

Technical Series

Issue 7

Automation of oestrus detection

It is estimated that around 80 New Zealand dairy farms are using automated systems for oestrus detection. This article investigates the reasons why farmers are turning to technology for help in detecting cows in oestrus, explores a number of approaches that have been tested and commercialised, describes the performance of these systems in the field where known, and provides a technology checklist for those considering investing in automated oestrus detection systems.

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The incorporation of North American, Holstein-Friesian genetics in recent decades improved the genetic potential for individual cow production but, conversely, reduced reproductive performance resulting in increased cow wastage and higher replacement costs. An extended lactation or 24-month inter-calving interval is a management strategy that may overcome these problems, by taking advantage of the superior milk production capacity from these high-yielding cows whilst reducing cow wastage.

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DairyNZ 

Automation of oestrus detection



Jenny Jago, DairyNZ Senior Scientist; Chris Burke, DairyNZ Senior Scientist; Brian Dela Rue, DairyNZ Research Engineer and Claudia Kamphuis, DairyNZ Scientist.

Summary

- The benefit of an automated oestrus detection system is determined by the farm's current oestrus detection efficiency (ODE), the sensitivity of the automated detection system (how many cows that are in oestrus are identified by the system), the ability of the farmer to correctly sort the falsely 'alerted' cows, and the overall cost of implementing the system
- Your farm's ODE can be estimated using the InCalf Fertility Focus reports (see your InCalf Advisor)
- The likely sensitivity of an automated system for oestrus detection is more difficult to obtain as few, if any, of the systems have been tested in field conditions against robust gold standard measures such as progesterone profiles
- Recent field evaluations indicate that performance is variable, with some systems performing almost as well as an experienced operator using manual detection methods assisted by tail-head visual detection aids (e.g. tail paint and/or heat patches), but most perform below this level
- All systems require regular maintenance and daily monitoring of technical performance
- Current automated systems should be used as tools to assist in oestrus detection, and cannot be used as standalone systems. A secondary method of detection (e.g. tail paint) is essential to confirm the status of the 'alerted cows', and to act as a back-up because the economic consequence of equipment failure is too great for a seasonal calving farm business.

It is estimated that around 80 New Zealand dairy farms are using automated systems for oestrus detection. The majority of these are activity-monitoring systems or a camera that inspects tail-head mount detection aids. This article investigates the reasons why farmers are turning to technology for help in detecting cows in oestrus, explores a number of approaches that have been tested and commercialised, describes the performance of these systems in the field where known, and provides a technology checklist for those considering investing in automated oestrus detection systems.

Why are farmers interested in automating oestrus detection?

Economic benefit: Oestrus detection efficiency (ODE) has a direct impact on farm productivity and profitability. This is because the efficiency with which cows are detected when in oestrus is a key influencer of in-calf rates, which in turn determines empty rates and calving patterns, a critical determinant of a farm's economic performance. The relationships between ODE, 6-week in-calf rate and empty rate following a 12 week mating period are shown in Figure 1.

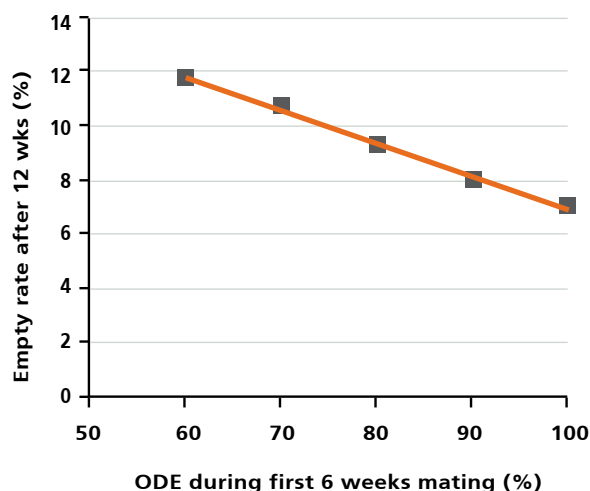
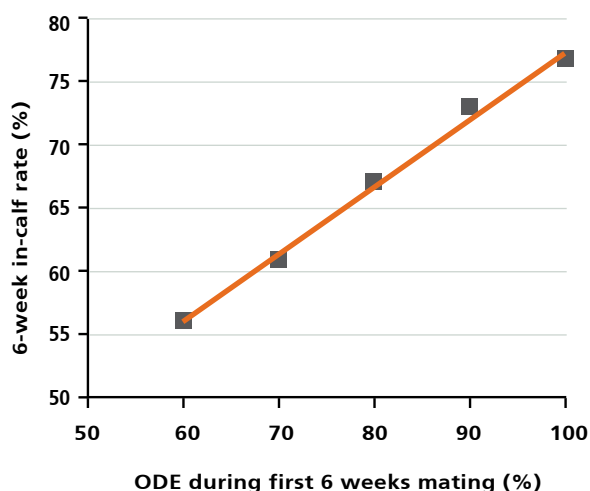
The benefit of good ODE has been assessed using the InCalf Economic Benefit model¹. The model predicts that for a herd of 400 cows there is potentially \$19,680 to be gained by improving ODE from 75% to 90%. This equates to improving 6-week in-calf rate from 64% to 72%, and empty rate after 12 weeks of mating from 9.9% to 8.1% and is a \$1,312 benefit for every 1% increase in ODE. These outcomes are calculated for one year only. The full benefits of improved reproductive performance will be realised over several years.

Labour: The most common method of detecting cows in oestrus is by visual observation assisted by tail paint or heat-patches. Farmers report that the major problems with these

Figure 1. Relationships between oestrus detection efficiency (ODE) and;

(a) 6-week in-calf rate and;

(b) empty rate after 12 weeks of mating.



methods are their labour intensiveness and a requirement for a high level of skill. Large farms are often most affected, where managers rely on less experienced staff for oestrus detection. Smaller farms managed by a single, experienced operator can also be affected in that the operator is unable to delegate this task. For these reasons some farmers are turning to technology to automate the detection of cows in oestrus.

What are farmer expectations of an automatic oestrus detection system?

