The relationship between lactation persistency and reproductive performance in New Zealand dairy cattle

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ABSTRACT

The objective of this study was to investigate the relationship between lactation persistency for milk yield (PerM) and fertility traits in first lactation grazing cows in New Zealand. Milk herd-test records from 810 first lactation cows were used to obtain individual lactation curves using a random regression model fitting five knots splines. All cows were second cross Friesian x Jersey from a crossbreeding experiment established for quantitative trait loci identification. PerM was defined as the proportion of milk yield from day 121 to day 180 with respect to milk yield from day 1 to day 60. Measurements of reproductive performance, typical of seasonal grazing systems were calculated for each cow. Cows were classified into one of four quartiles evenly distributed according to lactation persistency. Compared to low persistency cows (bottom 25%), high persistency cows (top 25%) had higher total milk yield (3113 vs 2791 kg; P<0.001), lower peak yield (14.8 kg vs 16.2; P<0.001), higher proportion of cows cycling at the start of mating season (96 vs 89%; P<0.05) but they had similar proportion of pregnant cows at 24 days after the start of the mating season (69 vs 67%) and at the end of the mating season (90 vs 94%). PerM was negatively correlated to intervals from calving to first heat (-0.13, P<0.001) and from the start of the mating season to first mating (-0.15, P<0.001). These results suggest that there is relationship between reproductive performance and lactation persistency in New Zealand crossbred dairy cattle.

INTRODUCTION

Milk production in New Zealand is almost entirely based on high quality fresh pasture. There is a seasonal pattern of milk production determined by the seasonal pattern of pasture production, to which the lactation curve of milk production of the dairy cow and the calving pattern of the dairy herds are synchronised. This minimises the need for harvesting pasture surplus or feeding supplements and has traditionally been achieved by calving cows in spring and running cows at high stocking rates in order to harvest the rapid growth that occurs in spring.

A seasonally concentrated spring calving pattern is achieved by a concentrated period of mating in late spring. The farmer starts the mating season on a fixed calendar date between late September and early November. Once the mating season has started, every cow detected in oestrus will be mated irrespective of the number of days since calving. Cows are bred by artificial insemination for first 6 to 8 weeks and by natural mating for about 4 weeks. The objective of the farmer is to achieve the highest pregnancy rate during the six first weeks after the starting of the mating season. A calving interval of 365 days is maintained because cows that do not get pregnant during the mating season are generally culled.

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 (Sölkner and Fuchs, 1987; Swalve and Gengler, 1999; Tekerli et al., 2000). There are several ways to calculate lactation persistency but no consensus has been reached on a suitable method (Swalve and Gengler, 1999). Studies in other countries have shown that persistency is a trait of economic importance and have promoted its inclusion in the selection objective (Sölkner and 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 and 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 and Lin, 2003).

A crossbreeding experiment with Friesian and Jersey breeds has been established to identify the underlying genetic differences between these two breeds and to exploit the results through marker assisted selection (Spelman et al., 2004). Approximately 810 second cross cows have calved as two-year-olds and completed their first lactation. These cows will be milked for four lactations. Extensive phenotype information will be collected on milk production and milk characteristics, reproduction, health and disease and growth and development. This study reports the relationship the relationship between lactation persistency and fertility traits in first lactation grazing crossbred cows.

MATERIAL AND METHODS

Data

Daily herd-test records of milk yield from 810 first lactation cows of the crossbreeding experiment were used to obtain individual lactation curves. 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 rotary 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. Reproductive data for each cow included dates of heat detections, inseminations and calvings (Sanders et al., 2004) and were merged with the productive data set.

Lactation curve function

Individual lactation curves for daily yields of milk 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:

$$y_{ijmcp} = b_0 + sire_m + cg_c + b_1 x_p + b_2 x_p^2 + b_3 t_j + b_{i0} + b_{i3} t_{ij} + \sum_{k=2}^{5} v_k z_k(t_{ij}) + \sum_{k=2}^{5} v_{ik} z_k(t_{ij}) + e_{ij}$$

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 and Waddington, 1998).

