Genetic parameters for female fertility and milk production traits in first-parity Czech Holstein cows

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ABSTRACT: The aim of this study was to estimate genetic parameters for female fertility and production traits in first-parity Czech Holstein cows and to quantify the effect of using this information on the accuracy of a selection index in seven different scenarios. In order to estimate genetic (co)variance components, the DMU software running an AI-REML algorithm was used. The analyses were made using a series of bivariate animal models. The pedigree included 164 125 animals and it was set up using a pruned animal model design. The present study included the following female fertility traits for the first lactations: calving to the first insemination (CF), days open (DO), calving from the first to the last insemination (FL), and milk production traits: milk production (MLK), kg of fat (FAT), and kg of protein (PROT). The heritability for all the investigated fertility traits was low and close to 0. Moderate heritabilities for production traits ranging from 0.20 (MLK) to 0.23 (PROT) were estimated. The strongest unfavourable correlation was found between PROT and DO (0.49). Other estimated correlations between fertility traits and production traits were moderate, ranging from 0.26 to 0.41. The results of this study evidence that cows with the poorest genetic potential for reproductive performance are those having high genetic potential for milk production and milk components. The results also show that the number of days from calving to new pregnancy depends on the production level. Seven investigated scenarios using selection index theory show a clear trend for increasing accuracy when more fertility traits were added as well as when higher numbers of daughters with information on reproduction traits per sire were available.

Keywords: dairy cattle; reproduction; production; genetic parameters

A long-lasting selection for high milk production has led to reduced reproductive performance, especially in Holstein herds. This situation has reduced profitability in high-producing dairy herds. The present study examines the relationship between production and reproductive performance in the Czech Holstein population and points to a possible direction in selecting concerning these two economically important trait groups. High genetic merit cows have higher milk production, which is followed by greater BCS losses between calving and first service (Snijders et al., 2001). BCS at the time of calving as well as BCS nadir and amount of BCS losses post-calving are associated with milk production, reproduction and health (Roche et al., 2009). Because of their high production in early lactation, dairy cows are in negative energy balance at that time (Friggens et al., 2007). The cows tending to remain longer in negative energy balance have the worst reproductive performance (Dechow et al., 2002) and get a later start in their reproductive activity (De Vries et al., 1999). BCS is negatively re-

Supported by the Ministry of Agriculture of the Czech Republic (Project No. QI 91A238 and Project No. MZE 0002701404).

lated to milk production, as has been described by numerous authors (e.g. Berry et al., 2003; Dechow et al., 2004). The changes occurring after parturition and at the beginning of lactation can cause poor reproductive performance. Unfavourable relationships between BCS and BW losses during lactation and the reproductive ability of cows have been observed (Pryce et al., 2001; Roche et al., 2007). Moreover, there exists a contradictory relationship between genetic merit for milk production and fertility (Veerkamp et al., 2001). Berry et al. (2003) have noted, however, that there is a possibility to select increasing milk production without negatively impacting fertility. Some authors have attempted to use milk components in conjunction with BCS and BW in a combined index as a predictor of negative energy balance and poorer reproduction (De Vries and Veerkamp, 2000; Buckley et al., 2003). These traits, as well as some components of milk (e.g. urea), can be useful as indicators of reproductive performance (Řehák et al., 2009). The present studies clearly show the need of a more comprehensive view on reproduction management in dairy herds that should include accessible information easily exploitable in field conditions.

The aim of this study was to estimate genetic parameters for the fertility traits (days from calving to the first insemination (CF), days open (DO), and days from the first to the last insemination (FL)) as well as the milk production traits – milk yield (MLK), kg of fat (FAT), and kg of protein (PROT) in first-parity Czech Holstein cows. Estimation of genetic parameters is important for estimating breeding values and for the use in selection indexes. The present study provides information about these two parameter sets important for production and fertility traits that are greatly related to the profitability of the dairy industry. At the same time, the study aims to help in improving this status in conjunction with other research projects involving the Czech Holstein population.