Farmer expectations were explored in a workshop. They want a system that will identify and draft out cows in oestrus accurately, quickly and reliably without disturbing the flow of the milking operation. Importantly it should remove the 'human' element from this farm task. The perceived benefits are that a successful technology would improve the reproductive performance of the herd and increase discretionary time for farm staff to focus on other important farm issues or leisure.

What are the technology options?

Numerous physiological and behavioural changes are associated with oestrus and various approaches to utilise these changes to automate oestrus detection have been explored. These include: activity monitoring systems (pedometers or accelerometer technologies); mount detectors in which pressure-sensors are placed on the cow's tail head and that are stimulated each time the cow is mounted²; changes in temperature^{3,4}; vaginal mucus resistance⁵ and changes in hormones such as milk progesterone⁶, lying behaviour⁷ and rumination time⁸. Finally, combinations of these measures in the formulation of oestrus detection algorithms have been used to increase detection rates and reduce the number of false positive alerts⁹. In New Zealand, the two main approaches

that are commercially available are the activity monitoring systems (pedometer or accelerometer technologies that are either leg or collar mounted) and a camera-based system that automates the inspection of heat patches¹⁰. All automated monitoring systems include electronic identification so cows can be automatically drafted using alert data.

The camera system eliminates the need for manual inspection of heat patches and enables automatic drafting of 'alerted' cows. It uses image analysis to classify a heat patch as being non-activated, partially activated, fully activated or missing, at each milking for every cow. The performance of this system is governed firstly by the performance of the heat patch technology and secondly by the accuracy of the image analysis.

The first use of leg-mounted pedometers to measure activity associated with oestrus behaviour was in 1977¹¹, but their commercial sale is a relatively recent development in New Zealand. Early models were based on simple technology, such as a mercury-switch to count movement events indicative of a step, with the number of steps taken between milkings recorded¹². Newer technologies use accelerometers that measure changes in acceleration of the activity device due to animal movements. These measures allow a motion index value or activity deviation to be calculated which can be used to assess changes in the cow's activity level. A reference period is used to establish baseline information for each cow from which a meaningful deviation in motion is derived. For example, a system may calculate a seven-day rolling mean for activity (the reference period) against which the current activity value can be compared. The cow is 'alerted' as in oestrus when the ratio or deviation exceeds a preset threshold.

Setting the threshold value involves a trade-off between sensitivity (the % true oestrus events detected) and success rate (the % of alerts that are correct), shown in Figure 2.

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The graph presents a theoretical situation of a high performing system operating at 90% sensitivity with an 80% success rate, for a given threshold. A lower threshold will increase the sensitivity but will also generate more false alerts. These can become unmanageable at high sensitivity. The shaded area in Figure 2 covers the range in the activity deviation threshold for minimum performance criteria of >80% for both sensitivity and success rate. This means that at least 80% of all progesterone-based oestruses are to be detected and that at least 80% of all automatically alerted cows are truly in oestrus.

Unfortunately, it is not straight forward to compare the reported performance of different detection systems. This is because data used to calculate performance measures differ between

studies and there are very few studies on system performance in large commercial grazing herds. One source of variation is the method of determining a gold standard to establish the timing of oestrus against which system alerts are compared. Milk progesterone concentrations are the most common reference measure for validating these technologies, however, even this method cannot accurately determine the exact timing because of sampling frequency. For this reason different time windows (hours or days) are often used to determine if an alert is valid. DairyNZ has been evaluating the performance of a range of oestrus detection systems in use on commercial farms in New Zealand and has proposed the development of standardised methods to report outcomes. Table 1 provides a summary of the recent New Zealand studies.

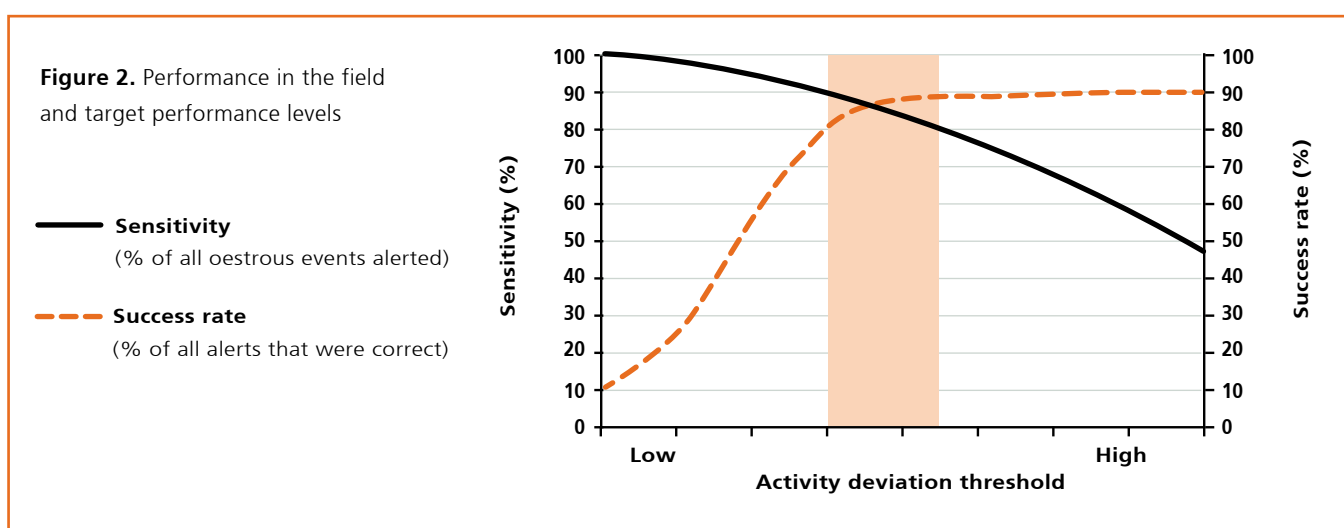


Table 1. Sensitivity and success rate for different oestrus detection systems evaluated in recent New Zealand field trials on three farms

Trial	Season	Duration (weeks)	Technology	Number of oestrus events	Performance measures (%)*	
					Sensitivity	Success Rate
Farm 1	2010	5	Experienced operator #	835	91.3	94.5
			Neck collar 1	415	62.4	76.6
		Neck collar 2	420	76.9	82.4	
		4.5	Patches (visual)	782	90.8	83.9
		4.5	Patches (camera)	782	90.5	76.6
Farm 2	2008	3	Neck collar 3	343	69.7	32.9
Farm 3 [‡]	2008	3	Pedometer 1	195	89.2	83.3

Oestrus detection was a designated task at milking. Time window = 24h

* All analyses, except experienced operator, used a time-window of 72 hours in which an alert by the system was considered valid. Oestrus was confirmed using progesterone data (gold standard).

