New Zealand Society of Animal Production online archive

This paper is from the New Zealand Society for Animal Production online archive. NZSAP holds a regular annual conference in June or July each year for the presentation of technical and applied topics in animal production. NZSAP plays an important role as a forum fostering research in all areas of animal production including production systems, nutrition, meat science, animal welfare, wool science, animal breeding and genetics.

An invitation is extended to all those involved in the field of animal production to apply for membership of the New Zealand Society of Animal Production at our website www.nzsap.org.nz

View All Proceedings | Next Conference | Join NZSAP

The New Zealand Society of Animal Production in publishing the conference proceedings is engaged in disseminating information, not rendering professional advice or services. The views expressed herein do not necessarily represent the views of the New Zealand Society of Animal Production and the New Zealand Society of Animal Production expressly disclaims any form of liability with respect to anything done or omitted to be done in reliance upon the contents of these proceedings.

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License.

You are free to:

Share— copy and redistribute the material in any medium or format

Under the following terms:

Attribution — You must give appropriate credit, provide a link to the license, and indicate if changes were made. You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

NonCommercial — You may not use the material for commercial purposes.

NoDerivatives — If you remix, transform, or build upon the material, you may not distribute the modified material.

http://creativecommons.org.nz/licences/licences-explained/

Estimation of lactation persistency in crossbred grazing dairy cattle

N. LOPEZ-VILLALOBOS, R. J. SPELMAN[1], B. L. HARRIS[1], G. STANLEY[1] and S. HARCOURT[1]

Institute of Veterinary, Animal and Biomedical Sciences
Massey University, Private Bag 11-222, Palmerston North, New Zealand

ABSTRACT

Lactation persistency is commonly referred to as the rate of decline in daily yield after the peak of lactation and can be measured in different ways. The objective of this study was to calculate different measures of persistency for milk traits and estimate the correlations between parameters of the lactation curve in crossbred cattle. Herd test records of milk, fat, protein and lactose from 810 first lactation cows were used to obtain individual lactation curves using a mixed model fitting six knots splines. The model included the fixed effects of contemporary group (year-calving week), sire, age at calving (linear and quadratic) and an average spline and the random effect of cow-spline interaction. All cows were in their first lactation, second cross Friesian x Jersey from a crossbreeding experiment established for quantitative trait loci identification. Persistency was measured in three different ways: P1, slope of the line fitted using linear regression of daily yield on day of lactation from day 60 to day 220; P2, the area under the lactation curve from day 121 to 180 divided by the area under the curve from day 1 to 60; and P3, the 240-day lactation yield divided by peak yield multiplied by 240. Correlations between measurements of persistency ranged from 0.24 to 0.81 and were significantly different to zero ($P < 0.001$). Correlations between lactation yield and measurements of persistency ranged from -0.43 to +0.33 and were significantly different to zero ($P < 0.01$). These results indicate that measurements of persistency are not invariant and highlight the need to calculate persistency in a more consistent way. When cows were classified for persistency P2 of fat plus protein, cows of high persistency (top 25%), compared with cows of low persistency (bottom 25%), had significantly ($P < 0.05$) more days in milk, higher total yields of milk and its components, lower peak yields, later day of peak yield and lower rate of decline in daily yield from day 60 to day 220 (P1), but similar 240-day total yield of fat and protein. Farming cows of high persistency may be an alternative to reduce farm investments in peak notes and risks of metabolic problems and reproductive failures.

Keywords: lactation persistency; milk yield.

INTRODUCTION

Lactation persistency is usually defined as the ability of the cow to maintain a relatively stable level of milk production after peak yield, and is affected by genetic and environmental factors (Danell, 1982; Sölkner & Fuchs, 1987; Swalve & Gengler, 1999; Tekerli *et al*., 2000). Although several ways to calculate persistency have been proposed, no consensus has been reached yet on the most suitable method (Swalve & Gengler, 1999). Persistency has been calculated based on the ratio between milk yield in different parts of lactation or on differences between milk yield at different test days during lactation (Madsen, 1975; Jamrozik *et al*., 1997; Jakobsen *et al*., 2002). Other studies have calculated persistency as the decline of daily yield after the peak using parameters of the lactation curve described by mathematical models (Wood, 1970; Wilmink, 1987). Other measures include the standard deviation (Sölkner & Fuchs, 1987) or coefficient of variation (Tekerli *et al*., 2000) of test day yields during the lactation.

