Estimation of genetic and phenotypic parameters for body condition score, milk yield and milk composition, and factors affecting related traits during the first 150 days of lactation in Holstein cows

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SUMMARY

This study aimed to estimate the genetic and phenotypic parameters for BCS, milk yield and its composition in Holstein cows. The data were collected in the first 150 days in milk (DIM) of 317 Holstein cows calved between 2017 and 2018 raised at a private dairy cattle farm located in Kırşehir of Turkey. In this study, parity and DIM were included as fixed factors in the model. The cows were grouped according to their BCS: low (BCS≤2.50), moderate (BCS=2.75-3.00) and high (BCS≥3.25). The results showed that effects of parity and DIM on BCS, test-day milk yield (TDMY), solids-non-fat (SNF), protein content (PC), lactose (LACT), fat yield (FY) and protein yield (PY) were significantly important ($P<0.05$), whereas fat content (FC) was not. The highest TDMY, FY and PY were determined in cows with low BCS. FC, SNF, PC and LACT were the highest in cows with high BCS compared to those with low BCS and moderate BCS. The estimated heritability were 0.188, 0.301, 0.184, 0.197, 0.194, 0.223, 0.196 and 0.342 for BCS, TDMY, FC, SNF, PC, LACT, FY and PY, respectively. Repeatability for these traits was estimated to vary from 0.257 to 0.521. Genetic correlations between BCS and milk yield traits were generally low and ranged from -0.175 to 0.191. Low to moderate phenotypic correlations were also observed between BCS and milk yield traits (-0.234 to 0.217). Despite estimated low heritability and correlations during the early lactation period in our study, these results showed that cows with lower BCS had higher milk yield and lower milk contents, and selection programs including BCS will lead to slight improvements of milk yield traits in Holstein cows.

KEY WORDS

Body Condition Score; Milk Composition; Milk Yield; Milk Quality; Holstein.

INTRODUCTION

Dairy cows may enter the negative energy balance (NEB) during early lactation due to their inability to consume enough feed to meet the nutrient and energy requirements for milk production[1]. In early lactation, NEB leads cows to mobilize body tissue energy and lose body condition to balance the deficit between milk energy output and food energy intake[2, 3]. NEB is associated with reduced dry matter intake during the calving period[4].

Direct energy balance measures are mainly based on milk yield[5] and individual feed intake[6]. However, the measurement of individual feed intake is unfeasible and expensive in a commercial herd[7]. The body condition score (BCS) is a subjective measure evaluating the body energy reserves that can be used as an indirect indicator of energy status[8]. It is a cheap, quick, visual and tactile method[8] to assess the energy status and body fat reserves in dairy animals[9].

Significantly lead to the variation of milk fat content (FC) and change different milk compositions[4] in relation to the lactation period and energy balance. Previous studies have reported phenotypic and genetic correlations between BCS and milk productivity. Mushtaq et al.[10] reported negative correlations between BCS and milk yield and lactose (LACT), but a positive correlation between FC and protein content (PC). Zink et al.[11] reported genetic and phenotypic correlations between BCS and milk yield were -0.34 and -0.15, respectively. Therefore, an ideal BCS for dairy cattle during lactation optimizes not only milk yield but also milk quality[8].

Genetic and environmental factors affecting milk yield and quality are critical for developing breeding strategies. Environmental factors may counteract or increase the actual genetic value of the animal. If the environmental effect on a trait is lower, the influence of the genetic is expected to be high on that trait and it may produce a larger impact on trait variation[12]. Therefore, in dairy cattle the availability of reliable genetic parameter estimates is critical for the genetic improvement of milk yield and

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milk quality through selection practice. Proper estimations of genetic parameters such as heritability and genetic correlations among traits is essential for the design of practical animal breeding programs[13].
BCS has been regularly used in dairy cattle management in several countries for a long time. In Turkey, on the other hand, it is a relatively new method and has been used mostly for research so far. It has been suggested that there are no consistent results regarding the correlations of BCS with milk yield and milk composition[14]. This fact partially depends on the non-linear relationships occurring among the traits, having BCS optima intermediate values[7]. Further studies are needed to investigate relationships between BCS and milk production traits having economic importance during the early postpartum period. Therefore, this study aimed to estimate the genetic and phenotypic parameters for BCS, milk yield and its composition in Holstein cows.

