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Assessment of Inbreeding Depression and Inbreeding Trend of Production Traits in Iraqi Holstein Cows

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Inbreeding is defined as the probability that two alleles at any locus are identical by descent and occur when related individuals are mated to each other. A total of 123427, 115810 and 88361 records of 412-d yields of milk, fat and protein of Iraqi Holstein cows were collected from 1995 to 2010 in 838 herds used to estimation the inbreeding depression and inbreeding trend. Pedigree records of Iraqi Holstein cow were used to assessment inbreeding coefficients and these coefficients ranged from 0 to 42%. Animal model was used to estimation inbreeding depression on traits. Fixed effects included in statistical model were herd – year, age at calving and inbreeding coefficient as continuous and discrete variable. When considering inbreeding as continuous variable in model, the inbreeding depression for 412-d yields of milk, fat and protein were -28.19, -0.98 and -0.88 kg per 1% increase in inbreeding in Iraqi Holsteins, respectively. In this group of animal that inbreeding coefficient was between $0 < F \leq 5.34$ inbreeding was not caused reduction in production traits. However, in group of animal that inbreeding coefficient was greater than 5.34, and inbreeding depression in production traits was observed. The result of this study confirms of inbreeding depression in Iraqi Holstein cows.

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Keywords: Fat yield; inbreeding trend; inbreeding depression; Iraqi holstein cows; protein yield.

1. INTRODUCTION

Inbreeding is defined as the probability that two alleles at any locus are identical by descent and occur when related individuals are mated to each other [1]. The initial consequence of inbreeding is inbreeding depression, which reduces the performance of growth, production, health, fertility and survival traits. This concern has become more serious in present day animal breeding, in which selection responses are maximized by the use of animal model best linear unbiased predictors (BLUP) of breeding value. The use of these breeding values alone may result in more closely related selection candidates preferred for selection, with increased levels of inbreeding since they share most of their familial information [2]. The practical importance of inbreeding in livestock improvement programs is two-fold. Firstly, inbreeding reduces the additive genetic diversity in the population, which negatively effect on the prospects for long-term genetic response to selection. Secondly, inbreeding decreases mean phenotypic performance particularly for those traits that are related to fitness [3,4]. Milk yield, fat and protein are the most important traits in dairy cattle breeding programs, and genetic improvement and high economic value due to interest are livestock breeders [5].

In most dairy cattle breeding programs and selection has concentrated mainly on increasing milk [6]. The best animals build up in pedigrees so that today it is almost unfeasible in a given dairy cattle breed to find animals without multiple genetic ties to certain individuals. Therefore, the probability of mating relatives and generating inbred offspring is increased [7]. Probability, 2 alleles at any locus are identical by descent as inbreeding [8]. Inbreeding will occur when related animal are mating with each other. The consequence of inbreeding is reduces heterozygosis that can caused the reduction in mean of phenotypic traits that is referred to as inbreeding depression. Inbreeding also reduces additive genetic variance within lines [9,10,11,12,13]. This phenomenon is called inbreeding depression. The effect of inbreeding on performance is of particular interest in the dairy cattle industry where the typical production animal is a purebred. An raise in inbreeding in dairy cattle has been shown to be associated with major economic losses in the form of reduced lifetime performance [14]. In the U.S. marketplace, relative net income adjusted for opportunity cost was decreased by $15.78 for a fluid market and $13.23 for manufacturing pricing system per 1.5% increase in inbreeding [15]. Croquet and coauthor have also reported a reduction in lifetime economic profitability associated with an increase in inbreeding in the Holstein breed in the Walloon region of Belgium [16]. The increase in inbreeding in dairy cattle was mainly due to widespread use of certain sires through reproductive technologies such as artificial insemination. The rate of inbreeding was estimated at 0.17% per year in this study; which was the highest rate of inbreeding among the four South African dairy cattle breeds studied [17,18]. Weller and Ezra reported a similar rate of inbreeding of 0.18% per year for Israeli Holstein cows [19]. The rate of inbreeding for the South African Jersey population is considerably lower than the rate of 0.21% per year reported for the U.S. Jersey population [20]. In a population undergoing selection, effects of inbreeding on performance depend on the rate of inbreeding, selection pressure, and mean production levels for traits under consideration. In small populations inbreeding depression is one of the farmers concerns. Inbreeding has harmful effects on reproductive traits in addition to the production traits, udder health and calving, fertility and affects survival [21,22]. The purpose of the present study was to investigation the trend of average inbreeding and estimation the effect of inbreeding on 412-d yield of milk, fat and protein via the first lactation records of Iraqi Holstein cows.