Studies in other countries have shown that persistency is a trait of economic importance and have promoted its inclusion in the selection objective (Sölkner & Fuchs, 1987; Dekkers *et al*., 1998). Persistency of milk yield has been related to reproductive performance, health and feed costs (Bar-Anan *et al*., 1985; Sölkner & Fuchs, 1987; Lean *et al*., 1989; Haile-Mariam *et al*., 2003; Muir *et al*., 2004). Cows with high peak milk yields present higher risks of negative energy balance because their energy intake is generally lower than their energy requirements. This negative energy balance creates higher risks of metabolic problems and fertility failure. A possible way to increase total yields and minimise these negative effects of high peak milk yields is to select for increased lactation persistency in addition to total production. This selection strategy could be achieved by decreasing peak yields and maintaining a high stable level of production after peak yield, thereby flattening and extending the lactation curve (Ferris *et al*., 1985; Togashi & Lin, 2003). Under New Zealand (NZ) grazing systems this strategy has many other implications related to feed costs and plant capacity of milk factories. Fonterra is currently sending economic signals, through the Peak Notes System, to its suppliers to flatten the curve of milk supply. Farmers supplying milk solids (fat plus protein) with higher peaks than the average of the other suppliers are required to increase their investment in peak notes.

A crossbreeding experiment with Friesian and Jersey breed has been established to identify loci that affect traits of economic importance in NZ dairy cattle

[1] Livestock Improvement Corporation, Private Bag 3016, Hamilton, New Zealand

(Spelman *et al*., 2004). Studies in other countries have reported significant quantitative trait loci (QTL) affecting variation of lactation persistency. Boichard *et al*. (2003) reported a QTL in Chromosome 11 that explains 8% of the total variation for lactation persistency in French dairy cattle. Similarly, Rodriguez-Zas *et al*. (2002) identified QTL in chromosomes 3, 6, 7, 14 and 21 that affect parameters of the lactation curve in North American Holstein cattle, suggesting that the identified positions can be incorporated into marker-assisted selection decisions to alter the persistency and peak production.

This study reports different measurements of persistency that will be used for QTL identification. Correlations between parameters of the lactation curve for yield of milk and components were estimated.

MATERIALS AND METHODS

Data

Daily herd test records of milk volume and fortnightly herd test records of fat, crude protein (referred to as protein hereafter) and lactose from 810 first lactation cows were used to obtain individual lactation curves. All cows were second cross Friesian x Jersey from the crossbreeding experiment established for QTL identification. There were two cohorts of cows. The first cohort comprised 354 cows milked during the season 2002-2003 and the second cohort comprised 456 cows milked during the season 2003-2004. The herd was managed as a conventional spring calving herd grazing on rye grass/white clover pastures, milking twice a day in a rotory milk harvesting system. Dry-off date of cows was determined by condition score (less than 4.0) and level of production (less than 5 litres per day for 2 consecutive weeks) of individual cows and pastures availability to ensure that the cows will start the next lactation with a condition score of 5.5.

Lactation curve function

Individual lactation curves for daily yields of milk, fat, protein and lactose were modelled using a mixed model fitting six knots splines as described in White *et al*. (1999), using the statistical software ASReml (Gilmour *et al*., 2002). Contemporary group was defined as a group of cows calving in the same year and calving week. The mixed model was defined as shown in the equation at the **bottom of the page**, where y_{ijmcp} is the yield of cow i at day of lactation j, in contemporary group c, daughter of sire m, calving at age p (days). The terms t_j and t_{ij} represent the day of lactation j at a particular herd test and cow i. The first (b_0) and sixth (b_3t_j) terms represent an overall linear regression of yield on day of lactation, the seven (b_{i0}) and eight ($b_{i3}t_{ij}$) terms describe the deviations from the overall regression for cow i, and the ninth and tenth terms (spline and animal × spline) represent, respectively, a mean spline deviation and the deviation from the mean spline for cow i. Splines were fitted using 6 knots at days 20, 70, 120, 170, 220 and 270. e_{ij} is the residual error with variance assumed to be homogenous in this data.