MATERIALS VE METHODS

The study was conducted on Holstein cows in a private dairy cattle farm situated at 38 ° 50'-39 ° 50 ' North latitudes and 33 ° 30'- 34 ° 50' East latitudes in Kırşehir, in the Central Anatolian Region of Turkey. The average altitude is, approximately, 985 meters above sea level. The winter months are cold and hard, and the summer months are hot and dry. The annual average temperature is 11.3 °C and ranges from 0.8 to 21.8 °C during winter and summer.
The data were collected from 317 Holstein cows during the first 150 days in milk (DIM) of lactation between 2017 and 2018. This period was chosen to characterize energy balance throughout the duration of negative energy balance (NEB). There is the highest milk yield during early lactation[15]; therefore, it is critical to control body condition score (BCS) during this period. The cows were assigned to three groups in terms of parity; the first lactation (n=107), the second lactation (n=97), and the third and older lactation (≥3, n=113).
The cows were housed in a free-stall and milked three times a day. Test-day milk yield records (TDMY) were taken during each milking. Milk sampless were collected once a month. For the analysis of milk composition, milk samples were taken on individuals in the morning milking for 30, 60, 90, 120 and 150 DIM (±15 days) on a monthly basis, and these cows were scored in terms of BCS on these days.
The samples were collected in sterile 50 mL tubes and stored at +4°C until the analysis (for maximum of 12 h). The daily milk yield data were automatically recorded on a computer by the robotic milking system.
Fat content (FC), solids-non-fat (SNF), protein content (PC) and lactose (LACT) in milk were recorded on the same day of milk sample collection and were quantified as a percentage on 1 mL of milk with an automatic milk analyzer (Funke-Gerber, Labortechnik, Article No 3510, Berlin, Germany).
Fat yield (TDMY*FC) and protein yield (TDMY*PC) were calculated with the help of the values obtained as a result of the analyses.
Body condition was scored monthly by a single trained evaluator, using a 5-point scale (1-thin, 5-fat) with 0.25-point intervals[9]. The cows were divided into three groups in terms of BCS: l*ow BCS* (BCS≤2.50), *moderate BCS* (BCS=2.75-3.00) and *high BCS* (BCS≥3.25).

In this study, statistical analysis was examined using the general linear model (GLM) procedure in the SPSS (SPSS 21.0) statistical program. The values were presented means ± standard error (SE). The significant differences between means were determined by Duncan's multiple range tests.
The model used to examine the effect of environmental factors is given below:

$$Y_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + e_{ijkl}$$

$Y_{ij\kappa l}$: Observation for the target trait, representing the l^{th} record of the cow, i^{th} parity, j^{th} stage of lactation, k^{th} body condition score, μ: Population average, α_i: effect of the i^{th} parity (i: 1, 2, 3), β_j: j. effect of lactation stage (j: (from 30 to 150 ± 15), γ_κ: effect of the k^{th} body condition score (k: (≤2.50, 2.75-3.00, ≥3.25), $e_{ij\kappa l}$: random error.
Estimates of (co) variance components were obtained using the Restricted Maximum Likelihood (REML) method by the WOMBAT package[16].
The animal model including repeated individual measurements (up to 5 repeats) used for estimating the variance components and breeding values are given below.

