Genetic correlations among fertility traits within and across Holstein herds with different milk-production during the first three lactations

T. Yamazaki[1], H. Takeda[2], T. Osawa[3], S. Yamaguchi[4] & K. Hagiya[5]

[1] Hokkaido Agricultural Research Center, NARO, Sapporo, 062-8555, Japan
yamazakt@affrc.go.jp *(Corresponding Author)*
[2] Institute of Livestock and Grassland Science, NARO, Tsukuba, 305-0901, Japan
[3] National Livestock Breeding Center, Fukushima, 961-8511, Japan
[4] Livestock Improvement Association of Japan, Tokyo, 135-0041, Japan
[5] Obihiro University of Agriculture and Veterinary Medicine, Obihiro, 080-8555, Japan

Summary

Genotype by environment interaction (G×E) effects for lactating cows' fertility traits with regard to herd production levels may differ with lactation number. Our objective here was to investigate the genetic correlations among several fertility traits in cows within and across herds with different milk-production levels by using lactation records of Japanese Holstein cows (475,446 records for first lactation, 378,540 for second, and 265,560 for third). Herds with data were categorized into three groups (LOW, MID, and HIGH) based on the average herd-year effects in each herd for 305-day milk yield at the first lactation. The fertility traits evaluated were conception rate at first insemination (CR); number of inseminations (NI); and days open (DO). Genetic parameters were estimated within each lactation by using a multiple-trait animal model that considered the traits of different herd milk-production groups (HPGs) as separate traits. The genetic correlations among fertility traits were strong; values did not differ greatly among HPGs or lactations. Some of the genetic correlations of CR or NI among different HPGs for the second and third lactations were lower than those for the first lactation. These findings suggest that G×E effects on a cow's ability to conceive with respect to herd production level are larger in later lactations than in the first lactation.

Keywords: dairy cattle, fertility, genotype by environment interaction, herd milk production

Introduction

Female fertility is an important factor for improving the lifetime productivities of dairy cattle. The existence of a genotype by environment interaction (G×E) for fertility traits has been examined by considering differences in several environmental descriptors. Some G×E effects for fertility traits in the first lactation have been examined with respect to herd-average production (Haile-Mariam et al., 2008; Strandberg et al., 2009). However, to our knowledge there have been no reports of these effects in lactations beyond the first.

Therefore, our objective here was to investigate the genetic relationships among several fertility traits; conception rate at first insemination (CR); number of inseminations (NI); and days open (DO) during the first three lactations of Holstein cows by using a multiple trait model that considered the trait values of herds with different milk-production levels as separate traits.

Material and methods

Data

Monthly test day milk records within 305 DIM and insemination records during the first three lactations of Holstein cows with first inseminations from 20 to 200 DIM that were recorded between 2007 and 2011 were collected through the Dairy Herd Improvement program. The data set for the first lactation consisted of records for 475,446 cows; the second, 378,540 cows; and the third, 265,560 cows. Age at first insemination ranged from 20 to 46 months in the first lactation (i.e., for the second calving), from 32 to 66 months in the second, and from 44 to 86 months in the third. Pedigree records were traced back at least five generations.

The average milk production of each herd (Herd production) was defined as the average of the herd-year solution for 305-day milk yield at first lactation. Herd-year solutions for 305-day milk yield were obtained from the following single-trait animal model:
$y_{ijkl} = HY_i + M_j + A_k + u_l + e_{ijkl}$,
where y_{ijkl} is the 305-day milk yield at first lactation of cow l; HY_i is the fixed effect of herd year i; M_j is the fixed effect of calving month j; A_k is the fixed effect of calving age group k; u_l is the random additive effect of animal l; and e_{ijkl} is a random residual effect associated with y_{ijkl}. Solutions for fixed effects of 305-day milk yield were obtained by using the BLUPF90 program (Misztal et al., 2002). The variance components estimated by Yamazaki et al. (2014) were used to solve the fixed effects. Herds with data were categorized into three groups based on the deviations of Herd production; LOW (lower than –1 standard deviation [SD] of Herd production), MID (± 1 SD), and HIGH (higher than +1 SD). The numbers of cows, herds, and means of 305-day milk yield for each Herd production group (HPG) in the first three lactations are shown in Table 1.