‡ Mature cows only.

In Table 1, data are from a study during the 2010 mating season at the Lincoln University Dairy Farm (LUDF) during which three technologies were evaluated as well as the performance of an experienced operator (Farm 1). The operator's performance is based on the use of tail paint and heat patches as well as previous cycling and mating data for the animal. These results are consistent with the ODE measured on 16 large farms using visual observations and which ranged from 78% to 94% (average 88%) (Burke, unpublished). Also, an international study¹³ that reported that skilled personnel would miss 10% of animals in oestrus, even with visual observations at 4-5 hour intervals from early morning to late evening. Using the performance of the experienced operator on Farm 1 as a benchmark, the activity based systems (both collar and leg on Farms 1, 2 and 3) achieved lower sensitivity and success rates. Reasons for the poor performance of neck collars 1 and 3 included a number of faulty collars and older style devices. A higher sensitivity could have been achieved for all activity systems by changing the alert threshold; however, this would have resulted in more falsely alerted cows (lower success rate) which must then be sorted prior to insemination. The analysis assumes cows were 'alerted' without any additional filtering, e.g. of cows inseminated in recent days or checks. In practice, farmers may use additional filters to sort cows alerted falsely. A high performing system should have high sensitivity and high success rate (suggested minimum of 80%).

The heat patches (Bulling Beacon) were scored visually and detected 90.8% of the oestrus events, similar to that achieved by the experienced operator, although using a wider time window for accepting an alert. However, the success rate was lower (83.9%) indicating more cows were falsely identified as being in oestrus. Technical problems with the camera set-up meant that only morning milking images were scored and it was necessary

to enhance the images digitally. The camera system identified a similar percentage of cows in oestrus, but 24% of alerts were false. In this instance the camera system was poorer at decision making than visual assessment by an experienced operator, due to the technical problems with the set-up. An earlier published study reported that the camera was able to detect changes in the heat patch (in that case KAMAR[®] were used) to the same accuracy level as achieved by visual assessment¹⁰.

The results from these studies lead to the conclusion that technical faults with any automated oestrus detection systems can occur. It would not be prudent to rely on them as stand-alone systems until there is sufficient evidence of better accuracy. With respect to farmer expectations, experience to date suggests that it is not yet possible to remove the skilled human element completely from oestrus detection; however, the manual effort required by an experienced operator can be significantly reduced by using these technologies.

Economic implications

A partial budget is a first step to evaluate the costs and benefits of investing in a technology, although full investment analysis is recommended to determine long-term returns. Three scenarios examining change in ODE as a result of implementing an automated system were investigated; (1) ODE improved from 75% to 90%; (2) no change in ODE; (3) decrease in ODE from 90% to 75%. The changes in reproductive performance indicators were converted to an economic benefit¹ in alignment with values in Figure 1, assuming a \$4 benefit per cow per 1% increase in 6-week in-calf rate and \$10 per cow for every 1% decrease in empty rate after 12 weeks of mating. The assumptions and outcomes of the partial budget are shown in Figure 3.

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Figure 3. Partial budget on the economics of installing an automated oestrus detection system

Increased income		Decreased income	
Assumptions			
Herd size 400 cows; electronic ID system and computer already in place, tail painting is required as back-up system; the automated oestrus detection system has a 5 year life-span, depreciation is at 20% per year, the range in capital is \$20,000-\$40,000 depending on which system is purchased, 2 hours per day are saved in labour for oestrus detection over a 6-week mating period.			
Three scenarios:			
1) ODE increases from 75% to 90% (\$19,680)		3) ODE reduces from 90% to 75% (-\$19,680)	
2) ODE remains constant (\$0)			
Decreased costs		Increased costs	
Labour 2 hours/day, 6 weeks AI, \$40/hour		<ul style="list-style-type: none"> Interest on capital (7.5% \$1,500-\$3,000) Repair and maintenance (3% of capital \$600-\$1,200) Operating equipment e.g. heat patches (\$0-\$2,400) Depreciation over 5 years (\$4,000-\$8,000) 	
Total decreased costs for all scenarios \$3,360		Total increased costs range from \$8,500-\$12,200 depending on technology used	
Net gain or loss			
Scenario	Low capital (\$20,000)	High capital (\$40,000)	
1. ODE increases from 75% to 90%	+ \$14,540	+ \$10,840	
2. ODE remains constant	- \$5,140	- \$8,840	
3. ODE reduces from 90% to 75%	- \$24,820	- \$28,520	
Other factors to consider:			
<input type="checkbox"/> Enabling technologies are essential (EID, auto-drafting capability required)			
<input type="checkbox"/> Additional uses of technology (e.g. health monitoring)			

Scenario 1 shows that if current oestrus detection is poor, there is significant opportunity to improve overall farm performance by investment in an automated detection system, if it delivers a sensitivity of 90% with a manageable number of false alerts. The extent of this gain is determined by the capital invested in the system. Gains may still be made if the increase in ODE were smaller (e.g. 5% gain in ODE is equivalent to \$1,340), but only at the lower level of capital investment. Scenario 2 shows that if there is no change in ODE after the implementation of an automated system, whatever the current performance of that farm, there will be a loss. Scenario 3 shows that if ODE is already above average and performance declines substantially (e.g. from 90% to 75%) when using an automated system, significant losses will be incurred. Again the extent of the loss is influenced by the size of the capital investment.

There is a clear industry need for improved oestrus detection as it is a critical factor influencing farm performance. Automated systems can play a role in achieving this improvement, but farmers should consider the pros and cons, and the likelihood of achieving an improved detection outcome carefully when considering investment in automatic oestrus detection systems.