$$Y_{ijklm} = F_{ij} + a_k + p_l + e_{ijklm}$$

$Y_{ij\kappa lm}$: Observed value for the target trait, F_{ij}: Constant environmental factors (i^{th} parity and j^{th} body condition score; Note: In the analysis of body condition scores, j. body condition score effect was not used), α_κ: k^{th} additive gene effects, p_i: l^{th} permanent environmental effect (from 30 to 150 days- 5 repeats), $e_{ij\kappa lm}$: Random error.
The estimates of heritability (h^2) for traits were obtained as the following:

$$h^2 = \frac{\sigma_a^2}{\sigma_a^2 + \sigma_{pe}^2 + \sigma_e^2}$$

h^2: Heritability, σ_a^2: Additive Genetic Variance, σ_{pe}^2: Permanent Environmental Variance, σ_e^2 : Residual Variance.
Repeatability (r) values were calculated by[17]:

$$r = \frac{\sigma_a^2 + \sigma_{pe}^2}{\sigma_a^2 + \sigma_{pe}^2 + \sigma_e^2}$$

r: Repeatability, σ_a^2: Additive Genetic Variance, σ_{pe}^2: Permanent Environmental Variance, σ_e^2 : Residual Variance.
Genetic correlations (r_g) were estimated as the following:

$$r_{g(xy)} = \frac{Cov_{g(xy)}}{\sqrt{Var_{g(x)} \cdot Var_{g(y)}}}$$

$Cov_{g(xy)}$ is the genetic covariance between x and y traits;
$Var_{g(x)} \cdot Var_{g(y)}$ are the additive genetic variances of x and y traits.
Phenotypic correlations (r_p) were estimated as the following:

$$r_{p(xy)} = \frac{Cov_{p(xy)}}{\sqrt{Var_{p(x)} \cdot Var_{p(y)}}}$$

$Cov_{p(xy)}$ is the phenotypic covariance between x and y traits;
$Var_{p(x)} \cdot Var_{p(y)}$ are the phenotypic variances of x and y.

RESULTS

As shown in Table 1, the effect of parity on BCS was significant (P<0.05). The highest value for BCS was in cows at first parity compared to the second to the third parity. Cows at the third parity had the highest TDMY, FY and PY. Also, SNF, PC and LACT had the highest values in cows at first parity than in other parity groups (P<0.05).

Table 2 shows that BCS was significantly affected by DIM ($P<0.05$). BCS was the highest in 150 DIM, and the lowest in 30 DIM. The effect of DIM on TDMY, FY and PY were significant ($P<0.05$). TDMY, FY and PY in the beginning of lactation were the highest, however decreased linearly throughout lactation. Table 3 reports that milk yield and milk components were significantly affected by BCS ($P<0.05$). Cows with high BCS had the highest FC, SNF, PC and LACT compared to cows with low and moderate BCS. The higher TDMY was found in cows with the lowest BCS.

In this study, moderate heritability for BCS, TDMY, FC, SNF, PC, LACT, FY and PY were estimated as 0.188, 0.301, 0.184, 0.197, 0.194, 0.223, 0.196 and 0.342, respectively. Standard errors for heritability ranged from 0.078 to 0.115. Repeatability for related traits was observed to vary from 0.257 to 0.521 (Table 4).

The genetic correlations (Table 5) between BCS with TDMY, FY and PY were found to be negative and weak, ranging from -0.033±0.095 to -0.175±0.082. Positive, but low genetic correlations between BCS with FC, SNF, PC and LACT were cal-

Table 1 - Effect of parity on body condition score, milk yield and composition.

Parity	N	BCS	TDMY (kg)	FC (%)	SNF (%)	PC (%)	LACT (%)	FY (kg)	PY (kg)
1	468	2.93±0.017^{a}	32.33±0.274^{c}	3.32±0.028	8.96±0.021^{a}	3.29±0.009^{a}	4.88±0.013^{a}	1.06±0.011^{c}	1.06±0.009^{c}
2	414	2.86±0.018^{b}	36.21±0.295^{b}	3.34±0.038	8.97±0.020^{a}	3.29±0.008^{a}	4.89±0.012^{a}	1.20±0.015^{b}	1.19±0.010^{b}
3	477	2.83±0.018^{c}	39.07±0.372^{a}	3.36±0.037	8.88±0.019^{b}	3.25±0.008^{b}	4.83±0.011^{b}	1.30±0.018^{a}	1.27±0.012^{a}
Overall	1359	2.87±0.010	35.88±0.199	3.34±0.020	8.94±0.012	3.28±0.005	4.86±0.007	1.19±0.009	1.17±0.006

^{a,b,c} - values within the same column with different letters are different at the level $P<0.05$.
BCS: body condition score, TDMY: test-day milk yield, FC: fat content, SNF: solids-non-fat, PC: protein content, LACT: lactose, FY: fat yield, PY: protein yield.

