Analyses of genetic relationships between linear type traits, fat-to-protein ratio, milk production traits, and somatic cell count in first-parity Czech Holstein cows

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ABSTRACT: Genetic and phenotypic correlations between production traits, selected linear type traits, and somatic cell score were estimated. The results could be useful for breeding programs involving Czech Holstein dairy cows or other populations. A series of bivariate analyses was applied whereby (co)variance components were estimated using average information (AI-REML) implemented via the DMU statistical package. Chosen phenotypic data included average somatic cell score per a 305-day standard first lactation as well as the production traits milk yield, fat yield, protein yield, fat percentage, and protein percentage per the standard first lactation. Fifteen classified linear type traits were added, as they were measured at first lactation in the Czech Holstein population. All phenotypic data were collected within the progeny testing program of the Czech-Moravian Breeders Corporation from 2005 to 2009. The number of animals for each linear type trait was 59 454, except for locomotion, for which 53 424 animals were recorded. The numbers of animals with records of milk production data were 43 992 for milk yield, fat percentage, protein percentage, and fat-to-protein percentage ratio and 43 978 for fat yield and protein yield. In total, 27 098 somatic cell score records were available. The strongest positive genetic correlation between production traits and linear type traits was estimated between udder width and fat yield (0.51 ± 0.04), while the strongest negative correlation estimated was between body condition score and fat yield (–0.45 ± 0.03). Other estimated correlations were between those two extremes but generally they were close to zero or positive. The strongest negative phenotypic correlations were estimated between udder depth and milk yield and protein yield (both –0.17), while the strongest positive phenotypic correlations were estimated between milk yield, protein yield, and udder width (both 0.32).

Keywords: Holstein cattle; genetic parameters; milk yield; somatic cell score

INTRODUCTION

The importance of associations between conformation traits, milk production traits, and somatic cell score (SCS) is well known from numerous studies (e.g. Rupp and Boichard 1999; Samore et al. 2010). It is of great economic importance for the farmer to obtain large amounts of milk from healthy, reproductive cows. Preventing disease is also ethically important in order to ensure high quality consumer products as well as well-being of the cows. Genetic relationships exist between udder conformation traits, milk production, and SCS (Rupp and Boichard 1999), and relationships among these traits and conformation traits have also been reported in other studies (Kadarmideen 2004; Samore et al. 2010). De Haas et al. (2007) reported differences in the genetic relationships

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between conformation traits, SCS, and production traits in three dairy cattle populations. To some extent the selection based on conformation traits has historically been made in order to create a breed of cows that were aesthetically beautiful and that could perform well in the show ring. Conformation traits serve today as indicators for other traits that are of economic importance, including health, reproduction, and production. The selection index theory has shown that the use of indicator traits can substantially increase accuracy in enhancing traits with low heritability such as health and reproduction (Zink et al. 2012).

The Czech population of Holstein cattle has been subject to long-time selection for increasing milk production. This has been accompanied by the decline in fertility and health performance.

In the post-calving period, dairy cows are generally in negative energy balance. After calving, they are unable to consume sufficient amount of feed to cover both their increasing milk production and body maintenance requirements (Olson et al. 2010). One consequence of that state is a drop in body condition score in early lactation which can be so severe that it may influence performance in later lactation in relation to milk production, health, and fertility. Using body fat reserves to compensate for the deficiency in energy intake is reflected in the future relative fat percentage of the milk produced. Therefore, recent studies have shown there might be a relationship between the fat : protein ratio (F/P) in milk during early lactation and the performance during the same lactation (e.g. Buttchereit et al. 2012; Koeck et al. 2013). In a review by Roche et al. (2009), problems associated with negative energy balance influencing production, reproduction, and health performance in dairy cattle are described in detail. It has also been shown that cows that were genetically extreme for angularity, stature, and body depth tend to perform poorly on fertility traits (Zink et al. 2011). At the same time, cows that were genetically predisposed for low body condition score or high locomotion score are generally inferior in relation to fertility.

The aim of this study was to estimate genetic parameters for production, health, and conformation traits in the population of first-lactation Holstein cows in the Czech Republic.

