Genetic Relationship between Milk Production, Calving Ease and Days Open at First Parity in Holstein Cows

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ABSTRACT : Data containing 14,188 lactation and reproductive records of Korean Holstein cows at first parity distributed across 3,734 herd-year-season groups were analyzed to get genetic (co)variance estimates for milk yield, fat yield, calving ease, and days open. Milk and Fat yields were adjusted to 305 d. Heritabilities and genetic correlations were estimated in two different animal models on which were included direct genetic effects (Model 1) and direct+maternal genetic effects (Model 2) using REML algorithms. Milk and fat yields were affected by age at first calving as linear and quadratic. Heritability estimates of direct effects were 0.25 for milk yield, 0.17 for fat yield, 0.03 for calving ease and 0.03 for days open in Model 2. These estimates for maternal effects were 0.05, 0.08, 0.04 and less than 0.01 for each corresponding trait. Milk productions at first lactation were to show genetically favorable correlation with calving ease and days open for direct genetic effects (-0.24 - -0.11). Moreover, calving ease was correlated with days open of 0.30 for direct genetic effects. Correlations between direct and maternal effects for each trait were negatively correlated (-0.63 - -0.32). This study suggested that maternal additive genetic variance would be not ignorable for genetic evaluation of milk production as well as reproductive traits such as calving ease and days open at first parity. Furthermore, difficult calving would genetically influence the next conception. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 2 : 153-158)***

Key Words : Genetic Parameters, Korean Holstein, Reproductive Performance, Calving Ease, Days Open

INTRODUCTION

Many dairy farmers have pursued to maintain satisfactory reproductive performances with high levels of milk production. Some researchers (Roman and Wilcox, 2000; Dechow et al., 2001) have reported antagonistic relationship with respect to both phenotypes and genotypes between milk production and reproductive traits such as fertility, days open and calving ease. However, others have reported genetic correlations that were close to zero (Raheja et al., 1989) or low (Dong and VanVleck, 1989). Under experimental conditions, Hageman et al. (1991) reported that high genetic lines had longer postpartum anestrus and subsequently longer times to first breeding. Consequently, calving interval and days open were 10 d longer for high milk yield lines in the first and second parities. Calving difficulty (Dystocia) and the attendant increase in the interval from calving to conception is also a critical problem especially in seasonal calving herds and delay in conception due to poor fertility increases calving interval.

Heritabilities of fertility traits are generally very low, in other words, these implicate to be highly influenced by environmental factors especially management decisions taken by the breeder (Luo et al., 1999; Weigel and Rekaya, 2000; Dematawewa and Berger, 2002). However, there is significantly genetic co-variation between cows in the interval from calving to first breeding that is positively correlated with number of services per conception. The interval from calving to first breeding and number of services per conception have both positive correlation with days open which is the variable component of calving interval (Dematawewa and Berger, 1998).

Maternal effects have been defined as any influence from a dam on its offspring, excluding the effects of directly transmitted genes that affect performance of the offspring. Biological mechanisms to explain maternal effects include cytoplasmic inheritance, intrauterine and postpartum nutrition provided by the dam, antibodies and pathogens transmitted from dam to offspring, and maternal behavior. Phenotypic variation in the offspring is partially due to genetic variation that can be influenced by two genetic components, animal genotype (direct genetic effect) and dam genotype (maternal genetic effect) (Willham, 1963). However, there are indications that maternal genetic effects are not important for yield traits of dairy cattle (Schutz et al., 1992; Albuquerque et al., 1998). However, some evidences suggested that maternal lineage effects, considered as cytoplasmic line effects, could affect yield and reproductive traits of dairy cattle (Schutz et al., 1992; Albuquerque et al., 1998). Otherwise, the variation of calving ease would be partially due to maternal genetic effects as well as direct genetic effects (Luo et al., 1999; Lee, 2002). Luo et al. (1999) are also reported the direct heritability of 0.11 and the maternal heritability of 0.12 for calving ease using Bayesian approach.

