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Estimation of Genetic Parameters for Daily Milk Yield, Somatic Cell Score, Milk Urea Nitrogen, Blood Glucose and Immunoglobulin in Holsteins

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ABSTRACT : This study estimated the effects of parity (1-3) and stage of lactation (early, mid and late) on daily milk yield (DMY), somatic cell score (SCS), milk urea nitrogen (MUN), blood glucose, and immunoglobulin G (IgG), their heritabilities and genetic correlations between them in Holsteins (n = 200). Means and standard deviations of DMY, SCS, MUN, blood glucose, and IgG in the experimental herd were 23.35±7.75 kg, 3.81±2.00, 13.99±5.68 mg/dl, 44.91±13.12 mg/dl, and 30.36±6.72 mg/ml, respectively. DMY was the lowest in first parity, and in late lactation. SCS increased with parity; however, it was lowest in mid-lactation. MUN was lowest in first parity, and no difference was noted across stage of lactation. Blood glucose was similar between parities, however the highest blood glucose was observed during mid lactation. IgG level was significantly different between first and second parity; however, stage of lactation did not affect its level. Heritability of DMY was 0.16. Its genetic correlations with SCS and with blood glucose were -0.67 and 0.98, respectively. Heritability of SCS was 0.15. Genetic correlations of SCS with MUN, glucose, and IgG were -0.72, -0.59, and 0.68, respectively. Heritability of MUN was estimated to be 0.39 and had a genetic correlation of -0.35 with IgG. Heritabilities of blood glucose and IgG were 0.21 and 0.33, respectively. This study suggested that MUN, blood glucose and IgG could be considered important traits in future dairy selection programs to improve milk yield and its quality with better animal health and welfare. However, further studies are necessary involving more records to clarify the relationship between metabolic and immunological traits with DMY and its quality. (**Key Words :** Genetic Parameters, SCS, MUN, Glucose, IgG)

INTRODUCTION

Future dairy profitability and sustainability essentially demands continuous genetic progress for milk yield, its quality and animal health. Milk quality is graded from first to fourth class by number of microorganism in milk and from first to fifth class by somatic cell counts (SCC) in Korea. Somatic cell count is not only important to evaluate milk quality but it is also regarded as one of the important indicators of udder health (Philipsson et al., 1995; Detilleux, 2002). Somatic cell count may vary with the parity, stage of lactation, pathological load, management and climatic factors and etc. Low heritability of SCC has poses difficulty to its control through genetic selection in dairy cows. In spite of previous research including genetic relationship between milk yield and SCS (Kehrli, Jr. and Shuster, 1994), marker assistant selection (Kelm et al., 1997), and vaccination against pathogens causing mastitis (Nordhaug et al., 1994; Riollet et al., 2000; Nash et al., 2003), the mastitis is still an unresolved issue in dairy industry. An alternative metabolic (Blood glucose, MUN, etc) and immunological (IgG) trait in Holsteins may provide another opportunity to SCC control through genetic selection. However, scientific literature is valuable in explaining such an opportunity.

Milk urea nitrogen is an important tool to examine the herd nutritional status, because it has a strong positive correlation with blood urea nitrogen (BUN; Broderick, 1995). Further, it is much easier to collect and analyze a sample for MUN than BUN. Immunoglobulin G (IgG) is an important immunological trait however few studies have been reported on its genetic relationship with milk yield and its quality in Holsteins. Blood glucose is physiologically and genetically related (Detilleux, 2002) to higher milk yield in dairy cows. Blood glucose and IgG may vary with the parity and stage of lactation in Holsteins and they may have a genetic relationship with milk yield and its quality

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Table 1. Number of experimental animal by parity and stage of lactation

Source	Parity			Days in milk			Total
	1st	2nd	3rd	≤80	81-180	181-305	
Heads	83	57	60	37	51	112	200

Table 2. Statistics of daily milk yield, somatic cell score, milk urea nitrogen, blood glucose and immunoglobulin G

Variables	Heads	Maximum	Minimum	Means	SD
DMY [1] (kg/day)	188	46.4	9.20	23.35	7.75
SCS [2]	188	9.6	0.05	3.81	2.00
MUN [3] (mg/dl)	178	35.5	4.20	13.99	5.68
Blood glucose (mg/dl)	192	75.0	19.0	44.91	13.12
IgG [4] (mg/ml)	172	50.0	10.0	30.36	6.72

[1] Daily milk yield. [2] Somatic cell score. [3] Milk urea nitrogen. [4] Immunoglobulin G.