MATERIAL AND METHODS

Data. Phenotypic data for linear type traits classified from October 2005 to February 2009 on a scale of 1–9, milk production traits, and SCS from first-parity Holstein cows were collected from 936 herds in the Czech Republic. Linear type traits were used only from first-parity cows classified between 30 and 210 days postpartum. A three-generation pedigree was constructed containing approximately 160 000 animals. Linear type traits were classified by seven authorized classifiers according to the official methodology over the period of 5 years. Each year was divided into four seasons (starting in January of each year). All data were extracted from the official progeny testing database of the Czech-Moravian Breeders Corporation (http://www.cmsch.cz/store/vysledky-ku-2009-2010-metoda-a4-at-a.pdf). Logarithmic transformation of somatic cell count (SCC) form test-day data to SCS was performed according to the methodology described by Ali and Shook (1980). For this study 27 098 SCC records were available. The total number of animals with lin-

Table 1. Basic statistics for production traits and somatic cell score, including number of records (n), mean, standard deviation (SD), minimum (Min), maximum (Max), heritability (h^2), and standard error of estimate (SE)

Trait	n	Mean	SD	Min.	Max.	h^2 (SE)
MY	43 992	8 641.87	1 695.20	2 232.00	1 6576.00	0.30 ± 0.02
FY	43 978	321.05	60.19	87.00	711.00	0.23 ± 0.01
PY	43 978	280.61	50.97	75.00	552.00	0.26 ± 0.02
FP	43 992	3.75	0.46	2.26	6.43	0.54 ± 0.02
PP	43 992	3.26	0.20	2.00	5.50	0.55 ± 0.02
F/P	43 992	1.15	0.13	0.66	1.93	0.42 ± 0.02
LSCS	27 098	3.36	1.09	0.19	6.95	0.09 ± 0.01

MY = milk yield, FY = fat yield, PY = protein yield, FP = fat percentage, PP = protein percentage, F/P = fat and protein percentage ratio, LSCS = lactation average somatic cell score

Table 2. Basic statistics for linear type traits (scored on a 9-point scale) in Holstein cows, including number of records (n), mean, standard deviation (SD), heritability (h^2), and standard error of estimate (SE)

Trait	n	Mean	SD	h^2 (SE)
Stature	59 454	6.14	1.28	0.39 ± 0.02[a]
Chest width	59 454	5.77	1.31	0.17 ± 0.01[a]
Body depth	59 454	5.76	1.34	0.22 ± 0.01[a]
Angularity	59 454	5.51	1.20	0.19 ± 0.01[a]
Rear legs set	59 454	5.05	1.31	0.12 ± 0.01[a]
Fore udder attachment	59 454	5.15	1.51	0.22 ± 0.01[b]
Front teat placement	59 454	5.00	1.27	0.26 ± 0.01[b]
Teat length	59 454	4.68	1.16	0.26 ± 0.01[b]
Udder depth	59 454	5.79	1.47	0.28 ± 0.01[b]
Rear udder height	59 454	5.47	1.47	0.20 ± 0.01[b]
Central ligament	59 454	5.66	1.52	0.19 ± 0.01[b]
Rear teat position	59 454	5.63	1.45	0.27 ± 0.01[b]
Udder width	59 454	5.38	1.47	0.13 ± 0.01[b]
Locomotion	53 424	5.15	1.56	0.03 ± 0.01[a]
Body condition score	59 454	4.96	1.25	0.30 ± 0.01[a]

[a]Zink et al. (2011), [b]Zink et al. (2010)

ear type data was 59 454, whereas the number of animals with locomotion score was 53 424. The number of records for milk production traits varied by traits, ranging from 43 978 for fat yield (FY) and protein yield (PY) to 43 992 for milk yield (MY), fat percentage (FP), protein percentage (PP), and fat-to-protein percentage ratio (F/P). All milk production data were based upon a standard 305-day lactation. Somatic cell score was taken as a per-lactation average (LSCS). The present study considered 15 type traits: stature, chest width, body depth, angularity, rear legs set side view, fore udder attachment, front teat placement, teat length, udder depth, rear udder height, central ligament, rear teat position, udder width, locomotion, and body condition score (BCS). The basic descriptive statistics for production traits, LSCS, and the 15 selected linear type traits are presented in Tables 1 and 2, respectively.

