Evaluating management strategies for a pasture-based extended lactation system with 24-month calving intervals

Lydia J. FARRELL[1]*, Pierre C. BEUKES[1], Chris B. GLASSEY[1] and J. Paul EDWARDS[2]

[1]*DairyNZ Ltd, Private Bag 3221, Hamilton 3240, New Zealand*
[2]*DairyNZ Ltd, PO Box 85066, Lincoln University, Lincoln 7647*
*Corresponding author: lydia.farrell@dairynz.co.nz

Abstract

Extended lactation (EL) systems, with calving interval voluntarily extended beyond 12 months, may alleviate dairy sector challenges of labour scarcity and non-replacement calves. This study used bio-economic simulation to investigate how the profitability of an EL system could be improved through strategic management and tested system robustness across different climate and economic years. An EL system with half of cows calving each spring at 24-month intervals was compared with a conventional (Control) system calving all cows each spring. Both systems were modelled with Ruakura climate and Holstein-Friesian cows at 2.8 cows/ha with > 80% of feed from grazed pasture. Profitability of the EL system relative to Control was better during years with greater pasture growth, particularly where growth was greater in summer and autumn, and in years with low supplement feed expenses relative to milk price. The EL system profitability was improved by shortening grazing rotation length in autumn and winter to harvest more pasture. Overall, a strategically managed EL system could achieve similar or improved production, profit and environmental outcomes to a conventional system, provided the herd achieves a similar final herd dry off date and has sufficiently lower expenses, e.g. via health and breeding.

Keywords: calving interval, non-replacement calves, profit, simulation, Whole Farm Model.

Introduction

Extended lactation (EL) systems, where calving interval is voluntarily extended beyond 12 months, have been proposed as potential solutions for dairy sector challenges of labour availability, surplus non-replacement calves, and higher than desired not in-calf rates (Farrell et al. 2023). New Zealand (NZ) farm systems where the whole herd undergoes EL are uncommon, particularly those with 24-month calving intervals as this duration represents a large increase in desired lactation length compared with conventional 12-month calving intervals, i.e., in excess of 300 additional days. A 12-month calving interval has been suggested as most profitable, through maximising milk yield, in both housed (Kok et al. 2019) and pasture-based (Farrell et al. 2023) dairy systems. However, the analysis by Farrell et al. (2023) identified that a pasture-based system with at 24-month intervals and half of the herd calving each spring could achieve similar profitability to 12-month calving intervals when modelled in a region with strong winter pasture growth. The same analysis identified that changes in supplement feed costs had larger effects on the profitability of EL systems relative to conventional systems compared with changes in revenue or other costs (i.e., labour, calving, or mating).

Making the best use of pasture is important for the profitability of pasture-based dairy systems as it is a relatively cheap feed source, and the typical system of annual spring (or late-winter) calving is based on matching feed demand and pasture supply curves (Holmes et al. 2002). Previous modelling and field studies have explored how changes in farm systems and management to alter the herd's feed demand profile, such as calving dates (Garcia and Holmes 1999) and stocking rate (Macdonald et al. 2011; Romera and Doole 2016), affect the profit of conventional systems. An EL system with 24-month calving intervals results in cows having different timing of physiological states across the year compared with a conventional system. This includes lactating through winter and producing less milk during the second spring of their lactation (Phyn et al. 2009). Furthermore, EL cows are expected to have a larger body condition change between calvings (Kolver et al. 2007), with the timing of body condition gain occurring largely in the second spring of lactation rather than during autumn and winter. For this reason, the feed demand profile for a system with 24-month calving intervals is expected to differ compared with a conventional system, as suggested by Farrell et al. (2023). Therefore, investigation into the EL system and farm management that best utilises pasture for any improvements in economic performance is warranted.

The objective of this study was to compare the profitability of a conventional (Control) system with 12-month calving intervals to a 24-month EL system either before (Baseline EL) or after (Improved EL) changes in management strategies.

ISSN 2463-2872 (Print) ISSN 2463-2880 (Online) https://doi.org/10.33584/jnzg.2024.86.3680

Materials and Methods

The first step of the study was to establish modelled scenarios for the Control and Baseline EL systems, with all cows calving each spring at 12-month intervals, and half the herd calving each spring at 24-month intervals, respectively. An economic comparison of the Control and Baseline EL systems was made through simulation over different climate years. The second step was to model the Baseline EL system with various changes in management to achieve an Improved EL system with greater profit. The third step was an economic comparison of the Control and Improved EL system through simulation with combinations of different climate and economic years.