Table 1. Numbers of cows, herds, and average 305-day milk yield in each HPG.

		HPG			
	Lactation	LOW	MID	HIGH	Overall
Number of cows	First	53,505	320,851	101,090	475,446
	Second	46,583	255,825	76,132	378,540
	Third	36,363	179,752	49,445	265,560
Number of herds	First	1533	6470	1407	9410
	Second	1468	6219	1353	9040
	Third	1427	6020	1292	8739
305-day milk yield (SD), kg	First	6466 (1015)	8193 (1249)	9610 (1369)	8300 (1522)
	Second	7485 (1245)	9389 (1549)	10,948 (1708)	9469 (1824)
	Third	7887 (1304)	9774 (1610)	11,393 (1784)	9817 (1885)

The female fertility traits used were CR, NI, and DO. CR = 1 indicated that the first insemination achieved pregnancy, and 0 indicated otherwise. NI was classified into five levels (1, 2, 3, 4 to 5, and ≥6 times). Records in which DO was greater than 365 days were set to 365 days. The DO data of cows in which pregnancy could not be confirmed from the insemination records were treated as missing. Summary statistics of each trait for the three HPGs are given in Table 2.

Table 2. Summary statistics of fertility trait in each HPG.

	Lactation	HPG			Overall
		LOW	MID	HIGH	
CR	First	0.38	0.38	0.37	0.38
	Second	0.37	0.34	0.33	0.34
	Third	0.36	0.34	0.32	0.34
NI (SD), times	First	2.4 (1.8)	2.5 (1.9)	2.6 (2.0)	2.5 (1.9)
	Second	2.4 (1.8)	2.6 (1.9)	2.7 (1.9)	2.6 (1.9)
	Third	2.5 (1.8)	2.6 (1.8)	2.7 (1.9)	2.6 (1.9)
DO (SD), days	First	146 (83)	144 (83)	144 (82)	144 (83)
	Second	151 (83)	151 (83)	151 (81)	151 (83)
	Third	153 (85)	154 (83)	154 (81)	154 (83)

Models

The data were analyzed within each lactation by using a multiple-trait linear model that took into account the genetic covariance among records for the three HPGs:

$y_{ijklmn} = FHY_i + FM_j + FA_k + s_n + u_{lm} + e_{ijklmn}$,

where y_{ijklmn} is the fertility trait of cow m; FHY_i is the fixed effect of herd year i for first insemination; FM_j is the fixed effect of region (two levels) – month j at first insemination; FA_k is the fixed effect of age group k at first insemination; s_n is the random effect of service sire m at first insemination; u_{lm} is HPG l × the random additive effect of animal m; and e_{ijklmn} is a random residual effect associated with y_{ijklmn}. The age effect at first insemination was not considered in the third lactation record.

Genetic parameters for CR, NI, and DO were estimated by using a three-HPG × three-trait animal model. The GIBBS3F90 program (Misztal, 2008) was used for Gibbs sampling to estimate the variance components. For Gibbs sampling, the first 100,000 samples were discarded as burn-in. The subsequent 100,000 samples were saved to calculate posterior means and standard deviations for the (co)variance components.

Results and Discussion

Heritabilities and genetic correlations within each HPG

The heritability estimates for CR and NI differed little among different HPGs and among lactations (Table 3). The heritability of DO for LOW HPG in the first lactation was slightly higher than those for the other HPGs in the same lactation, and those in the third lactation decreased with rising HPG level. Our heritability estimates were in line with previous findings (e.g., Abe et al., 2009; Ghiasi et al., 2011; Hagiya et al., 2013), except that those of DO for the third lactation were slightly higher than in these studies.