Estimation of genetic parameters. Variance components were analyzed using a restricted maximum likelihood algorithm based upon average information (AI-REML) (Jensen et al. 1997). This was implemented in the DMU statistical package (Version 6, release 4.7, 2008) through a series of bivariate animal models. The vector of additive genetic effects (**a**) was assumed to be $N(\mathbf{0},\mathbf{A}\sigma_a^2)$, where **A** is the additive genetic relationship matrix. The vector of residual effects (**e**) was assumed to be $N(\mathbf{0},\mathbf{I}\sigma_e^2)$, where **I** is the identity matrix and cov(**a**, **e**) = **0**. For each trait variance components and their standard errors were calculated as averages of all estimates. Standard errors of the estimates were calculated using the Taylor Series approximation.

Depending of the nature of the trait two different models were applied. For conformation traits the model took the following form:

$$y_{ijklm} = h_i + z_j + s_k + c_l + \alpha \times d_{ijklm} + \beta \times aac_{ijklm} + \delta \times \times aac^2_{ijklm} + a_m + e_{ijklm}$$

where

h_i = fixed class effect of herd of calving
z_j = fixed class effect of year of calving
s_k = fixed class effect of season of calving
c_l = fixed class effect of classifier
d_{ijklm} = days in milk at classification
aac_{ijklm} = age at calving
aac^2_{ijklm} = age at calving squared
α, β, δ = fixed regression coefficients
a_m = random animal effect
e_{ijklm} = random residual effect

For milk production traits and LSCS, the model contained the following effects:

$$y_{ijklm} = h_i + z_j + s_k + \alpha \times aac_{ijklm} + \beta \times aac^2_{ijklm} + a_m + + e_{ijklm}$$

where
h_i = fixed class effect of herd of calving
z_j = fixed class effect of year of calving
s_k = fixed class effect of season of calving
aac_{ijklm} = age at calving
aac^2_{ijklm} = age at calving squared
α, β = fixed regression coefficients
a_m = random animal effect
e_{ijklm} = random residual effect

RESULTS AND DISCUSSION

Heritability

Milk production traits. Heritabilities ranged between 0.55 (PP) and 0.23 (FY). The highest heritabilities were estimated for PP, FP, and F/P (0.55, 0.54, and 0.42). F/P is not a commonly observed milk production trait. More farmers and breeders are taking an interest in F/P, since it has relatively high correlation with the occurrence of ketosis and some other health traits in dairy cattle and the phenotype is easily obtained (e.g. Buttchereit et al. 2012; Koeck et al. 2013).

The heritability of F/P of 0.42 is not as high as the heritability of 0.71 ± 0.02 reported by Jamrozik and Schaeffer (2012). In their study of 1693 Holstein cows in Germany Buttchereit et al. (2012) estimated a heritability of F/P of 0.30 ± 0.05. So it can be stated that F/P is a relatively highly heritable trait. The trait might be helpful in selecting concerning metabolic and other disorders. The traits of milk, fat, and protein production showed substantially lower heritability.

Lactation somatic cell score. As anticipated, the heritability of somatic cell score per lactation was found to be quite low (0.09), as was its standard error (0.01). Despite the relatively low number of available observations for SCS, the low heritability was in accordance with most other published research findings for various dairy cattle breeds. Recently reported heritabilities for SCC are between 0.07 and 0.17 (Berry et al. 2004; Samore et al. 2010; Jamrozik and Schaeffer 2012). There is no essential difference in heritability of somatic cell count, lactation somatic cell score, or test-day somatic cell score that would make one more useful than the other for purposes of dairy cattle breeding (e.g. to select for higher resistance to mastitis). LSCS is favourably and strongly correlated with mastitis (Rupp and Boichard 1999). Ptak et al. (2011) did estimate a somewhat higher heritability for LSCS (h^2 = 0.20), but that value is still rather low. Rupp and Boichard (1999) suggested that information about LSCS, clinical mastitis, and some chosen udder conformation traits might be included into an udder health index in order to increase accuracy of the selection index for the traits. Similarly, Jamrozik and Schaeffer (2012) have suggested that information about additional traits (F/P and MY) might be combined with information about SCS in selecting against mastitis.