This approach to fitting lactation curves using the mixed model smoothing method has been demonstrated to provide a more accurate means of predicting total lactation yields than other parametric curves (Woolliams & Waddington, 1998).

Persistency

Persistency was defined as the ability of a cow to maintain production after the peak. Using daily yields predicted from the mixed model, three different persistency measures (P1, P2 and P3) were calculated for each cow:

P1: Slope (multiplied by 100) of the line fitted using linear regression of daily yield on day of lactation from day 60 to day 220.

P2: The area under the lactation curve from day 121 to 180 divided by the area under the curve from day 1 to 60, expressed as a percentage.

P3: The 240-day lactation yield divided by peak lactational yield multiplied by 240 expressed as a percentage, i.e.

$$P3 = \frac{\text{240-day lactational yield}}{(\text{peak yield} \times 240)} \times 100$$

Large values of P1, P2 and P3 indicate high lactation persistency.

Statistical analysis

Phenotypic correlations between parameters of the lactation curve for yield of milk and each of its components were calculated using the CORR procedure of SAS (2001) considering lactation curves with lactation lengths greater or equal to 220 days. In a subsequent analysis, cows were classified into one of four quartiles evenly distributed according to lactation persistency P2 for fat plus protein yield. Parameters of the lactation curve for the top 25% (high persistency) and bottom 25% (low persistency) groups were calculated and multiple comparisons between groups of persistency were performed using the GLM procedure of SAS (2001).

RESULTS AND DISCUSSION

The initial data base contained records on 810 first lactations for the two cohorts. Lactations with fewer than 220 days in milk were removed, leaving 733 lactations. Descriptive statistics are shown in Table 1.

$$y_{ijmcp} = b_0 + sire_m + cg_c + b_1x_p + b_2x_p^2 + b_3t_j + b_{i0} + b_{i3}t_{ij} + \sum_{k=2}^{5} v_k z_k(t_{ij}) + \sum_{k=2}^{5} v_{ik} z_k(t_{ij}) + e_{ij}$$

TABLE 1: Descriptive statistics (mean ± SD) of the lactation curve for yields of milk and milk components and three measures of lactation persistency (P1, P2 and P3) from 733 first lactation crossbred Friesian-Jersey cows

	Milk	Fat	Protein	Lactose
Days in milk		256 ± 18		
Total yield (kg)	3074 ± 420	164 ± 20	119 ± 15	149 ± 20
Yield at peak (kg)	15.6 ± 2.0	0.80 ± 0.10	0.58 ± 0.07	0.78 ± 0.10
Day at peak	46 ± 27	40 ± 37	49 ± 35	45 ± 26
P1[1]	-4.72 ± 1.06	-0.20 ± 0.04	-0.17 ± 0.04	-0.26 ± 0.05
P2[1]	77 ± 13	80 ± 14	81 ± 14	74 ± 13
P3[1]	79 ± 5	81 ± 6	81 ± 4	77 ± 5

[1]Measures of lactation persistency. P1, slope (multiplied by 100) of the line fitted using linear regression of daily yield on day of lactation from day 60 to day 220; P2, the area under the lactation curve from day 121 to 180 divided the area under the curve from day 1 to 60, expressed as a percentage; and P3, the 240-day lactation yield divided by peak yield multiplied by 240, expressed as a percentage.

Average milk yield was 3074 kg milk in 256 days in milk. Milk yield at peak was 15.6 kg at day 46 after the start of the lactation. The average decline in daily milk yield from day 60 to day 220 (P1) was 0.047 kg per day and the average proportion of milk produced from day 121 to 180 with respect to the production from day 1 to 60 (P2) was 77%.

Correlations between parameters of the lactation curve for yields of milk, fat, protein and lactose are shown in Tables 2 and 3. Correlation between total and peak yield was greater than 0.63 indicating that cows with high peak yields will achieve high total yields. High phenotypic and genetic correlations between total and peak yields have consistently been reported in many other studies (Madsen, 1975; Ferris *et al*., 1985; Batra *et al*., 1987; Sölkner & Fuchs, 1987; Tekerli *et al*., 2000; Muir *et al*., 2004).