Table 3. Mean square of daily milk yield, somatic cell score, milk urea nitrogen, blood glucose and immunoglobulin G by parity and stage of lactation

Source	df	DMY [1]	SCS [2]	MUN [3]	Blood glucose	IgG [4]
Parity	2	860.95**	21.88**	64.65 [n]	268.84 [n]	99.37[n]
Stage of lactation	2	416.22**	17.10**	7.99 [n]	343.32 [n]	28.51[n]
Error	183	46.35	3.73	32.24	168.44	44.97
				(173)[a]	(187)[a]	(167)[a]

** p<0.01, n: Not significant. [a] df.
[1] Daily milk yield. [2] Somatic cell score. [3] Milk urea nitrogen. [4] Immunoglobulin G.

traits in Holsteins. However, scientific literature is scarce in explaining the genetic relationship between DMY, SCS, blood glucose MUN and IgG.

This study was to estimate the statistic variation in DMY, SCC, blood glucose, MUN, and IgG at different parities and lactation stage in Holsteins and genetic parameters for these traits to explore any possibility of indirect selection through metabolic or immunological trait for milk yield and its quality.

MATERIALS AND METHODS

Holstein cows and management

Two hundred Holstein cows with average 2.1±1.3 parity, and 196.7±118.6 days in milk (DIM) were fed according to NRC (2001) at National Livestock Research Institute, Korea. All the cows received total mixed ration *ad libitum*. Cows were housed in free-barn with potable tap and were milked twice daily at equal intervals (12 h) using herring-bone milking parlor. Numbers of animals for this experiment by parities and DIM are presented in Table 1.

Sampling and analysis

Individual daily milk yield was recorded at every 30±5 days. Milk samples (p.m. and a.m.) were collected at each milk recording day in plastic bottles, mixed and were analyzed immediately for percent milk protein, fat and SCC by Somascope MK2/Lactoscope FTIR (Delta Instruments, Netherland). Somatic cell counts were transformed into somatic cell scores (SCS) by log function (Ali and Shook, 1980). The blood samples were also collected at the recording day from jugular vein after 2 h post feeding in vacuum tubes without any anti-coagulant. Blood samples were centrifuged (2,000×g, 15 min) and serum was analyzed for blood glucose by blood chemistry analyzer (Express-plus 550, Ciba Corning, USA).

Statistical analysis

Stage of lactation was divided into three periods such as early lactation (earlier than 80 days after calving), middle lactation (81 to 180 days) and late lactation (181 to 305 days). The records more than 305 days in milk and parities more than four were deleted on this analysis. To estimate effects of parity and stage of lactation on DMY, SCS, MUN, blood glucose and IgG, the GLM procedure of SAS (Ver 8.1) was used with its model of $y_{ijk} = \mu + P_i + D_j + e_{ijk}$. Where μ was overall mean, P was a fixed effect as $_i$th parity ($_i$ = 1, 2, 3), D was a fixed effect as $_j$th stage of lactation ($_j$ = 1, 2, 3), and e_{ijk} was residual random error. The interaction between parity and stage of lactation was not significant for all traits stated above. The heritabilities and genetic correlations between traits were estimated by VCE-5 program (Kovac and Groeneveld, 2003). The VCE-5 computes restricted maximum likelihood (REML) estimates of (co)variance matrices for a large variety of statistical model. The model to estimate genetic parameters was $y_{ijkl}=A_i+P_j+D_k+e_{ijkl}$. Where A_i is random effect of cow contributed as N (0, $A\sigma_c^2$), P_j is fixed parity effect, D_k is fixed stage of lactation effect, and e_{ijkl} is residual random effect contributed as N (0, $I\sigma_e^2$).

Table 4. Least square means and standard errors of daily milk yield, somatic cell score, milk urea nitrogen, blood glucose and immunoglobulin G

Source		DMY [1]	SCS [2]	MUN [3]	Blood glucose	IgG [4]
Parity	1st	19.8^{a}±0.8	3.41^{a}±0.23	12.93^{a}±0.69	46.06^{a}±1.51	29.05^{a}±0.87
	2nd	26.8^{b}±1.0	3.56^{a}±0.28	15.05^{b}±0.87	42.25^{a}±1.91	30.72^{ab}±1.00
	3rd	25.4^{b}±0.8	4.50^{b}±0.23	14.19^{b}±0.72	46.17^{a}±1.63	31.59^{b}±0.85
Stage of lactation	≤80	24.6^{a}±1.0	4.30^{a}±0.30	13.57^{a}±0.92	44.66^{ab}±2.09	31.30^{a}±1.08
	81-180	26.2^{a}±0.8	3.20^{b}±0.25	14.29^{a}±0.74	47.10^{a}±1.61	29.75^{a}±0.86
	181-305	21.4^{b}±0.7	3.97^{a}±0.21	14.31^{a}±0.64	42.71^{b}±1.42	30.32^{a}±0.80

[1] Daily milk yield. [2] Somatic cell score. [3] Milk urea nitrogen. [4] Immunoglobulin G.
Different superscripts in same column mean significantly different.