Genetic correlations

Genetic correlations between linear type traits, production traits, and lactation somatic cell score. Genetic correlations among the observed milk production traits and chosen linear type traits, including their standard errors, are presented in Table 3. The strongest negative genetic correlation between BCS and FY (–0.45) indicates that cows with higher total milk fat yield during the 305-day lactation tend to have lower BCS. The strongest positive genetic correlation was estimated for FY and udder width (0.51). Thus, cows with wider udders show generally higher fat production. Udder width also showed a relatively high correlation with MY and PY, at 0.37 and 0.50, respectively. Samore et al. (2010) reported the same correlation as in the present study between udder width and MY (0.37) and slightly lower correlation estimates for FY (0.37) and PY (0.36). They determined the same tendency as seen in our results, expressed by estimated negative correlations for udder width vs FP (–0.04) and PP (–0.16). Other very low correlations in our study were estimated for FP and PP vs other type traits related to udders. Similarly, Samore et al. (2010) reported no strong correlations for FP and PP vs fore udder attachment, udder width, rear udder height, central ligament, udder depth, and teat length in Italian Brow Swiss cows. Weak correlations were estimated between front teat placement, teat length, rear teat position, and central ligament with MY, FY, and PY. Slightly higher but still low negative genetic correlations were estimated between fore udder attachment and MY, FY, and PY. F/P was very weakly associated with all linear type traits. Its highest positive genetic correlation was 0.09 for body depth and the strongest negative correlation was with udder width (–0.17). Nevertheless attention should still be paid to F/P and the incorporation of fat-to-protein ratio into breeding programs should be

Table 3. Genetic correlations between milk production traits and linear type traits and their standard errors

Trait	MY	FY	PY	FP	PP	F/P	LSCS
Stature	0.19 ± 0.04	0.30 ± 0.03	0.27 ± 0.04	–0.12 ± 0.03	–0.13 ± 0.03	–0.07 ± 0.03	0.02 ± 0.06
Chest width	0.02 ± 0.04	–0.05 ± 0.04	–0.01 ± 0.04	0.07 ± 0.04	0.08 ± 0.04	0.03 ± 0.04	–0.02 ± 0.06
Body depth	0.19 ± 0.04	0.10 ± 0.04	0.11 ± 0.04	0.06 ± 0.04	–0.01 ± 0.04	0.09 ± 0.04	0.08 ± 0.07
Angularity	0.32 ± 0.04	0.42 ± 0.04	0.34 ± 0.04	–0.13 ± 0.04	–0.27 ± 0.04	–0.008 ± 0.04	0.15 ± 0.07
Rear legs set	0.21 ± 0.05	0.18 ± 0.05	0.19 ± 0.05	0.01 ± 0.04	–0.02 ± 0.04	0.03 ± 0.04	0.09 ± 0.07
Fore udder attachment	–0.11 ± 0.04	–0.13 ± 0.04	–0.13 ± 0.04	0.02 ± 0.04	0.05 ± 0.04	0.004 ± 0.04	–0.25 ± 0.06
Front teat placement	0.03 ± 0.04	0.06 ± 0.04	0.06 ± 0.04	0.0005 ± 0.04	0.01 ± 0.04	–0.03 ± 0.04	–0.005 ± 0.06
Teat length	0.01 ± 0.04	0.08 ± 0.04	0.06 ± 0.04	–0.06 ± 0.04	–0.07 ± 0.03	–0.04 ± 0.03	–0.01 ± 0.06
Udder depth	–0.23 ± 0.04	–0.22 ± 0.04	–0.24 ± 0.04	0.04 ± 0.04	0.03 ± 0.04	0.01 ± 0.04	–0.36 ± 0.06
Rear udder height	0.15 ± 0.04	0.22 ± 0.04	0.18 ± 0.04	–0.10 ± 0.04	–0.12 ± 0.04	–0.05 ± 0.04	–0.08 ± 0.07
Central ligament	–0.12 ± 0.04	–0.04 ± 0.04	–0.06 ± 0.04	–0.06 ± 0.04	0.01 ± 0.04	–0.08 ± 0.04	–0.12 ± 0.07
Rear teat position	–0.04 ± 0.04	0.02 ± 0.04	–0.007 ± 0.04	–0.02 ± 0.04	–0.03 ± 0.04	–0.02 ± 0.04	0.04 ± 0.06
Udder width	0.37 ± 0.04	0.51 ± 0.04	0.50 ± 0.04	–0.21 ± 0.04	–0.18 ± 0.04	–0.17 ± 0.04	0.16 ± 0.07
Locomotion	–0.10 ± 0.07	–0.04 ± 0.07	–0.05 ± 0.07	–0.05 ± 0.07	0.01 ± 0.07	–0.06 ± 0.06	–0.12 ± 0.10
BCS	–0.34 ± 0.04	–0.45 ± 0.03	–0.39 ± 0.03	0.14 ± 0.03	0.22 ± 0.03	0.05 ± 0.03	–0.18 ± 0.06