Technology check list

Determining if an automated oestrus detection system is an option for your farm business requires an understanding of what you wish to achieve, as well as knowledge of the requirements, capabilities and limitations of available automated systems and an assessment of the costs and benefits. Consider:

- Use the InCalf Fertility Focus report and InCalf advisor to determine your current ODE
- What changes in ODE you want to achieve and is this goal realistic?
- Has the performance of the technology been evaluated independently?
- What do farmers using the technology think? Have they determined the system's performance objectively and separate from any other changes made in farm management?
- Does an investment analysis result in a positive financial prediction? (e.g. partial budget or full investment analysis).

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Recently published by DairyNZ

DairyNZ researchers publish their findings in high calibre national and international journals, so they remain at the leading edge of dairy industry research.

Peer reviewed publications

- Beukes, P., M. R. Scarsbrook, P. Gregorini, A. J. Romera, D. A. Clark and W. Catto. 2011. The relationship between milk production and farm-gate nitrogen surplus for the Waikato region, New Zealand. Journal of Environmental Management, 93:44-51.
- Jago, J. 2011. Automatic milking - is it an option for small to medium herds in NZ? Primary Industry Management Journal, 15: 18-21.
- Jago, J., and D. Berry. 2011. Associations between herd size, rate of expansion and production, breeding policy and reproduction in spring-calving dairy herds. Animal, 5:10, 1626–1633.
- Lee, J., P. Sathish, D. J. Donaghy, and J. R. Roche. 2011. Impact of defoliation severity on photosynthesis, carbon metabolism and transport gene expression in perennial ryegrass. Functional Plant Biology, 38:808-817.

See page 15 for the science conference publications

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How does an extended lactation affect performance?



Jane Kay, DairyNZ Scientist; Claire Phyn, DairyNZ Scientist; Agustin Rius, DairyNZ Scientist and John Roche, DairyNZ Principal Scientist Animal Science.

Key messages

- Extending lactations up to 22 months (e.g. calving once every two years) is feasible in a pasture-based dairy system
- Potential benefits of an extended lactation (EL) include:
 - fewer days dry within a cow's lifetime,
 - improved reproductive performance,
 - lower costs associated with mating, calving, animal health and culling,
 - more even spread of labour requirements, input costs and income throughout the year
- There is large variation in the suitability of cows for EL:
 - some cows produce as much milksolids during a two year EL as they do from two standard (10-month) lactations
 - but others produce 25% less milksolids
- Milksolids production during the EL is affected by nutrition, in particular during the winter months and the second season
- Possible adverse effects associated with an EL include:
 - substantial losses in milk production and excess gains in BCS
 - extra investment required for milking during the winter months (labour, supplementary feeds, capital investment in feed systems)
 - higher SCC during the second season of an EL.

Background

Pasture-based systems have traditionally used compact seasonal calving to ensure pasture supply matches nutrient demand, thereby maximising milk production from grazed pasture and increasing profitability^{1,2}. The incorporation of North American (NA), Holstein-Friesian (HF) genetics into these seasonal systems in recent decades improved the genetic potential for individual cow production; but, conversely, reduced reproductive performance^{3,4,5} resulting in increased cow wastage and higher replacement costs. An extended lactation (EL) or two year inter-calving interval is a management strategy that may overcome these problems by taking advantage of the superior milk production capacity from these high-yielding cows whilst reducing cow wastage.

Extended lactations are possible in pasture-based dairy systems

Extending lactations from the standard eight to 10 months to 16 to 22 months is possible in pasture-based dairy systems. Research conducted in New Zealand, Ireland and Australia indicates that most cows (approximately 95%) are able to continue milking for a 16-month lactation (with cows dried off when milk production falls below 5 kg/d), but only about a third of cows can achieve a 22-month lactation^{6,7,8}. Additionally, there is a large variation in the performance (days in milk [DIM], milk production, reproduction and body condition score (BCS)) of individual cows during an EL, which largely depends upon cow genetics and nutrition^{7,9}. Profitable EL may therefore be achieved in pasture-based systems by optimising the combination of cow genetics and nutrition, particularly if lactations longer than 16 months are targeted.

How is performance affected during an EL?

Milk production

Milk production during an EL is influenced by cow genetics and nutrition^{7,9}. Holstein-Friesian cows with a high proportion of NA genetics have more DIM, produce more milksolids and gain less BCS during a 22-month EL than cows with predominantly New Zealand HF genetics (Figure 1 and 2^{7,9}). The response to supplementary feeding during an EL also differs between genetic strains^{6,7,9}. The most meaningful method of comparing milk production during an EL with a traditional 10 month lactation is to use the ratio of annualised production (i.e. total production during the EL divided by 2 yr) compared with the standard (10-month) lactation production. In a DairyNZ experiment, NA HF that were supplemented with 0, 3 or 6 kg concentrate DM/d for an entire EL, produced 89, 100, and 95% of the milksolids that they would have produced from two standard (10-month) lactations, whereas New Zealand HF fed 0, 3 or 6 kg concentrate DM/d produced 78, 83 and 75%, respectively⁷.

Level of supplementary feeding is an important management consideration during the second season of an EL (i.e. beyond 300 DIM). During a standard (10-month) lactation there is a linear relationship between increasing supplementation and milksolids production per cow (i.e. production increases with supplement amount); however, this relationship changes during the second season of an EL^{7,9}, when milksolids production per cow increases with low supplementation but is lower at high levels of supplementation. For example, New Zealand HF fed 3 kg concentrate DM/d during an EL produced more milksolids (on an annualised basis) than those fed either 0 or 6 kg concentrate DM/d⁷. This finding is supported by Australian research where NA HF cows were fed either a pasture-based diet supplemented with 3 or 5 kg grain DM/d to provide 160

or 180 MJ ME/cow/d, respectively, or fed a total mixed ration (TMR), which supplied between 220-280 MJ ME/cow/d, for the 22-month lactation. During the first season of the EL, milk production increased with increasing energy intake; however, during the second season, cows fed TMR with the highest ME intake produced less milksolids (on an annualised basis) and had to be dried off earlier relative to cows fed at lower ME intakes⁹.