DairyNZ Whole Farm Model

The DairyNZ Whole Farm Model (WFM) was used as the modelling platform. The WFM is a climate-driven, day-step model that simulates farm system components of a pasture-based NZ dairy farm, including a comprehensive set of user-defined management policies dealing with pasture, feed, fertiliser, effluent and animal management (Beukes et al. 2005). The cow sub-model is the mechanistic Molly model representing individual cows differing in breed, age, genetic merit, calving, dry off and culling. Molly has a mammary component that was modified to enable simulations of extended lactations beyond the conventional length (Beukes et al. 2005). Individual paddocks are each simulated with an instance of the pasture model, AgPasture (Vogeler and Cichota 2016). Paddocks differ in initial pasture cover (biomass), timing of grazing or cutting for silage, post-grazing residual, daily growth rates and annual pasture yield. The WFM takes economic inputs including milk price based on annual Economic Farm Survey data (DairyNZ 2023) and produces financial outputs including operating profit (OP) based on revenue, expenses and adjustments to account for the economic value of changes between start and end of year feed inventory and average farm pasture cover (Beukes et al. 2019).

Control and Baseline Extended Lactation scenarios

The modelled Control system (Table 1) was based on the Benchmark herd of 42 cows farmed on 15 ha since 2001 at DairyNZ's Scott Farm near Hamilton, NZ. In the Control system, all 42 cows calved each spring with a 12-month interval between annual PSC (planned start of calving date). All cows in the Control and EL systems were modelled as predominantly Holstein-Friesian, i.e. for liveweight and milk production curve, because published data from cows in EL in NZ are from this breed (Kolver et al. 2007; Phyn et al. 2009). Milk production per cow for the Control system was simulated to match that of Holstein-Friesian cows on Scott Farm, then cows in the EL system were modelled with the same milk production potential. In the EL system, half of the herd calved each spring; thus, cows had an approximately 24-month interval between calvings.

The model was run over two consecutive farming seasons for each of the Control and Baseline EL systems, initially 2021-22 and 2022-23. Outputs from the second season were used for results because it represented a steady-state year. The first year was regarded as a run-in year due to half of the herd needing to begin the season in-milk in the EL system. For the EL system the same herd of 42 cows as in Control were modelled: 20 cows calved in the 2021-22 season and milked through into the 2022-23 season (mob one) and 22 cows calved in the 2022-23 season (mob two). The reason for this imbalance is that some cows (i.e. two cows in the modelled scenario) were allowed to be culled during year one of lactation and then the mob due to calve in the steady-state year was bolstered by replacement heifers calving and joining the herd. Replacement rates were 24% and 14% for the Control and EL systems, respectively, assumed primarily because cows in EL systems have fewer opportunities to leave the herd due to diagnosis as being not pregnant.

Observed climate data from the Ruakura weather station were used as inputs for driving the AgPasture sub-model on a Horotiu soil in the WFM. The Control system had treatment for anoestrous as part of the mating policy. This was assumed not to be needed for the EL system because of the additional time cows have for cycling before start of mating. The same calving spread was assumed for both systems. In both Control and EL, 100% of the farm received dairy effluent irrigation. We used economic input data for the 2020-21 season with a milk price of \$7.07/kg MS and supplement prices of \$330/t DM for pasture silage, \$340/t DM for maize silage, and \$460/t DM for palm kernel expeller meal. These prices were chosen to represent average economic conditions over the five previous years. No differences in annual expenses for labour or repairs and maintenance were assumed because effects of this novel EL system are not yet known.

Results for Control and EL scenarios for the 2022-23 season were checked for sensibility based on how they aligned with preliminary data from a farmlet trial comparing Control and EL currently running at Scott Farm (Newstead, Hamilton, NZ). Then Control and Baseline EL were run for more climate year sequences, 2020-22, 2019-21, 2018-20, 2017-19, and 2016-18. Output for the second year (steady-state year) of these sequences were taken as results, including annual pasture yield, pasture growth curve, OP, and

Table 1 Selected farm characteristics and model predicted parameters for the Control, Baseline EL (extended lactation), and Improved EL systems, with climate year 2021-22 and economic year 2020-21. PSC = planned start of calving. APC = average pasture cover.