MY = milk yield, FY = fat yield, PY = protein yield, FP = fat percentage, PP = protein percentage, F/P = fat and protein percentage ratio, LSCS = lactation average somatic cell score, BCS = body condition score

considered. As noted by Buttchereit et al. (2012), improvement in the overall health of dairy cattle can be expected if energy balance traits are included into breeding programs. F/P can be quite easily combined with BCS.

LSCS was most strongly related to udder depth (–0.36) followed by fore udder attachment (–0.25). The strongest positive relationship was with udder width (0.16).

There were strong negative genetic correlations between BCS and the three production traits – MY (–0.34), FY (–0.45), and PY (–0.39). BCS showed positive and desirable correlations with FP (0.14) and PP (0.22). Kadarmideen (2004) reported the same or similar modest correlations between BCS and the milk production traits MY, FY, and PY (r_g= –0.50, –0.43, –0.39). Lower BCS is strongly related to high MY, FY, and PY. For cows having high genetic merit for milk, fat, and protein yield it is highly probable that there will be a lower genetic merit for body condition. Moderate negative genetic correlations were observed between udder width and FP, PP, and F/P. So, these cows probably had lower average FP and PP, which could be related to their higher average overall milk production.

Genetic correlations for MY, FY, and PY vs body-related linear type traits were mostly close to zero. The strongest but still only moderate correlation was observed between angularity and FY (0.42). The same tendency was observed also in the present study for MY (observed correlation 0.32) and for PY (0.34). In a study of the Italian Brown Swiss population, Samore et al. (2010) also estimated moderate to low genetic correlations for angularity vs MY, FY, and PY of 0.36, 0.39, and 0.23, respectively. Estimated correlations in both studies clearly showed that cows with high angularity have higher milk and protein yield per lactation than those with lower angularity. Stronger relationships than those estimated in the present study between body conformation traits and milk production traits were described by de Haas et al. (2007). They estimated moderate to high genetic correlations for stature and body depth with MY, FY, and PY for all three breeds investigated in their study. They reported that genetically deeper, wider and taller cows are predisposed for higher milk production. The same tendencies were found in our study. Both sets of results suggest the possibility for using stature and body depth as traits which may indicate cows' genetic merit for total milk, fat, and protein production.

Correlations between body depth, angularity, and FP, PP were not as strong as those for MY, FY, and PY, although these, too, were the strongest for angularity (–0.13, –0.27). Numerous correlations were close to zero in this study. This has also been shown in other studies e.g. between angularity and FP (0.02) and PP (−0.04) as estimated by Samore et al. (2010). Other correlations between FP, PP, and stature, chest width and body depth were low. While Samore et al. (2010) reported r_g = 0.00 for body depth vs FP and PP, in our study weak negative correlations (−0.12 and −0.13, respectively) were observed.

Genetic correlations between MY, FY, and PY and both linear type traits related to feet and legs (rear legs set and locomotion) were low. The correlations estimated for rear legs set were slightly higher (ranging from 0.18 for FY to 0.21 for MY) than those estimated for locomotion (ranging from −0.04 for FY to −0.10 for MY). Berry et al. (2004) also estimated a genetic correlation of 0.21 between milk yield to day 240 of lactation and rear legs set. Samore et al. (2010), however, reported very low genetic correlations between this trait and all investigated production traits, which is also seen in this study with the exception of F/P. The reason that the total number of animals scored for locomotion (53 424) was lower than that for the other linear type traits (59 454) is due to the fact that only those animals having no injury or disability that could influence the classification were assessed for locomotion. When it was not appropriate to classify locomotion, animals were classified for all traits except locomotion.