Milk traits

Phenotypes describing the lactation curve were calculated for each cow using daily yields predicted from the mixed model. The following traits were calculated: total predicted milk yield (MILK) based on actual days in milk (DIM), milk yield at peak (PeakM), day in milk of peak milk yield (PeakD) and a measure of lactation persistency (PerM) calculated as 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. Large values of PerM indicate high lactation persistency.

Measures of Fertility

Several fertility traits were defined for each the 810 cows using dates of heat detection, calving dates, mating dates and pregnancy tests (Sanders et al., 2004). The following fertility traits were defined to describe the reproductive performance of this experimental herd: interval from calving to first heat (CFH), interval from start of mating season to first mating (SMFM), interval from start of mating season to conception (SMCO), percentage of cows cycling within the first 42 days after calving (PC42), percentage of cows cycling at the start of the mating season (PCSM), percentage of cows pregnant at 24 days after start of the mating season (PR24) and percentage of cows pregnant at the end of the mating season (PREM). Interval from calving to conception was calculated but is not reported in this study because this phenotype is distorted by the effect of calving spread and a fixed date for the start of the mating season.

Statistical analysis

Phenotypic correlations between parameters of the lactation curve for yield of milk and fertility traits were calculated using the CORR procedure of the Statistical Analysis System, version 9.1 (SAS Institute, Cary, NC, USA), considering lactation curves with lactation lengths greater or equal to 180 days and cows that did not received anoestrous treatment. After imposing this restriction only 731 cows were analysed. The percentage of cows treated for anoestrous problems with controlled intravaginal drug release devices (CIDR™) was 7%.

In a subsequent analysis, cows were classified into one of four quartiles evenly distributed according to PerM. Parameters of the lactation curve and fertility traits for the top 25% (high PerM) and bottom 25% (low PerM) groups were calculated and multiple comparisons between groups of PerM were performed using the GLM (for continuos traits) and GENMOD (for binomial traits) procedures of the Statistical Analysis System, version 9.1 (SAS Institute, Cary, NC, USA). The linear model for milk traits included only the fixed effect persistency class because these phenotypes were already adjusted by other environmental factors when the individual lactation curves were derived. The linear model for fertility traits considered the effects of persistency class and year of calving with mean calving date (within year) as a covariable.

RESULTS AND DISCUSSION

Descriptive statistics of productive and reproductive performance

Descriptive statistics for the traits analysed are shown in Table 1. Average total milk yield was 3023 kg milk in 252 days in milk. Milk yield at peak was 15.6 kg at day 46 after the start of the lactation. These values are representative of typical of first calving cows under commercial grazing conditions of New Zealand (Livestock Improvement, 2004). The average proportion of milk produced from day 121 to 180 with respect to the production from day 1 to 60 was 76.3%.

Table 1. Descriptive statistics (mean ± SD) of the lactation curve for milk yield and fertility traits of 731 first lactation crossbred Friesian-Jersey cows.

Trait	N	Mean	SD
DIM (days)	731	252	22
MILK (kg)	731	3023	457
PeakM (kg)	731	15.6	2.0
PeakD (days)	731	46.0	28.9
PerM (%)	731	76.3	13.1
CFH (days)	730	40.8	19.9
SMFM (days)	730	9.8	7.7
SMCO (days)	671	19.0	16.9
PC42 (%)	731	54	49
PCSM (%)	731	92	27
PR24 (%)	731	68	47
PREM (%)	731	92	27

[1]MILK = total predicted milk yield based on actual days in milk (DIM); PeakM = milk yield at peak; PeakD = day in milk of peak milk yield; PerM = lactation persistency calculated as the area under the lactation curve from day 121 to 180 divided by the area under the curve from day 1 to 60; CFH = interval from calving to first heat; SMFM = interval from start of the mating season to first mating; SMCO = interval from start of the mating season to conception; PC42 = percentage of cows cycling within the first 42 days after calving; PCSM = percentage of cows cycling at the start of the mating season; PR24 = percentage of cows pregnant at 24 days after start of the mating season; PREM = percentage of cows pregnant at the end of the mating season.

