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The genetic relationship between heifer and cow fertility

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ABSTRACT

Initial predictors of dairy bulls' fertility proofs are currently limited to body condition score (BCS), milk yield and success of mating in the first 21 days (PM21) for their two-year-old lactating daughters. The first calving rate trait (CR42) is available after a cow has calved for a second time. Obtaining an earlier indication of fertility would be useful for genetic evaluation purposes. The aim of this study was to investigate the genetic and phenotypic control of heifer fertility in addition to investigating the relationship between heifer fertility and traits already included in the prediction of the fertility breeding value. Data were available on LIC's Sire Proving Scheme animals born from 1989 to 2003 and included records on 244,453 animals. Using data on the first calving, planned start of calving was defined as the day within contemporary group when greater than 10% of animals had calved. A multivariate genetic analysis was undertaken with the traits PM21, CR42, BCS and 270-day milk yield recorded in lactating cows, in addition to a heifer fertility trait where success is defined as heifers that calve within 21 days from the planned start of calving (CR21). The model fitted to these traits included contemporary group of the milking herd, breed proportions and age at first calving as linear and quadratic effects. The mean CR21 in this dataset was 71%. Heifers failing to calve within 21 days of the herd's planned start of calving for heifers also had poorer fertility in first lactation, with a least-squares-mean of 75.5% (s.e. 0.2) versus 81.5% (0.1) for PM21 and 54.2% (0.22) and 62.4% (0.1) for CR42. The heritability estimate of CR21 was low (0.012), yet the genetic variation was comparable to other fertility measures. CR21 had a positive genetic correlation with CR42, indicating that CR21 may be a useful early indicator of fertility for use in genetic evaluations.

Keywords: heifer fertility; genetic parameters.

INTRODUCTION

The current model for genetic evaluation of dairy cow fertility in New Zealand is based on eight traits measured after the first calving and include presented for mating in the first 21 days from the planned start of mating (PM21) in first, second and third lactations; success or failure of calving in the first 42 days from the herd's planned start of calving (CR42) for their second, third and fourth calvings (*e.g.* that correspond to the PM21 traits); in addition to milk yield and body condition score (BCS) measured in the first lactation. The fertility breeding value is expressed as the CR42 trait that initiates the second lactation.

First lactation PM21, BCS and milk yield are the first predictors on which a bull's fertility proof is based; these become available after around 100 days of lactation. The first CR42 trait is available after a cow has calved for a second time, being the result of mating in the first lactation. Using heifer fertility data would be useful, if the trait used is a good predictor of CR42, especially as it would be available before all other currently used indicators of cow fertility.

Estimates of genetic correlations between maiden heifer and lactating cow fertility are not consistent, ranging from 0.7 to 0.88 for Swedish Red and White (Oltenacu *et al*., 1991; Röxstrom *et al*., 2001) to 0.34 and 0.50 for non-return rates in Danish Jerseys and Black and whites respectively (Pedersen & Jensen, 1996) and 0.12 for non-return rates in Dutch Holsteins (de Jong, 1995).

The aim of this study was to define a suitable heifer fertility trait and subsequently estimate genetic parameters for the trait chosen including genetic and phenotypic relationships with cow fertility, with a view to assessing the suitability of a heifer fertility trait as an additional selection criterion in calculating fertility breeding values (BVs).

MATERIALS AND METHODS

Data

Data were available on Sire Proving Scheme animals born from 1989 to 2003 and included records on 244,453 animals.

Using data on the first calving, planned start of calving was defined as the day within the contemporary group (CG) when greater than 10% of animals had calved. If the difference between the planned start of calving and first calving date was less than seven days, then the first calving date in the contemporary group was used as the planned start of calving. Heifers that calved within 21 days from the planned start of calving (CR21) were classified as successful, while those with longer intervals were classified as fails.