Table 2 - Effect of days in milk (DIM) on body condition score, milk yield and composition.

DIM	N	BCS	TDMY (kg)	FC (%)	SNF (%)	PC (%)	LACT (%)	FY (kg)	PY (kg)
30	296	2.64±0.016^{e}	37.94±0.459^{a}	3.33±0.044	8.87±0.026^{c}	3.25±0.010^{c}	4.79±0.014^{c}	1.26±0.023^{a}	1.23±0.015^{a}
60	284	2.74±0.020^{d}	37.52±0.407^{a}	3.29±0.041	8.81±0.024^{c}	3.23±0.009^{c}	4.82±0.015^{c}	1.23±0.019^{ab}	1.21±0.013^{ab}
90	261	2.90±0.021^{c}	36.07±0.440^{b}	3.29±0.049	8.94±0.026^{b}	3.28±0.011^{b}	4.86±0.016^{b}	1.18±0.021^{bc}	1.18±0.014^{bc}
120	270	3.01±0.022^{b}	34.62±0.416^{c}	3.39±0.041	9.02±0.023^{a}	3.31±0.011^{a}	4.91±0.014^{a}	1.17±0.018^{c}	1.15±0.014^{c}
150	248	3.13±0.024^{a}	32.68±0.423^{d}	3.41±0.049	9.06±0.028^{a}	3.32±0.011^{a}	4.94±0.017^{a}	1.10±0.018^{d}	1.09±0.014^{d}

^{a,b,c,d,e} - values within the same column with different letters are different at the level $P<0.05$.
BCS: body condition score, TDMY: test-day milk yield, FC: fat content, SNF: solids-non-fat, PC: protein content, LACT: lactose, FY: fat yield, PY: protein yield.

Table 3 - Effects of body condition score on milk yield and composition.

BCS groups	N	TDMY (kg)	FC (%)	SNF (%)	PC (%)	LACT (%)	FY (kg)	PY (kg)
Low (≤2.50)	374	38.21±0.388^{a}	3.27±0.041^{b}	8.83±0.021^{c}	3.23±0.009^{c}	4.80±0.012^{c}	1.24±0.019^{a}	1.24±0.013^{a}
Moderate (2.75-3.00)	640	36.01±0.272^{b}	3.32±0.028^{b}	8.92±0.016^{b}	3.27±0.007^{b}	4.85±0.010^{b}	1.19±0.013^{b}	1.18±0.009^{b}
High (≥3.25)	345	33.10±0.383^{c}	3.47±0.038^{a}	9.08±0.023^{a}	3.34±0.009^{a}	4.95±0.014^{a}	1.14±0.016^{c}	1.10±0.013^{c}

^{a,b,c} - values within the same column with different letters are different at the level $P<0.05$.
BCS: body condition score, TDMY: test-day milk yield, FC: fat content, SNF: solids-non-fat, PC: protein content, LACT: lactose, FY: fat yield, PY: protein yield.

Table 4 - Variance components, repeatability and of BCS, milk yield and milk content traits.