Parameter	Control	Baseline EL	Improved EL
Calving interval (months)	12	24	
Cow breed	Friesian	Friesian	
Stocking rate	2.8	2.8	
PSC	4 July	4 July	
Final dry off date	1 May	1 May	
Cows calving per year (head)	42	22	
Heifers calving per year (head)	10	6	
Replacement rate (%)	24	14	
Non-replacement calves (head)	31	15	
Herd average age (years)	4.7	5.1	
Herd average parity (count)	2.7	2.0	
Days in milk for cows calved spring 2021	270	307	312
Days in milk for cows calved spring 2020	NA	332	333
Milksolids for cows calved spring 2021 (kg/cow)	419	466	479
Milksolids for cows calved spring 2020 (kg/cow)	NA	364	364
Milksolids produced (kg/ha)	1,174	1,167	1,182
Milksolids sold ($/ha)	1,125	1,139	1,152
Pasture grown (t DM/ha)	13.9	13.7	13.9
Pasture eaten (t DM/ha)	12.1	11.7	12.0
Pasture silage conserved (t DM/ha)	1.6	1.8	1.8
Pasture silage fed (t DM/ha)	2.3	2.5	2.4
Imported maize silage fed (t DM/ha)	2.7	2.7	2.7
Imported palm kernel expeller fed (t DM/ha)	0.5	0.6	0.3
Total intake (t DM/ha)	14.9	14.7	14.7
APC at 1 June 2021 (kg DM/ha)	2,304	2,263	2,181
APC at PSC 4 July 2021 (kg DM/ha)	2,010	1,970	1,791
APC at 31 May 2022 (kg DM/ha)	2,051	2,041	1,930
Fertiliser applied (kgN/ha)	117	117	117
Greenhouse gas emissions (kg CO_2-eq./ha)	15.2	14.6	14.6
Greenhouse gas emissions (kg CO_2-eq./kg milksolids)	12.9	12.5	12.3
Nitrogen leaching (kg/ha)	39.4	38.3	40.6
Revenue ($/ha)			
Milk sales	7,990	8,212	8,306
Livestock sales	1,540	740	740
Net cash	9,571	8,993	9,087
Expenses ($/ha)			
Animal health	343	286	286
Breeding	233	135	135
Net feed made or purchased	1,974	1,973	1,849
Youngstock grazing	708	543	538
Farm working expenses	6,517	6,195	6,072
Labour adjustment (unpaid labour)	419	419	419
Feed inventory adjustment	0	0	0
Pasture cover adjustment	-112	-101	-119
Depreciation	516	516	516
Operating profit ($/ha)	**2,007**	**1,763**	**1,961**

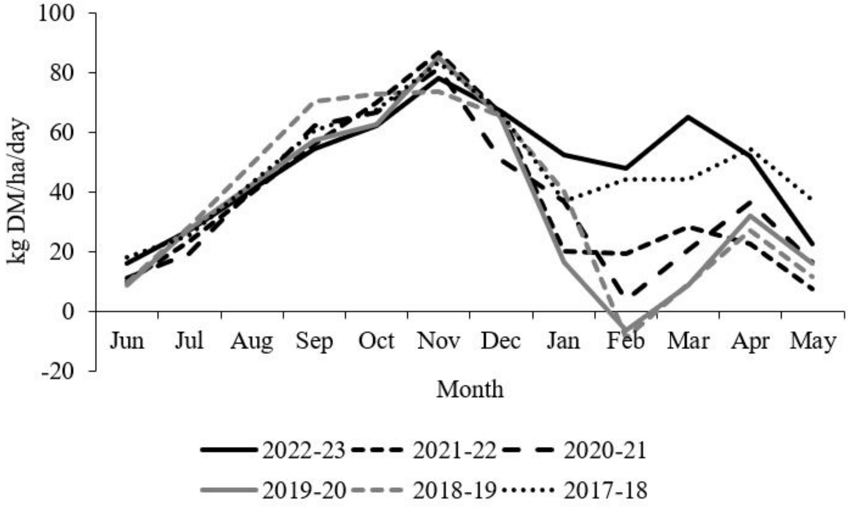

Figure 1 Monthly average pasture growth rates for Scott Farm using Ruakura climate data, predicted using the Whole Farm Model's AgPasture sub-model.

supplementary feed expenses. Pasture yield and growth curves for the six steady-state years were compared, and the most typical yield and growth curve for the Waikato region was identified as 2021-22 (Figure 1). The climate sequence with 2021-22 as the steady-state year was used in the next part of the study, evaluating the management strategies for the EL system.