MATERIAL AND METHODS

Data

The phenotypic data for milk production and reproduction traits were collected from Czech Holstein cows calving in the years 2002–2008 and were taken from the official progeny testing database of the Czech-Moravian Breeders' Corporation. The pedigree used for the analyses contained 164 125 animals, including information in a three-generation structure. In total, information on 936 herds was available. Numbers of animals in each of the analyzed fertility trait were as follows: 58 686 animals calving to the first insemination, 53 026 days open and 52 632 animals calving from the first to the last insemination. Only records in the interval between 21 and 180 days for calving to the first insemination and from 40 to 220 days for days open were used for the analyses. Numbers of records for the milk production traits used in this study were as follows: 59 454 milk production and 59 430 kg of fat and protein.

Models

(Co)variance components were estimated in a number of bivariate analyses. Animal models were used to utilize the pedigree information from three generations.

For production traits and fertility traits, models containing the following effects were used:

$$yP_{ijklm} = h_i + y_j + s_k + \beta * aac_{ijklm} + \delta * aac^2_{ijklm} + a_m + e_{ijklm}$$

$$yF_{ijklm} = h_i + y_j + s_k + \beta * aac_{ijklm} + \delta * aac^2_{ijklm} + a_m + e_{ijklm}$$

where:

h_i = herd, 936 levels, fixed class variable
y_j = year, 7 levels, fixed class variable
s_k = season, 4 levels, fixed class variable
aac_{ijklm} = age at calving, fixed regression
aac^2_{ijklm} = squared age at calving, fixed regression
β, δ = regression coefficients
a_m = random animal
e_{ijklm} = random residual effect

(Co)variance structure

The vector of additive genetic effects (**a**) was assumed to be N(**0**, **A**σ^2_a), where **A** is the additive genetic relationship matrix. The vector of residual effects (**e**) was assumed to be N(**0**, **I**σ^2_e) where **I** is identity matrix and cov(**a**, **e**) = **0**.

To estimate (co)variance components, the DMU software package developed by Madsen and Jensen

(2008) was used. An AI-REML algorithm was implemented (Jensen et al., 1997).

Selection Index Program

The effects of the genetic parameters found in this study were quantified using the Selection Index Program software (SIP; Wagenaar et al., 1995). The software calculates accuracies for an index of a given trait and breeding goal using selection index theory. We set up an index for a bull assuming different amounts of available information. Five scenarios were evaluated in which the following added information was combined: observation on DO, observations on CF and FL, and observations on production traits. In all the scenarios, we calculated the accuracy of an index for days open given different numbers of the recorded traits and four different daughter group sizes. The groups were defined as including 0, 30, 60, and 120 daughters per sire. For all the traits it was assumed that when information on daughters of the given bull was available, the information on 1000 daughters of the bull's sire and grandsire was available, too.

RESULTS AND DISCUSSION

Basic statistics

Basic descriptive statistics for the fertility and production traits are presented in Table 1. In general, the reported results are similar to those seen in other countries advanced in cattle breeding which are discussed below. In some cases, comparison and interpretation of fertility status findings between different populations can be quite problematic due to the differences in conditions between these populations, definitions of different fertility traits, and year of evaluation. The reported mean for CF (80.86 days) is slightly higher than 72.8 days reported for the Irish Holstein population evaluated by Berry et al. (2003). It is lower, however, than the figure published by König et al. (2008), who reported 93.85 days from calving to the first insemination, and also lower than 89 days reported by Veerkamp et al. (2001) for the same trait (both figures also being for the Holsteins). It is difficult to compare results from different populations and from different years, because of different average milk production as well as different cows' genetic merit for milk production. One can presume that animals from earlier studies had lower genetic merit for milk production, which could lead to lower actual milk production and, consequently, better reproduction.