Phenotypic analysis

Age-CG deviation was calculated as the age of the animal minus the mean age of heifers in the same CG at any given point in time. Six age groups were defined, approximating the six weeks from the birth of the first calf and corresponds with the typical period of artificial inseminations in New Zealand herds. Animals born outside this period (12,221 records or 5% of the records) were excluded from this analysis. ASReml (Gilmour *et al*., 2002) was used to calculate least squares means for each of the six age groups for the following traits: 1) interval from PSM to conception date, which was determined using subsequent calving records 2) CR21. The model included contemporary group, age group, breed proportions (New Zealand Holstein-Friesian, NZHF; Overseas origin Holstein-Friesian, OSHF and Jersey, J) and heterosis (crosses between these breeds, NZHFxJ, OSHFxJ and NZHFxOSHF).

The relationship between age-CG deviation and the following traits was estimated using regression analysis: age at calving; presented for mating in the first 21 days in the first lactation (PM21); calving in the first 42 days from the planned start of calving (2nd calving) (CR42); first lactation 270-day cumulative milk volume (milk); body condition score in the first lactation (BCS); liveweight in the first lactation (LWT); and survival to completion of the first lactation (surv1).

Variance component analysis

The model fitted to CR21 included contemporary group of rearing, breed proportions and heterosis (NZHF, OSHF, J, NZHFxJ, OSHFxJ and NZHFxOSHF) and age-CG deviation as linear and quadratic effects.

A multivariate analysis was performed using AIREML (Johnson & Thompson, 1995) that included PM21, CR42, BCS and 270-day milk yield recorded in first parity, in addition to CR21. The model fitted to traits other than CR21 included contemporary group of the milking herd, breed proportions and age at first calving as linear and quadratic effects.

Using the genetic parameters obtained from the analysis, the contribution of CR21 to predicting the fertility BV was assessed using selection index theory (Hazel, 1943).

RESULTS

Phenotypic analysis

The mean heifer fertility, CR21, in the dataset was 71% while CR42, fertility in first lactation cows, was 60% (Table 1). Heifers failing to calve within 21 days of the herd's heifer-planned start of calving had poorer fertility in first lactation, with a least-squares-mean of 75.5% (s.e. 0.2) versus 81.5% (0.1) for PM21 and 54.2% (0.22) versus 62.4% (0.1) for CR42. Thus, poor fertility as a heifer translated into poorer fertility as a cow.

Older animals had shorter intervals from the planned start of mating to the conception date (determined using calving dates) and consequently had better rates of calving in the first 21 days from the planned start of calving (Table 2). Animals that were born earlier were obviously older at first calving, had better fertility in first lactation, produced more milk and survived longer (Table 3).

Table 1: Means and standard deviations (SD) of traits included in the genetic analysis.

	Records	Mean	SD
CR21	154907	0.71	0.44
PM21	146592	0.80	0.37
CR42	139717	0.60	0.38
BCS	54073	3.96	45.7
Milk	154917	14.76	506

CR21: calved within 21 days from planned start of calving including heifers that were culled prior to entering the herd; PM21: presented for mating within 21 days from the planned start of mating in the first lactation; CR42: calved within 42 days from the planned start of calving in first lactation; BCS: body condition score; Milk: First lactation 270-day cumulative milk yield deviations from CG mean (kg).

Table 2: Relationship between age-CG class (week of birth relative to first born contemporaries) and heifer fertility and culling.

Week of birth*	Interval from PSM to conception date (d) **	CR21** %
1	15.6 (0.11)	73.8 (0.3)
2	16.1 (0.09)	72.9 (0.3)
3	16.5 (0.07)	72.4 (0.2)
4	16.9 (0.07)	71.5 (0.2)
5	17.4 (0.09)	69.9 (0.3)
6	18.5 (0.11)	67.6 (0.3)

*Week of birth relative to first born contemporaries (oldest to youngest)
** confirmed using calving dates

Table 3: Relationship between stage of birth relative to contemporaries (in days) and first lactation indicators of fertility.

Trait	Regression coefficient
Age at calving (d)	0.88 (0.003)
PM21 %	0.13 (0.07)
CR42 %	0.12 (0.08)
Milk (d)	2.9 (0.09)
BCS	0.02 (0.012)
LWT (kg)	0.112 (0.003)
Survivability*	0.059 (0.006)

Survivability*: survival rate first to second lactation.