Management strategies to improve the extended lactation system

To achieve an Improved EL system, climate (2021-22) and economic (2020-21) input years were kept constant while changing management strategies to explore effects on OP. The first management strategies explored changes to days in milk, with a focus on reducing the days in early spring and/or late autumn by either delaying PSC and/or drying off earlier. This strategy was investigated to alleviate feed supply challenges due to having half of the EL herd milking through winter. It may be beneficial to reduce the total feed demand in the shoulders of winter to lower supplement feed expenses. The next strategies focused on management of average pasture cover (APC) leading into and during winter, evaluated through modelling changes in autumn and winter grazing rotation lengths. Altering APC through autumn and winter when half of cows are in milk may reduce reliance on supplement feed and lower farm working expenses. The final strategy evaluated was varying stocking rate to levels both below and above the baseline. It was expected that the higher feed demand of cows in the EL system during winter would affect supplement feed expenses and the profitability of EL at the different stocking rates.

Environmental impacts

Once the Improved EL system was determined, greenhouse gas emissions and nitrate leaching were compared with the Control system using the WFM and its Urine Patch Framework (UPF) sub-model. Greenhouse gas emissions were predicted by the Molly cow sub-model (for methane) and using inventory methods for nitrous oxide and carbon dioxide (Beukes et al. 2011a). The UPF prepares the inputs from the WFM and runs the APSIM model which predicts nitrogen leaching at paddock scale while accounting for urine patches and urine patch overlaps (Beukes et al. 2011b).

Climate and economic-year effects

The Improved EL system was tested for effects of interactions between climate and economic years on OP relative to the Control system. The climate year was expected to impact feed supply, cow condition, and milk production due to feed surpluses and deficits playing out differently each year. Milk price and farm revenue were expected to be affected by the economic year, as were farm working expenses due to impacts of interactions between supplement feed expenses and feed balance variation. In this way the consistency of the Improved EL system's performance compared with Control could be evaluated. For this exercise the WFM was set up to model both the Improved EL and Control systems with all combinations of three climate and three economic years (totalling nine simulations for each system). Selected climate years were the base year (2021-22) used to investigate management strategies for EL and then the recent climate years with the highest (2022-23) and lowest (2019-20) pasture yields and summer growth rates (Figure 1). Three economic input years were selected with high ($8.69/kg MS; 2022-23), average ($7.07/kg MS; 2020-21), and low milk prices ($6.43/kg MS; 2018-19).

Results

Control and Baseline Extended Lactation scenarios

The cows calving in 2021 (the steady-state year) for the Baseline EL system had greater milksolids (MS) production (averaging 466 kg/cow over the first 307 days of lactation) than cows in the Control system (419 kg/cow) as they milked through to 31 May (Table 1). In the second year of their lactation cows in EL were predicted to produce less; on average 364 kg MS over a further 332 days of lactation. The systems differed in replacement rate and therefore herd age structure, which affected milk production in the Molly sub-model, as did also cow pre-calving body condition. The WFM predicted the variations in production at the cow level would even out for the system comparison, with similar annual production on a per hectare basis for the two systems, at 1,174 and 1,167 kg/ha for Control and Baseline EL, respectively. The Baseline EL system sold $222/ha worth of milk more than the Control scenario after having fewer calves to feed. The $578/ha lower total net cash revenue of the Baseline EL system reflects the reduced livestock revenue, with fewer cows culled and non-replacement calves available for sale each year. The Baseline EL system was predicted to conserve 0.2 t DM/ha more pasture and feed 0.2 t DM/ha more supplement feed compared with the Control system, and there was a negligible difference in total feed-related expenses. The Baseline EL system was predicted to have lower animal health, breeding, and youngstock grazing expenses, and thus $322/ha lower farm working expenses than the Control system. However, the lower operating expenses for Baseline EL did not fully offset the lower total revenue and OP was $244/ha (12.2%) lower than that of the Control system. The OP of the Baseline EL system was lower than Control across the modelled climate years while using the same 2020-21 economic year (Table 2). The OP difference was least in the most productive years for both systems such as 2017-18 (1.2% lower than Control) and 2022-23 (4.1% lower than Control) years, which had strong pasture growth in late-summer and autumn (Figure 1) and high annual pasture yield (Table 2). In general, the OP difference, of up to 19.5% lower for Baseline EL, was larger in the less productive years with worse pasture growth.

