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Automatic milking

A new technology on New Zealand farms

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Summary

- A small and growing number of farmers are pioneering the use of automatic milking technology in New Zealand in a range of farm systems and sizes
- There are conflicting international reports on the impact of automatic milking on labour. The experience in New Zealand is that there is a substantial change in work tasks, with more flexible use of working hours, more monitoring and less manual work, but not necessarily a reduction in total labour input
- Financially, automatic milking systems have higher capital costs and greater operating costs (servicing, power and water use) compared with traditional milking systems
- Automatic milking systems have been integrated into the range of farming systems in New Zealand. However, a reduction in capital and operating costs, and/or significant labour advantages, are required before more widespread adoption of the technology is expected to occur.

The introduction of automatic milking systems (AMS) has given New Zealand farmers a new option when assessing the best milking facilities for their farm.

The first AMS were installed on two commercial farms in 2008[1], following a successful proof-of-concept Greenfield project led by DairyNZ[2,3]. Today there are about 3000 cows, in ten herds, being milked by this technology.

This article describes the special features of the early adopting farms and discusses the implications of robotic milking on labour and farm financial performance.

What is an automatic milking system?

The generic term ‘automatic milking system’ refers to automated systems that complete the whole milking process without the direct assistance of milking staff. Automatic milking systems are often referred to, or branded, as “robotic” or “voluntary” milking systems.

They typically consist of a milking stall, or crate, with a robotic arm that attaches the teat cups to each cow without human intervention, using an electronic identification system and a milking machine. “Robotic” refers to the robotic arm that performs key functions of the system (e.g. cup attachment).

The term “voluntary” is used because cows can choose when, and to some extent how often, they are milked. Due to the hands-off nature of this technology, sensors that monitor cow health and milk quality are used, as well as facilities to manage cow movements remotely, such as separating cows for later inspection or treatment and drafting cows to different areas on the farm.

All systems have the ability to deliver feed while the cow is milking, usually grains or pellets, but liquid feeds such as molasses are also an option. The systems are designed to operate 24 hours per day and, therefore, an essential component of the technology is remote monitoring, which sends alerts to cell phones when there is a technical or cow issue.

Who are the early adopters?

A striking feature of the early adopters is the diverse range of farming systems into which the technology is being integrated (Table 1, pg 4). The farms differ in herd size, location (Figure 1), feeding system, calving pattern, breed, use of housing and reasons for investing in the technology.

Two of the ten herds use traditional spring-only calving, a system used by 90-95 percent of farms nationally[4], and three farms have combined automatic milking with housed systems.

Equally diverse are the reasons given by the farmers who have invested in the technology. Reasons include: difficulty in getting labour; farm succession; greater flexibility; wanting to remain on the farm although not milking; a focus on individual cow performance; an interest in technology; the challenge of developing new methods of farming and an old dairy requiring replacement.

Figure 1. Location of the ten herds using automatic milking systems in New Zealand[6].

