OPTIMAL STRATEGY TO MODIFY THE SHAPE OF THE LACTATION CURVES

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INTRODUCTION

Lin and Togashi (2002) presented two equivalent selection methods to improve both total lactation yield and persistency which was affected by various factors such as the partition of lactation stages, intended genetic gain, distribution of pre-specified genetic gain among lactation stages, and genetic covariance matrix of the stages. The purpose of this study is to investigate the optimal combination of these factors for genetic improvement of total yield and persistency in dairy cows.

MATERIALS AND METHODS

This study applied a 5-order Legendre polynomial function (i.e. 6 parameters including 0 order) to model the shape of the lactation curve in dairy cows. A lactation period of 305 days was partitioned into six stages to match the six random regression (RR) coefficients fitted. For ease of reference, days in milk (DIM) from day 5 to 60 will be hereafter referred to as early lactation and DIM from 61 to 305 as late lactation. Two scenarios of partitioning a whole lactation into six stages are examined : a) three stages each in early and late lactations (i.e. 3-3 partition) and b) two stages in early lactation and four stages in late lactation (i.e. 2-4 partition). For example, 5-23-42-60-180-300-305 where the figures are the DIM for partitioning the lactation period represents a 3-3 partition because three stages each are partitioned before and after day 60 whereas 5-30-60-140-220-300-305 is a 2-4 partition because there are two stages before day 60 and four stages after day 60. With the exception of the last stage with zero restriction imposed, the stages in early or late lactation have the same length, respectively.

Lin and Togashi (2002) presented a selection index based on stage EBV to improve both lactation yield and persistency. The index coefficients (b_i) were derived as $b = G\underline{\Delta}$ where G is the genetic covariance matrix of the 6 stages and vector $\underline{\Delta}$ contains genetic gains of the 6 stages. According to their approach, the genetic improvement of the existing “typical” lactation curve needs to be predetermined. Because this study aims to improve persistency, all genetic gains are intended for late lactation (day 61-305) with the imposition of zero genetic change in early lactation (day 5-60). The distribution of total genetic gains between stages is defined in two ways : a) 50-50 % split between DIM 61-170 and DIM 171-305 in late lactation and b) 66-34 % split. Four different restriction options were used : zero restriction (no genetic gain) on the last stage of three different intervals (DIM261-305, 281-305, 301-305) vs. no zero restriction for the purpose of examining the impact of zero restriction on the shape of the lactation curves. The restriction of zero genetic gain in the last stage may be necessary because increased milk production in the last stage would result in a longer calving interval. Three levels of genetic improvement over the typical curve are assumed : 1 %, 3 % and 5 %. The lactation EBV of the typical curve was taken to be 1427.9 kg for Holstein population (Pool and Meuwissen, 2001). As an example, a combination of 1 % of genetic improvement (i.e. 1 % of 1427.9 = 14.279) and a 66-34 % split means that a genetic gain of 9.424 kg EBV (66 % of 14.279 = 9.424) was pre-specified for DIM 61-170 and 4.855 kg EBV (i.e. 34 % of 14.279 = 4.855) for DIM 171-305.

A total of 48 possible combinations (2x2x4x3) of these factors was available for studying the optimal combination to achieve the intended curve. Each of these 48 combinations has resulted in a lactation curve to be compared with typical curve or conventional selection based on lactation EBV. Current selection for 305-day milk yield is based on lactation EBV, i.e. $\mathrm{EBV_L} = \mathbf{1}'\Phi\alpha$ where **1** is the summing vector, Φ is the Legendre polynomial matrix of a whole lactation, and α is a vector of RR coefficients. Correlated response for the i^{th} day across lactation (i = 5,6,…305) due to conventional selection on lactation EBV was estimated as $\underline{\Delta}_c = G^* 1 \, (\bar{i}/\sigma_{\mathrm{EBV_L}})$ where $\underline{\Delta}_c$ is a vector of correlated responses from days 5 to 305, G^* is the genetic covariance matrix of days 5 to 305, $\bar{i}$ = (genetic improvement of 1 %, 3 %, or 5 %) / $\sigma_{\mathrm{EBV_L}}$, and $\sigma_{\mathrm{EBV_L}} = \sqrt{1'\Phi K \Phi' 1}$ with **K** being the genetic covariance matrix of RR coefficients. Matrix **K** was adapted from Pool and Meuwissen (2001).

