Short communication: Genetic effects of heat stress on days open for Thai Holstein crossbreds

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ABSTRACT

Seasonality of days open (DO) for Thai crossbred Holsteins was examined and genetic effects of heat stress on DO open were determined. Data included 18,413 records for first and second parities of 12,162 cows that calved between 1990 and 2006. Least squares means for DO were estimated using a model with fixed effects of herd-year of calving, breed group based on percentage of Holstein genetics, calving month, calving age, and parity. A reaction norm model and solutions for calving month were used to calculate a heat stress index. Variance components were estimated with a multitrait random regression model. Days open were greatest for cows calving in March (summer) and fewest in October (late rainy season) for all breed groups and parities. Estimates of additive genetic and residual variances and heritability varied by calving month. Residual variances increased and additive genetic variance decreased with percentage of Holstein genetics and parity. Heritability estimates for DO ranged from 7.1 to 8.4% for first-parity cows with <87.5% Holstein genetics, 5.9 to 8.0% for 87.5 to 93.6% Holstein genetics, and 5.8 to 7.8% for ≥93.7% Holstein genetics and from 6.3 to 7.9, 4.9 to 7.3, and 4.5 to 7.7% for the corresponding breed groups for second parity. Genetic correlations between additive genetic effects on DO with and without heat stress considered were 0.43 for first-parity cows with <87.5% Holstein genetics, 0.46 for those with 87.5 to 93.6% Holstein genetics, and 0.52 for those with ≥93.7% Holstein genetics; correlations were 0.46, 0.51, and 0.55 for the corresponding breed groups for second parity. Effect of heat stress on DO was greater for second than first parity and was particularly large for cows with ≥93.7% Holstein genetics. Fewer DO can be achieved in Thailand through selective breeding of cows with <87.5% Holstein genetics.

Key words: heat stress, days open, genetic effect, Thailand

Short Communication

One of the major reasons for culling dairy cattle is low fertility because of its direct negative effects on the profitability of dairy producers (De Vries, 2006). Decline in fertility depends on many factors, including increased milk yield, management, nutrition, herd size, disease, environment, and genetics (Fourichon et al., 2000; Lucy, 2001; Jordan, 2003). Generally, environmental factors such as calving month or season are major sources of variation for fertility traits (Ray et al., 1992; Oseni et al., 2003). In addition, global warming, and associated heat stress, is becoming an important issue in livestock production (Morton et al., 2007), especially because of possibly severe effects on fertility. Although poor fertility during hot weather can be managed by avoiding breeding during that season and by using estrus synchronization or timed artificial insemination, fertility continues to decline (De Vries and Risco, 2005). Genetic selection may be an alternative for sustainable improvement of fertility traits, thus increasing income of dairy producers.

Recently, a reaction norm model was used to study changes in both production and fertility traits, which are affected by environment (De Jong, 1995). This model is highly efficient in detecting stability and plasticity when phenotypes change gradually and continuously over an environmental gradient (De Jong, 1995). In addition, the reaction norm model can be easily implemented via random regression and, therefore, may be a good model for genetic evaluation and selection (Calus et al., 2002).

Days open (DO) is an economically important fertility trait that is popular for genetic selection because of recording ease (VanRaden et al., 2004). For purebred dairy cattle, DO variability based on region and across calving month can be used to construct a heat stress index (HI) for fertility (Oseni et al., 2004b). Using that index, Oseni et al. (2004a) found substantial genetic

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Table 1. Data structure for days open records by parity for Thai Holstein crossbreds

Category	Parity	
	1	2
Records by calving month (n)		
January	769	487
February	825	373
March	842	379
April	843	450
May	990	535
June	873	565
July	890	667
August	1,125	684
September	1,018	762
October	1,106	1,020
November	1,005	840
December	926	439
Records by breed group (n)		
<87.5% Holstein genetics	3,972	2,923
87.5 to 93.6% Holstein genetics	3,824	2,494
≥93.7% Holstein genetics	3,416	1,784
Mean 305-d milk yield ± SD (kg)		
<87.5% Holstein genetics	3,570 ± 1,026	3,950 ± 1,017
87.5 to 93.6% Holstein genetics	3,978 ± 1,076	4,483 ± 1,201
≥93.7% Holstein genetics	4,367 ± 1,110	4,939 ± 1,283
All records	3,953 ± 1,068	4,421 ± 1,207

variation in DO related to heat stress. Pszczola et al. (2009) used the index for a national evaluation of US Holsteins and found a detrimental trend for DO under heat stress.

