic improvement of days open seems to be difficult due, first, to its low heritability estimate, and secondly, because of its unfavorable genetic and phenotypic correlations with milk production traits. Results suggested possibility of combined genetic improvement of milk production and reproduction traits by selection for 305-DMY alone. Decline in fertility measures can be controlled and reversed in dairy cows, but a collective effort within the dairy community (e.g., farmers, animal scientists, researchers, veterinarians and extension agents) will be highly required to overcome this serious problem.

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تحاليل وراثية ومظهرية لفترة الأيام المفتوحة ومحصول اللبن فى ٣٠٥ يوم فى قطيع هولشتين فريزيان تجارى

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إستُخدم فى هذه الدراسة ٤٩٦ سجلاً لعدد ٢٩٨ بقرة بنات ٢٨ طلوقة فى قطيع تجارى من أبقار هولشتين فريزيان المرباه فى مصر، التابعة لشركة إسكندرية كوبنهاجن لإنتاج الألبان واللحوم، وذلك لتحليل العوامل المؤثرة على فترة الأيام المفتوحة ومحصول اللبن فى ٣٠٥ يوم. تم تجميع البيانات لمدة ٥ سنوات (٢٠٠٦ – ٢٠١٠) وتحليلها إحصائياً باستخدام برامج SAS، XLSTAT و WOMBAT. كان تأثير ترتيب موسم الحليب معنوياً (P <٠.٠٥) على محصول اللبن فى ٣٠٥ يوم فقط. بينما كان تأثير فصل الولادة معنوياً (P <٠.٠٥) على فترة الأيام المفتوحة فقط. كانت تقديرات العمق الوراثى لمحصول اللبن فى ٣٠٥ يوم وفترة الأيام المفتوحة ٠,٢٥ و ٠,١١، على الترتيب. بلغت القيم المناظرة لمعامل التكرار ٠,٣٩ و ٠,٠٥، على الترتيب. تعكس هذه النتيجة مساهمة صغيرة جداً للتباين الوراثى التجمعى، كما تشير أيضاً لإمكانية تحسين كلا الصفتين عن طريق تبنى وسائل رعاية وتغذية محسنة. كانت معاملات الإرتباط المظهرى والوراثى بين كلا الصفتين – ٠.٠١ و ٠.٠٨، على الترتيب. أشارت النتائج إلى إمكانية التحسين الوراثى لصفات إنتاج اللبن والصفات التناسلية عن طريق الإنتخاب لصفة محصول اللبن فى ٣٠٥ يوم فقط نظراً لإمتلاكها قيمة عمق وراثى عالية، وأيضاً لما لها من معامل إرتباط مظهرى سالب (مرغوب) ومعامل إرتباط وراثى موجب (معقول) مع فترة الأيام المفتوحة. على الرغم من أن المعايير الوراثية تعتبر أدوات هامة لتحسين الصفات الكمية عن طريق الإنتخاب، لا يزال هناك مجال لتحسين صفات إنتاج اللبن والتناسل من خلال تطبيق وسائل الرعاية المتطورة.