2. MATERIALS AND METHODS

2.1 Data Structure

The current study was done in from spring to autumn 2018 Department of Animal Science, College of Agriculture, Garmian University, Kalar, As Sulaymaniyah, KRG of Iraq. The used data were collected by dairy producers according to procedure of Animal Breeding Center of As Sulaymaniyah, KRG of Iraq. In order to estimation the inbreeding trend and inbreeding depression on production traits, 123427, 115810 and 88361 records of 412-d yields of milk, fat and protein of Iraqi Holstein cows were collected from 1995 to 2010 in 838 herds in Iraqi. Cow's age at first calving were required to be between from 22 to 42 month, and 412-d yields of milk ranged from 1995 to 15340 kg. Also, fat and protein yield was between 48 to 500 kg and 58 to 460 kg, respectively.

2.2 Studied Traits

In this study, data covered assessment of inbreeding trend and inbreeding depression on production traits such as protein, milk and fat in Iraqi Holstein Cows.

2.3 Statistical Analysis

The inbreeding coefficient for each animal in the pedigree was calculated using CFC described by Sargholzaei et al. [23]. Investigated of fixed and random effects for traits of protein, milk, and fat for cattle breeding and inbreeding using GLM (Generalized Linear Models) procedure of SAS (9.1) software. Estimation of genetic parameters, inbreeding trend and depression were obtained using ASREML software [24]. Variance components were estimated by considering and not considering inbreeding coefficient as continuous variable in model.

The following model was fitted for data:

$$Y = X\beta + Za + e$$

Here: y, is vector of observations; β, is vector of fixed effects including herd (727), year (1984), age at calving (20 to 40 month) and inbreeding coefficient (as continuous and discrete variable); When considering inbreeding coefficient as discrete variable animal were group according to their inbreeding coefficient as follow: $F = 0$, $0 < F \leq 6.25$, $6.25 < F \leq 12.5$, $12.5 < F \leq 18.5$ و $F > 18.5\%$ [25], a, is vector of random effects; e, is vector of random residual effects; X and Z are incidence matrices relating observations to fixed and random effects, respectively.

It is assumed that additive genetic effects and residual effects are normally distributed with mean zero and variance A σ_a^2 and Ie σ_e^2, respectively, where: A is additive numerator relationship matrix obtained from pedigree structure, Ie is identity matrix with orders of N (number of records) and σ_a^2 and σ_e^2 are additive genetic variance and residual variance, respectively.

Data were subjected to standard statistical analysis using SPSS software and linear regressing analysis was made by keeping the inbreeding trend as the dependent variable and inbreeding depression as independent variables.

Model was fitted for inbreeding trend as the dependent variable (1) and inbreeding depression as independent variable:

(1) Yinmljk = μ + Hn + YEk + b1 Agei + b2 Fm + aL + eijnmk

(2) yijkml = μ + Hn + YEk + b1 Agei + Fm + aL + eijkml

Where Yijklm and yijkml are represents the dependent and independent variable, μ is overall mean of traits, Hn represent the fixed effect of the n^{th} herd, YEk represent the fixed effect of the k^{th} birth year, Agei represent for fixed effect of the i^{th} age of calving, Fm represent for m^{th} inbreeding coefficient, b1and b2 victor of fixed regression coefficients for age of calving and inbreeding coefficient associate to traits, aL represent the random effect of the a^{th} animals, eijkm and eijnmk are the residual effects.