Table 5. Heritabilities and correlation of daily milk yield, somatic cell score, blood glucose and immunoglobulin G

	DMY [1]	SCS [2]	MUN [3]	Blood glucose	IgG [4]
Daily milk yield	0.16±0.11	-0.67±0.32	0.15±0.41	0.98±0.07	-0.18±0.37
Somatic cell score	-0.20	0.15±0.10	-0.72±0.24	-0.59±0.35	0.68±0.29
Milk urea nitrogen	0.29	-0.05	0.39±0.16	0.13±0.39	-0.35±0.26
Blood glucose	0.01	-0.03	0.27	0.21±0.15	0.03±0.40
Immunoglobulin G	-0.11	0.27	-0.19	-0.01	0.33±0.15

[1] Daily milk yield. [2] Somatic cell score. [3] Milk urea nitrogen. [4] Immunoglobulin G.
Diagonal; heritability, upper diagonal; genetic correlation, below diagonal; phenotypic correlation.

RESULTS AND DISCUSSION

Over all means and standard deviations of DMY, SCS, MUN, blood glucose and IgG in experimental Holsteins were presented in Table 2. Mean values of MUN (13.99) and blood glucose (44.91) in experimental Holsteins were consistent with those previously reported (Kwon et al., 2000; Smith, 2002; Han et al., 2004; Yoon et al., 2004; Ahn et al., 2005). The ANOVA table pointed out only DMY and SCS were affected by parity and stage of lactation (Table 3).

Least square means and standard errors for the traits studied were presented in Table 4. Daily milk yield, MUN and SCS were increased with increasing parity, however DMY was decreased with DIM. IgG was increased with the parity; however, it was similar across the stage of lactation. IgG may vary with the pathogenic microorganisms load, dietary situations, and environmental stress (Bering et al., 1993; Nordhaug et al., 1994; Butler, 1995). However in present study increasing trend with the parity may indicate an adaptation response of the immune system with increasing age. MUN decreased to the lowest value after 80 days of parturition thereafter it increases with DIM. Similar trend of MUN in Holsteins has been previously reported by Wood et al. (2003) and Wattiaux et al. (2005). Blood glucose was noted similar across parities however; it has shown an increasing polynomial trend with stage of lactation.

Heritabilities and genetic correlations between traits were presented in Table 5. Heritability of DMY was low when comparing to previous lactation yield heritability estimates 0.22-0.30 for mature equivalent milk yield of first parity (Welper and Freeman, 1992; Castillo-Juarez et al., 2002). The small herd size because of the complex and time taking analytical procedures for immunological and metabolic traits and thus large variations (DMY, SCS, MUN, blood glucose and IgG) has resulted in higher standard errors of the estimates. However, further studies involving large herd size with more rapid and sophisticated analytical assays may help to enhance the reliability of genetic estimates for these traits. Genetic correlation between DMY and SCS (-0.67) was higher and opposite to the correlation (0.22) between lactation yield and lactation mean SCC previously estimated by Castillo-Juarez et al. (2002). Negative genetic correlation between DMY and SCS was probably because of the reduction of milk synthesis by infected mammary gland. The present results are consistent with the genetic correlation estimates (-0.36) between milk yield and SCC (Othmane et al., 2002). Genetic correlation between DMY and MUN was positive (0.15) and are consistent with previous estimates of Hojman et al. (2004). Genetic correlation between DMY and blood glucose was very high (0.98). The high genetic correlation between blood glucose and DMY may reflect the more prevision of sugars for lactose synthesis that is one of the most important indicator of milk yield (Larson et al., 1985). Heritability of SCS (0.15) was consistent with previous reports of 0.10-0.17 (Castillo-Juarez et al., 2002; Detilleux, 2002; Mrode and Swanson, 2003; Ødegård et al., 2003). However, Choi et al. (1999) presented that heritability of SCS was very low (0.03). Genetic correlations of SCS with MUN, blood glucose, and IgG were -0.72, -0.59, and 0.68, respectively. Negative correlation between SCS and MUN was consistent with previous reports (Johnson and Young, 2003; Hojman et al., 2004). The highly negative genetic correlation between SCS and blood glucose may indicate an important relation between milk quality and metabolic

condition of the animal. The blood glucose may be considered as an alternative trait for future selection programs to improve milk quality in Holsteins. Heritability of MUN was 0.39 which was lower than previous estimates (0.44 to 0.70) by Wood et al. (2003), however; it was higher than those (0.20 to 0.21) reported by Nishimura et al. (2005). Genetic correlation between MUN and IgG was negative (-0.35). Heritability of blood glucose was medium (0.21), however previous study reported high heritability (0.69) after intravenous injection of glucose to Holsteins (Sasaki et al., 2003). In this study heritability of IgG was estimated 0.43. Previously Johann et al. (1994) reported that heritability of IgG may vary from 0 to 0.87. They attributed this variation to various stress factors such as pathological, physiological and environmental. However, in present study it was lower than that previously estimated by Ahn et al. (2001).

This study suggested that MUN, blood glucose and IgG could be considered important traits in future selection programs to improve milk yield, and its quality along with better animal health. However, further studies are needed using records from more animals to clarify the relationship between metabolic and immunological traits with milk yield and its quality.

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