Body condition score

Cow genetics and nutrition also influence BCS during an EL, particularly during the second season^{7,9}. In conjunction with the decrease in milk production described above, New Zealand HF cows fed the highest supplement level (6 kg concentrate DM/d), and NA HF fed a TMR, gained excessive body condition during the later stages of the EL^{7,9}. This finding indicates that these animals were fed in excess of requirements and partitioned energy towards body reserves instead of milk production. As these animals got fatter, their capacity to produce milk diminished and they were dried off earlier because of low daily milksolids yield.

Plasma hormones and metabolites measured during this period supported these arguments. In NA HF cows fed a TMR and New Zealand HF fed 6 kg concentrate DM/d, circulating concentrations of hormones indicating surplus energy (i.e. IGF-I, leptin and insulin) were higher^{10,11}. Such a metabolic profile favours the partitioning of energy towards body tissue instead of milk production. The complex relationship between cow genetics, nutrition and stage of lactation reinforces the importance of selecting diets that do not provide too much energy during the second season. Monitoring individual cow BCS is important to ensure optimum milk production during an EL.

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Figure 1. North American (NA) Holstein-Friesians produced more milksolids than New Zealand (NZ) Holstein-Friesians; however, production depends on the level of supplementation, with New Zealand and NA cows that were fed 3 kg concentrate DM/d producing more in the second season that those fed 0 or 6 kg concentrate DM/d.

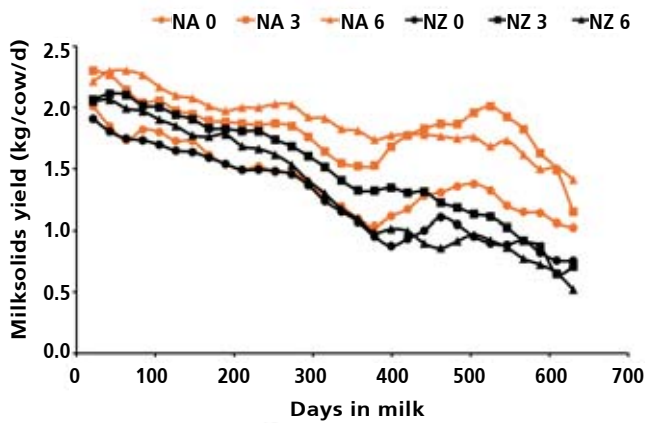
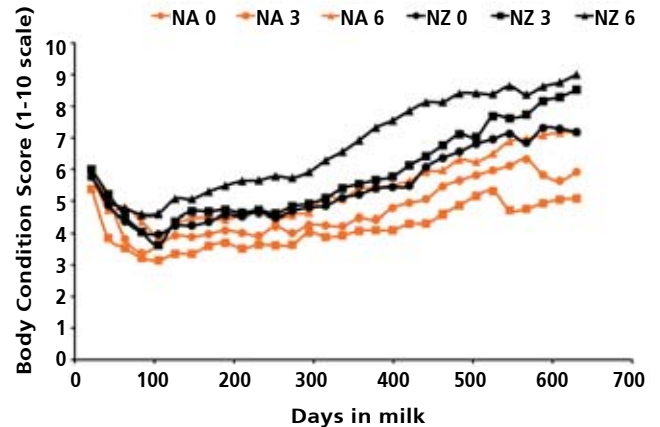


Figure 2. New Zealand (NZ) Holstein-Friesians that were fed 6 kg concentrate DM/d gained excessive BCS during the second season of the extended lactation.



Reproduction

Reproductive performance is improved in an EL system relative to an annual seasonal calving system, and is most probably due to cows being in a more positive energy balance with a greater BCS at mating^{7,8}. Although it is difficult to compare reproductive performances over two different seasons, research conducted at DairyNZ indicated that mating NA HF cows at ~ 450 DIM to target a two year inter-calving interval compared with ~ 80 DIM for an annual calving system improved 21-d submission rate (85 vs. 59%), first-service conception rate (48 vs. 19%) and final empty rate (30 vs. 48%)⁷. While the reproductive performance of NA HF cows at 450 DIM was still less than industry targets and not as good as New Zealand HF in the same study⁷, the improvement is consistent with Irish research where empty NA HF cows continued milking for a second season, and when animals were mated again at ~450 DIM, 85% were scanned pregnant⁸.

How do we know which cows will produce more during an EL?

Although NA HF cows are more suited to an EL than New Zealand HF, there is also large variation within these strains and other breeds in a cow's ability to maintain milk production during an EL. Research at DairyNZ investigated if there were any indicators that could identify cows that would be more successful in an EL¹², thereby allowing a decision on which cows were worth persisting with in this management strategy.

The strongest predictors for increased milksolids production during an EL were greater daily milksolids yield and lower BCS when a cow would normally be dried off in late lactation. These parameters accounted for approximately 50% and 40%,

respectively, of the variation in EL milksolids production, irrespective of cow genetic strain or nutrition. There was no correlation between Breeding Worth or Production Worth and milksolids production during the EL; however, it must be noted that only a relatively small dataset was available to examine these relationships. Nevertheless, these results have been confirmed in additional experiments¹³ and indicate that it is possible to identify a cow that will perform well during an EL based on milk production and BCS during a standard lactation.

Table 1. Milk and milksolids yield from 120 Holstein-Friesian x Jersey cows milked either twice (2X) or thrice (3X) daily and fed a generous pasture allowance with either no supplement or 6 kg concentrate DM/d. During the 70 d treatment period (330 to 400 DIM), supplementation increased milk and milksolids yield, while 3X milking increased milk but not milksolids yield. There was no effect of 3X milking or supplementation on milk production during the carry-over period (400 to 650 DIM) when all cows were milked 2X and received no supplement.

	No supplement		Supplement (6 kg DM/d)	
	2X	3X	2X	3X
Treatment period (330 to 400 DIM)				
Milk yield (kg/d)	11.6	12.6	12.4	13.9
Milksolids yield (kg/d)	1.08	1.09	1.12	1.16
Carry-over period (400 to 650 DIM)				
Milk yield (kg/d)	10.3	10.2	9.6	10.7
Milksolids yield (kg/d)	0.98	0.93	0.89	0.95

Are there management strategies that can improve production during an EL?