3. RESULTS

3.1 Descriptive Statistics

In present study, Descriptive statistics for analysis data were used and presented in Table 1.

3.2 Estimated of Fixed Effect in Module

Calving year; in this study results showed that age of calving has significant different (P<0/0001) on the milk, fat and protein (Fig. 1).

Table 1. Descriptive statistics including number of records maximum, minimum and mean for different traits including: Milk production, fat and protein

Trait	No. of records	Minimum	Maximum	Mean
Milk production(kg)	123427	1995	15340	8312
Fat (kg)	115810	48	500	251
Protein (kg)	88361	58	460	239

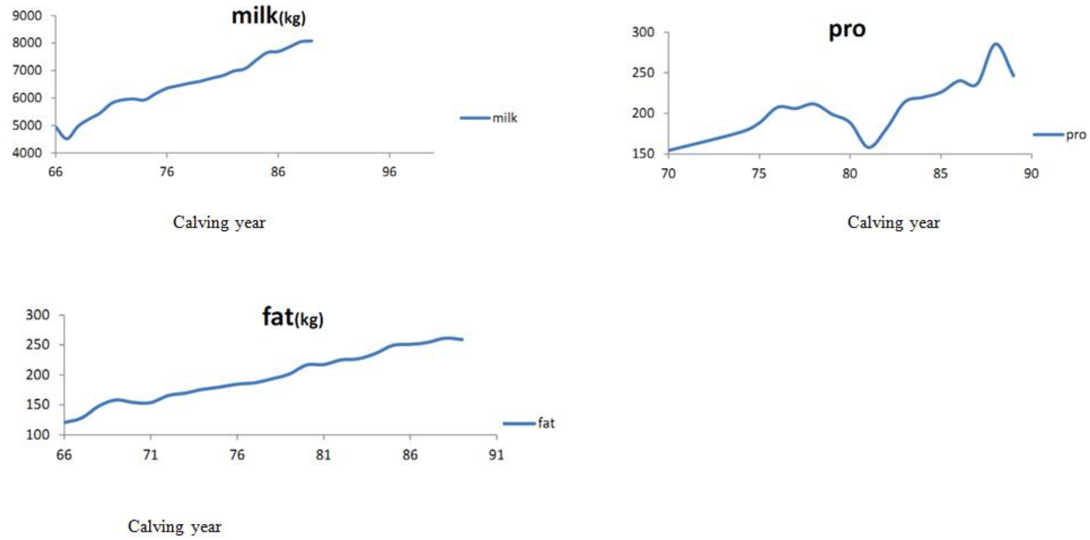

Fig. 1. Least squares means (LS mean) of different levels of protein, milk and fat (Calving year)