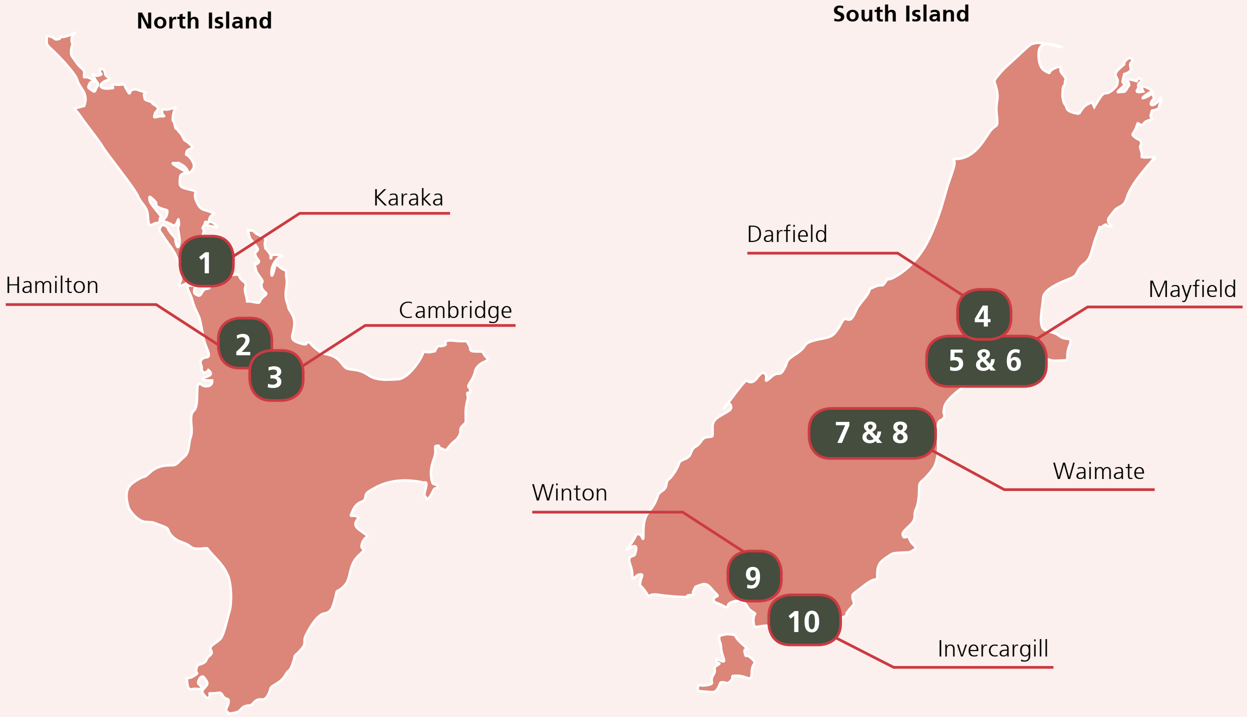

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Table 1. Description of the physical features of farms using automatic milking systems

Farm	Peak no. of cows	Land area (ha)	No. milking units	Calving pattern	Start date	Special features
1	180	95 milking 50 dry stock	2	Spring & Autumn	Oct 2010	Organic, all pasture.
2	100 (aiming for 240)	79	3	Spring & Autumn	Aug 2012	Converted existing herringbone, predominantly pasture.
3	335	78	4	Spring only	Mar 2011	Grass focus, seasonal milk supply, 35 ha effluent irrigated supplements (Nutriliq, PKE, maize silage) fed to fill feed gaps.
4	200 (aiming for 250)	70*	4	Year round	May 2012	Zero grazing during lactation, housed.
5	550 (aiming for 650)	245*	8	Three blocks	July 2012	Four grazing areas plus feed pad.
6	300	75	4	Year round	Sep 2008	Pasture-based, intensive supplementary feeding, pivot irrigated.
7	500	170	8	Four 4-week blocks	2010	Zero grazing during lactation, year-round milk supply, Jersey herd, housed.
8	500	350ha, supporting two dairies (rotary and AMS)**	8	Four 4-week blocks	2009	Zero grazing during lactation, year round milk supply, Holstein-Friesian herd, housed.
9	320	100	4	Spring & Autumn	Sep 2008	Pasture-based with silage, meal and molasses supplements, year-round milk supply, wintering barn.
10	150	67***	2	Spring only	Sep 2011	Pasture-based, seasonal milk supply.

** Includes all crop with some young stock*
*** Includes dry stock area*
**** Includes dry stock and young stock*

Impacts on labour

The introduction of AMS is arguably the most significant change to labour organisation on New Zealand dairy farms, since the advent of machine milking in the early 1900s[6].

For the majority of farms in New Zealand, the working day is structured around the need to fetch the herd(s) and carry out morning and afternoon milking, with other farm jobs carried out in between fixed milking times.

On an AMS farm, manual milking is no longer required, although some farms continue to use small conventional dairies for the period immediately post-calving. There is an increase in the monitoring of the farm and cows, and a decrease in physical work.