	σ^2_a	σ^2_c	σ^2_e	σ^2_p	h^2	r
BCS	0.027±0.012	0.011±0.011	0.106±0.005	0.144±0.006	0.188±0.078	0.264
TDMY	13.24±5.33	9.69±4.76	21.08±0.92	44.02±2.42	0.301±0.115	0.521
FC	0.101±0.049	0.040±0.045	0.408±0.018	0.549±0.024	0.184±0.087	0.257
SNF	0.034±0.015	0.027±0.014	0.111±0.005	0.172±0.008	0.197±0.087	0.355
PC	0.006±0.003	0.004±0.002	0.019±0.0008	0.029±0.001	0.194±0.085	0.345
LACT	0.014±0.006	0.009±0.005	0.038±0.002	0.061±0.003	0.223±0.091	0.377
FY	0.020±0.009	0.013±0.009	0.069±0.003	0.102±0.005	0.196±0.089	0.324
PY	0.017±0.006	0.008±0.005	0.024±0.001	0.049±0.003	0.342±0.112	0.510

BCS: body condition score, TDMY: test-day milk yield, FC: fat content, SNF: solids-non-fat, PC: protein content, LACT: lactose, FY: fat yield, PY: protein yield.
σ^2_a : genetic variance, σ^2_c : permanent environmental variance.

Table 5 - Genetic (below diognal) and phenotypic (above diognal) correlations between body condition score with milk yield and composition.

	BCS	TDMY (kg)	FC (%)	SNF (%)	PC (%)	LACT (%)	FY (kg)	PY (kg)
BCS		-0.234 (0.032)	0.118 (0.031)	0.217 (0.031)	0.201 (0.031)	0.204 (0.031)	-0.074 (0.032)	-0.182 (0.033)
TDMY	-0.175 (0.082)		-0.182 (0.033)	-0.069 (0.037)	-0.065 (0.036)	-0.069 (0.036)	0.570 (0.023)	0.963 (0.003)
FC	0.191 (0.098)	-0.276 (0.080)		0.196 (0.031)	0.173 (0.031)	0.172 (0.031)	0.687 (0.018)	-0.131 (0.033)
SNF	0.124 (0.092)	-0.045 (0.078)	0.420 (0.082)		0.916 (0.005)	0.968 (0.002)	0.119 (0.033)	0.175 (0.035)
PC	0.104 (0.093)	-0.055 (0.079)	0.423 (0.084)	0.992 (0.006)		0.928 (0.005)	0.103 (0.033)	0.200 (0.035)
LACT	0.105 (0.091)	-0.049 (0.077)	0.410 (0.082)	0.978 (0.006)	0.952 (0.012)		0.100 (0.033)	0.182 (0.035)
FY	-0.033 (0.095)	0.692 (0.045)	0.494 (0.068)	0.283 (0.083)	0.275 (0.085)	0.270 (0.082)		0.588 (0.022)
PY	-0.162 (0.083)	0.976 (0.004)	-0.181 (0.083)	0.169 (0.076)	0.158 (0.077)	0.165 (0.075)	0.744 (0.041)	

BCS: body condition score, TDMY: test-day milk yield, FC: fat content, SNF: solids-non-fat, PC: protein content, LACT: lactose, FY: fat yield, PY: protein yield.

culated ranging from 0.105±0.091 to 0.191±0.098. Negative phenotypic correlations between BCS, TDMY, FY and PY were moderate to low. Also, BCS and TDMY was moderately negative correlated with -0.234±0.032. BCS had low to moderate positive phenotypic correlations between FC, SNF, PC and LACT (ranged from 0.118±0.031 to 0.217±0.031).

There were positive high phenotypic (0.916±0.005) and genetic correlations (0.992±0.006) between PC and SNF. The phenotypic and genetic correlations were also positively and high for the LACT with SNF (0.968±0.002 and 0.978±0.006) and PC (0.928±0.005 and 0.952±0.012). FC had favorable genotypic (0.494±0.068) and phenotypic correlation (0.687±0.018) with FY. Genotypic (0.744±0.041) and phenotypic correlations (0.588±0.022) between FY and PY were positive and strong. TDMY was positively correlated with PY (0.976±0.004 and 0.963±0.003) and FY (0.692±0.045 and 0.570±0.023) at both phenotypic and genotypic level (Table 5).