Genetic correlations between linear type traits and LSCS. The strongest genetic correlations were those estimated between LSCS and udder depth and fore udder attachment (−0.36 and −0.25, respectively). In a study of the Polish Holstein population, Ptak et al. (2011) estimated a very similar genetic correlation (−0.26) between LSCS and fore udder attachment and a slightly lower r_g for udder depth (−0.23). The estimated negative correlation between LSCS and udder depth indicates that cows with the lowest part of the udder floor closer to the level of the hock or below the hock have higher average SCS per lactation. In general, cows with high milk yield typically have the lowest parts of the udder floor close to or below the hock and high milk yield is unfavourably associated with clinical mastitis (Koeck et al. 2010). Cows having such udders are more exposed to being soiled from the bedding, floor splash, and other sources. This results in a much higher risk of udder contamination and thus the average LSCS per lactation may be higher for those animals. The highest positive unfavourable, although still low, genetic correlations were estimated between LSCS and udder width (0.16) and angularity (0.15). These results indicate that more angular cows and cows with higher capacity udders are predisposed to a higher average SCC per lactation. A significant negative correlation between body condition score and mastitis was estimated by Buttchereit et al. (2012). Due to the antagonistic relationship between BCS and angularity it is highly predictable that angular cows with lower body condition will be at the highest risk of mastitis. Thus, they will probably have high milk yield. Moreover, a higher average SCC per lactation is associated with a higher milk production (Rupp and Boichard 1999). This is directly related to an increased risk of culling, as reported by Sewalem et al. (2006). Other correlations estimated between LSCS and linear type traits were low. For instance, genetic correlation estimated between locomotion and LSCS was −0.12 with a high standard error of 0.10. A higher estimate (−0.28) was reported by Berry et al. (2004). A much lower correlation (of 0.09) was estimated between LSCS and rear legs set. Kadarmideen (2004) and Samore et al. (2010) published very similar findings (0.10 and 0.12, respectively).

Phenotypic correlations

Phenotypic correlations between linear type traits and production traits. In general, the estimated phenotypic correlations between milk production traits and linear type traits (Table 4) presented in this study showed much weaker relationships than did the estimated genetic correlations between those traits. The strongest positive phenotypic correlations were estimated between udder width, MY, and PY (both 0.32). Similar but slightly higher correlations were estimated for the same traits in Guernsay dairy cows by Harrys et al. (1992). These authors also found higher but still only moderate to low phenotypic correlations between udder type traits and milk, protein, and fat yield in a Guernsey population. Phenotypic correlations between other linear type traits related to udder and all milk production traits considered in this study were low. A low phenotypic correlation close to zero was also estimated between udder depth and udder width with FP, PP and F/P, although the estimated correlations were negative for udder width contrary to positive correlations for udder depth.

Table 4. Phenotypic correlations between milk production traits and linear type traits

Trait	MY	FY	PY	FP	PP	F/P	LSCS
Stature	0.13	0.11	0.14	–0.03	–0.01	–0.04	0.02
Chest width	0.05	0.08	0.08	0.04	0.08	0.003	0.01
Body depth	0.15	0.18	0.18	0.03	0.03	0.02	0.04
Angularity	0.16	0.11	0.12	–0.07	–0.13	–0.001	0.02
Rear legs set	–0.02	–0.02	–0.04	0.01	–0.04	0.03	0.02
Fore udder attachment	–0.05	–0.03	–0.03	0.03	0.06	–0.01	–0.08
Front teat placement	0.02	0.03	0.02	0.02	0.001	0.02	–0.01
Teat length	0.04	0.02	0.04	–0.03	–0.01	–0.03	–0.01
Udder depth	–0.17	–0.16	–0.17	0.03	0.05	0.01	–0.12
Rear udder height	0.13	0.08	0.12	–0.07	–0.07	–0.04	–0.05
Central ligament	0.05	0.02	0.04	–0.03	–0.02	–0.02	–0.08
Rear teat position	0.001	–0.004	–0.01	–0.01	–0.02	0.003	–0.001
Udder width	0.32	0.25	0.32	–0.09	–0.08	–0.06	0.01
Locomotion	0.05	0.03	0.06	–0.02	0.02	–0.03	–0.02
BCS	–0.15	–0.08	–0.09	0.09	0.21	–0.01	–0.03