Management strategies to improve the extended lactation system

Delaying PSC from the Baseline EL date was less profitable, reducing OP by $138/ha due to losing two weeks of milk production (Figure 2). Drying off the EL cows a month earlier also reduced OP, though by a smaller value of $85/ha. Shortening grazing rotation lengths by ten days in autumn (for lower APC on 1 June) and winter were shown to improve profitability for EL and were the two changes from the Baseline that achieved the Improved EL system. These shorter grazing rotations increased pasture harvest and milk production while reducing supplement feed requirements (Table 1). They were also associated with a lower APC of 1,791 kg DM/ha at PSC for the Improved EL system compared with 1,970 kg DM/ha for Baseline EL. Varying stocking rate from 2.8 cows/ha did not further improve on OP (Figure 2). In summary, to achieve the Improved EL system the grazing rotations were shortened in autumn and winter, while the PSC, final dry off date, and stocking rates were maintained and the same as the Control scenario.

The Improved EL system had OP $198/ha greater than the Baseline EL system and $46/ha lower than the Control system modelled with the same climate (2021-22) and economic years (2020-21).

Table 2 Annual pasture yield (t DM/ha), supplement feed expenses (net feed made or purchased; $/ha) and operating profit (OP; $/ha) predicted for modelled Control and Baseline EL systems with varying climate years and a constant economic year (2020-21 with milk price $7.07/kg MS). Systems were simulated over two consecutive climate years and results reported for the second year.

Climate year	Pasture yield	Control		Baseline EL		Difference in OP (% in brackets)
		Supplements	OP	Supplements	OP	
2017/18	17.6	770	3,469	766	3,427	- 42 (- 1.2)
2018/19	13.7	1,615	1,952	1,852	1,572	- 380 (- 19.5)
2019/20	12.5	2,663	1,394	2,870	1,206	- 188 (- 13.5)
2020/21	13.8	2,208	1,929	1,962	1,753	- 176 (- 9.1)
2021/22	13.9	1,974	2,007	1,973	1,763	- 244 (- 12.2)
2022/23	18.0	1,070	3,645	983	3,497	- 148 (- 4.1)

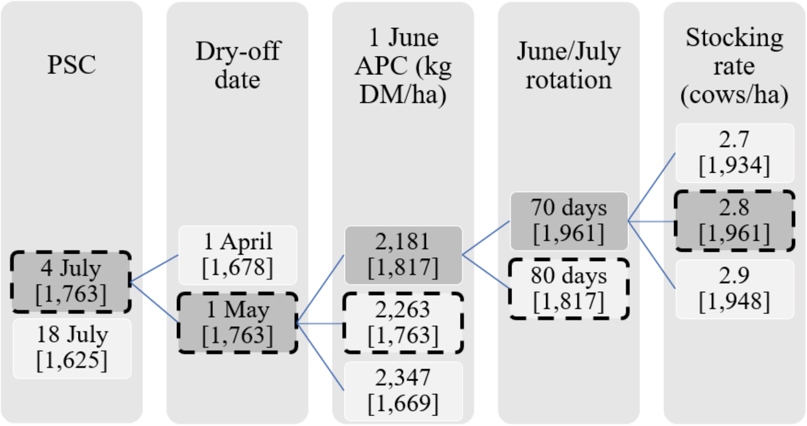

Figure 2 Management strategies investigated for the extended lactation (EL) system, where dashed borders indicate the Baseline EL parameter and darker shading indicates the strategy with greater operating profit ($/ha; in brackets) which was further investigated to achieve the Improved EL system. Modelled with climate year 2021-22 and economic year 2020-21. PSC = planned start of calving, APC = average pasture cover.

Environmental impacts

The Control system had higher feed eaten (14.9 t DM/ha) than EL (14.7 t DM/ha; Table 1). The Control system was also predicted to have higher GHG emissions than Improved EL; 15.2 versus 14.6 t CO_2-eq./ha, or 12.9 versus 12.3 kg CO_2e/kg MS, respectively. Annual nitrogen leaching losses for the 2021-22 season were predicted to be very similar, 39.4 and 40.6 kg/ha for Control and Improved EL, respectively.

