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Economic weights for genetic improvement of lactation persistency and milk yield

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ABSTRACT

This study aimed to establish a criterion for measuring the relative weight of lactation persistency (the ratio of yield at 280 d in milk to peak yield) in restricted selection index for the improvement of net merit comprising 3-parity total yield and total lactation persistency. The restricted selection index was compared with selection based on first-lactation total milk yield (I_1), the first-two-lactation total yield (I_2), and first-three-lactation total yield (I_3). Results show that genetic response in net merit due to selection on restricted selection index could be greater than, equal to, or less than that due to the unrestricted index depending upon the relative weight of lactation persistency and the restriction level imposed. When the relative weight of total lactation persistency is equal to the criterion, the restricted selection index is equal to the selection method compared (I_1, I_2, or I_3). The restricted selection index yielded a greater response when the relative weight of total lactation persistency was above the criterion, but a lower response when it was below the criterion. The criterion varied depending upon the restriction level (c) imposed and the selection criteria compared. A curvilinear relationship (concave curve) exists between the criterion and the restricted level. The criterion increases as the restriction level deviates in either direction from 1.5. Without prior information of the economic weight of lactation persistency, the imposition of the restriction level of 1.5 on lactation persistency would maximize change in net merit. The procedure presented allows for simultaneous modification of multi-parity lactation curves.
Key words: criterion, restricted index, total milk yield, total lactation persistency

INTRODUCTION

Milk yield and lactation persistency are two economically important traits in dairy production. Lactation persistency refers to the rate of decline in daily yield after the peak within lactation. The lower the rate of decline after the peak, the higher the lactation persistency and the more desirable it is economically. Various measures of lactation persistency have been reported in the literature (see review by Gengler, 1996; Swalve and Gengler, 1999). A cow with a higher lactation persistency makes better use of inexpensive forage (Solkner and Fuchs, 1987), suffers less stress from high peak yield (Zimmermann and Sommer, 1973; Muir et al., 2004; Weller et al., 2006), is more resistant to disease (Jakobsen, 2002; Harder et al., 2006), shows an increased conception rate (Bar-Anan and Ron, 1985) and probability of pregnancy (De Vries, 2006), and is more profitable (Dekkers et al., 1998). Lactation persistency received a greater emphasis on organic dairy farms than on conventional farms (Rozzi et al., 2007).

Currently, most selection indices treat protein yield as the main trait of interest (VanRaden, 2004; Miglior et al., 2005) without consideration of increased lactation persistency. One of the main obstacles to incorporate lactation persistency into a selection scheme is the determination of the economic weights for lactation persistency, which requires the expensive collection of a comprehensive data set and involves the difficulty of objectively assessing the economic effects of lactation persistency components such as stress and disease resistance. For these reasons, there is a lack of reports about the economic values of lactation persistency relative to milk production and other economic traits. However, an effective breeding program designed to maximize milk yield subject to the restriction on lactation persistency requires predetermination of the level of restriction to be imposed and the relative weights between milk yield and lactation persistency. The purpose of this study was to determine the restriction level on total lactation persistency of the first 3 parities for the construction of a restricted index to maximize the genetic response

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in net merit comprising 3-parity total yield and total lactation persistency.

MATERIALS AND METHODS

Genetic Parameter Estimates

The genetic parameter estimates of the first 3 lactations used for this study were based on Togashi et al. (2008) who used a 3-lactation random regression (**RR**) test-day (**TD**) model with a cubic Legendre polynomial (**LP**) to analyze TD data of Japanese Holstein cows. The number of covariates fitted for the cubic LP is k = 4. The 3-parity RR TD model fitted with the cubic LP produced a (12 × 1) vector ($\boldsymbol{\alpha}$) of the additive genetic RR coefficients of a particular animal (3 lactations × k = 12) with a (12 × 12) additive genetic RR covariance matrix $\mathbf{K}$ of the first 3 lactations:

$$\boldsymbol{\alpha} = \begin{bmatrix} \boldsymbol{\alpha}_{(1)} \\ \boldsymbol{\alpha}_{(2)} \\ \boldsymbol{\alpha}_{(3)} \end{bmatrix},$$

with the variance of $\boldsymbol{\alpha}$ being

$$\mathrm{Var}(\boldsymbol{\alpha}) = \mathbf{K} = \begin{bmatrix} \mathbf{K}_{11} & \mathbf{K}_{12} & \mathbf{K}_{13} \\ \mathbf{K}_{21} & \mathbf{K}_{22} & \mathbf{K}_{23} \\ \mathbf{K}_{31} & \mathbf{K}_{32} & \mathbf{K}_{33} \end{bmatrix},$$