More time is spent checking and servicing equipment, training cows, fetching individual or small groups of cows, checking cows that appear on attention lists, and in some cases, cleaning[7,8,9]. For grazing farms, pasture management and feed allocation require special attention.

Despite the widespread use of AMS in Europe, North America and elsewhere, little published data exists on the impacts on labour. One European study reported a 20 percent labour saving[7], however the authors noted a large variation among farms.

A recent comprehensive analysis of the financial records from 63 Dutch farms using AMS and 337 using traditional milking methods reported no difference in total full-time equivalents employed. They concluded that there had been no substitution of capital for labour, as hypothesised.

However they also noted that, from the data available, they were unable to determine if fewer hours were worked, or to place a value on increased flexibility.

In New Zealand, the Greenfield project indicated a 25 percent decrease in labour could be achieved, assuming 50 percent of labour was required for milking on a conventional farm[10]. Experience from the first farms using AMS confirms that there is a substantial change in work tasks and, therefore, skills required[11].

There is an increased demand for labour during the transition to AMS and possibly when training new animals. The major change is in the type of work and flexibility in undertaking the tasks, rather than overall labour input.

There is some anecdotal evidence that labour input reduces once farms are established. One of the first farmers to adopt AMS, milking 320 cows, reports spending approximately three hours per day on farm-related work, which mainly involves cleaning, shifting fences and checking reports generated by the herd management system[11].

As the number of farms using AMS increases, it will be important to gather data to understand better the labour implications of this technology.

Economic considerations

It is widely reported that capital, operating and maintenance costs are higher for AMS compared with traditional milking systems[10,11,12,13,14,]. Costs for energy and water were reported to be 29.5 percent higher on Dutch AMS farms[14].

However, the adoption of automatic milking continues to increase, despite these additional costs and apparent lack of change in total labour input[14]. According to the 2011 European Dairy Federation Agri-benchmarking survey of 2600 farms from 20 countries, more than 40 percent of all new milking system investments are robotics[15] and by 2016, AMS will be milking 18 percent of cows in Europe, currently 9 percent.

New Zealand economic data generated following the first phase of the Greenfield project suggested 27 percent higher costs of production and 1.7 percent lower operating ROA (return on assets), for a 450 cow herd milked with AMS compared with a rotary[10].

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There were major differences between the costs associated with the two milk harvesting methods. The AMS had substantially higher service and maintenance contract costs; lower labour costs (less time required for milking related tasks); higher depreciation costs; lower dairy expenses; higher electricity costs and slightly lower animal health costs, due to less lameness. There was no change in udder health-related costs.

The model also assumed 5 percent lower production, however the experience of early adopting farmers is that this production difference can be avoided through better training, farm layout and management.

The analysis considered traditional pasture-based dairy systems. However, given the broad range of farm systems automatic milking is being integrated with, further economic analysis is required to determine their relative financial performance and update the assumptions used in the economic model, as new data becomes available from commercial farms.

A more comprehensive discussion of the economic considerations is available on the DairyNZ website[16] at **dairynz.co.nz/ams.**

Automatic milking technology in the future

There is ongoing development of automation technology to meet the needs of a broad range of herds and management systems.

The most common AMS design is a single stall which milks one cow at a time. Recently there has been a re-emergence of multi-box designs in which a single robotic arm services more than one cow at a time, either in stalls that are adjacent or in a series.

Recently, technology developers have focussed on systems for larger herds and grazing cows. In 2011 the first commercial Automatic Milking Rotary (AMR)[17] was commissioned on a farm in Tasmania, Australia. It uses several robotic arms to clean teats, attach cups and apply teat disinfectant while cows are on an internal rotary.

Technology developers have focussed on making the technology more affordable by streamlining the production and design of single stall AMS and by moving some production outside of Europe.