The objectives in this studies are 1) to determine the relationship between milk production and reproductive

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Table 1. Information of data structure for productive and reproductive traits of Holstein cows from 1,788 dairy herds in Korea

	No.of obs.	Mean	SD	Min	Max
No. of cows/sire	180	25.77	50.86	2	345
No. of cows/herd	1,788	4.93	6.95	1	85
Age at 1st parturition (month)	14,188	26.25	3.22	19.7	39.4
MY305 (kg)	14,188	7,489	1,582	2,032	15,329
FY305 (kg)	14,188	282	65	58	618
CE (score)	11,552	1.24	0.48	1	5
DO (days)	11,472	113.4	45.4	32	200

MY305=305 d adjusted milk yield; FY305=305 d adjusted fat yield; CE=calving ease; DO=days open.

traits at first parity and 2) to investigate the maternal genetic effects for milk production and reproduction and finally 3) to investigate the amount of genetic effects of calving ease to influence days open at first parity of Holstein cows in Korean dairy industry.

MATERIALS AND METHODS

Data source and edits

Field Data for milk yields, fat yields, calving ease and days open in Holstein cows were collected from dairy herds on which farmers have been participated Dairy Herd Improvement program organized by Dairy Herd Improvement Center (DCIC) as a branch of NongHyup Co-operative federation in Korea from 1999 to 2002. Milk yields and compositions (fat yields) were recorded at twice per month from 6 days in milk (DIM) to date at dry-off. After Records from cows that have milked less than 75 d were discarded, the others were corrected to 305 d milk yields (MY305) and fat yields (FY305) using Korean standard correction programs. The traits studied were MY305, FY305, calving ease (CE) at first parity that was scored from 1 (easy calving) to 5 (extreme difficulty), and days open (DO) that is days from calving to conception. Records with milk yield observed less than 2.000 kg or more than 20.000 kg or DO having less than 32 days or more than 200 days were discarded. Records from cows with age of 19.7-39.4 mo. at first parturition were retained. Records of cows with the invalid identification numbers or invalid sire registration number were also excluded. Records on which herds have a least 3 records were retained. Records for these traits from 14.188 cows at first lactation were used for estimating genetic parameters.

Statistical analyses

Two different multivariate statistical models for this study were used:

Model 1: $y_i = Z_h hys_i + Z_a a_i - e_i$

Model 2: $y_i = Z_h hys_i + Z_a a_i - Z_m m_i + e_i$

where y_i is a vector of observations (i=MY305, FY305, CE, and DO); hys_i is a vector of herd-year-season effects treated as random; a_i is a vectors of direct effects treated as additive genetic random effects; e_i is a vector of random residual effects for i^{th} trait. Z_h, Z_a are incidence matrices that link data with respective effects. Variances were assumed of the form:

$$\mathrm{var}(h,a,e)=\begin{bmatrix} V_{h(4\cdot 4)}\otimes \mathrm{I}_{n_h} & 0 & 0 \\ & V_{a(4\cdot 4)}\otimes A & 0 \\ Symm. & & R_{e(4\cdot 4)}\otimes \mathrm{I}_N \end{bmatrix}$$

in Model 1 and

$$\mathrm{var}(h,a,m,e)=\begin{bmatrix} V_{h(4\cdot 4)}\otimes \mathrm{I}_{n_h} & 0 & 0 & 0 \\ & V_{a(4\cdot 4)}\otimes A & V_{a\cdot m(4\cdot 4)}\otimes A & 0 \\ & & V_{m(4\cdot 4)}\otimes A & 0 \\ Symm. & & & R_{e(4\cdot 4)}\otimes \mathrm{I}_N \end{bmatrix}$$

in Model 2.

Where A is a numerator relationship matrix and ⊗ is direct product.

It was assumed that traits considered were correlated for each random effect in Model 1. Assumption in Model 2 was that Maternal genetic effects were correlated to direct genetic effects with including assumptions of Model 1.

Variance and covariance components for each random effects were estimated using EM-REML algorithms and heritability and genetic correlation estimates were calculated using estimated (Co)variance components.