RESULTS AND DISCUSSION

Partition of lactation period.

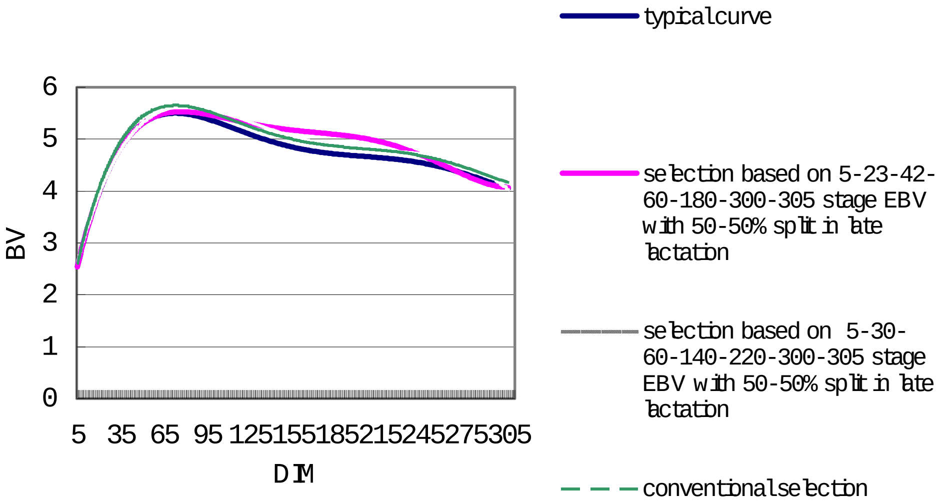

Figure 1. Comparison of BV between conventional selection and selection based on stage EBV with zero restriction on DIM301-305 at 3 % of genetic gain

This study involved a total of 48 combinations that resulted in 48 realized curves. Because of space limitation for this presentation, only a few combinations were shown. At 3 % of genetic gain with the restriction of zero genetic change in the last stage (DIM301-305), the realized curves for 2-4 partition and 3-3 partition are compared in figure 1. Obviously, the 3-3 partition achieved a higher persistency than the 2-4 partition because peak yield or the number of days to peak yield remain unchanged under 3-3 partition whereas the 2-4 partition increased both peak yield and days to peak yield. This observation indicates that when lactation period is partitioned into stages, it is advantageous to shorten the stage interval by increasing the number of stages before DIM 60 and to increase the stage interval through reducing the number of stages after DIM 60.

Distribution of genetic gains. With the exception of zero restriction on DIM301-305, the last stage of all realized curves of the 3-3 partition showed an upward trend whereas an acute descent was observed for the 2-4 partition. On the other hand, zero restriction in DIM300-305 does not lead to an ascent or a rapid descent in the last stage of the realized curve (figure 1) simply because it has a short interval of only 5 days. As expected, the distribution of intended genetic gain in late lactation by 66-34 % split resulted in more genetic gain in the stage of DIM61-170 than in the stage of DIM171-305. In particular, a combination of 66-34 % split and 3-3 partition yields a smaller BV than the typical curve in the stage of DIM261-305.

The results of the above comparisons obtained at 3 % of genetic gain became more conspicuous at 5 % of genetic gain and became less apparent at 1 % of genetic gain. Partition of 5-23-42-60-180-300-305 with equal distribution of genetic gain in late lactation (50-50 % split) is considered as the best combination to improve persistency. The next alternative is the partition of 5-30-60-140-220-300-305 coupled with a 50-50 % split. The realized curves for these two partitions were shown in figure 1.