The three measures of persistency were negatively correlated with peak yield for all milk traits ranging from -0.28 to -0.73 ($P < 0.001$). Similar estimates of this phenotypic correlation have been estimated in other populations of dairy cattle (Madsen, 1975; Tekerli *et al*., 2000; Muir, 2004). This phenotypic correlation indicates that cows that achieve high peak yields tend to have a high rate of decline of daily yield after the peak (less persistency). Other studies (Batra *et al*., 1987; Ferris *et al*., 1985) reported this correlation close to zero or significantly positive (0.70) when total yield was adjusted to 305 days in milk.

Correlations between total yields of milk and fat with persistency P2 were positive and significantly different to zero ($P < 0.001$). Correlations between total yields of all milk traits with persistency P3 were positive and significantly different to zero ($P < 0.001$). In contrast, total yields of all milk traits were negatively and significantly related to P1 ($P < 0.001$). These results indicate that the correlation between persistency and total yield is dependent on the way persistency is calculated. Phenotypic correlations between total yield and persistency have been reported close to zero (Ferris *et al*., 1985), negative (Madsen, 1975; Muir *et al*., 2004) or positive (Madsen, 1975; Batra *et al*., 1987; Tekerli *et al*., 2000) depending how persistency was defined as found in the present study. Clearly, there is a relationship between the shape of the lactation curve and total yield.

Swalve and Gengler (1999) indicated that a good measure of persistency should be independent of total yield. Total yield is a measure of the area below the lactation curve, and the yield at every day of the lactation is a function of the curve. A cow that has very high peak yield will tend to have a steeper slope after peak compared to a cow with a low peak therefore creating an inevitable relationship between yield and persistency when persistency is measured as rate of decline in milk after peak as found in this study (negative correlation between P1 and total yield). Van Raden (1998) proposed a methodology to calculate persistency independent of total yield and this appears to be an efficient way to select for total yield and persistency simultaneously.

The estimates of phenotypic correlations between peak day and peak yield are negative and significantly different to zero ($P < 0.001$) within each milk trait. In contrast, the estimates of phenotypic correlations between peak day and persistency are positive and significantly different to zero ($P < 0.001$), except for protein yield. These results indicate that cows with higher persistency will peak later than cows with lower persistency. Similar trends were found in Canadian (Muir, 2004) and Turkish (Tekerli *et al*., 2000) Holstein cattle.

Least squares means of parameters of the lactation curve for milk traits and for each of the two groups of cows classified by P2 are shown in Table 4. Compared with cows of low persistency for fat plus protein yield (bottom 25%), cows with high persistency (top 25%) had significantly ($P < 0.05$) more days in milk, higher total yields of milk and its components, lower peak yields, later day of peak yield and lower rate of decline in daily yield from day 60 to day 220 (P1). These differences are better illustrated in Figure 1. These results agree well with the estimated correlations between the parameters of the lactation curve found in this study (Tables 2 and 3). Danell (1982) found that persistency is less related to total yield when the latter is adjusted to 305 days. A similar trend was observed in this study, when total yield of fat plus protein was adjusted to 240 days, there were no significant differences between high and low persistency cows (see Table 4).

Figure 1 on page 305 shows the difference in the lactation curves between high and low persistency cows. Farmers with cows of high persistency may have some economic advantages compared to farmers with cows of low persistency. The main economic benefits from farming high persistency cows may come from the savings on peak notes investments and less risks of metabolic problems and reproductive failures. The relationship between reproduction traits with persistency will be studied using data from this experiment.

In this study persistency was calculated in three different ways. Correlations among estimates of persistency, within each milk trait, were all positive and significantly different to zero (P < 0.001) ranging from 0.24 to 0.81. Similar phenotypic correlations between different measures of persistency of milk yield were reported by Madsen (1975) and Tekerli *et al*. (2000). This highlights the need to define persistency in a more consistent way because the measures of persistency were not invariant (correlations less than 1) and were calculated using different periods of the lactation.

The different measures of lactation persistency estimated for each cows in this study will be used for the identification of quantitative trait loci in NZ dairy cattle. The economic benefits of including lactation persistency into the breeding program dairy cattle have to be carefully evaluated and demand further studies.