The average CFH, SMFM and SMCO intervals were 40.8, 9.8 and 19.0 days. These values were similar to those reported by Macmillan et al. (1987) but lower than those reported by Grosshans et al. (1997). Macmillan et al. (1987) reported means of 48.5, 12.9 and 24.8 for CFH, SMFM and SMCO whereas Grosshans (1997) reported means of 18.7 and 33.3 days for SMFM and SMCO. This study did not included cows treated for anoestrus problems but means can be only slightly higher when those cows will included in the analysis (Macmillan et al., 1987). Pregnancy rate at 24 days after the mating season was 68% which is similar to the value of 72% reported by Harris et al. (2000). Results form this study shows that reproductive performance of this experimental herd is similar to commercial herds. The final pregnancy rate considering only cows that did not received anoestrus treatment is this study was 92% which is similar to that reported by Macmillan et al. (1987).

Phenotypic correlations

Estimates of phenotypic correlations between production and fertility traits are presented in Table 2. The phenotypic correlation between PeakM and MILK was 0.73 and significantly different to zero ($P<0.001$) indicating that cows with high peak yields achieve high total yields. High phenotypic correlations between total and peak yields have consistently been reported in other studies (Sölkner and Fuchs, 1987; Tekerli et al., 2000; Muir, 2004). The correlation between PerM and PeakM was negative (-0.22) and significantly different to zero ($P<0.001$). Similar estimates of this phenotypic correlation have been estimated in other populations of dairy cattle (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 persistent). Other studies (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. The estimate of phenotypic correlation between PeakD and PeakM was negative and significantly different to zero (-0.31; $P<0.001$). In contrast, the correlation between PeakD and PerM was positive and significantly different to zero (0.72; $P<0.001$). 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.

The two traits related to the start of mating, SMFM and SMCO, were negatively related to PR24 (-0.15 and -0.84, $P<0.001$). These estimates suggest that when a high proportion of cows are pregnant at 24 days after the start of the mating season, intervals SMFM and SMCO are shortened. Similar values were reported by Grosshans et al. (1997).

Pregnancy rate at 24 days after the start of the mating season was positively related to pregnancy rate at the end of the mating season (0.43, $P<0.001$). Grosshans (1997) reported a phenotypic correlation between pregnancy rate at 21 and 42 days after the start of the mating season of 0.54 in first lactation cows.

The correlations between milk and fertility traits are presented in Table 2. All correlations between MILK and fertility traits were close to zero except with CFH (0.11, $P<0.001$), which indicates that high yielding cows tended to have longer intervals from calving to first heat. Grosshans (1997) reported nosignificant phenotypic correlations between level of production and fertility in first lactation grazing cows in New Zealand. Muir (2004) reported a low correlation between 305-day milk yield and non-return rate at 56 days after first calving in Canadian dairy cows. However moderate antagonistic genetic correlations between milk production and fertility traits have been reported in New Zealand (Grosshans et al., 1997) and other countries (Pryce et al., 1997; Abdallah and McDaniel, 2000).

Table 2. Pearson correlation coefficients between milk and fertility traits in first lactation crossbred Friesian-Jersey cows (n=731 cows).

Trait[1]	MILK	PeakM	PeakD	PerM	CFH	SMFM	SMCO	PC42	PCSM	PR24	PREM
DIM	0.57***	0.00	0.25***	0.46***	0.11**	-0.14***	-0.10**	-0.10**	0.16***	-0.03	-0.13***
MILK		0.73***	0.11**	0.33***	0.11**	-0.06	-0.02	-0.09*	0.09*	-0.05	-0.07*
PeakM			-0.31***	-0.22***	0.09*	0.07	0.04	-0.07	-0.06	-0.02	0.00
PeakD				0.72***	-0.11**	-0.14***	-0.08*	0.13***	0.18***	0.05	0.04
PerM					-0.13***	-0.15***	-0.03	0.13***	0.20***	-0.01	0.02
CFH						0.11**	0.08*	-0.83***	-0.46***	-0.06	-0.04
SMFM							0.31***	-0.03	-0.25***	-0.15***	-0.06
SMCO								-0.02	-0.14***	-0.84***	NE
PC42									0.26***	0.00	0.02
PCSM										0.10**	-0.01
PR24											0.43***

Levels of significance: * P<0.05; P<0.01; P<0.001; NE = Non estimable.