RESULTS AND DISCUSSION

General performance

Average 26 cows per sire and 180 sires collected from 1.788 herds were involved for estimating genetic parameters (Table 1). Numbers of cows by herds should be relatively small and highly skewed with comparing to those of foreign countries. This is distinguishable characteristic of dairy herds due to agricultural circumstance in Korea. A subsequent characteristic is that most of cows have been managed in barn rather than pasture. Feeding systems are mainly utilized by way of grains and TMR. These feeding systems should influence milk production as well as reproduction. Under these management systems, the average of age at first parturition was examined at 26 month of age. Thompson et al. (1983) found that problems of

Table 2. Number of observations for calving eases by degree of calving difficulty at first parity of Holstein cows from 1,788 dairy herds in Korea

Score	Frequency	Percent
1=No problem	9,038	78.24
2=Slight problem	2,317	20.06
3=Needed assistance	175	1.51
4=Considerable force	13	0.11
5=Extreme difficulty	9	0.08

parturition increase significantly when age at first calving is less than 22 mo. However, for Simerl et al. (1992) frequency of dystocia was greater in the young (<24 mo.) or old (>27 mo.) heifers, partially explaining the detrimental effect of early calving on yield (Thompson et al., 1983; Simerl et al., 1992) and on reproductive performance (Erb et al., 1985). Milk yields and fat yields corrected to 305 d according to the national correction factors in Korea were estimated to about 7,500 kg and 280 kg, respectively. Furthermore, Days from first calving to conception (DO) were about 113 days. Most of heifers showed easy calving (CE score 1 and 2 ; 98%) and only less than 2% showed hard calving (Table 2). This looks apparently like a little problem with comparing that 86.4 percentage of Holstein cows in US filed data showed easy calving (Wiggans et al., 2002). However, Dystocia is openly problem at first parturition rather than later. F-statistics and significances for traits studied showed at Table 3. As shown at Table 3, we could not find any problems for calving difficulty and DO with respect to age at first parturition. These results did not agreed to the reports by Thompson et al. (1983) and Simerl et al. (1992).

305 adjusted milk yield and FY305 were shown to significantly increase according to birth years. Otherwise, calving ease and DO were shown little different by birth years (Table 4). The cows calved at fall milked highest amount of production and were taken short interval of DO. These trends would be influenced by seasonal management factors. Yields would be affected by age of first conception as linear and quadratic and these results were consistent with other reports (Pirlo et al., 2000). It was shown that CE and DO were not much influenced by age of first conception.

Heritabilities

Heritability estimates for MY305, FY305, CE and DO are in Table 5. Heritability estimates of MY305 were 0.219 in Model 1 and 0.248 and 0.045 for direct and maternal genetic effects, respectively, in Model 2. These estimates were smaller than estimates by other results (Abdallah and McDaniel, 2000). Heritability of 0.30 of milk yield has been used for national evaluation in United States from 1997 (AIPL-USDA Web site). Recently, it has been increased interest of random regression model for test-day records for milk production in dairy cattle. Heritability of milk yield at test-day milk production was lower (Gengler at al., 1999; Tijani et al., 1999) than 305 d milk yields.

Table 3. F-statistics and significances for milk yields (MY305), fat yields (FY305), calving ease (CE) and days open (DO) at first lactation of Holstein cows from 1,788 dairy herds in Korea

Source	DF	MY305	FY305	CE	DO
Herd	1,787	5.01^{**}	5.75^{**}	11.37^{**}	1.31^{**}
Birth year	3	51.66^{**}	30.93^{**}	1.39^{NS}	12.96^{**}
Season	3	2.61^{*}	21.77^{**}	2.24***	8.28^{**}
Age	1	6.63^{**}	7.69^{**}	0.17^{NS}	0.25^{NS}
Age^2	1	2.98^{+}	3.26^{+}	0.12^{NS}	0.19^{NS}

MY305=305d adjusted milk yield; FY305=305d adjusted fat yield; CE=calving ease; DO=days open. ** (p<0.01); * (p<0.05); *** (p<0.10).

Table 4. Least square means and standard errors for milk yields (MY305), fat yields (FY305), calving ease (CE) and days open (DO) at first lactation of Holstein cows from 1,788 herds in Korea

	MY305		FY305		CE		DO	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Year								
1999	7,100.8	45.01	267.3	1.80	1.25	0.012	116.1	1.81
2000	7,206.7	21.97	272.0	0.88	1.28	0.006	115.5	0.89
2001	7,514.4	24.70	283.4	0.99	1.28	0.007	113.3	0.97
2002	7,960.1	69.11	286.6	2.76	1.25	0.021	97.45	2.72
Season								
Mar.-May	7,438.9	34.57	273.6	1.38	1.25	0.010	114.8	1.40
Jun.-Aug.	7,445.7	35.77	277.9	1.43	1.26	0.010	111.8	1.42
Sep.-Nov.	7,503.4	31.25	284.7	1.25	1.26	0.009	107.5	1.24
Dec.-Feb.	7,394.1	29.01	273.1	1.16	1.28	0.008	108.2	1.15
Covariate								
Age	118.321	45.944	5.088	1.834	N/A		N/A	
Age^2	-1.39	0.803	-0.058	0.0321	N/A		N/A	

MY305=305d adjusted milk yield; FY305=305d adjusted fat yield; CE=calving ease; DO=days open.