Impact of conventional selection on lactation curve. Genetic curve derived from conventional selection based on lactation EBV was shown in figure 1. Conventional selection produced higher peak than the typical curve. Selection based on 5-30-60-140-22-300-305 had slightly higher persistency than conventional selection, but the difference is not noticeable in figure 1 because of the scale. Daily genetic gain due to conventional selection ranges from 0.05 to 0.15kg EBV in early lactation and remains about the same in late lactation (figure 2). This indicates that conventional selection would primarily raise the level of production coupled with a minor modification of the shape of the lactation curve at both ends of the lactation curve. The partition of 5-30-60-140-220-300-305 showed two peaks in daily genetic gain expressed as deviations from typical curve while the partition of 5-23-42-60-180-300-305 had a single peak (figure 2). Biologically, a genetic lactation curve with a single peak is easier to achieve than the one with two peaks. Obviously, a target curve would be better realized by distributing genetic gain directly to each day of the lactation period. However, this would require a full fit of 301 RR coefficients. From computation and practical breeding standpoints, a reduced fit of RR coefficients or a reduced number of lactation stages partitioned is desirable. This study demonstrates that an optimal strategy to improve lactation yield and/or persistency needs to consider the number and the length of stages partitioned and the proportion of genetic gains intended between stages.

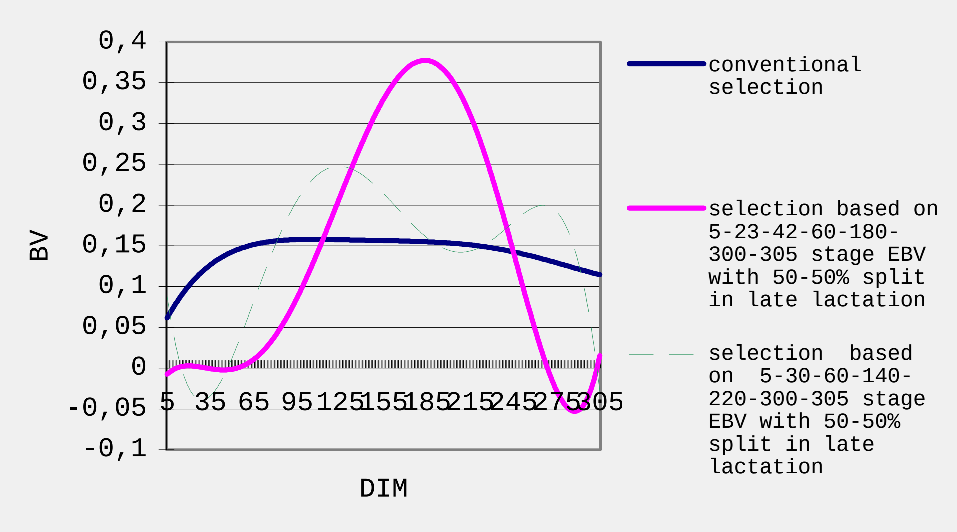

Figure 2. Daily genetic gains expressed as deviation from typical curve with zero restriction on DIM301-305 at 3 % of genetic gain in lactation EBV

CONCLUSION

In light of the above results, the shape of the lactation curve can be modified while holding genetic value of early lactation constant. To achieve a higher persistency, the interval of each stage should be reduced before the peak and increased after the peak. Furthermore, the distribution of genetic gains between DIM 61-170 and DIM 171-305 should be equal (50-50 % distribution). If it is necessary to restrict the last stage to zero genetic change, a short interval of the last stage is recommended over a long interval. The results observed above become more and more conspicuous with increasing level of genetic improvement. Of the 48 combinations studied, the combination of a 3-3 partition and a 50-50 % split of genetic gains between DIM 61-170 and DIM 171-305 improved total lactation yield and persistency without increasing the peak yield or the number of days to peak yield. Conventional selection based on lactation EBV has primarily increased the level of the lactation curve with little change to the shape of the lactation curve. Once a desired shape of the lactation curve is achieved, selection emphasis can then be directed exclusively to the level of the lactation curve. It is important do develop an optimal strategy to achieve a desired lactation shape with a reduced order of RR coefficients because a full fit of RR coefficients is impractical.

ACKNOWLEDGMENTS

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