TABLE 2: Correlations between parameters of the lactation curve for milk yield (above the diagonal) and lactose yield (below the diagonal).

	Total yield	Yield at peak	Day at peak	P1[1]	P2[1]	P3[1]
Total yield	…	0.75***	0.20***	-0.33***	0.24***	0.33***
Yield at peak	0.79***	…	-0.26***	-0.71***	-0.28***	-0.30***
Day at peak	-0.04NS	-0.46***	…	0.17***	0.83***	0.73***
P1	-0.43***	-0.73***	0.26***	…	0.43***	0.51***
P2	0.00NS	-0.45***	0.83***	0.49***	…	0.81***
P3	0.18***	-0.39***	0.73***	0.53***	0.79***	…

[1]Measures of lactation persistency. P1, slope (multiplied by 100) of the line fitted using linear regression of daily yield on day of lactation from day 60 to day 220; P2, the area under the lactation curve from day 121 to 180 divided the area under the curve from day 1 to 60, expressed as a percentage; and P3, the 240-day lactation yield divided by peak yield multiplied by 240, expressed as a percentage.

NS Non significantly different to zero

***Significantly different to zero

TABLE 3: Correlations between parameters of the lactation curve for protein yield (above the diagonal) and fat yield (below the diagonal).

	Total yield	Yield at peak	Day at peak	P1[1]	P2[1]	P3[1]
Total yield	…	0.73***	0.04NS	-0.29***	0.07NS	0.27***
Yield at peak	0.63***	…	-0.34***	-0.54***	-0.33***	-0.37***
Day at peak	0.00NS	-0.47***	…	0.00NS	0.86***	0.54***
P1	-0.26***	-0.61***	0.21***	…	0.24***	0.39***
P2	0.12***	-0.48***	0.79***	0.44***	…	0.57***
P3	0.20***	-0.55***	0.64***	0.46***	0.79***	…

[1]Measures of lactation persistency. P1, slope (multiplied by 100) of the line fitted using linear regression of daily yield on day of lactation from day 60 to day 220; P2, the area under the lactation curve from day 121 to 180 divided the area under the curve from day 1 to 60, expressed as a percentage; and P3, the 240-day lactation yield divided by peak yield multiplied by 240, expressed as a percentage.

NS Non significantly different to zero

***Significantly different to zero

TABLE 4: Least squares means of parameters of the lactation curve for groups of cows classified into high or low persistency P2[1] for fat plus crude protein

	Group of persistency P2 for fat + crude protein yield		
	High	Low	SEM
Days in milk	265[a]	249[b]	1.2
Total yield			
Milk	3147[a]	2976[b]	31
Fat	168[a]	158[b]	1.5
Protein	120[a]	116[b]	1.1
Lactose	148[a]	146[a]	1.4
240-day fat + protein	267[a]	266[a]	2.0
Peak yield			
Milk	14.7[a]	16.5[b]	0.14
Fat	0.75[a]	0.86[b]	0.007
Protein	0.55[a]	0.61[b]	0.005
Lactose	0.71[a]	0.83[b]	0.007
Day at peak			
Milk	69[a]	27[b]	1.6
Fat	74[a]	18[b]	2.2
Protein	83[a]	23[b]	2.0
Lactose	67[a]	27[b]	1.6
P1[1]			
Milk	-3.87[a]	-5.63[b]	0.063
Fat	-0.16[a]	-0.24[b]	0.002
Protein	-0.15[a]	-0.20[b]	0.002
Lactose	-0.22[a]	-0.30[b]	0.003
P2[1]			
Milk	93[a]	65[b]	0.6
Fat	97[a]	66[b]	0.6
Protein	98[a]	69[b]	0.6
Lactose	90[a]	62[b]	0.7
P3[1]			
Milk	83[a]	73[b]	0.2
Fat	86[a]	75[b]	0.3
Protein	84[a]	77[b]	0.2
Lactose	84[a]	74[b]	0.2

[1]Measures of lactation persistency. P1, slope (multiplied by 100) of the line fitted using linear regression of daily yield on day of lactation from day 60 to day 220; P2, the area under the lactation curve from day 121 to 180 divided the area under the curve from day 1 to 60, expressed as a percentage; and P3, the 240-day lactation yield divided by peak yield multiplied by 240, expressed as a percentage

[ab]Least squares means within the same row with different superscript differ significantly ($P < 0.05$)

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the skilful care and assistance of the staff collecting the records and the first author acknowledges the financial assistance of Livestock Improvement Corporation.