where $\boldsymbol{\alpha}_{(i)}$ is a (k × 1) vector of the additive genetic RR coefficients that apply to individual animals of the ith lactation. Let $\boldsymbol{\Phi}_{(i)}$ be the (301 × k) LP coefficient matrix of the ith lactation, where $\boldsymbol{\Phi}_{(1)} = \boldsymbol{\Phi}_{(2)} = \boldsymbol{\Phi}_{(3)}$. The diagonal blocks ($\mathbf{K}_{11}$, $\mathbf{K}_{22}$, and $\mathbf{K}_{33}$) of the matrix $\mathbf{K}$ are the additive genetic RR coefficient covariance matrices within parity, and the off-diagonal blocks ($\mathbf{K}_{ij}$) are the additive genetic RR coefficient covariance matrices between parities i and j. The EBV of the daily yields from DIM 5 to 305 of the ith lactation are $\boldsymbol{\Phi}_{(i)}\boldsymbol{\alpha}_{(i)}$ and the EBV for a particular animal of the ith lactation is $\mathbf{1}'\boldsymbol{\Phi}_{(i)}\boldsymbol{\alpha}_{(i)}$, where $\mathbf{1}$ is a summing vector. Throughout the text, subscript (i) refers to the number of lactations.

Selection Criteria Compared

Lactation persistency was defined as the ratio of yield at DIM 280 to peak yield (yield_{280} /$\mathrm{yield}_{\mathrm{peak}}$). Days to reach peak yield were 45, 40, and 36 for the first 3 parities, respectively (Togashi et al., 2008). Total lactation persistency is the sum of lactation persistency of the first 3 lactations and similarly, total yield is the sum of 305-d milk of the first 3 lactations. This study aims to develop the weight of total lactation persistency relative to total yield for deciding if genetic response due to a restricted index would be more than, equal to, or less than that due to the unrestricted indexes. Three unrestricted indexes and a restricted index compared are described as follows: 1) selection based on the first-parity milk EBV ($\mathbf{I_1}$); 2) selection based on the first 2-parity total milk EBV ($\mathbf{I_2}$); 3) selection based on the first 3-parity total milk EBV ($\mathbf{I_3}$); and 4) selection based on all eigenvectors of $\mathbf{K}$ with restriction on lactation persistency ($\mathbf{I^*}$).

Eigen Index Using All Eigenvectors of K with Restriction on Lactation Persistency. The restricted eigen index (I*) using all eigenvectors of $\mathbf{K}$ was designed to maximize the total milk subject to the restriction on lactation persistency of each of the 3 lactations. The genetic value for a particular animal of the first 3 lactation total yield is $\mathrm{H} = g_{(1)} + g_{(2)} + g_{(3)}$, where $g_{(i)}$ is the genetic value for a particular animal of the ith lactation milk. In matrix notation, $\mathrm{H} = \mathbf{1}'\mathbf{F}\alpha$, where the matrix $\mathbf{F}$ of order (903 × 3k) is:

$$\mathbf{F} = \begin{bmatrix} \boldsymbol{\Phi}_{(1)} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \boldsymbol{\Phi}_{(2)} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \boldsymbol{\Phi}_{(3)} \end{bmatrix}.$$

The following restrictions were imposed on lactation persistency of each of the 3 lactations:

$$\frac{\Delta G_{280(1)}}{\Delta G_{peak(1)}} = \frac{\Delta G_{280(2)}}{\Delta G_{peak(2)}} = \frac{\Delta G_{280(3)}}{\Delta G_{peak(3)}} = c,$$

where $\Delta G_{280(i)}$ and $\Delta G_{peak(i)}$ are the genetic responses at 280 DIM and peak DIM of the ith lactation (i = 1, 2, or 3), respectively. The ratio of $\Delta G_{280(i)}$ to $\Delta G_{peak(i)}$ is the genetic response in lactation persistency of the ith lactation. Therefore, the level of restriction (c) defined above is expected to be the same as the genetic response in lactation persistency due to the restricted index, but this is not the case for the unrestricted indexes. Different degrees of restrictions (c) were imposed to construct various restricted indexes with c ranging from 1.4 to 2.1 (Table 1). This study imposed the same restriction on lactation persistency of the 3 lactations [i.e., $c_{(1)} = c_{(2)} = c_{(3)} = c$] although different restrictions could be applied among lactations. Note that lactation persistency before and after selection remains unchanged when $c = 1$, increases when $c > 1$, and deteriorates when $c < 1$.