THE ECONOMIC VALUE OF GESTATION LENGTH

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SUMMARY

Calving pattern is one of the most important factors affecting the overall profitability and reproductive performance of pasture-based dairy herds. Genetic selection for fertility typically incorporates a variety of traits, including those that use calving dates as part of their definition. Early calving can also be achieved through shortened gestation length (GL). Although not an official component of fertility evaluations in New Zealand, GL is an unavoidable contributor to calving season day (CSD), which is an official component. This is because CSD is the combined result of the conception date and GL of the foetus.

GL is not a true reflection of fertility, which typically comprises oestrus, fertilisation, and maintenance of pregnancy, and it also has comparatively high heritability, allowing it to dominate genetic progress over conventional fertility traits. Therefore, there is growing interest in separating the influence of GL from cow fertility evaluations. In this paper we outline an approach to derive the direct economic value (EV) for GL for a situation where it would be included in an index containing a conception date-based fertility date. Even though GL is not a true fertility trait, we find a high EV for GL through its indirect effect on fertility when farmers respond to a shorter GL population by delaying mating to achieve an identical seasonal calving pattern. Cows that have had a longer period between calving and first mating conceive at higher rates. This research facilitates revisions to the way fertility traits are included in national selection indices for seasonal dairy cows, allowing the development of non-linear index functions to avoid favouring selection for excessively short GLs challenging the welfare, viability, and productive performance of the resulting calves.

INTRODUCTION

Calving pattern is one of the most important factors affecting the overall profitability and reproductive performance of pasture-based dairy herds (Macdonald and Roche 2023). Genetic selection for fertility traits based on calving dates is used in New Zealand (e.g., calving season day; CSD) and many other countries to improve fertility with the aim of tightening calving patterns and reducing non-pregnant rates (Bowley *et al*. 2015).

Bias and censoring caused by this approach in pasture-based systems are usually addressed through the addition of other fertility traits, including cyclicity (e.g., PM21 in NZ) and conception (e.g., non-return rate in Australia). More recent research, however, has emphasized that early calving can be achieved not only through improved submission and conception rates, but also through shortened gestation length (GL). Although not an official component of fertility evaluations in NZ, GL is an unavoidable contributor to the CSD phenotype, as the latter is the result of conception date and GL of the foetus.

However, GL is not a true reflection of fertility – i.e., a cow's ability to resume and express oestrus, or to achieve fertilisation and maintain pregnancy. Further, the comparatively high heritability of GL dominates genetic progress over conventional fertility traits. Finally, short GL may have adverse consequences on calf health which must be carefully managed as part of a responsible approach to breeding. Most countries are likely to be indirectly selecting for short GL in their dairy cattle, and the impact of this on health, performance, and management systems is a current topic of research activity.

There is growing interest in separating the GL component of the EBVs for fertility into performance that is influenced by conception rate and performance that is due to GL. However, this requires an understanding of the direct economic value (EV) of GL. Therefore, the objective of this study was to use a stochastic fertility model to calculate the EV of GL for NZ dairy herds.

MATERIALS AND METHODS

Stochastic fertility model. To estimate the EV of GL, we adapted a stochastic fertility model (SFM) developed by Dennis *et al.* (2018) to simulate the performance of high and low fertility cattle. Briefly, the model simulates a cohort of 200,000 heifers' reproductive lifetime through 5 lactations, including genetic, physiological and management factors. It has the capacity to adjust genetic merit, oestrus duration, and fertility-related breeding values, but also incorporates events such as pregnancy diagnosis, oestrus detection, and embryonic loss.

The original SFM was tuned to reflect the phenotypic performance of heifers that had been divergently bred for low and high genetic merit for fertility in an experimental setting. Therefore, to model the more-realistic effects of GL changes on low- and high-fertility performance in commercial NZ dairy herds, we adjusted the base fertility traits underlying the model. For the analysis we defined low, average, and high fertility herds as having differences in their breeding values for postpartum anoestrus interval (-3, +3), number of services per conception (-0.03, +0.03), and oestrus duration (-1.6, +1.6).