DISCUSSION

BCS was significantly affected by parity (P<0.05) as shown in Table 1. The highest BCS was observed in the first parity but declined gradually from the second to the third parity. Similar results were observed in Holstein also by Hossein Zadeh and Akbarian[3]. According to Gallo et al.[18], because the first-parity cows are still growing, they exhibit a flow of energy and nutrients toward growing processes. As in the present study, Erdem et al.[19] determined that parity had a significant effect on BCS.

The highest TDMY, FY and PY were detected in the third parity; contrariwise, SNF, PC and LACT were the lowest in the third parity. Third-parity cows displayed higher milk yields than first and second-parity cows (Table 1). This can be explained by the fact that milk production increased with age, reaching its maximum value at physiological maturity. Similar findings were reported by Erdem et al.[20]. These findings for FC, PC, SNF and LACT were different from the reports of Gurmesa and Melaku[21].

BCS increased consistently with progressing lactation (P<0.05). The lowest BCS was found in 30 DIM, whereas, the highest was observed in 150 DIM. The BCS increased in 150 DIM, but it was elevated significantly (P<0.05) (Table 2). Similar results in the this study were observed by Jílek et al.[15]. Erdem et al.[19] found that BCS was the lowest in the first stage of lactation (70±14 d). Maršalek et al.[22] determined that BCS decreased during the first three lactation months and this result was similar to the findings of previous studies.

The highest TDMY, FY and PY were determined in the beginning of lactation and decreased with progressing lactation (Table 2). A reduction was observed in TDMY until 150 DIM. This slight decrease may be seen in milk yield associated with lactation persistency[23]. SNF, PC and LACT were the lowest in the first 60 DIM, but the highest in 120 DIM and 150 DIM. BCS was parallel with SNF, PC and LACT contents by exhibiting almost increasing trend with the advancing lactation.

BCS reflects the energy reserves, physiological condition and nutrient status of dairy cows. BCS is a useful and simple indicator, which can assist to make good management decisions regarding feed quality and quantity needed to optimize performance during the lactation period[24]. Cows experiencing more BCS loss in early lactation tend to have higher milk yield, and lower FC and PC compared to thin cows[2]. According to Sobczuk-Szul et al.[25], the lowest PC and FC in the early stage of lactation may be related to the high milk yield of cows. The same researchers reported that the highest yield and the lowest PC and FC were typical of milk from the early stage of lactation. As lactation progressed, greater BCS was correlated with lower milk yield[10]. Increased lipolysis provided an energy substrate for non-mammary tissues in early lactation, thereby sparing glucose for mammary lactose synthesis and increasing milk yield. Therefore, a negative association was expected between BCS and milk production[3]. The decline in FC and PC in the peak of milk production or NEB period could be explained by the antagonistic relationship between milk yield and dry matter ratio[23].

Table 3 shows that the cows with low BCS had significantly higher TDMY, FY and PY compared to the cows with moderate BCS and high BCS (P<0.05). The association between BCS and milk production is probably due to signaling from the hypothalamus via the leptin hormone. Leptin regulates the body's metabolism and serves as an intake satiety signal by acting primarily on regions of the brain involved in the regulation of energy metabolism[26].

As shown in Table 3, the highest FC, SNF, PC and LACT in milk were recorded in cows with high BCS compared to the other BCS groups (P<0.05). Loker et al.[7] published very similar findings and they reported that cows having genetically higher BCS were genetically lower producing cow. Singh et al.[8] reported that fatty cows had significantly (P<0.05) higher SNF than thin cows. Jílek et al.[15] emphasized that cows with moderate BCS had the highest milk yield in the first lactation months. Ayaşan et al.[27] determined that BCS affected LACT content significantly (P<0.05) without affecting FC, PC and SNF. High-yielding dairy cows are often unable to consume sufficient nutrients to meet their energy requirements for milk production and, consequently, enter a NEB, which in turn is reflected in the mobilization of body tissue reserves[28]. Thus, thinner cows have a higher milk yield than fatter cows. Thus, close and negative relationships between milk production and body fat reserves may be due to mobilization of body reverses[24]. FC, PC, SNF and LACT increased in cows with high BCS, and it could be the result of lipid metabolism[3]. Similar findings in this study were obtained by Roche et al.[29], who determined that milk fat increased linearly with increasing BCS. This probably reflects the increased availability of NEFA from greater BCS mobilization, at least in early lactation when the difference is greatest[3]. Mushtaq et al.[10] suggested that BCS in dairy animals may be used routinely as a marker of milk yield and quality by farmers.

