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Genetic parameters for lactation yields of milk and milksolids of New Zealand pasture-based dairy cows undergoing standard and extended lactations

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Introduction

The typical New Zealand milk production system is a seasonal grazing, pasture-based system whereby cows begin lactating after calving in spring and are dried off in late autumn of the following year. For calving to occur annually in spring, a seasonally concentrated period breeding starts in October, which is also when cows are at peak milk production and feed demand, and when feed supply from low cost pasture is optimum. Under this standard lactation system, cows are milked for up to 300 days, largely depending on pasture availability, and cows that are not culled generally achieve a calving interval of about 12 months (Holmes *et al*. 2002).

Extending lactation by voluntarily extending the calving interval beyond the usual 12-month spring cycle has been proposed as a way of reducing the number of calvings per year, flattening seasonal peaks in labour demand and reducing the number of non-replacement calves (Stelwagen *et al*. 2024). However, if farmers deliberately transition their production systems to extended lactation and manage cows under these regimes, the estimation of breeding values for milk and milksolids (fat+protein) yields becomes necessary to select cows genetically suitable for extended lactation. One important trait to consider when identifying cows that are well adapted to extended lactation systems is lactation persistency, defined as the ability of a cow to maintain milk production beyond peak yield (Gengler 1996). Although definitions of persistency vary across the literature, heritability estimates for persistency range from 0.03 to 0.30 (Gengler 1996; Abdelsayed *et al*. 2015).

Evidence from Australian dairy cattle (Haile-Mariam and Goddard, 2008) suggests the existence of both phenotypic and genetic variation in the capacity of cows to continue milking for extended periods, and that information from a traditional 305-day lactation can be used to predict genetic merit for longer lactations. This supports the feasibility of incorporating persistency-related traits into New Zealand genetic evaluation systems to better align cow genetics with emerging extended lactation management strategies. This requires accurate estimates of the genetic variances and covariances associated with these traits. The objective of this study was to estimate genetic parameters for total yields of milk and milksolids of dairy cows undergoing standard and extended lactations under New Zealand grazing conditions.

Materials & Methods

Historic cow-level data from the Dairy Industry Good Animal Database (New Zealand Animal Evaluation Ltd, Hamilton, New Zealand) for the period from 2008 to 2023 was available for this study. The data included herd tests for individual cows (milk yield and percentages of milk fat and protein) and parameters such as sire, dam, breed, year born, calving dates, breeding dates, herd identification number, and dates cows were in each herd. As the focus of the study was on cows that had intentionally delayed breeding (i.e. an extended voluntary waiting period)

to achieve extend lactations (voluntary extended lactation), these cows needed to be distinguished from carry-over cows. Carry-over cows represent involuntary extended lactation, whereby cows failed to become pregnant during the seasonal breeding period but were continued to be milked beyond 305 days in milk. Cows that may have calved early and were bred late in a spring-calving system or had early breeding records but a longer calving interval indicating an involuntary extended lactation were removed from the dataset if their first breeding record was <230 days from calving (i.e. within the typical seasonal breeding period for a standard lactation). Only spring-calving cows, those calving between 1 June and 31 December, were retained in the dataset. Following the application of these selection criteria, 14 commercial and research dairy herds were identified as containing cows with extended and standard lactations. The final dataset comprised 19,154 standard (4.2 herd tests on average) and 5,223 extended (7.9 herd tests on average) lactation records from 2,791 Holstein-Friesian, 1,130 Jersey and 3,893 Holstein-Friesian×Jersey crossbred cows.

Standard and extended lactation curves were modelled using random regression models with a 4th order Legendre polynomial. A standard lactation was defined as when herd tests occurred between 15 and 410 days in milk and the animal in that lactation did not have herd tests after 410 days in milk. An extended lactation was defined as when the herd tests occurred between 15 and 670 days in milk. Persistency of lactation for milksolids was defined as (B/A)×100; where A was milk produced from day 1 to 305 and B was the total milk produced from day 306 up to 610.

Estimates of variances for total milk and milksolids yield were obtained using the ASReml program (Gilmour *et al.* 2021) with an animal model. The model included the fixed effects of herd year and month of calving, age at calving and breed group, and random effects of animal and residual. Estimates of covariances for the estimation of genetic and phenotypic correlations between total yields of milk and milksolids and lactation persistency of milksolids of standard and extended lactations were obtained using a bivariate animal model that included the same effects described in the univariate animal model. A total of 1,197 sires and 769 maternal grandsires were represented.

Results & Discussion

Descriptive statistics for total milk and milksolids yields for standard and extended lactations are presented in Table 1. The coefficients of variation for the traits were similar between standard and extended lactations. These results confirm New Zealand (Kolver *et al*. 2007) and Australian (Abdelsayed *et al.* 2013) studies reporting that there is phenotypic variation in the capacity of cows to continue milking for extended periods. The level of milk production of cows undergoing standard lactation considered in this study was slightly higher than the average values reported for New Zealand national herd for the period from 2008 to 2023: 4,149 L milk and 369 kg milksolids in 275 days in milk (LIC and DairyNZ, 2025).