To calculate the EV of GL, we reduced the mean GL (GL-3) and delayed planned start of mating (PSM) by 3 days in total (PSM+3). This reflects management changes currently being implemented by NZ dairy farmers in conjunction with the use of short GL semen. For each of the six runs (i.e., no intervention and GL-3/PSM+3 for low, average, and high fertility herds), 100 iterations were completed for a herd size of 200,000 animals, resulting in a dataset of 20 million lactations. Although Table 1 shows the effects of 3 days fewer GL for high and low fertility performance herds, these values are mainly provided to compare the effect of GL under a range of conditions. For index development, the following EV calculations are based on the performance of average herds.

EV calculation. The EV of GL is built from four component EVs that influence profitability: milk production, empty rate, value of artificially bred (AB) and beef calves sold, and number of natural mate (NM) bulls required. Component EVs were calculated as the change in \$ profitability per lactation, per day change in GL, independent of changes in other New Zealand dairy breeding objective traits. Key parameters are summarised in Table 2. See Amer *et al.* (2013), Santos *et al.* (2022) and https://www.dairynz.co.nz/animal/animal-evaluation/interpreting-the-info/economic-values/) for details on the breeding objective and Breeding Worth index.

The milk component EV ($EVGL_{milk}$) was calculated as

$$EVGL_{milk} = \left[\left(\sum_{g=1}^{3} Pmilk_g \times \rho_{g_{GL}-3}\right) - \left(\sum_{g=1}^{3} Pmilk_g \times \rho_{g\_base}\right)\right] \Big/ -3,$$

where $Pmilk_g$ is the average milk profit per lactation in groups (denoted by *g*) of early (first 21 days of season), mid (21-42 d) and late (>42 d) calving cows. For each group, $Pmilk_g$ (\$/lactation) was calculated from weighted averages of milk production from Holstein-Friesian, Jersey and crossbred breeds in upper and lower North and South Islands, and average feed costs per lactation based on energy requirements and industry feed prices. In each group, $\rho_{g_{GL}-3}$ and ρ_{g_base} are the proportions of cows in the GL-3 and base herds, respectively (Table 1). -3 is the days change in GL in the base herd compared to the GL-3 herd.

The empty rate component EV ($EVGL_{empty}$) was calculated as

$$EVGL_{empty} = \left(\sum_{p=1}^{4} \Delta e_p \times \pi_p \times \rho_p\right) / -3,$$

where Δe_p is the change in the proportion of empty cows in the GL-3 herd at parity (p = 1, 2, 3 and 4+) compared to the base; π_p is the average value of an empty cow culled following parity p based on milk income, replacement rates, feed/purchase costs, and salvage value; and ρ_p is a weighting factor aggregating effects for parities based on the proportion of cows finishing lactation p.

The AB and beef calves sold component EV ($EVGL_{calf}$) was calculated as

$$EVGL_{calf} = \left[\left(\sum_{p=1}^{4} \Delta 6WICR_p \times \rho_p\right)/-3\right] \times \tau,$$

where $\Delta 6WICR_p$ is the change in 6-week in-calf rate (6WICR) from the base herd compared with the GL-3 herd at parity p (Table 1). τ is the average benefit of AB and high-value beef-sired calves per unit change in 6WICR ($/calf per proportion), based on industry data of proportions and prices for the range of AB and natural mating sired dairy and beef crossbred calves.

The NM bulls component EV ($EVGL_{NM}$) was calculated as

$$EVGL_{NM} = \left[\left(\sum_{p=1}^{4} \Delta 6WICR_p \times \rho_p\right)/-3\right] \times \nu,$$

where ν is the cost of NM bull per cow not-in-calf at the end of the 6-week AI mating season ($/cow) based on industry data of average yearly bull lease rate and ratio of cows to NM bull.

The total GL EV ($EVGL$) was calculated as

$$EVGL = \left(EVGL_{milk} + EVGL_{empty} + EVGL_{calf} + EVGL\_nm\right) \times \rho_{mp} ,$$

where ρ_{mp} is the industry average herd proportion of multiparous cows modified slightly to allow for delayed expression.