MY = milk yield, FY = fat yield, PY = protein yield, FP = fat percentage, PP = protein percentage, F/P = fat and protein percentage ratio, LSCS = lactation average somatic cell score, BCS = body condition score

The strongest negative phenotypic correlations were estimated between udder depth, MY, and PY (both –0.17). Very weak relationships were estimated for F/P. The strongest positive correlation was with rear leg set (0.03) and the strongest negative correlation was for udder width (–0.06).

No phenotypic correlations of particular interest were observed between lactation somatic cell score (LSCS) and linear type traits. Estimated phenotypic correlations ranged from –0.12 for udder depth to 0.04 for body depth.

As expected, the phenotypic correlations estimated between milk production traits and linear type traits were very weak as compared to the genetic correlations. For linear type traits related to body (stature, chest width, and angularity) the correlations generally ranged from 0.11 to 0.18, although the correlations between chest width and MY were 0.05 and 0.08 for FY and PY, respectively. Phenotypic correlations for those linear type traits vs FP, PP, and F/P were close to zero, except that a slightly higher correlation was estimated between angularity and PP (–0.13). Compared to our results, de Haas et al. (2007) estimated much stronger relationships between linear type traits and milk yield. In their study the authors estimated a high phenotypic correlation between dairy character and milk yield (0.75) and moderate correlation between body depth and the same production trait. In the same study similar relationships based on phenotypic correlations were found for other dairy breeds. This is similar to the present study.

No phenotypic correlations of particular interest were found for any production trait considered vs rear legs set and locomotion in this study. All estimated correlations between these two linear type traits and the production traits were very low, close to zero.

The strongest positive and favourable phenotypic correlation between BCS and milk production traits was estimated for PP (0.21) compared to the strongest negative phenotypic correlation with MY (–0.15). The same phenotypic correlation between MY and BCS was estimated by Kadarmideen (2004) also reporting similar estimates for FY and PY. A much stronger relationship suggesting an unfavourable association between BCS and total milk yield production, as indicated by a phenotypic correlation of –0.35 between BCS and MY, stated de Haas et al. (2007) for the Swiss Holstein cattle population. They gave lower phenotypic correlations (–0.15, –0.10), however, between FY, PY, and BCS. Those results are more in line with our estimate for MY. As in the case of most other linear type traits, phenotypic correlations estimated between BCS and other milk production traits considered in this study were low and close to zero.

Phenotypic correlations between linear type traits and LSCS. The estimated phenotypic correlations between LSCS and the chosen linear type traits were expectedly very low. Any strong relationships between linear type traits and LSCS were not found in the literature either, except de Haas et al. (2007) mentioning phenotypic correlations between SCS and BCS of −0.21 and between SCS and body depth of 0.19 in Holstein cows. In the same study, the authors did not determine similar correlations for BCS and body depth vs SCS or in relation to the other traits investigated for Brown Swiss and Red & White cows. Kadarmideen (2004) stated a very low phenotypic correlation between BCS and LSCS (−0.02).

CONCLUSION

Interesting genetic correlations between the chosen linear type traits and production traits in first-lactation Holstein cows in the Czech Republic were estimated. A strong genetic correlation was found between udder width and fat yield. In addition to udder width, significant correlations were estimated between milk production traits and BCS and angularity. The study revealed that more angular cows with wider udders should have lower body condition. The same cows are generally predisposed to have higher genetic merit for milk production with higher fat and protein yields. An increase in genetic merit for milk production will probably lead to a decrease in BCS. Furthermore, estimated genetic correlations between LSCS and fore udder attachment, udder depth, and BCS might be very useful in the Czech Holstein dairy cattle breeding. These relationships predict higher average LSCS for cows with weaker and looser strength of the attachment of the fore udder to the abdominal wall, with distance to the lowest part of the udder floor level with the hock or below, and with lower BCS. This is typical of cows with a higher merit for milk production. No strong relationship was found between the fat and protein ratio and any linear type trait investigated in the study.

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