Estimates of variance components and heritabilities for the studied traits are presented in Table 2. Heritability estimates for milksolids were similar between standard and extended lactations (0.29 and 0.30, respectively). Likewise, heritability estimates for milk yield were the same for standard and extended lactations, with both estimated at 0.40. These results indicate that selection for extended lactation is expected to be as feasible as selection for standard lactation. The heritability estimate for lactation persistency of milksolids was 0.34, which indicates that this trait can genetically be improved. The heritability estimates in this study are higher than few estimates reported in the literature for grazing cows due to potential for type of cows and management in those herds currently operating extended lactations, and also to the different

method to calculate lactation persistency. Abdelsayed *et al.* (2013) reported heritability estimates of 0.13 and 0.09 for cumulative milk yield up to day 610 days in milk and lactation persistency (yield at 305 day in milk/yield at peak), respectively. Haile-Mariam and Goddard (2008) reported heritability estimates of 0.23 and 0.19 for milk and protein produced after 400 days in milk in first lactation Holstein-Friesian cows in Australia.

Table 1. Number of lactations (N), mean, standard deviation (SD), minimum and maximum values for standard (up to 410 days in milk) and extended (up to 670 days in milk) lactations for total yields of milk and milksolids (fat+protein), and lactation persistency for milksolids in New Zealand dairy cows.

Trait	Mean	SD	CV (%)	Minimum	Maximum
Standard lactations (N=19,154)					
Lactation length (days)	254	48	19	151	409
Milk (L)	4,427	1,701	38	365	14,333
Milksolids (kg)	381	139	36	37	1,022
Extended lactations (N=5,223)					
Lactation length (days)	485	52	11	410	670
Milk (L)	7,678	2,879	37	2,017	17,938
Milksolids (kg)	682	225	33	180	1,535
Persistency (%)	71.1	16.6	23	11.3	150.1

Table 2. Estimates of variance components[1] and standard error (SE) for standard (up to 410 days in milk) and extended (up to 670 days in milk) lactations for total yields of milk and milksolids (fat+protein), and lactation persistency for milksolids in New Zealand dairy cows.

Trait	σ^2_g	SE	σ^2_e	SE	σ^2_p	SE	h^2	SE
Standard lactations								
Milk	287,357	10,002	425,302	5,293	712,660	9,818	0.40	0.01
Milksolids	1,299	56	3,136	39	4,435	56	0.29	0.01
Extended lactations								
Milk yield	655,316	42,197	978,399	32,089	1,633,700	35,391	0.40	0.02
Milksolids	3,296	273	7,585	238	10,880	230	0.30	0.02
Persistency	59	5	113.9	4.1	172.8	3.8	0.34	0.03

[1] σ^2_g = additive genetic variance, σ^2_e = residual variance, σ^2_p = phenotypic variance ($\sigma^2_g + \sigma^2_e$), h^2 = heritability calculated as $h^2 = \sigma^2_g / \sigma^2_p$.

Table 3. Estimates of genetic and phenotypic correlations[A] and standard errors for standard (up to 410 days in milk) and extended (up to 670 days in milk) lactations for total yields of milk and milksolids (fat+protein). and lactation persistency for milksolids in New Zealand dairy cows.

		Standard lactation		Extended lactation		
Trait		Milk	Milksolids	Milk	Milksolids	Persistency
Standard	Milk		0.87±0.00			
lactation	Milksolids	0.70±0.01				
Extended	Milk	0.74±0.03	0.38±0.04		0.85±0.00	0.32±0.01
lactation	Milksolids	0.46±0.04	0.62±0.04	0.67±0.02		0.39±0.01
	Persistency	0.17±0.04	0.19±0.05	0.53±0.04	0.71±0.01	

[A]Genetic below and phenotypic correlations above the diagonal, respectively.

Estimates of genetic correlations between the studied traits are presented in Table 3. Estimates of genetic correlation between total milk and milksolids yields were 0.70 and 0.67 in standard

and extended lactations, respectively. The estimate of 0.70 is within the range of estimates of genetic correlations between milk and fat yields and between milk and protein yields in standard lactations previously reported in New Zealand dairy cattle using much larger data sets (Lembeye *et al*. 2016; Jayawardana *et al*. 2023). Estimates of genetic correlation between milk and milksolids in extended lactations are not found in the literature.

The estimates of genetic correlations of the same trait, but expressed as standard and extended lactation, were 0.74 and 0.62 for milk and milksolids, respectively. These estimates were statistically lower than unity ($P < 0.001$) and lower than a threshold of 0.80 suggested by Robertson (1959), and hence there is a significant genotype by environment interaction, and reranking of animals evaluated in two environments can be expected. This means that animals ranking high for milk and milksolids breeding values in standard lactations would not be ranking high for these traits in extended lactations. Hence, the current estimated breeding values for milk and milksolids yields would not be suitable for selecting the best sires and cows for dairy systems focused on extended lactation.

Estimates of genetic correlations of milksolids persistency with total milk and milksolids yields in extended lactations were 0.53 and 0.71, respectively, but the estimates of genetic correlations of milk and milksolids yields in standard lactations with milksolids persistency in extended lactation were lower, 0.17 and 0.19, respectively. This means that selection for milksolids yield in extended lactations will result in a positive genetic response to lactation persistency for milksolids, which is a desired trait for cows selected for extended lactations.

Conclusions

The results indicate that sires and cows ranking high for milksolids in standard lactation would not rank high for milksolids and persistency in extended lactations. This reranking will require modifications to the current system of genetic evaluation to identify sires and cows genetically suitable for production systems using extended lactations.

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