Heritability explains the extent to which observed differences between individuals are associated with additive genetic variance[30]. Repeatability explains how a production trait or parameter that is measured can keep a constant value in the following measurements in the future[31]. The high heritability and repeatability indicated that these traits were largely affected by genetic factors[30]. Recently, similar but slightly higher heritability for BCS reported ranged from 0.20 to 0.30[7, 11, 32]. Slightly closer values to the heritability estimated for BCS in the current study was found by Dal Zotto et al.[33] and Battagin et al.[34], who reported estimates of heritability between 0.114 and 0.15. Also, Dechow et al.[35] reported that a heritability of ranged from 0.07 before dry-off to 0.20 at postpartum in the first three lactation. Bilal et al.[32] determined that heritability for milk yield was 0.40. Heritability for milk yield estimated by Dal Zotto et al.[33], Battagin et al.[34] and Sneddon et al.[36] were ranged between 0.108 and 0.22, which is lower than our result. Kul et al.[13] reported that heritability estimates for TDMY, FC and PC in Jersey cows were 0.38, 0.19, and 0.36, respectively. Repeatability for TDMY, FC and PC in Jersey cows in the study by Kul et al.[13] were similar to the ones of this study and ranged between 0.35 and 0.45.

Moderate to low negative phenotypic correlations in our study were observed between BCS, TDMY, FY and PY. BCS had negatively and desirable correlation with TDMY (-0.234). This result indicates that cows with high BCS have a low milk yield. Zink et al.[11] estimated the same phenotypic correlation between BCS and milk yield (-0.15), FY (-0.08), PY (-0.09), FC (0.09) and PC (0.21). Bilal et al.[32], however, reported high genetic (-0.38) and low phenotypic correlations (-0.15) between BCS and milk yield. Similar negative genetic correlations of the ones of this study, but showing slightly higher magnitudes, were determined for BCS and TDMY (-0.34), FY (-0.45) and PY (-0.39) by Zink et al.[11].

High genotypic and phenotypic correlations in our study were estimated for TDMY with PY (0.976±0.004 and 0.963±0.003) and FY (0.692±0.045 and 0.570±0.023). So, the higher FY and PY of these cows could be related to their higher milk yield. Sneddon et al.[36] reported very similar relationships for phenotypic correlations between TDMY with FY (0.75) and PY (0.92). Compared to this study results, Sneddon et al.[36] determined the negative genetic correlation between TDMY and SNF. Mushtaq et al.[10] reported that milk yield was negatively correlated with postpartum BCS due to body fat mobilization in early lactation.

CONCLUSION

In this study, except for FC, the effects of parity and DIM on BCS, SNF, PC, LACT, FY and PY were significantly important. TDMY, FY and PY usually increased; whereas, SNF, PC and LACT decreased with advancing parity. Also, BCS, SNF, PC and LACT increased throughout the lactation, but TDMY, FY and PY decreased. TDMY, FY and PY were the highest in cows with low BCS. However, the highest FC, SNF, PC and LACT were determined in cows with high BCS. Relatively high heritability were estimated for TDMY, LACT and PY. However, the traits of BCS, FC, SNF, PC and FY showed lower heritability. Moderate to low genetic and phenotypic correlations were determined between BCS and related all traits. In addition to TDMY, strong genetic and phenotypic correlations were estimated with FY and PY, and slightly higher correlation for FC. Despite estimated low heritability and correlations during the early lactation period in our study, the present study showed that cows with lower BCS had higher milk yield and lower milk contents, and selection programs including BCS will lead to slight improvements of milk yield traits in Holstein cows.

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