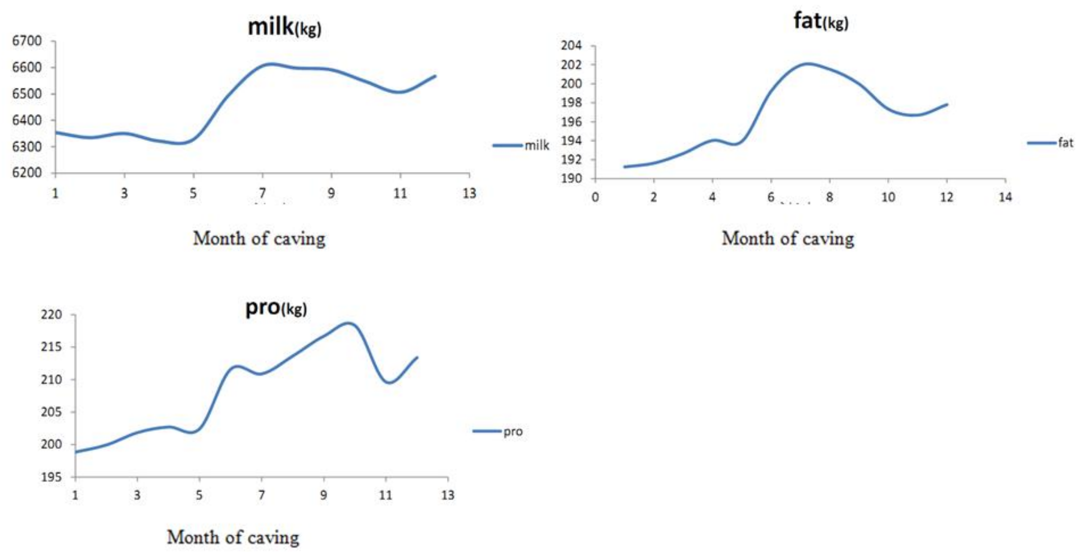

Fig. 2. Least squares means (LS mean) of different levels of protein, milk and fat (Month of calving)

Month of calving: our results showed that month of calving have significant different on the milk and fat (P<0/0001) but did not any significant different on the protein (P>0/0001), (Fig. 2). As shown in Fig. 2, least squares mean was higher milk yield and fat for autumn calves the compared to summer calves. But, least square mean for protein show that winter calves produced higher protein as compared to spring calves.

Inbreeding coefficient range was from 0 to 19. The distribution of animal in inbreeding class were F = 0, 0 < F ≤ 5.34, 5.34< F ≤ 11.5, 11.5 < F ≤ 19 and F > 19%, respectively (Table 2). In continue our result showed that effect of inbreeding have significant different on milk production and fat trait both (P<0/0001) but did not any significant different on protein trait (P>0/0001) (Fig. 3).

Table 2. The inbreeding depression (F) in the case of grouped traits of inbreeding

Inbreeding groping	Traits		
	Milk(kg)	Fat (kg)	Protein (kg)
0< F ≤ 5.34	+28.1±1.28	+0.566719±1.28	+1.993241±2.90
5.34 < F ≤ 11.5	-114.263±2.33	-5.43008±2.87	-3.20081±1.20
11.5 < F ≤ 19	-160.958±3.11	-11.0012±2.99	-6.91998±2.15
F > 19	-291.122±2.95	-7.99919±2.95	-4.97625±1.96

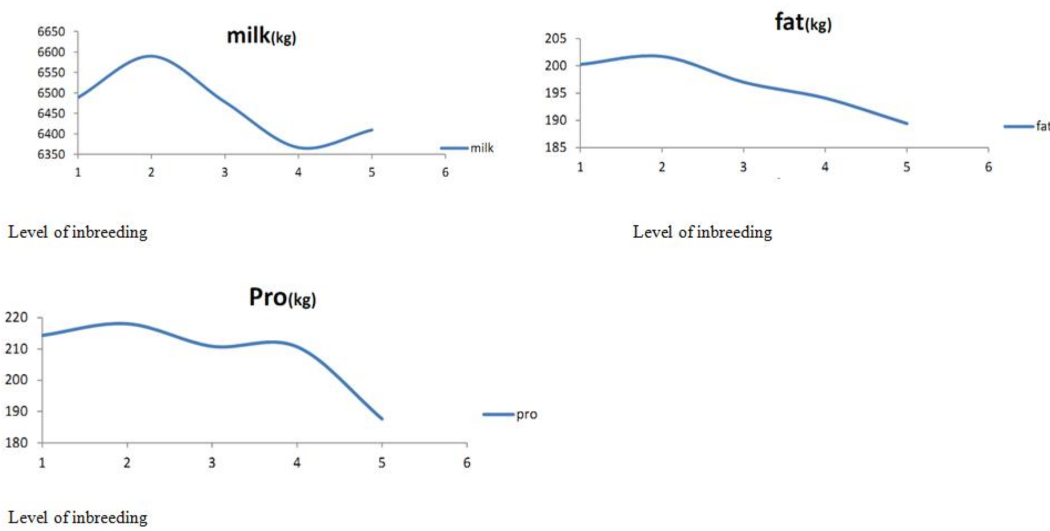

Fig. 3. Least squares means (LS mean) of different levels of inbreeding in the fat, milk production and protein