Few studies on genetics of heat stress have been conducted in tropical countries. In Thailand, crossbreeding between *Bos taurus* (Holstein, Jersey, Brown Swiss, and Red Dane) and *Bos indicus* (Sahiwal, Red Sindhi, Brahman, and Thai Native) has been widely used. However, the major crossbred dairy cattle (>95%) has been a cross between Holstein and Sahiwal or Thai Native breeds. Crossing these breeds aims to combine the benefits of improved milk yield from *B. taurus* breeds with tolerance to heat and tick-borne and other tropical diseases from zebu breeds (Chanvijit et al., 2005). Today, Holstein crossbreds with ≥75% Holstein fractions are the main population in Thailand. Compared with that in the United States and European countries, heat stress in Thailand lasts longer and humidity is high all year. Because economics restricts the use of cooling devices to a few herds, production of Thai dairy cattle usually is low. Decreased cow fertility in Thailand because of heat stress may be compensated for by less stress from production. The objectives of this study were to determine DO seasonality for Thai Holstein crossbreds and compute genetic parameters for DO with and without heat stress considered.

Data for DO from 94 Thai herds were obtained from the Department of Livestock Development (Pathumthani, Thailand) and private farms and includ-

ed 18,413 first- and second-parity records for 12,162 Thai Holstein crossbreds that calved between 1990 and 2006. Records with <21 or >365 DO were excluded from analysis. Records with 21 to 49 DO were set to 50 DO, and records with 251 to 365 DO were set to 250 DO, as suggested by VanRaden et al. (2004). Calving ages were restricted to 18 to 48 mo for first parity and 26 to 65 mo for second parity. Records were grouped by percentage of Holstein genetics (breed group) as follows: <87.5%, 87.5 to 93.6%, and ≥93.7%. Calving seasons were summer (March to June), rainy (July to October), and winter (November to February). The milk recording system was run by the Thai government under the Department of Livestock Development. Each registered farm was visited monthly by a government officer to record milk production and collect milk samples of individual cows. Pedigree data were handled by the regional AI supervisor. All records were submitted online to maintain at the central database for genetic evaluation. A more detailed description of the data is shown in Table 1.

A fixed-effect model was used to estimate least squares means for DO and solutions for calving month separately by breed group and parity using the GLM procedure of SAS (SAS Institute Inc., Cary, NC):

$$y_{ijklmn} = HY_i + CM_{jk} + CA_l + P_m + b(MY_{305}) + e_{ijklmn}, \quad [1]$$

where y_{ijklmn} is DO for cow n that calved in herd-year of calving (HY) class i ($i = 1$ to 596) during calving month (CM) j nested within breed group (BG) k at calving age (CA) l (twelve 4-mo groups) for parity (P) m ; b is a fixed regression coefficient for 305-d milk yield (MY_{305}), and e_{ijklmn} is random residual.

Standardized solutions for calving month derived from model [1] were used to calculate HI, which represented a reaction norm model to explain effects of heat stress affecting DO across calving month within breed group and parity:

$$HI_{jk} = (LS_{jk} - \min_k) / (\max - \min_k),$$

where LS_{jk} is the least squares solution for calving month j within breed group k , $\min_k$ is the minimum solution for calving month within breed group k , and $\max$ is maximum solution for calving month.

A second model was fitted using a reaction norm model between breed groups on HI function within parity using the AIREMLF90 program (Misztal et al., 2002):

$$y_{ijklmn} = HY_{ikm} + CM_{jkm} + CA_{klm} + b(MY_{305}) + a_{kmn} + b_{kmn}(HI_{jk}) + e_{ijklmn}, \quad [2]$$

Figure 1. Least squares means of days open across calving month for Thai crossbred Holsteins within breed group based on percentage of Holstein genetics for a) parity 1 and b) parity 2.

where y_{ijklmn} is DO for cow n in breed group k and herd-year of calving class i within parity m , calving month j , calving age l , and level j of HI (0 to 1), a_{kmn} is the additive genetic effect of cow n within parity m in breed group k , b_{kmn} is the linear random regression coefficient for heat stress for cow n within parity m in breed group k , HI_{jk} is the heat stress index for calving month j and breed group k , and e_{ijklmn} is the random residual.

The (co)variance structure was

$$\text{Var} \begin{bmatrix} \mathbf{a} \\ \mathbf{e} \end{bmatrix} = \begin{bmatrix} \mathbf{A} \otimes \mathbf{G}_0 & \mathbf{0} \\ \mathbf{0} & \mathbf{I} \otimes \mathbf{R}_0 \end{bmatrix},$$

where $\mathbf{A}$ is the additive numerator relationship matrix, $\mathbf{G}_0$ is a 6×6 matrix of (co)variances of the additive genetic effects by parity (1 to 2) and breed group (1 to 3), $\mathbf{I}$ is an identity matrix, and $\mathbf{R}_0$ is a 3×3 a diagonal matrix of residual variances corresponding to each breed group (1 to 3). Residuals for each breed group were assumed to be uncorrelated and heterogeneous across calving month.