The genetic correlations among fertility traits (Table 4) did not differ greatly within HPGs among lactations or among HPGs for the same lactation. The genetic correlations between CR and NI were the strongest. Those of DO with CR or NI were also strong. Our genetic correlation estimates were similar to previous findings (e.g. Abe et al., 2009; Ghiasi et al., 2011; Yamazaki et al., 2014) Our results suggest that differences in herd milk production do not affect the genetic relationships among fertility traits.

Table 3. Posterior means (posterior SDs) of heritability for fertility traits in each HPG.

	HPG

	Lactation	LOW	MID	HIGH
CR	First	0.037 (0.004)	0.026 (0.002)	0.033 (0.003)
	Second	0.026 (0.004)	0.024 (0.002)	0.039 (0.004)
	Third	0.050 (0.007)	0.022 (0.003)	0.038 (0.009)
NI	First	0.066 (0.004)	0.044 (0.003)	0.048 (0.004)
	Second	0.038 (0.004)	0.036 (0.003)	0.051 (0.005)
	Third	0.059 (0.006)	0.043 (0.004)	0.052 (0.007)
DO	First	0.120 (0.006)	0.076 (0.004)	0.076 (0.005)
	Second	0.084 (0.008)	0.064 (0.004)	0.072 (0.008)
	Third	0.186 (0.011)	0.135 (0.008)	0.116 (0.013)

Table 4. Posterior means (posterior SDs) of genetic correlations among fertility traits within each HPG.

		HPG		
	Lactation	LOW	MID	HIGH
CR - NI	First	–0.939 (0.006)	–0.967 (0.006)	–0.946 (0.010)
	Second	–0.825 (0.049)	–0.955 (0.006)	–0.929 (0.014)
	Third	–0.936 (0.011)	–0.969 (0.003)	–0.914 (0.009)
CR - DO	First	–0.851 (0.014)	–0.866 (0.014)	–0.832 (0.020)
	Second	–0.635 (0.056)	–0.761 (0.022)	–0.757 (0.039)
	Third	–0.799 (0.031)	–0.773 (0.027)	–0.782 (0.046)
NI - DO	First	0.898 (0.013)	0.857 (0.016)	0.841 (0.015)
	Second	0.764 (0.040)	0.772 (0.022)	0.833 (0.025)
	Third	0.806 (0.028)	0.820 (0.023)	0.761 (0.037)

Genetic correlations of each trait across different HPGs

Positive and strong genetic correlations (greater than 0.7) were estimated for each trait across different HLGs, except in the case of some estimates of CR and NI in the second and third lactations (Table 5). The genetic correlations of CR for the LOW-MID and LOW-HIGH HPGs in the second and third lactations ranged from 0.394 to 0.600, and those of NI for the LOW-HIGH HPG were 0.675 and 0.550, respectively, in these lactations. Genetic correlations of 0.74 for calving interval between low and high herd-average production groups have been reported for the first lactation (Haile-Mariam et al., 2008; Strandberg et al., 2009). Some of our genetic correlations for CR and NI in the second and third lactations across the different HPGs were lower than these previous estimates for the first lactation. Our results suggest that the G×E effects on a cow's ability to conceive with respect to herd milk production are larger in the second and third lactations than in the first lactation.

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Table 5. Posterior means (posterior SDs) of genetic correlations for each fertility trait across HPG.

	Genetic correlation between different HPGs

	Lactation	LOW–MID	MID–HIGH	LOW–HIGH
CR	First	0.814 (0.040)	0.868 (0.021)	0.723 (0.039)
	Second	0.591 (0.080)	0.758 (0.030)	0.600 (0.047)
	Third	0.506 (0.047)	0.717 (0.069)	0.394 (0.095)
NI	First	0.852 (0.028)	0.918 (0.008)	0.783 (0.030)
	Second	0.759 (0.057)	0.862 (0.024)	0.675 (0.040)
	Third	0.766 (0.027)	0.728 (0.049)	0.550 (0.053)
DO	First	0.911 (0.015)	0.934 (0.012)	0.868 (0.031)
	Second	0.777 (0.023)	0.924 (0.016)	0.730 (0.029)
	Third	0.916 (0.018)	0.886 (0.025)	0.801 (0.018)

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