Table 3. Genetic parameters for milk, fat and protein

Traits	Model	σ	σ	σ	h^2
Milk	1	398493	1122790	1399879	0.311332
	2	401508	1100112	13987156	0.30023
Fat	1	450.778	150011	1743.120	0.249845
	2	503.689	1411.31	1901.362	0.241235
Protin	1	350.133	1150.11	1403.361	0.239865
	2	351.232	1113.65	1412.546	0.247861

3.3 Estimation of Variance Component and Effect of Inbreeding

To evaluation the effect of including inbreeding on genetic parameter estimation of production traits two models were examined: model 1 including inbreeding coefficient as continuous variable in model and model 2 without including inbreeding coefficient in model.

Estimated variance components and heritability of production traits based on models 1 and 2 are presented in Table 3. Additive genetic obtained in model 1 is somewhat greater than ones obtained in model 2, but In general differences in variance component and heritability obtained based on model 1 and model 2 were negligible (Table 3).

Model 1: With regard to inbreeding for continuously variable, Mode 2: regardless of kinship in the model. δ_a^2 : additive genetic variance, δ_e^2: residual variance , δ_p^2: Phenotypic variance, h^2 heritability, b_2: regression coefficient of inbreeding).

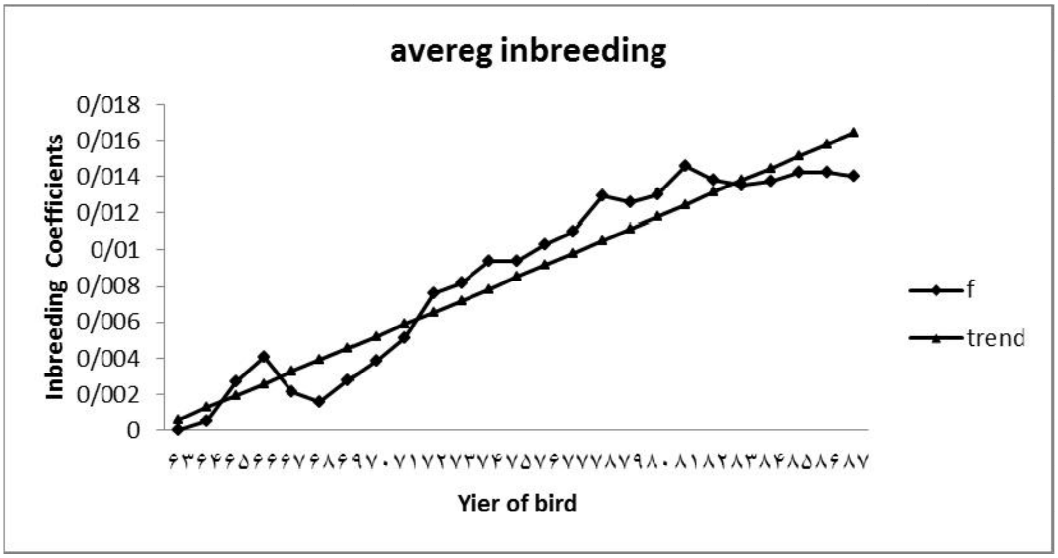

Fig. 4. The 0.055 percent of inbreeding in sexual intercourse in the formula (F = (-0.000044 + 0.00055x)) is estimated

The 0.055 percent of inbreeding in sexual intercourse in the formula F = -0.000044 + 0.00055x)) is shown in Fig. 4.

4. DISCUSSION

A few studies have been reported the effect of year, month of calving, herd on the traits production in Iraqi. First time, our study show that thesis effects had significant different on traits production (P<0/0001) (Fig. 1). But Month of calving showed that did not any significant different on the protein (P>0/0001) (Fig. 2). Also, the phenotypic process the show that there is significant different between of fat and milk but show not significant different on the protein (P>0/0001). This result of my study indicates of the additive genetics and use of bull's semen that have high breeding value for milk. Recently, Van Wyk and co-author reported that use of bull's semen cause improvement genetics industry of dairy farms [25]. Rokouei et al. reported monitoring inbreeding trends and inbreeding depression for economically traits of Holstein cattle in Iran. But, not reported the estimation of inbreeding and inbreeding depression on trait production [24].