REFERENCES

Bar-Anan, R.; Ron, M.; Wiggans, G. R. 1985: Association among milk yield, yield persistency, conception, and culling of Israeli Holstein dairy cattle. *Journal of dairy science 68:* 382-386

Batra, T. R.; Lin, C. Y.; McAllister, A. J.; Lee, A. J.; Roy, G. L.; Vesely, J. A.; Wauthy, J. M.; Winter, K. A. 1987: Multitrait estimation of genetic parameters of lactation curves in Holstein heifers. *Journal of dairy science 70:* 2105-2111

Boichard, D.; Grohs, C.; Bourgeois, F.; Cerqueira, F.; Faugeras, R.; Neau, A.; Ruppa, R.; Amigues, Y.; Boscher, M. Y.; Leveziel, H. 2003: Detection of genes influencing economic traits in three French dairy cattle breeds. *Genetics, selection, evolution 35:* 77-101

Danell, B. 1982. Studies on lactation yield and individual test-day yields of Swedish dairy cows. III. Persistency of milk yield and its correlation with lactation yield. *Acta agriculturae Scandinavica 32:* 93-101

Dekkers, J. C. M.; Ten Hag, J. H.; Weersink, A. 1998: Economic aspects of persistency of lactation in dairy cattle. *Livestock production science 53:* 237-252

Ferris, T. A.; Mao, I. L.; Anderson, C. R. 1985: Selecting for lactation curve and milk yield in dairy cattle. *Journal of dairy science 68:* 1438-1448

Gilmour, A. R.; Gogel, B. J.; Cullis, B. R.; Wellham, S. J.; Thompson, R. 2002: ASReml User Guide Release 1.0, VSN International Ltd., Hemel Hempstead, HP1 1ES, UK

Haile-Mariam, M.; Bowman, P. J.; Goddard, M. E. 2003: Genetic and environmental relationship among calving interval, survival, persistency of milk yield and somatic cell count in dairy cattle. *Livestock production science 80:* 189-200

Jakobsen, P.; Madsen, P.; Pedersen, J.; Chrisensen, L. G.; Sorensen, D. A. 2002: Genetic parameters for milk production and persistency for Danish Holsteins estimated in random regression models using REML. *Journal of dairy science 85:* 1607-1616

Jamrozik, J.; Schaeffer, L. R.; Dekkers, J. C. M. 1997: Genetic evaluation of dairy cattle using test day yields and random regression model. *Journal of dairy science 80:* 1217-1226

Lean, I. J.; Galland, J. C.; Scott, J. L. 1989: Relationships between fertility, peak milk yields and lactational persistency in dairy cows. *Theriogenology 31:* 1093-1103. 1989

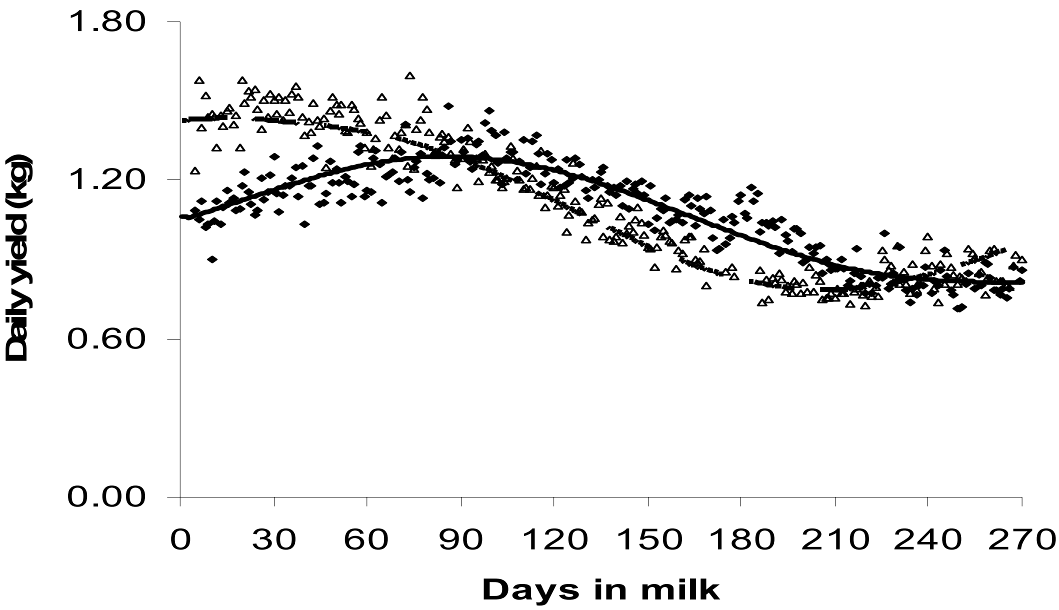
Madsen, O. 1975. A comparison of some suggested measures of persistency of milk yield in dairy cows. *Animal production 20:* 191-197