Genetic analysis

Breed and heterosis estimates for CR21 are presented in Table 4. Of the three breeds evaluated, NZHF had the most favourable effect on CR21, followed by Jerseys and OSHF; the difference in CR21 between the two HF strains was around 5%; these estimates should be treated cautiously as standard errors were large indicating that real differences may not exist. There were beneficial heterosis effects ranging from +0.9% to +2.9% for NZHFxOSHF to OSHFxJ respectively.

Table 4: Breed and heterosis estimates for CR21.

	Effect (%)
OSHF	-5.3% (3.3)
NZHF	-0.05% (3.0)
Jersey	-1.6% (3.0)
NZHFxJ	+2.2% (0.7)
OSHFxJ	+2.9% (1.1)
NZHFxOSHF	+0.9% (1.1)

The heritability estimate of CR21 was 0.012 (Table 5). CR21 had a positive genetic correlation with fertility measures in first lactation (CR42 and PM21), but genetic correlations with BCS and milk yield were not significantly different from zero; confirming that heifers that are genetically more fertile become more fertile cows, but that this relationship is independent of yield.

Assuming sires had on average 80 daughters, the accuracy of predicting CR42 was 16.8% when CR21 alone was available; when CR21, BCS, MY and PM21 were included the accuracy increased to 72.9%, becoming 76.3% when CR42 was available as well (Table 6).

Table 6: Accuracy of the fertility BV when different sources of information are included *e.g.* CR21 only, CR21 + BCS *etc*.

Traits included	Accuracy
CR21	16.8
CR21+BCS	44.7
CR21+BCS+PM21	72.4
CR21+BCS+PM21+Milk	72.9
CR21+BCS+PM21+Milk+CR42	76.3

DISCUSSION

Heifer fertility is phenotypically superior to cow fertility, with calving rates in the first 21 days from the planned start of calving of 71% in heifers compared to 60% in the first 42 days from the planned start of calving in cows calving for the second time (CR42). In our study, the trait definition of fertility used for heifers differs from cow fertility as an opportunity window of calving within 21 days from the planned start of calving is used to determine success or failure in heifers compared to 42 days in cows. Setting the opportunity window to 42 days in heifers would result in a very high proportion of successes, which would cause problems in identifying heifers that are more fertile; 21 days is the average length of the reproductive cycle and thus the shortest interval that should be used.

Production and, in turn, metabolic pressures in early lactation are widely believed to hamper reproductive performance (*e.g.* Pryce & Veerkamp, 2001). Thus as yields increase fertility declines, at the genetic as well as the phenotypic level (as both genetic and phenotypic correlations of yield traits with fertility are unfavourable *e.g.* Harris *et al*., 2006). Since lactational pressures impact on fertility, the genetic correlation between maiden heifer fertility and cow fertility is not expected to be as strong as genetic correlations between fertility in consecutive lactations.

We estimated that the genetic correlation between CR21 in heifers and CR42 was 0.38 (0.10), which is moderate, yet strong enough for consideration as a selection criterion for fertility; it is also comparable to the genetic correlations in Danish cattle estimated by Pedersen and Jensen (1996). The genetic correlation estimate between CR42 of second and third calvings has been reported to be 0.86 and between second and fourth calvings was 0.76 (Harris *et al*., 2006).

The phenotypic relationships between fertility in heifers and first lactation fertility, demonstrate that heifers that calve early as heifers have better fertility as cows, since there is a greater interval between calving and mating which allows more

Table 5: Genetic correlations between heifer fertility traits, first lactation fertility traits, body condition score and milk volume. Heritability on diagonal, genetic below diagonal, phenotypic above.