Inbreeding coefficient range was from 0 to 19. A similar result was reported by Maiwashe et al. [26]. Most portions of animals were belonging to 19 inbreeding class. Low average of inbreeding coefficient belonging to a group. Animal to two first inbreeding coefficients represents two things: first, the results of first step indicate that the parents of animal have few common ancestors and farmer avoided mating close relative animal. The results of second step showed incomplete pedigree information in Iraqi Holstein population. In this study, pedigree information was available up to seven generation. The incomplete pedigree information could not be the reason of low average of inbreeding coefficient.

4.1 Fixed Effects on Milk Yield, Fat and Protein

The results of our study showed that the effects of herd, year of calving, calving season and inbreeding grouped for two traits and milk fat content are significant. These results are agreement with obtained results by Nyamushamba et al. [27] and Khanzadeh and co-author [28]. The fixed effect of inbreeding grouped on protein yield was not significant, when inbreeding coefficient as continuous variable the regression coefficient was significant. In order to, reported that, Effects of factors (calving year, calving age, and parity and calving season) on 412-days milk yield have been differenced significant [29]. Also, Hamidi et al. [28] reported that the effect of year and season of calving and parity have significant (P<0.001). As well as, recently have been showed that calving year on dry period were statistically significant (P<0.001) [29,30], but in our study not reported the same results.

4.2 Effect of Inbreeding on Production Traits

Estimation of the effect of inbreeding group on production traits are expressed as deviation from non-inbreed animal (group F=0). In this study, inbreeding group had negative effect on production tait for group of animal that had inbreeding coefficient more than 5.34. Animal in second inbreeding group ($0 < F \leq 5.34$) produce 28.1, 0.566 and 1.99 kg milk, fat and protein more than non- inbreed animal. Reduction in milk production was high for F>19 but for fat and protein yield most reduction occurred for $11.5 < F \leq 19$ group this can be because of unbalanced distribution of record among inbreeding group. Similar results were reported by Sewalem et al. [31] and Hudson and Van Vleck [32]. When considering inbreeding as continuous variable in model, the inbreeding depression for 412-d yields of milk, fat and protein were -28.19, -0.98, -0.88 kg per 1% increase in inbreeding in Iraqi Holsteins, respectively. Szyda et al. [33] reported that 1% increase in inbreeding coursed reduction about 37 kg of milk, 1.2 kg of fat and 1.2 kg of protein in Holstein cow. Thompson [34] showen in Holstein cow inbreeding depression for milk production was 35 kg. These results for inbreeding depression was greater than obtained in current study and obtained results by Rokouei et al. [24] is agreement with result of our study.

4.3 Effect of Including Inbreeding in Model to Estimation of Variance Component

To evaluation the effect of including inbreeding on genetic parameter estimation of production traits two models were examined: model 1 including inbreeding coefficient as continuous variable in model and model 2 without including inbreeding coefficient in model. Estimated variance components and heritability of production traits based on models 1 and 2 are presented in Table 3. Additive genetic obtained in model 1 is somewhat greater than ones obtained in model 2, but in general differences in variance component and heritability obtained based on model 1 and model 2 were negligible that is agreement with result reported by Rokouei et al. [24]. Jamrozik and coauthor [35] showed the Pearson and Spearman's correlation between estimated breeding value of animal for model including and not including inbreeding coefficient in genetic evolution of fertility and calving ease traits was 0.98 that means including inbreeding could not change the rank of animal in genetic evolution of production traits in Iraqi Holstein cow. Genetic parameters for milk, fat and protein presented in Table 3. My research is agreement with Rokouei et al. [24]. To increase genetic variance (1.33, 1.45, 1.72 percent for milk, fat and protein), residual variance (0.55, 0. 41, 0.52 percent for milk, fat and protein) and heritability (1.13, 1.32, 1.17 percent for milk, fat and protein), respectively. Obtained heritability for milk, fat and protein were 28%, 24%, 25% that these results were similar to ones obtained by Ravagnolo and Misztal [36].