Heritability

Estimated heritabilities of the analyzed fertility traits, along with their corresponding standard errors (SE), are presented in Table 2. For the analyzed production traits they are given in Table 3. As a final result, averages from all bivariate analyses calculated as an average from all analyses for each of the investigated traits were reported for heritabilities and genetic correlations. The estimated heritabilities for the reproduction traits were close to zero. These results unambiguously correspond with the results presented by many other authors (e.g. Pryce et al., 2001; Dechow et al., 2004) which explicitly express that reproduction has a very low heritability. Therefore, direct selection for fertility

Table 1. Basic statistics for investigated fertility and production traits

Trait	*n*	Mean	SD
Calving to first insemination (days)	58.686	80.86	29.19
Days open (days)	53.026	113.93	46.07
First to last insemination (days)	52.632	34.26	41.81
Milk yield (kg)	59.454	8353.76	1815.37
Fat (kg)	59.430	310.59	64.63
Protein (kg)	59.430	271.16	55.31

n = number of records, SD = standard deviation

Table 2. Estimated heritabilities and their standard errors of fertility traits (diagonal), genetic correlations (above diagonal), residual correlations (below diagonal)

h^2	Calving to first insemination (days)	Days open (days)	First to last insemination (days)
Calving to first insemination	0.04 ± 0.01	0.83 ± 0.05	0.23 ± 0.14
Days open	0.43 ± 0.004	0.03 ± 0.004	0.80 ± 0.06
First to last insemination	–0.18 ± 0.01	0.83 ± 0.001	0.01 ± 0.003

h^2 = heritability

Table 3. Heritabilities and their standard errors of production traits

Trait	h^2	SE
Milk yield (kg)	0.20	± 0.01
Fat (kg)	0.21	± 0.01
Protein (kg)	0.23	± 0.01

h^2 = heritability, SE = standard error

is not possible. Because fertility is so complex, it is necessary to look for all possible tools to improve fertility in dairy herds. There do exist some traits related to reproduction performance useful in field conditions, such as BCS (Jílek et al., 2008), linear type traits (Pryce et al., 2000), and milk production (Berry et al., 2003; Buckley et al., 2003). Our estimates of milk production heritabilities were moderate and very similar for all the three traits: 0.20 (MLK), 0.21 (FAT) and 0.23 (PROT). The results presented generally correspond with the findings estimated by various authors in other populations. In the study by Dechow et al. (2001), the estimated heritabilities for milk production in the first and second lactations were 0.29 and 0.17, respectively, which is generally close to the results estimated by Dal Zotto et al. (2007) in Italian Brown Swiss (0.15). Our result of 0.20 for MLK, however, is also closer to the estimate of Dechow et al. (2001) published for cows on the second lactation. Very low heritabilities of 0.09 for fat production and of 0.13 for protein production were estimated by Dal Zotto et al. (2007) compared to our estimates of 0.21 and 0.23, respectively. In conclusion, the estimated heritabilities in our study as well as in the cited literature generally acknowledge that selection on production traits has much more potential to be successful than the selection for improved fertility.

Genetic correlations

The relationships between CF, DO and FL in the Czech Holstein population expressed as genetic correlations (r_g) are presented in Table 2. A stronger relationship between DO and FL than that found in the present study had been estimated by González-Recio and Alenda (2005). Their estimate for r_g was 0.99 compared to our 0.80. A very similar result (0.82) was presented by the same authors for CF and DO, whereas our estimate of r_g between these two traits was 0.83. While González-Recio and Alenda (2005) estimated a high genetic correlation between CF and FL (0.50), we determined a more moderate correlation of 0.23 albeit with a high SE of 0.14. Despite our estimate of moderate correlation, the estimated correlations between the observed reproduction parameters logically correspond with the formulations of the traits and their mutual similarities.