Muir, B.L. 2004: Genetics of lactation persistency and relationships with reproductive performance in Holsteins. Ph D Thesis. University of Guelph. Guelph, Ontario, Canada

Muir, B. L.; Fatehi, J.; Schaeffer, L. R. 2004: Genetic relationships between persistency and reproductive performance in first-lactation Canadian Holsteins. *Journal of dairy science 87:* 3029-3037

Rodriguez-Zas, S. L.; Southey, B. R.; Heyen, D. W.; Lewin, H. A. 2002: Detection of quantitative trait loci influencing dairy traits using a model for longitudinal data. *Journal of dairy science 85:* 2681-2691

FIGURE 1: Lactation curves for fat plus protein yield of first lactation crossbred grazing cows. Averages of actual (♦) and predicted (–––) daily yields of high persistency cows and averages of actual (Δ) and predicted (– –) daily yields of low persistency cows.



SAS. 2001. SAS/STAT software: changes and enhancements, release 8.2. SAS Institute Inc., Cary, NC, USA

Sölkner, J.; Fuchs, W. 1987: A comparison of different measures of persistency with special respect to variation of test day milk yields. *Livestock production science 16:* 305-319

Spelman, R. J.; Hooper, J. D.; Stanley, G.; Kayis, S.A.; Harcourt, S. 2004: Friesian Jersey crossbreed trial: Generating phenotypes for the discovery of quantitative trait loci. *Proceedings of the New Zealand Society of Animal Production 64:* 92-95

Swalve, H. H.; Gengler, N. 1999: Genetics of lactation persistency. *In*: Oldham, J. D.; Simm, G.; Groen, A. F.; Neilsen, B. L.; Pryce, J. E.; Lawrence, T. L. J. *ed*. Metabolic stress in dairy Cows. Occasional Publication No. 24. British Society of Animal Science. Pp. 75-82

Tekerli, M.; Akinci, Z.; Dogan, I.; Akcan, A. 2000. Factors affecting the shape of lactation curves of Holstein cows from the Balikesir province of Turkey. *Journal of dairy science 83:* 1381-1386

Togashi, K.; Lin, C. Y. 2003: Modifying the lactation curve to improve lactation milk and persistency. *Journal of dairy science 86:* 1487-1493

Van Raden, P. M. 1998: Best prediction of lactation yield and persistency. *Proceedings of the 6th World Congress on Genetics Applied to Livestock Production. Armidale, Australia. 23:* 347-350

White, I. M. S.; Thompson, R.; Brotherstone, S. 1999: Genetic and environmental smoothing of lactation curves with cubic splines. *Journal of dairy science 82:* 632-638

Wilmink, J. B. M. 1987. Comparison of different methods of predicting 305-day milk yield using means calculated from within-herd lactation curves. *Livestock production science 17:* 1-17

Wood, P. D. P. 1970: A note on the repeatability of parameters of the lactation curve in cattle. *Animal production 12:* 535-538

Woolliams, J. A.; Waddington, D. 1998: The effectiveness of mixed-model smoothing for prediction of lactation yields. *Proceedings of the British Society of Animal Science.* Pp.10