5. CONCLUSION

In finally, the results of my study showed that the major sources of variation in milk production, lactation length and dry period are genotype, environment and the interaction between the them. The influence of environmental factors on dairy production has been well documented. The present results suggested that milk yield, protein and fat were related to effects herd, month and year of calving since, the effect of herd, year and month calving milk yield, fat and protein that the effect of these factors were significant (P<0.001).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Falconer DS, Mackay TFC. Introduction to quantitative genetics. Fourth edition. Addison Wesley Longman, Harlow, Essex, UK. 1996;464.
2. Fernandez J, Toro MA. The use of Mathematical programming to control inbreeding in selection schemes. Journal of Animal Breeding Genetic. 1999;116: 447-466
3. Karoui S, Díaz C, Serrano M, Cue R, Celorrio I, Carabano MJ. Time trends, environmental factors and genetic basis of semen traits collected in Holstein bulls under commercial conditions. Animal Reproduction Science. 2011;124: 28–38.
4. Thompson JR, Everett RW, Hammerschmidt NL. Effects of inbreeding on production and survival in Holsteins. Journal of Dairy Science. 2000;83:1856-1864.

5. Tohidi R, Vaez Torshizi R, Moradi Shahrbabak M, Sayyad Nejad MB. Inbreeding and its effects on milk and fat yields ofIran Holsteins. Proc. 7th World Congr. Genet. Appl. Livest. Prod., CD-ROM Commun. 2002;21:01–55.
6. Parland MC, Kearney JF, Rath M, Berry DP. Inbreeding effects on milk production, calving performance, fertility and conformation in Irish Holstein Friesians. Journal of Dairy Science. 2007;90:4411–4419.
7. Croquet C, Mayeres P, Gillon A, Vanderick S, Gengler N. Inbreeding depression for global and partial economic indexes, production, type, and functional traits. Journal of Dairy Science. 2006;89:2257-2267.
8. Falconer DS, Mackay TFC. Introduction to quantitative genetics. 4th Ed. Longman, Essex, UK; 1996.
9. Hennas SA, Young CW, Rust JW. Effects of mild inbreeding on productive and reproductive performance of Guernsey cattle. Journal of Dairy Science. 1987;70: 712-719.
10. Hodges J, Tannen L, McGillivray BJ, Hiley PG, Ellis S. Inbreeding levels and their effect on milk, fat and calving interval in Holstein-Friesian cows. Can. Journal of Animal Science. 1987;59:153-159.
11. Hudson GFS, Van Vleck LD. Effects of inbreeding on milk and fat production, stayability and calving interval of registered Ayrshire cattle in the Northeastern United States Journal of Dairy Science. 1984; 67:171-179.
12. Kunaka K, Makuza M. Environmental factors affecting milk production in the holstein-friesian population of Zimbabwe. Pakistan Journal of Biological Sciences. 2005;8(7):989-994.
13. Falconer DS. Introduction to quantitative genetics. John Willey and Sons, Inc. New York, NY. 3rd ed. Loogman, Burnt Mill. Harlow, Essex. Eogl; 1989.
14. Smith LA, Cassell BG, Pearson RE. The effects of inbreeding on the lifetime performance of dairy cattle. Journal of Dairy Science. 1998;45:2729-2737.
15. Fuerst-Waltl B, Schwarzenbacher H, Perner C, Sölkner J. Effects of age and environmental factors on semen production and semen quality of Austrian Simmental bulls. Animal Reproduction Science. 2006;95:27–37.
16. Ponzoni RW, Newman S. Dvelopment of breeding objectives for Australian beef cattle production. Animal Reproduction Science. 1989;49:35-47.
17. Weller J, Ezra E. Genetic analysis of Israel. Holstein dairy cattle population for production and nonproduction traits with a multitrait animal model. J. Dairy Sci. 2005;87:1519-1527.
18. Sewalem A, Kistemaker GJ, Miglior F. Relationship female fertility and production traits in Canadian Holsteins . Journal of Dairy Science. 2010;93:4427-4434.
19. Henderson CR. A simple method for computing the inverse of a numerator relationship matrix used in prediction of the Asturcon pony as an example. Genetics Selection Evolution. 1976;30:397-405.
20. Sargolzaei M, Iwaisaki H, Colleau JJ. CFC: A tool for monitoring genetic diversity. In: Proceedings of 8th World Congress on genetic applied to livestock production. Belo Horizonte, Minas Gerais. Brazil. 2006; 27-28.
21. Gilmour AR, Gogel BJ, Cullis BR, Welham SJ, Hompson R. ASREML user guide release 1.0. VSN International Ltd., Hemel Hempstead, U.K; 2002.
22. Miglior F. Centre for genetic improvement of Uvestock. Department of animal and poultry Science University of Guelph, ON, Canada N1G 2W1. Journal of Dairy Science. 1992;54:76-82.
23. Schacffer LR. Application of random regression models in animal breeding. Journal Livestock Production Science. 2004;86:35-45.
24. Rokouei M, Vaez Torshizi R, Moradi Shahrbabak M, Sargolzaei M, Sorensens AC. Monitoring inbreeding trends and inbreeding depression for economically important traits of Holstein cattle in Iran. Journal of Dairy Science. 2010;93:3294–3302.
25. Hamami H, Rekik B, Bastin C, Soyeurt H, Bormnn J, Stoll J, Gengler N. Environmental sensitivity for milk yield in Luxembourg and Tunisian Holsteins by herd management level. Journal of Dairy Science. 2009;92:4604-4612.
26. Maiwashe A, Nephawe KA, Theron HE. Estimates of genetic parameters and effect of inbreeding on milk yield and composition in South African Jersey cows. South African Journal of Animal Science. 2008;38(2):119-125.