Table 5. Heritability estimates for milk yields (MY305), fat yields (FY305), calving ease (CE) and days open (DO) at first lactation in a multivariate animal model using REML of Holstein cows from 1,788 herds in Korea

	Model 1	Model 2	
	Direct	Direct	Maternal
MY305	0.219	0.248	0.045
FY305	0.154	0.172	0.077
CE	0.015	0.030	0.035
DO	0.024	0.033	0.005

MY305=305d adjusted milk yield; FY305=305d adjusted fat yield; CE=calving ease; DO=days open.

Gengler at al. (1999) estimated heritabilities for test-day milk yields of mean of 0.20 at first lacation records. Furthermore, some evidence suggested that maternal sibs are more alike than are paternal sibs (Seykora et al., 1983; Dong et al., 1988). Dong et al. (1988) reported higher heritability estimates with animal models than with sire models. However, maternal additive genetic effects have been ignored for genetic evaluation in several countries because of little contribution of their effects. Otherwise, on this study, maternal genetic effects could contribute 4.5 percentage of total variance. This result should indicate that additive maternal genetic effects were also important for genetic evaluation of milk yield.

Heritability estimates for FY305 were 0.154 in Model 1 and 0.172 and 0.077 for direct and maternal genetic effects, respectively, in Model 2. These estimates were smaller than estimate of 0.28 by Abdallah and McDaniel (2000) and were similar to estimate of 0.177 by Dematawewa and Berger (1998). Heritability estimates for CE at first parity were very small as 1.5% in Model 1 and 3.0 and 3.5% for direct and maternal genetic effect, respectively, in Model 2. These estimates were similar to or smaller than those of other reports (Weller et al., 1988; Luo et al., 1999; Carner et al., 2000). These reports were estimated in animal models with maternal genetic effects as well as direct genetic effects. This implied that maternal additive genetic effects were also important effects for genetic evaluation for calving ease. Luo et al. (1999) estimated heritabilities for calving ease of 0.05 and 0.03 for direct and maternal effects and Carnier et al. (2000) reported estimates of 0.19 and 0.09 for direct and maternal effects, respectively, at first parity using Italian Piedmontese field data. We expect that these estimates should be higher if applied threshold model rather than linear model (Varona et al., 1999; Lee, 2001) because of violating normality.

Heritability estimates for DO were 0.024 in Model 1 and 0.033 and 0.005 for direct and maternal effects, respectively, in Model 2. These estimates are in good agreement with those reported by numerous studies (Makuza and McDaniel, 1996; Dematawewa and Berger, 1998; Adballah and McDaniel, 2000).

Table 6. Phenotypic and genetic correlation estimates between milk yields (MY305), fat yields (FY305), calving ease (CE) and days open (DO) at first lactation in a multivariate animal model using REML of Holstein cows from 1,788 herds in Korea

	Phenotypic	Model 1	Model 2	
		Direct	Direct	Maternal
MY305-FY305	0.766	0.860	0.863	0.619
-CE	0.003	-0.039	-0.235	0.025
-DO	0.061	-0.279	-0.237	0.085
FY305-CE	0.002	0.011	-0.111	-0.293
-DO	0.077	-0.208	-0.190	-0.186
CE-DO	0.006	-0.029	0.303	0.072

MY305=305d adjusted milk yield; FY305=305d adjusted fat yield; CE=calving ease; DO=days open.