	CR21	PM21	CR42	BCS	Milk
CR21	**0.012 (0.003)**	0.050 (0.003)	0.053 (0.003)	0.020 (0.005)	0.071 (0.003)
PM21	0.24 (0.08)	**0.070 (0.005)**	0.270 (0.003)	0.119 (0.005)	-0.014 (0.003)
CR42	0.38 (0.10)	0.92 (0.04)	**0.027 (0.003)**	0.071 (0.005)	0.001 (0.003)
BCS	-0.04 (0.11)	0.54 (0.05)	0.48 (0.08)	**0.15 (0.01)**	-0.048 (0.005)
Milk	0.00 (0.06)	-0.18 (0.04)	-0.18 (0.05)	-0.03 (0.05)	**0.31 (0.01)**

opportunity to start cycling and become pregnant early as first lactation cows. The phenotypic relationships between age-CG deviation and measures of fertility demonstrate that there is an advantage in fertility and production of animals that are born early. This is because they calve earlier and have an opportunity to achieve more days in milk. Poorer rearing may contribute, but older animals have a longer period from puberty to insemination and are likely to be better grown by the time they calve. The relationship between heifer growth rates and onset of puberty in different age classes of heifers is worthy of further research to investigate whether poorer rearing contributes to the poorer fertility of late-born heifers; unfortunately heifer liveweights were not collected in the present study.

The value of including heifer fertility as an additional selection criterion for fertility was assessed using selection index theory. Including CR21 as a predictor of CR42 improves the accuracy of CR42 for a bull with 80 daughters by 0.3% when the traits available include CR21, PM21, CR42, BCS and milk volume. The value of CR21 is as an early predictor, by itself the accuracy of selecting for CR21 to predict CR42 was 16.8%; when CR21, BCS, milk and PM21 are available the accuracy is 72.9%. Without CR21 the accuracy would be 0.8% lower. The accuracy of selecting on CR42 alone was 59%. Therefore, there is some value in having the additional selection criteria. Adding heifer fertility to this list will have a small impact, but its main value is that it is available early; by the time other predictors become available, its contribution to the BV decreases and the accuracy of the BV increases.

The research described here is a preliminary investigation of incorporating maiden heifer fertility into the fertility BV. Further work is required to estimate genetic correlations between heifer fertility and second and third parity fertility and assessing the value of incorporating an additional selection criterion to the fertility BV.

REFERENCES

de Jong, G. 1995: Sire breeding values for daughters' fertility in the Netherlands. Proc. of the open session of the Interbull Annual Meeting, Prague, Czech Republic. Sept 7-8, 1995.

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

Harris, B.L.; Pryce, J.E.; Xu, Z.Z.; Montgomerie, W.A. 2006: Development of new fertility breeding values in the dairy industry. *Proceedings of the New Zealand Society of Animal Production* **66**: 107-112.

Hazel, L.N. 1943: The genetic basis of constructing selection indexes. *Genetics* **28**: 476-490.

Johnson, D.L.; Thompson R. 1995: Restricted maximum likelihood estimation of variance components for univariate models using sparse matrix techniques and average information. *Journal of Dairy Science* **78**: 449-456.

Oltenacu, P.A.; Frick, A.; Lindhe, B. 1991: Relationship of fertility to milk yield in Swedish cattle. *Journal of Dairy Science* **74**: 264-268.

Pedersen, J.; Jensen J. 1996: Evaluation of female fertility of Danish Sires. In: Groen, A.F.; Solkner, J.; Strandberg, E.; Gengler, N. ed. *Proceedings International Workshop on Genetic Improvement of Functional Traits in Cattle, Gembloux, Belgium, Interbull bulletin* **12**: 72-77.

Pryce, J.E.; Veerkamp, R.F 2001: The incorporation of fertility indices in genetic improvement programmes. In: Diskin, M.G. ed. Fertility in the High-Producing Dairy Cow. British Society of Animal Science Occasional Publication No. 26, Edinburgh, Scotland. Pp. 223–236.

Röxstrom, A.; Strandberg, E.; Berglund, B.; Emanuelson, U.; Philipsson, J. 2001: Genetic and environmental correlations among female fertility traits and milk production in different parities of Swedish Red and White dairy cattle. *Acta Agriculturae Scandinavica* **51**: 7-14.