Least squares means of DO across calving month within breed group and parity are shown in Figure 1. Days open were greatest for March (summer) for all breed groups and parities: 154, 166, and 176 DO for <87.5%, 87.5 to 93.6%, and $\geq 93.7\%$ Holstein genetics,

respectively, for first parity, and 158, 171, and 187 DO for the corresponding breed groups for second parity. Days open were fewest for October (late rainy season): 128 DO for <87.5% Holstein genetics, 132 DO for 87.5 to 93.6% Holstein genetics, and 136 for $\geq 93.7\%$ Holstein genetics for parity 1 and 124, 126, and 137 DO for the corresponding breed groups for second parity. Summer (March to June) in Thailand, which has a mean temperature of 34°C and a mean humidity of 67%, is associated with poor conception (McDowell et al., 1976) and thus increased DO. In contrast, the rainy season (July to October) has a mean temperature of 27°C and a mean humidity of 80%, which is close to the thermal neutral zone range for dairy cattle (Hahn, 1981). Therefore, the rainy season may be the most appropriate time for mating dairy cattle in Thailand. Figure 1 shows an increase in DO with percentage of Holstein genetics for both first and second parities, an indication that milk yield is correlated unfavorably with DO, as has been reported by Pryce et al. (2004). Thus, selection for high milk yield has led to increased DO. In addition, the phenotypic effect of heat stress is greater for second parity, especially for cows with $\geq 87.5\%$ Holstein genetics. Later parity may be associated with a greater risk of stress from environmental factors (e.g., reproductive diseases) than first parity.

Figure 2. Heat stress index of days open across calving month for Thai crossbred Holsteins within breed group based on percentage of Holstein genetics for a) parity 1 and b) parity 2.

Figure 3. Estimates of additive genetic and residual variances and heritability of days open across calving month for Thai crossbred Holsteins within breed group based on percentage of Holstein genetics for a) parity 1 and b) parity 2.

The HI across calving month within breed group and parity is shown in Figure 2. The index ranges from 0 (no heat stress) to 1 (greatest heat stress). The highest and lowest HI values correspond to the pattern for least squares means of DO for both first and second parities, which indicates that heat stress is associated with increased DO. This index has been successfully used in several studies to describe different phenotypic and genotypic values (variance components and parameters) across different environments (De Jong, 1995; Oseni et al., 2004a,b; Pszczola et al., 2009). This index is also

easy to implement because it does not require the collection and analysis of weather information.

Estimates of additive genetic and residual variances and heritability of DO across calving month within breed group and parity are shown in Figure 3. Both additive genetic and residual variance fluctuated by calving month. Residual variance increased with percentage of Holstein genetics and parity, whereas additive genetic variance decreased. Heritability estimates for DO ranged from 7.1 to 8.4% for <87.5% Holstein genetics, 5.9 to 8.0% for 87.5 to 93.6% Holstein genetics,

and 5.8 to 7.8% for $\geq 93.7\%$ Holstein genetics for first parity and from 6.3 to 7.9, 4.9 to 7.3, and 4.5 to 7.7%, respectively, for the corresponding breed groups for second parity. These estimates were slightly higher than heritabilities reported in other studies of purebred dairy cattle (Oseni et al., 2004a; Abe et al., 2009). This result indicated that environmental variation increases as the percentage of Holstein genes goes up. This would also cause heritability estimates to go down as the percentage of Holstein genes increases. Heritability estimates were highest for summer (March) calving and lowest for late rainy season (October) calving for all breed groups and parities (Figure 3). Heat stress appears to have a substantial effect on genetic variation for DO. A decline in DO heritability estimates for second parity compared with first parity was also found. Results revealed that genetic variation of DO was affected by heat stress more in March than October, in second parity.

Genetic correlations between additive genetic effects with and without heat stress considered were 0.43 for $<87.5\%$ Holstein genetics, 0.46 for 87.5 to 93.6% Holstein genetics, and 0.52 for $\geq 93.7\%$ Holstein genetics for first parity and 0.46, 0.51, and 0.55 for the corresponding breed groups for second parity. These correlations indicate that increase of Holstein genetics and parity would increase the effect of heat stress.

High heat stress was associated with greater DO, especially for Thai crossbreds with $\geq 87.5\%$ Holstein genetics. Holstein dairy cattle are generally selected for high milk yield in temperate climates and thus may not be appropriate for tropical countries because of the negative relationship between heat stress and fertility. In Thailand and other hot, humid countries, breeding dairy cattle with a high percentage of Holstein genetics should be carefully monitored.

In summary, calving month (or season) greatly affected both phenotypic and genetic DO variation of Thai Holstein crossbreds. Substantial genetic variation exists for DO under heat stress. Fewer DO can be achieved in Thailand through selective breeding while keeping breed composition at $<87.5\%$ Holstein genetics. The phenotypes for DO would be most useful for dairy production under stressful conditions.

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