Correlations

Table 6 shows phenotypic and genetic correlation estimates among the four traits at first parity. Estimates of genetic and phenotypic correlations found between MY305 and FY305 for first parity Holstein in the US (Schutz et al., 1990) and Canada (Moore et al., 1991) are similar to our resultsfindings of 0.860 in Model 1 and 0.863 in Model 2 for direct genetic effects. Furthermore, on this study, correlation estimates for maternal genetic effects between MY305 and FY305 was also high (0.62) even if genetic variation of these traits were small. Correlation estimates of MY305 were favorable to CE (-0.039 in Model 1 and -0.235 in Model 2) and DO (-0.279 in Model 1 and -0.237 in Model 2). Generally, increased DO indicated loss of fertility. Dematawewa and Berger (1998) reported an antagonistic relationship between yield and fertility at first parity. Their estimates of correlation between MY305 and DO were 0.27 and 0.55 for phenotypic and genetic variation, respectively, when used for first lactation. Otherwise, Makuza and McDaniel (1996) found much low correlation of -0.04.

Correlation estimates between FY305 and reproductive traits (CE and DO) were very small (0.002 and 0.077) in Phenotypic observations. These estimates were negative for direct genetic effects in Model 2 as -0.111 and -0.190, respectively. Furthermore, for maternal genetic effects in Model 2, these estimates were -0.293 between FY305 and CE and -0.186 between FY305 and DO. These results indicated that the prolonged DO would influence low milk production at first parity. Dematawewa and Berger (1998) found an antagonistic relationship between FY305 and DO to be 0.54. Seykora and McDaniel (1983) also estimated the genetic correlation between FY305 and DO to be 0.44. Nevertheless, Roman et al. (1999) reported that, for first parity records, genetic correlations of milk production and parturition to first observed estrus and parturition to first breeding ranged from -0.01 to -0.52. Calving ease would be apparently uncorrelated with DO in phenotypic measure. Otherwise, genetic correlation between these corresponding

Table 7. Genetic correlation estimates between direct and maternal genetic effects for milk yields (MY305), fat yields (FY305), calving ease (CE), and days open (DO) at first lactation in a multivariate animal model using REML of Holstein cows from 1,788 herds in Korea

	$MY305_m$	$FY305_m$	CE_m	DO_m
$MY305_d$	-0.448	-0.373	0.334	0.054
$FY305_d$	-0.373	-0.396	0.220	0.060
CE_d	-0.033	0.192	-0.625	-0.157
DO_d	-0.164	0.099	-0.378	-0.318

MY305=305d adjusted milk yield; FY305=305d adjusted fat yield; CE=calving ease; DO=days open.
$Subscript_d$=direct genetic effects; $Subscript_m$=maternal genetic effects.

traits was -0.029 in Model 1. In Model 2, correlation between CE and DO was estimated as 0.303 for direct genetic effects and 0.072 for maternal additive genetic effects. This result would imply that difficult calving lead to prolong estrus and conception.

Genetic correlations between direct and maternal genetic effects for four traits in this study were shown in Table 7. These estimates are negatively correlated as -0.448 for MY305, -0.396 for FY305, -0.625 for CE and -0.318 for DO. For CE, this result indicated that antagonistic relationships exist between calving ease as a trait of calf and as a trait of the dam and that, from a genetic point of view, female calves born more easily are expected to exhibit greater difficulties when giving birth as dams. A number of studies reported antagonistic genetic relationship between direct and maternal effects on calving ease in Dairy (Dwyer et al., 1986; Carnier et al., 2000). These phenomeni were shown on estimates for MY305, FY305, and DO.

IMPLICATIONS

Heritability and genetic correlation estimates for MY305, FY305, CE, and DO with taking into account both direct and maternal effects have been obtained from Holstein cows with first lactation in two different animal models. Our heritability estimates for yield traits were lower than estimates from other studies in the US (Schutz et al., 1990). Furthermore, maternal heritability estimates for these traits were found in an animal model with taking into account for maternal effects although estimates were small. However, genetic evaluation including maternal effects is still questionable because of little information of data in this study. Heritability estimates for fertility traits were low. However, genetic effects for days open with respect to direct and maternal effects would be on indication to improve genetically reproductive performance. Furthermore, dystocia would influence conception rate. The genetic correlations between yield traits (MY305 and FY305) and fertility traits (CE and DO) were shown to be negative (desirable) at first lactation. Hence, deteriorative fertility would influence to diminish milk production. However, these results were not consistent with comparing other reports (Dematawewa and Berger, 1999). Further studies were needed to find relationship between production and reproductive performance with including records from cows in second or later lactation.

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