Climate and economic-year effects

The difference in OP of the Improved EL system compared with Control ranged from -14.9% to +4.7 % across modelled climate and economic year combinations, with consistently lower supplement feed expenses for Improved EL (Table 3). The Improved EL system was predicted to have $41 to 47/ha greater OP on average than Control in the good and average climate years, but $122/ha lower OP in the poor climate year with low summer and autumn pasture growth. In the good and average climate years, the OP of the Improved EL system was higher than Control only when modelled with a high or low milk price. The margin between milk price and market prices for the various supplement feeds modelled was smaller during the average economic year (2020-21; $7.07/kg MS). This disadvantaged the OP of the EL system for which low feed expenses was important in offsetting lower livestock revenue.

Discussion

Model predictions of profitability for the Improved EL system were encouraging, with higher OP than Control in some climate and economic year combinations (Table 3). For a more balanced test of the robustness of the Improved EL system, these three modelled climate years can be weighted according to their occurrence in annual pasture yield data from the past 30 years at Scott Farm (Glassey et al. 2021) to produce an average of 0.2% ($4/ha) lower OP for Improved EL. The average milk price from recent decades in real terms is likely between the average ($7.07/kg MS) and low ($6.43/kg MS) prices modelled, for which this study did not suggest large profitability losses for Improved EL compared with Control. A recent bio-economic modelling study of a similar EL system predicted profitability to be slightly ($31/ha) lower than a conventional system for the Ruakura climate (Farrell et al. 2023), similar to the overall findings of the current study. Analysis by Farrell et al. (2023) found the long-term winter pasture growth to drive the economic performance of the EL system when comparing between regions. The current study using climate driven pasture growth for recent years in Ruakura, took this a step further to identify that strong summer and autumn growth, as well as high total annual pasture yield, resulted in the most favourable profit comparison for EL within a specific region.

The worse OP from delayed PSC showed that the importance of additional days in milk for dairy systems holds true for EL even when accounting for the higher feed demand and supplement requirements over autumn and winter, as earlier PSC is advantageous as long as there is sufficient feed in early spring (Garcia and Holmes 1999). If implementation of an EL system improves herd reproductive performance and achieves a more condensed calving profile, this would be expected to further increase profit due to greater herd days in milk and harvest of spring pasture (Bryant and L'Huillier 1986). The later final dry-off on 1 May was identified as more profitable than 1 April, with

Table 3 Supplement feed expenses (net feed made or purchased; $/ha) and operating profit (OP; $/ha) of Control and Improved EL systems modelled in a matrix of climate and economic years. Modelled years were selected as representing good, typical, or poor years in terms of annual pasture yield (t DM/ha; predicted by AgPasture) and summer growth for climate year or milk price ($/kg milksolids) for economic year. Systems were simulated over two consecutive climate years and results reported for the second year.

Climate year (pasture yield in brackets)	Economic year (milk price in brackets)	Control		Improved EL		Difference in OP (% in brackets)
		Supplements	OP	Supplements	OP	
2017-18 (17.6) "good"	2022-23 (8.69)	980	4,169	862	4,304	+ 135 (+ 3.2)
	2020-21 (7.07)	783	3,503	688	3,442	- 61 (- 1.7)
	2018-19 (6.43)	685	3,252	603	3,319	+ 67 (+ 2.1)
	Average	816	3,641	718	3,688	+ 47 (+ 1.2)
2021-22 (13.9) "typical"	2022-23 (8.69)	2,301	2,479	2,181	2,595	+116 (+ 4.7)
	2020-21 (7.07)	1,974	2,007	1,849	1,961	- 46 (- 2.3)
	2018-19 (6.43)	1,703	1,977	1,625	2,028	+ 51 (+ 2.6)
	Average	1,993	2,154	1,885	2,195	+ 41 (+ 1.7)
2019-20 (12.5) "poor"	2022-23 (8.69)	2,925	1,947	2,834	1,876	- 71 (- 3.6)
	2020-21 (7.07)	2,663	1,394	2,571	1,186	- 208 (- 14.9)
	2018-19 (6.43)	2,070	1,673	2,009	1,586	- 87 (- 5.2)
	Average	2,553	1,671	2,471	1,549	- 122 (- 7.9)