RESULTS AND DISCUSSION

SFM results. The mean reproductive performance metrics, produced by the SFM for each of the six scenarios are shown in Table 1. These do not include the performance of nulliparous heifers, which are often managed separately to the milking herd. The effect of GL-3/PSM+3 differs depending on the herd's existing reproductive performance. This is likely because a greater proportion of cows in a high fertility herd are already calving early at an optimal time.

Table 1. Reproductive performance metrics produced by the stochastic fertility model, adjusted for no intervention (base) and short gestation length (GL-3/PSM+3) scenarios

	Average fertility			Low fertility			High fertility		
	Base	GL-3/PSM+3	Δ	Base	GL-3/PSM+3	Δ	Base	GL-3/PSM+3	Δ
6-week in-calf rate (6WICR)	65.0%	67.0%	**2.0%**	41.3%	43.5%	**2.3%**	73.8%	75.3%	**1.5%**
Empty rate	12.3%	11.2%	**-1.1%**	27.9%	26.0%	**-1.9%**	7.9%	7.2%	**-0.6%**
% Calved by 21 days	48.6%	55.3%	**6.7%**	32.8%	38.3%	**5.5%**	55.5%	62.3%	**6.8%**
% Calved by 42 days	74.5%	78.3%	**3.9%**	58.5%	63.3%	**4.8%**	80.3%	83.5%	**3.2%**

EV results. The EVs for GL (Table 2) show that reducing mean GL by 3 days and delaying planned start of mating can have a significant impact on dairy farm profitability, especially in average and low fertility herds. Most of this is due to the indirect contribution of GL to improved fertility, with early calving allowing greater time for uterine involution and resumption of cyclicity.

The largest contributor to GL EVs was a reduction in empty rate at -$5.31 per extra day of gestation. Improving cow longevity not only reduces the need for more heifer replacements – which are costly to rear to maturity and take multiple seasons to achieve peak lactation – but is also consistent with societal expectations around animal welfare and survival. The second-most significant contributor was lactation profit at -$4.11 per extra day of gestation, which came from having a lower proportion of cows calving late in the season (i.e., a tighter calving pattern). Note that early in the calving season, the pattern of calving is relatively unchanged when farmers delay PSM as the average GL EBV of their herd shortens. Having more cows at peak lactation in conjunction with peak pasture availability is a key driver of profitability for pasture-based dairy herds. Finally, the contributions of having more high genetic merit artificially bred heifers (-$0.20 per extra day of gestation) and fewer natural follow-up bulls (-$0.13 per extra day of gestation) were smaller but still significant.

Table 2. Key gestation length EV model parameters and resultant component EVs

	Description	Values and unit
Model parameter	Milk profit for early, mid, and late calving cows ($Pmilk_g$)	$2435, $2372, $2162 / lactation
	Empty cow culled value following parity 1, 2, 3 and 4+ (π_p)	$1704, $1710, $1614, $1350 / cow
	Weighting factor for parity 1, 2, 3 and 4+ proportions (ρ_p)	0.25, 0.20, 0.16, 0.39
	AB and high value beef calves benefit value (τ)	$30 / calf per unit 6WICR
	Natural mating cost (ν)	$20 / cow
	Proportion of multiparous cows in herd (ρ_{mp})	0.73
Economic value	**Milk profit component EV ($EVGL_{milk}$)**	**-$4.11 / lactation per d GL**
	Empty rate component EV ($EVGL_{empty}$)	**-$5.31 / lactation per d GL**
	AB and beef calf component EV ($EVGL_{calf}$)	**-$0.20 / lactation per d GL**
	Natural mating component EV ($EVGL_{NM}$)	**-$0.13 / lactation per d GL**
	Total EV adjusted for ρ_{mp} ($EVGL$)	**-$7.12 / lactation per d GL**

CONCLUSION

The economic value of gestation length includes 1) increased milk income from having a greater proportion of early-calving cows at peak lactation when there is also peak pasture availability, 2) reduced involuntary culling due to decreased empty rates, 3) the value of more artificially bred high genetic merit heifers, and 4) a reduction in natural follow-up bulls required for the herd.

Our results show that reducing mean gestation length by 3 days and delaying PSM can have a significant impact on dairy farm profitability, especially in average and low fertility herds.

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