MILK = total predicted milk yield based on actual days in milk (DIM); PeakM = milk yield at peak; PeakD = day in milk of peak milk yield; PerM = lactation persistency calculated as the area under the lactation curve from day 121 to 180 divided by the area under the curve from day 1 to 60; CFH = interval from calving to first heat; SMFM = interval from start of the mating season to first mating; SMCO = interval from start of the mating season to conception; PC42 = percentage of cows cycling within the first 42 days after calving; PCSM = percentage of cows cycling at the start of the mating season; PR24 = percentage of cows pregnant at 24 days after start of the mating season; PREM = percentage of cows pregnant at the end of the mating season.

Some fertility traits were significantly related to PerM (P<0.001) including CFH (-0.31), SMFM (-0.15), PC42 (0.13) and PCSM (0.20). These results indicate that cows with higher lactational milk persistency tend to have shorter intervals from calving to first heat and from start of the mating season to first mating, resulting in higher percentage of cows cycling at 42 days after calving and at the start of mating season. However, PR24 and PREM were not related to PerM. Muir (2004) reported a low phenotypic correlation but a moderate genetic correlation (0.32) between milk persistency and non-return rate at 56 days after first calving in Canadian dairy cows. Bar-Anan et al. (1985) reported moderate phenotypic (0.34, P<0.001) and genetic (0.42) correlations between lactational persistency and conception rate at first and second inseminations in Israeli Holstein dairy cattle. Haile-Mariam et al. (2003) reported a correlation close to zero between persistency and calving interval in Australian dairy cows.

Comparing high and low persistency cows

Least squares means of milk and fertility traits for each of the two groups of cows classified by lactation persistency are presented in Table 3. Compared to cows of low persistency for milk yield (bottom 25%), cows with high persistency (top 25%) had significantly (P<0.001) more days in milk, higher total milk yield, lower peak yield and later day of peak yield. These results agree well with the estimated correlations between the parameters of the lactation curve found in this study (Table 2). Cows of high lactation persistency had higher proportion of cows cycling at the start of mating season (96 vs 89%; P<0.05) than cows of low lactation persistency. Least squares means for other fertility traits were not significantly different between the two groups of cows.

In this study cows treated by anoestrus problems with CIDR^{TM} were not included to avoid the distortion of the estimates of reproductive parameters. However, it is important to report that cows with high lactation persistency had lower percentage of CIDR^{TM} treatment than low lactation persistency cows (4.0% vs 7.9%; P = 0.073).

Results from this study suggest that there is relationship between reproductive performance and lactation persistency. Further analysis of these data will explore the relationship between reproductive performance and energy balance.

Table 3: Least squares means (LSM), 95% confidence interval (CI) and standard error of the mean (SEM) of parameters of the lactation curve for groups of cows classified into high or low persistency for milk yield.

	Group of lactation persistency					
	High		Low			
Trait[1]	LSM	95% CI	LSM	95% CI	SEM	P[2]
DIM (days)	264		236		1.5	***
MILK (kg)	3113		2791		34	***
PeakM (kg)	14.8		16.2		0.2	***
PeakD (days)	67		28		2.0	***
PerM (%)	89		63		0.7	***
CFH (days)	39.5		39.4		1.5	NS
SMFM (days)	9.7		10.2		0.6	NS
SMCO (days)	18.6		19.3		1.3	NS
PC42 (%)	61	53 - 69	56	48 - 65		NS
PCSM (%)	96	92 - 99	89	85 - 94		*
PR24 (%)	69	61 - 75	67	58 - 74		NS
PREM (%)	90	84 - 94	94	89 - 97		NS

[1]MILK = total predicted milk yield based on actual days in milk (DIM); PeakM = milk yield at peak; PeakD = day in milk of peak milk yield; PerM = lactation persistency calculated as the area under the lactation curve from day 121 to 180 divided by the area under the curve from day 1 to 60; CFH = interval from calving to first heat; SMFM = interval from start of the mating season to first mating; SMCO = interval from start of the mating season to conception; PC42 = percentage of cows cycling within the first 42 days after calving; PCSM = percentage of cows cycling at the start of the mating season; PR24 = percentage of cows pregnant at 24 days after start of the mating season; PREM = percentage of cows pregnant at the end of the mating season.

[2]Levels of significance to test significant differences between groups of lactation persistency: * P<0.05; P<0.01; P<0.001; NS = Not significant.

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