Table 4. Genetic correlations and their standard errors between fertility and production traits

	Calving to first insemination (days)	Days open (days)	First to last insemination (days)
Milk yield (kg)	0.30 ± 0.06	0.39 ± 0.07	0.26 ± 0.09
Fat (kg)	0.27 ± 0.06	0.40 ±0.07	0.32 ±0.10
Protein (kg)	0.33 ± 0.06	0.49 ± 0.06	0.41 ± 0.10

Genetic correlations as an indicator of the relationship between production and reproduction traits are presented in Table 4. They ranged from 0.26 for MLK and FL to 0.49 for PROT and DO. The results show relatively strong unfavourable correlations between milk production and reproduction traits in the Czech first-parity Holstein cow population. Estimated genetic correlations between DO and production traits were MLK (0.39), FAT (0.40), and PROT (0.49). Slightly higher but similar results were presented in a study by Dal Zotto et al., (2007) between the same production traits and calving interval (CI). There is a very good opportunity to compare the studies where CI or DO is used, because of the similarity between the two traits where a strong genetic correlation was estimated in the study of González-Recio and Alenda (2005). Also, the genetic correlations are supported by the studies of Dal Zatto et al. (2007) and Pryce et al. (2000). Genetic correlations estimated between DO and milk production traits in our study were lower but still similar. Within the investigated population, a strongly unfavourable genetic relationship was observed for cows with higher milk production and milk compound yield and their reproductive abilities. These findings support the statement that animals with higher production have the poorest reproduction parameters. This is as true for CF as a trait that is clearly related to the ability of cows to show heat as it is for longer DO. Most studies focus on the relationship between CI and milk production traits (e.g. Pryce et al, 2000; Dal Zotto et al., 2007). Fewer studies have looked at other common reproduction traits along with those for milk production (e.g. Berry et al., 2003; González-Recio et al., 2006). Estimated genetic parameters for one population are not always accurate enough and useful in relation to other populations, because they can reflect essential differences in the levels of management and breeding strategies.

Accuracies of the index for days open

The results of all seven scenarios using different information and the investigated accuracy of an index using SIP are presented in Table 5. In scenario 1, information on the bull concerned only milk, fat and protein. Accuracies presented as the squared correlation between the true breeding value and the index were generally low and there was scarcely enough information for publishing the breeding values for days open concerning 120 daughters. In scenarios 2 and 3, data for correlated fertility traits were available and compared to scenario 1 the accuracy is higher. In scenarios 4, 5, 6, and 7, direct observations for the trait that is the breeding goal was available and therefore the accuracy of the index was the highest. Even when observations for all the three fertility traits were available, the accuracy was increased by including information also on production traits. However, compared to other studies (e.g. Pryce et al., 2000; Veerkamp et al., 2001), the heritability of the production traits was relatively low. Thus, with higher heritability estimates for production traits this effect would have been even higher. The accuracy of the index for days open scarcely changed from scenarios 2 to 7 when the index was based on pedigree information only (0 daughters).

Table 5. Squared correlations between the true breeding value and index (r_{IA}) for days open (DO) based on different amounts of information for days from calving to first insemination (CF), days from first to last insemination (FL), and the three production traits – milk (MLK), fat (FAT), and protein (PROT)

	Scenarios						
	1	2	3	4	5	6	7
Observations on DO				–	–	–	–
Observations on CF and FL		–	–			–	–
Observations on production traits: MLK, FAT, PROT	–		–		–		–
r_{IA} 0 daughters	0.08	0.27	0.28	0.29	0.29	0.29	0.29
r_{IA} 30 daughters	0.18	0.37	0.40	0.42	0.45	0.48	0.49
r_{IA} 60 daughters	0.20	0.45	0.49	0.50	0.53	0.56	0.58
r_{IA} 120 daughters	0.21	0.56	0.59	0.62	0.62	0.65	0.67

CONCLUSION

The results show relatively strong unfavourable correlations between all the investigated production as well as reproduction traits. Also, very low heritability for reproduction traits and moderate heritabilities for production traits were found. The results, profiting from preceding research results in the field of reproduction and other related traits, should contribute to addressing the general problem of poor reproduction performance in high-producing dairy herds. Hopefully, the present study should benefit future research dealing with the Czech Holstein population, namely as concerns the defined relationships between milk production and reproduction traits. The obtained results should extend the knowledge on formulation of breeding plans in high-producing dairy herds.

Acknowledgement

The authors thank the Czech-Moravian Breeders' Corporation for providing the data from the official database of progeny testing.

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Received: 2011–02–02
Accepted after corrections: 2011–10–12

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