the greater milk production justifying the increased autumn feed requirements. This 1 May dry-off date would require lactation lengths in excess of 600 days for the majority of the herd, which may be difficult to achieve in the short-term when reliant on cows that have been selected for performance within an annual calving system. However, if lactation persistency were not an issue, cows could milk until 60 days before calving, i.e., up to a 670-day lactation length, without the normal requirement for body condition gain over autumn. Cows in an EL system are expected to calve with greater body condition and thus have superior subsequent milk production (Grainger and McGowan 1982), as was modelled in the current study and benefited the profitability of the EL system. To date, animal and farmlet studies of EL, including the current analysis, have focused on Holstein-Friesian cows that are expected to be best suited for milk production in an EL (Kolver et al. 2007; Phyn et al. 2009). If outputs from current and future work on EL are encouraging, the performance of other breeds could be explored. Selection criteria for EL performance could be identified and validated which would give confidence to farmers interested in adopting EL regarding the suitability of their herd, though this may come at the expense of other traits.

Target APC for calving has been suggested as 2,200 kg DM/ha (MacDonald and Penno 1998) and target June rotation lengths of at minimum 60 or 100 days depending on feed balance (Bryant and L'Huillier 1986). Shortening of pasture rotation length in autumn and winter to harvest more pasture in the current study was shown to increase OP (Figure 2) but resulted in low APC at calving (Table 1) which requires careful pasture management in early spring and increases susceptibility to any unexpected shortfall in spring pasture growth. The most profitable rotation lengths would be expected to vary between years according to differences in pasture growth.

The total feed eaten for Baseline EL and Improved EL systems was similar and only 0.2 t DM/ha lower than the Control system (Table 1). The Control system was based on the Scott Benchmark herd with proven robustness as a low to medium input system with grazed pasture comprising more than 80% of feed eaten and stocked at 2.8 cows/ha. Therefore, this stocking rate being most profitable for the modelled EL system was not surprising. Economic comparisons of 24 and 12-month calving intervals may be different if modelled for a higher input dairy system where a greater level of supplement feeding can enable milk production to be more consistent across the entire extended lactation. Indeed, the current study is unlikely to have captured the full potential of an EL system.

Some of the assumptions in the current analysis are subject to large uncertainty because of the unproven nature of the modelled EL system. A farmlet trial currently underway at Scott Farm aims to provide insight into system feasibility, workable management, production, revenue, and supplement feed expenses, which will help improve confidence in these assumptions. One key unknown that is difficult to predict is the comparative labour cost of EL relative to a conventional system. Previous estimates that informed analysis of EL by Farrell et al. (2023) suggested a similar annual labour requirement, with some of the reduced workload from calving and mating half the number of cows each year for EL being offset by increased labour for milking over winter. Whether this difference will be more or less attractive to potential staff and any impacts on wage costs is not yet understood.

This analysis did not include any winter milk premiums for the EL system due to the uncertainty around future contract availability. The EL system would therefore need to be a convincing and profitable option without premiums for adoption by commercial farmers. A significant benefit of EL is the expected > 50% reduction in non-replacement calf numbers, thereby reducing the number of non-replacement calves. Knowledge of the most profitable and resilient management for EL systems is expected to improve over time if it is further researched and adopted by farmers in the New Zealand dairy sector.

Conclusions

Model outputs suggest an EL system can achieve similar or improved milk production, profit, and environmental outcomes compared with a conventional system in good to average pasture yield seasons in the Waikato. The autumn and winter pasture rotation lengths for EL can be shortened to increase pasture harvest and profitability, but with associated risks of low pasture covers in early spring. A caveat for EL to outperform the Control is that EL should have a herd capable of producing well to achieve the same final dry-off date as conventional systems and should have lower expenses, particularly for health and breeding. A substantial reduction in non-replacement calves makes the EL system an attractive option from an animal welfare perspective.

ACKNOWLEDGEMENTS

This study was funded by the dairy farmers of New Zealand through DairyNZ Inc (Hamilton, New Zealand), contract CRS2094 (Frontier Farms).