There are strategic time points during an EL that can be targeted to improve performance. In a predominantly pasture system, there is a trough in milk production during the winter months when pasture quality and/or quantity is low followed by a second peak in milk production during the second spring months, when pasture quantity and quality increase (Figure 1). Research conducted at DairyNZ and in Ireland indicated that supplementation during the second winter/spring of an EL increased milksolids production during the period of supplementation (Table 1)^{8,13,14}. In two of these studies, a positive carry-over response in milksolids yields was reported after supplementation had finished^{8,13}. The magnitude of the carry-over response may depend on the amount of concentrate fed, the length of the supplementation period and the length of the carry-over period¹⁴.

In addition to altering nutrition at strategic time points throughout an EL, research in the early 2000s indicated that short-term increases in milking frequency (from 2X to 3X) increased milksolids production during a 16-month EL in high-producing Swedish Red and White cows managed in a confinement system¹⁵. In a recent DairyNZ trial, cows that were milked 3X from ~ 330 to 400 DIM produced 1.1 kg of milk/d more than cows milked 2X during this period; however, cows that were milked 3X also had lower milk fat and protein

contents such that there was no increase in milksolids production (Table 1¹⁴). This is consistent with other DairyNZ research during a typical (10-month) lactation, where New Zealand HF cows fed a pasture-based diet were milked 3X from calving for 3 or 6 wks and produced more milk but no more milk solids than those milked 2X¹⁶.

Conclusions

Extended lactations can be successfully implemented in pasture-based dairy systems, with some combinations of cow genetics and nutrition producing as much milksolids as they would have during two standard (10-month) lactations. However, some cow genetics and nutrition combinations can produce up to 25% less milksolids. Extended lactations have the potential to improve the lifetime productivity of cows in some systems and reduce cow wastage. This management strategy is particularly applicable in larger herds (i.e. larger numbers of cows being culled involuntarily), where facilities allow the feeding of supplements during winter, and in split-calving systems where a 16-month lactation could be targeted. Cow milksolids production and BCS at the end of the first season are good predictors of a cow's suitability for EL. Body condition score should be monitored through the second season and nutrition strategies managed to ensure cows do not get too fat.

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Responses to Rumensin® under pasture systems



John Roche, DairyNZ Principal Scientist Animal Science and Jane Kay, DairyNZ Scientist and Team Leader, Nutrition.

Summary

- Rumensin® alters ruminal microbial populations to favour increased propionate production. This should increase milk protein yield
- Milk production responses to Rumensin®, however, have been inconsistent and difficult to predict. An international review and New Zealand pasture-based studies indicate that average responses are approximately 15-25 g milk protein/cow/day
- Research results indicate that feeding Rumensin® does not improve fertility, but reduces the incidence of bloat and the risk of ketosis in some circumstances.

The active ingredient in Rumensin® is sodium monensin, a compound that alters rumen microbial populations and, therefore, the predominance of different ruminal fermentation pathways¹. In theory, these changes result in a greater production of propionate in the rumen and a reduction in the production of acetate and butyrate². This effect has been reported in multiple studies in laboratory analyses and in cattle¹, but the extent of the effect appears to be diet dependent^{1,3}, because:

- a. Propionate results in greater glucose production by the liver⁴ and insulin by the pancreas
- b. Acetate and butyrate are precursors for milk fat⁵, and
- c. Rumensin® alters fatty acid metabolism (biohydrogenation) in the rumen⁶.

Rumensin® should, in theory, reduce milk fat and increase milk protein and milk volume. As methane production is a by-product of fermentation pathways that result in acetate production⁵, Rumensin® would also be expected, in theory, to reduce methane production^{7,8} and increase the efficiency with which feed energy is converted to milk and meat. Rumensin® also interferes with ruminal protein degradation, a key factor in the production of the stable foam that causes bloat in ruminants; Rumensin® is, therefore, reported to be an effective bloat preventative.

Although there is a sound basis for all of these claims, there are inconsistencies in the reported effect of Rumensin® on these important factors. Recent reviews^{3,9,10,11} summarised the effect of Rumensin® on dry matter intake (DMI), milk production, reproduction, body condition score, and cow health, particularly during the transition period and early lactation; the likely implications of Rumensin® use for New Zealand pasture-based systems are presented.

Rumen fermentation

Rumensin® alters the populations of micro-organisms in the rumen to increase the production of propionate and reduce the breakdown of protein.

Rumen micro-organisms ferment carbohydrates from the cow's diet to grow and they produce volatile fatty acids (VFA) as waste products. The cow has evolved to use these VFA as her primary sources of energy⁵. There are three main VFA: acetate, butyrate, and propionate; the ratio of these three VFA depend on the microbial populations in the rumen. Many factors can cause changes in rumen microbial populations and, as a result, the proportion of the different VFA:

1. Individual cows can have very different populations of micro-organisms¹² and, therefore, there is cow to cow variation in rumen VFA production
2. Diet influences the growth of different micro-organisms and can, therefore, influence VFA production. For example, fibre-based diets tend to direct rumen fermentation towards acetate production, while starch-based diets increase the proportion of propionate produced⁵
3. Feed additives (e.g. antibiotics¹, yeast cultures¹³) can selectively target certain types of micro-organisms, thereby altering rumen fermentation. For example, Rumensin® selectively targets bacteria that ferment carbohydrates to acetate, facilitating increased growth of bacterial communities that ferment carbohydrates to propionate.

In addition to fermenting carbohydrates, rumen bacteria break down dietary protein. This often results in the wastage of dietary protein, with a requirement for more protein in the diet to offset this inefficiency. Some of the bacteria that rapidly break down protein are sensitive to Rumensin®; supplementation with Rumensin®, therefore, tends to result in more high quality feed protein reaching the small intestine⁵. This is unlikely to be a benefit in pasture-based systems, where protein rarely limits milk production. However, its role in systems with greater use of low protein supplements (e.g. cereal grains, maize silage) or when pasture metabolisable energy (ME) or protein levels are low (e.g. drought) requires further evaluation.

Milk production

Milk production responses to Rumensin® supplementation are variable and impossible to predict. On average, under New Zealand dairy farming conditions, cows supplemented with Rumensin® produce 15-25g more milk protein per cow per day than unsupplemented cows. This effect could be more when feeding poor quality forages and less when pasture quality is highest.