27. Nyamushamba GB. Comparative evaluation of non-genetic factors affecting milk yield and composition of Red Dane and Jersey cattle in Zimbabwe. Available:http://creativecommons.org/licenses/by/2.0
28. Khanzadeh H, Gavi Hossin Zadeh N, Naserani M. Estimation of genetic Parameters and trends for milk fat and protein percentages in Iranian Holsteins using random regression test day model. Archives Animal Breeding. 2012; 56:1-21.
29. Mandal A, Pant KP, Rout PK, Roy R. Effects of inbreeding on lamb survival in aflock of Muzaffarnagari sheep. Asian-Australasian Journal of Animal Sciences. 2004;17(5):594-597.
30. Hamidi NM. Effects of environmental factors on milk yield, lactation length and dry period in Tunisian Holstein Cows; 2012. Available: http://dx.doi.org/10.5772/50803
31. Sewalem A, Kistemaker GJ, Miglor F, Vandoormal BJ. Analysis of inbreeding and its relationship with functional longevity in Canadian dairy cattle. Journal of Dairy Science. 2006;89:2210-2216.
32. Hudson GFS, VanVleck LD. Inbreeding of artificially bred daily cattle in the northeastern United States. Journal of Dairy Science. 1984;67:161-168.
33. Szyda J, liu Z, Reinhardt F, Reents R. Estimation of quantitative trait loci parameters for milk production traits in German Holstein dairy cattle population. Journal of Dairy Science. 2005;88(1):356-367.
34. Thompson R. Design of experiments to estimate genetic parameters within population. In: Evolution and Animal Breeding WG. Hill and TFC Mackay. CAB International. 1996;65:169-174.
35. Jamrozik J, Schaeffer LR. Estimates of genetic parameters for a test- day model with random regressions for yield traits of first lactation Holsteins. Journal of Dairy Science. 2007;90:1564-1574.
36. Ravagnolo O, Misztal I. Gentic component of heat stress in dairy cattle, parameter estimation. Journal of Dairy Science. 2000;83:2126-2130.

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