REFERENCES

Beukes PC, Thorrold BS, Wastney ME, Palliser CC, Macdonald KA, Bright KP, Lancaster JAS, Palmer CAJ, Auldist MJ. 2005 Modelling the bi-peak lactation curves of summer calvers in New Zealand dairy farm systems. *Australian Journal of Experimental Agriculture 45*: 1-7. https://doi.org/10.1071/EA03251

Beukes PC, Gregorini P, Romera AJ. 2011a. Estimating greenhouse gas emissions from New Zealand dairy systems using a mechanistic whole farm model and inventory methodology. *Animal Feed Science and Technology 166-167*: 708-720. https://doi.org/10.1016/j.anifeedsci.2011.04.050

Beukes PC, Romera AJ, Gregorini P, Clark DA, Chapman DF. 2011b. Using a whole farm model linked to the APSIM suite to predict production, profit and N leaching for next generation dairy systems in the Canterbury region of New Zealand. Presented at the *19th International Congress on Modelling and Simulation*, Perth, Australia, 12–16 December. https://www.mssanz.org.au/modsim2011/B1/beukes.pdf

Beukes PC, Romera AJ, Neal M, Mashlan K. 2019. Performance of pasture-based dairy systems subject to economic, climatic and regulatory uncertainty. *Agricultural Systems 174*: 95-104. https://doi.org/10.1016/j.agsy.2019.05.002

Bryant AM, L'Huillier PJ. 1986. Better use of pastures. *Proceedings of Ruakura Farmers Conference 38*: 43-51.

DairyNZ. 2023. *Dairy Sector.* Retrieved 8 August 2024 from: https://www.dairynz.co.nz/resources/dairy-sector/

Farrell L, Verhoek K, Edwards P. 2023. Pasture growth curve impacts the economic merit of extended lactation: a simulation study. *Journal of New Zealand Grasslands 85*: 253-261. https://doi.org/10.33584/jnzg.2024.85.3631

Garcia SC, Holmes CW. 1999. Effects of time of calving on the productivity of pasture-based dairy systems: A review. *New Zealand Journal of Agricultural Research 42*: 347-362. https://doi.org/10.1080/00288233.1999.9513384

Glassey C, Wills G, McCahon K, Dodd M, Chapman D. 2021. Long-term Central Waikato summer-autumn rainfall and pasture growth trends. Are conditions for pasture growth changing over time? *Resilient Pastures Symposium: Research and Practice Series 17*: 369-378. https://doi.org/10.33584/rps.17.2021.3456

Grainger C, McGowan AA. 1982. The significance of pre-calving nutrition of the dairy cow. Dairy production from pasture. *New Zealand Society of Animal Production*: 134-171.

Holmes CW, Brookes I, Garrick D, Mackenzie D, Parkinson TJ, Wilson G. 2002. *Milk Production from Pasture: Principles and Practice*. Massey University, Palmerston North, New Zealand.

Kok A, Lehmann JO, Kemp B, Hogeveen H, van

Middelaar CE, de Boer IJM, van Knegsel ATM. 2019. Production, partial cash flows and greenhouse gas emissions of simulated dairy herds with extended lactations. *Animal: An International Journal of Animal Bioscience 13*: 1074–1083. https://doi.org/10.1017/S1751731118002562

Kolver ES, Roche JR, Burke CR, Kay JK, Aspin PW. 2007. Extending Lactation in Pasture-based Dairy Cows: I. Genotype and Diet Effect on Milk and Reproduction. *Journal of Dairy Science 90*: 5518-5530. https://doi.org/10.3168/jds.2007-0324

MacDonald KA, Penno JW. 1998. Management decision rules to optimise milksolids production on dairy farms. *Proceedings of the New Zealand Society of Animal Production 58*: 132-135. https://www.nzsap.org/system/files/proceedings/1998/ab98040.pdf

Macdonald KA, Beca D, Penno JW, Lancaster JAS, Roche JR. 2011. Effect of stocking rate on the economics of pasture-based dairy farms. *Journal of Dairy Science 94*: 2581-2586. https://doi.org/10.3168/jds.2010-3688

Phyn CVC, Kay JK, Roach CG, Kolver ES. 2009. BRIEF COMMUNICATION: The effect of concentrate supplementation on milk production during an extended lactation in grazing dairy cows. *Proceedings of the New Zealand Society of Animal Production 69*: 43-45. https://www.nzsap.org/system/files/proceedings/2009/ab09010.pdf

Romera AJ, Doole GJ. 2016. Integrated analysis of profitable stocking-rate decisions in pasture-based dairy systems. *Grass and Forage Science* 71: 90-101. https://doi.org/10.1111/gfs.12149

Vogeler I, Cichota R. 2016. Deriving seasonally optimal nitrogen fertilization rates for a ryegrass pasture based on agricultural production systems simulator modelling with a refined AgPasture model. *Grass and Forage Science 71*: 353-365. https://doi.org/10.1111/gfs.12181