Milk production responses to Rumensin® supplementation in pasture-based systems have been inconsistent. In a recent international review³ of monensin supplementation, cows supplemented with Rumensin® produced 2% more milk and 2% more milk protein than unsupplemented cows, with no effect, on average, on milk fat production. This is approximately equivalent to an additional:

- 20 g milk protein from cows producing 2.4 kg milksolids (MS)
- 18 g milk protein from cows producing 2.1 kg MS
- 15 g milk protein from cows producing 1.75 kg MS
- 12 g milk protein from cows producing 1.4 kg MS, or
- 9 g milk protein from cows producing 1.0 kg MS.

At \$9.55/kg milk protein, such increases would result in a milk revenue increase of \$0.09-0.19/cow/day depending on MS yield/cow.

Results indicated an effect of diet and stage of lactation on the response to Rumensin®, with greater responses evident in pasture-based herds. Waghorn and co-workers¹¹ reviewed the research undertaken in pasture-based systems in Australia and New Zealand and, again, reported variable results. Australian studies¹⁴ reported a 30 g/cow/day increase in milk protein but these results were not achieved in subsequent trials on 18 dairy farms in Australia^{15, 16}, where Rumensin® increased milk yield but did not increase milk protein yield. Waghorn and co-workers¹¹ quoted unpublished experiments in New Zealand and Australia that reported an average increase of 40 g MS/cow/day across the dataset, but only an increase of 23 g MS/cow/day in those studies undertaken in New Zealand.

The reason for the inconsistency in milk production responses to Rumensin® is not clear, but it may reflect a negative effect of Rumensin® on DMI, as reported in many studies³, or an interaction with diet quality. Waugh and co-workers¹⁷ reported an increased effect of Rumensin® as diet ME declined; response to Rumensin® increased from -70 g/cow/day to +70 g/cow/day as ME declined from 12.1 MJ/kg DM to 11.6 MJ/kg DM. These data and published evidence of greater responses to Rumensin® when diet digestibility declines^{1,3} suggest that the best milk production response to Rumensin® may be during summer, while the lowest response is likely during spring, when pasture quality is highest. However, further research is required to determine the cow response under different diets.

(cont'd p14)

Reproduction and health

The majority of research studies indicate no effect of Rumensin® on fertility. Rumensin® is an effective bloat prevention agent and reduces the concentration of ketone bodies in blood, reducing the risk of ketosis.

Reproduction: Because of Rumensin®'s effect on rumen fermentation and consequential effects on blood glucose and β -hydroxy butyrate, it has been proposed that Rumensin® might improve reproduction. A comprehensive review of world literature indicated no effect of Rumensin® on either first service conception rate or days to pregnancy¹⁰. These results are consistent with a lack of effect of Rumensin® on fertility in a major experiment in Australia involving more than 1,000 cows across 12 farms¹⁶.

Bloat: Bloat is a serious disorder of cattle and sheep involving a severe distension of the animal's rumen¹⁸. The condition generally involves cows grazing lush, leafy and, often, legume-dominant pastures during spring and autumn and is the result of a gas-filled foam at the top of the rumen that the cow is unable to release (eructate)¹⁹. The actual cause of foamy bloat is not completely known, but products of the breakdown of proteins in legumes and grasses have been implicated¹⁹. Research undertaken in grazing cows in New Zealand and Australia indicates that monensin can reduce the incidence of visible bloat and bloat deaths by approximately 80%^{14,20,21}. However, no one method of prevention will be 100% successful against a large bloat challenge and farmer vigilance and experience is probably still the most important factor in bloat prevention.

Ketosis: Rumensin® has been proposed as a strategy for reducing the risk of ketosis. Ketosis is a disease that occurs when there is a disconnect between energy demand and energy supply, and cows are not able to fully utilise mobilised body fat²². In these situations the intermediaries in the breakdown of fat accumulate and cause ketosis. The disorder occurs when cows undergo a sudden reduction in intake (Type I ketosis) and is particularly prevalent in fatter cows after calving (Type II ketosis), particularly when energy demands are high in early lactation, or it can occur if cows are fed silages that have undergone secondary fermentation (silage ketosis).

One of the factors contributing to the disorder is a lack of propionate to stimulate glucose production in the liver and aid in the full breakdown of mobilised fat²². Therefore, one of the prevention strategies for ketosis is to provide dietary ingredients that shift ruminal fermentation towards more propionate production and increase the liver's production of glucose. In a comprehensive review⁹, authors concluded that monensin use in lactating dairy cattle reduced blood ketone body concentrations by 13% and circulating concentrations of fatty acids by 7%. Monensin also increased plasma glucose concentrations by 3%. These data imply that use of Rumensin® in early lactation will reduce the risk of ketosis.

Ketosis is not a common disorder, although negative effects on DMI, milk production and reproduction have been reported at blood β -hydroxy butyrate concentrations much lower than those required to elicit clinical ketosis symptoms²³. Monensin has been reported to reduce the incidence of this post-partum subclinical ketosis, but the benefits of this are hard to quantify in the pasture-based setting. Blood β -hydroxy butyrate concentrations tend to be higher on pasture-based diets²⁴ because of the greater production of butyrate in the rumen and not because of a greater risk of ketosis. Therefore, β -hydroxy butyrate results must be viewed with caution, taking other diagnostic factors into consideration.

Conclusions

Sodium monensin, the active ingredient in Rumensin®, alters the populations of micro-organisms in the rumen to increase ruminal propionate production and reduce acetate and butyrate production. In theory, this should increase blood glucose and, as a result, blood insulin, reduce β -hydroxy butyrate, and, through these alterations in metabolism, increase milk protein, reduce milk fat, reduce the risk of ketosis in early lactation, and improve fertility.

In reality, however, the response to Rumensin® in grazing cows is inconsistent, with both positive and negative effects on milk production (on average 15-25 g milk protein/cow/day), variable responses in blood metabolites and, on average, no effect on reproduction. Rumensin® is an effective bloat control strategy, although it must be recognised that no one strategy will offer 100% protection against bloat.

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Recently published by DairyNZ *(cont'd from pg 7)*

Science conference publications

- Brazendale, R., J. R. Bryant, M. G. Lambert, C. W. Holmes and T. J. Fraser. 2011. Pasture persistence: how much is it worth? *Pasture Persistence Symposium, Grassland Research and Practice Series No.15* pages 3-6.
- Crush, J. R., and E. R. Thom. 2011. Review: the effects of soil compaction on root penetration, pasture growth and persistence. *Pasture Persistence Symposium, Grassland Research and Practice Series No.15* pages 73-78.
- Dynes, R. A., D. C. Smeaton, A. P. Rhodes, T. J. Fraser and M. A. Brown. 2011. Modelling farm management scenarios that illustrate opportunities farmers have to reduce greenhouse gas emissions while maintaining profitability. *Proceedings of the New Zealand Society of Animal Production*., Invercargill, New Zealand, pages 167-171.
- Glasse, C. B. 2011. Summer pasture yield variation in a central Waikato location from 1979 to 2010: implications for pasture persistence. *Pasture Persistence Symposium, Grassland Research and Practice Series No.15* pages 15-20.
- Greenwood, S. L., D. E. Dalley, N. G. Purdie, I. Rugoho, and G. R. Edwards. 2011. Brief communication: Comparison of the performance of dairy cows offered energy supplements prior to drying off and kale at high and low allowance during winter. *Proceedings of the New Zealand Society of Animal Production*., Invercargill, New Zealand, pages 33-36.
- Kay, J. K., C. V. C. Phyn, A. Rius, S. R. Morgan, T. M. Grala and J. R. Roche. 2011. Effect of milking frequency and nutrition in early lactation on milk production and body condition in grazing dairy cows. *Proceedings of the New Zealand Society of Animal Production*., Invercargill, New Zealand, pages 37-41.
- McMillian, W. H., and M. G. Newman. 2011. An economic appraisal of sex-sorted semen in New Zealand dairy herds. *Proceedings of the New Zealand Society of Animal Production*., Invercargill, New Zealand, pages 131-135.
- Phyn, C. V. C., J. K. Kay, A. G. Rius, S. R. Morgan, C. S. Roach, T. M. Grala, and J. R. Roche. 2011. The effect of temporary alterations to milking frequency during the early post-partum period on milk production and body condition score in grazing dairy cows. *Proceedings of the New Zealand Society of Animal Production*, Invercargill, New Zealand, pages 45-49
- Tozer, K. N., C. A. Cameron and E. R. Thom. 2011. Pasture persistence: farmer observations and field measurements. *Pasture Persistence Symposium, Grassland Research and Practice Series No.15* pages 25-30.

For the full list of DairyNZ publications visit the news and media section of dairynz.co.nz

Focus on international research

The following is a brief summary of some key science papers recently published

Weimer and others (2010). Host specificity of the ruminal bacterial community in the dairy cow following near-total exchange of ruminal contents. *Journal of Dairy Science* 93:5902-5912.

The purpose of this study was to examine the stability and host specificity of a cow's ruminal bacterial community following a massive challenge with ruminal microflora from another cow. Cows receiving the same diet but with different rumen bacterial communities were identified. Total rumen content was exchanged between two cows, and rumen pH and volatile fatty acid concentrations measured before and after the switch. Within 24 hours, rumen pH and volatile fatty acid concentrations returned to their previous state, but it took 14 to 60 days for the bacterial communities to return to their previous state.

DairyNZ comment: This study highlights that cows are able to select their own rumen microbial population. Differences in microbial population may explain some differences in feed digestion and milk production between cows under the same grazing conditions.

Lavon and others (2011). Association of conception rate with pattern and level of somatic cell count elevation relative to time of insemination in dairy cows. *Journal of Dairy Science* 94:4538-4545.

Cow health can affect reproductive efficiency. Cows with mastitis or with high somatic cell count (SCC) have been reported to have poorer fertility, but the effect is dependent on the timing of the mastitis/elevated SCC event. The probability of cows conceiving is reduced when a high SCC (>450,000 cells/ml) occurs in the 10 days before mating and 30 days after mating. Cows with a higher SCC before and after mating had 8% lower conception rates compared with uninfected cows.

DairyNZ comment: These results are consistent with New Zealand data, which indicate that cows diagnosed with mastitis during the three weeks before or after the planned start of mating have a lower submission rate, and that mastitis after an AB insemination reduced the chance of the cow getting pregnant.

Gross and others (2011). Performance and metabolic profile of dairy cows during a lactational and deliberately induced negative energy balance with subsequent realimentation. *Journal of Dairy Science* 94:1820-1830.

In early lactation, the cow undergoes a natural lactation-induced negative energy balance. The dairy cow adapts to this situation differently to a management-induced negative energy balance that occurs due to insufficient supply or quality of feed. During the management-induced energy deficiency, milk production declines and the physiological changes that occur are minimal compared with the adaptations that occur immediately post-calving. The authors conclude that metabolic problems that occur in early lactation are not only due to the energy deficit but to specific hormonal and metabolic regulations that occur during this period.

DairyNZ comment: This supports DairyNZ research that the dairy cow is pre-programmed to produce milk at the expense of body tissue reserves during the early post-partum period. Management strategies such as milking frequency, supplementary feeding or pasture allowance have minimal effects on BCS loss and health problems for the first few weeks post-calving, as hormonal and physiological processes continue to mobilise body tissue for milk production.

Mollenhorst and others (2011). The relationship between milking interval and somatic cell count in automatic milking systems. *Journal of Dairy Science* 94:3446-3454.

This study characterised the link between milking interval and milk somatic cell count (SCC) in an automatic milking system (AMS). Cow parity and milk production rate (kg milk produced per hour) were strongly associated with SCC; when corrected for these factors, variation in milking interval immediately prior to the test milking had a greater association with SCC than actual milking interval. It could not be determined if cows with (sub)clinical mastitis were reluctant to attend milking, and, therefore, increased milking interval variation, or whether variation in SCC reflects natural changes in milking interval, and therefore needs to be accommodated in test-day models.

DairyNZ comment: Generating test-day SCC values from single milk samples for SCC remains a significant challenge for herd test systems working with AMS farms.