The first mobile systems, an AMS with all support services self-contained and which move with the herd, are being tested in three countries in Europe. As yet, there are no AMS technologies that can achieve the throughput rates achieved by batch milked herds using conventional milking systems. All systems are based on the concept of distributing milking over 24 hours.

The research outcomes and practical experiences of early adopting farmers suggests that the operational barriers to automatic milking can be overcome. However AMS remain a challenge economically, when compared with conventional milking alternatives, primarily due to the capital investment required and higher operating costs.

Frequently asked questions

Q: How many AMS do I need to milk my herd?

A: The number of AMS needed to milk a herd will depend on the number of cows milked, how often you want the cows milked, the peak yield of the herd and what level of utilisation of the milking stations can be achieved. Typical numbers of cows per AMS are 60 to 90, with milking frequency reducing as cow numbers per AMS increase.

Q: Can I re-use existing dairy infrastructure?

A: Most farms have built on a new site as they were new farm conversions, or in order to position the dairy centrally. One farm has reused the old herringbone dairy by filling in the pit and positioning three AMS across the rows, using the existing yard as a waiting area and with a three-way drafting gate positioned at the exit. Other farms continue to use the old dairy for veterinary treatments, immediately post-calving or for whole herd maintenance activities.

Q: How is mastitis detected?

A: AMS are equipped with a range of sensors (e.g. electrical conductivity, somatic cell count, blood, fat, protein; some of which are optional), that measure milk quality and udder health at every milking. An alert is generated if the sensors detect values outside of the normal range. These cows must be checked and, if necessary, treated. The AMS can be programmed to divert milk from treated cows automatically.

Q: How does pasture management change?

A: Excellent pasture management skills are required to combine automatic milking with grazing. Three-way grazing is widely practiced by farmers in both Australia and New Zealand. Three allocations of pasture are offered to the herd each day, in separate sections of the farm, creating a more even flow of cows through the AMS, particularly in typically quieter periods after midnight.

Q: How far will cows walk?

A: Experience suggests that walking distances of up to 1.2 km present few issues for cows. It is not necessary for cows to be able to see the dairy from all paddocks. The main consideration is positioning of laneways that allow cows to access three different areas on the farm. This is to facilitate three-way grazing.

There is comprehensive information about automatic milking available on the DairyNZ website.

The automated milking section includes information on making the decision if it's right for you, getting started, fine-tuning systems and a question and answer section. Visit **dairynz.co.nz/AMS**.

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

Baudracco, J., N. Lopez-Villalobos, C. W. Holmes, E. A. Cameron, K. A. Macdonald, T. N. Barry and N. Friggens. 2012. e-Cow: an animal model that predicts herbage intake, milk yield and live weight change in dairy cows grazing temperate pastures, with and without supplementary feeding. Animal 6:980-993.

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

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Selecting the right dairy for your farm

The pros and cons of herringbones vs rotaries

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Summary

- Field data demonstrates that the greatest cow throughput is achieved by rotary dairies greater than 40 bails
- Rotaries, with automation, are the most labour efficient
- For a 450 cow herd, an economic assessment favours a herringbone over a rotary dairy with automation (cluster removers, teat sprayer, drafting system).
- For larger herds (1000 cows) a 50-bail rotary is a more favourable investment than a 40-aside herringbone, and both are better than a large 80-bail rotary.
- Economic factors and other considerations, namely total milking duration, labour flexibility, work conditions and ability to automate are leading to greater investment in mid-size rotary dairies for large herds. However, the herringbone remains important for smaller farms.

Selecting the milking facility type and size is one of the most important decisions farmers make, influencing the financial performance of the business, labour requirements and work conditions.

This article considers the pros and cons of the two dominant dairy designs used on New Zealand farms: the herringbone and the rotary.

Herringbone

Rotary

The story so far

Farmers in two of the traditional power house regions of dairying can take the credit for introducing the two dairy types that have dominated the New Zealand dairy industry for over 30 years.

First, in 1952, Waikato farmer Ron Sharp developed his version of the herringbone[1], which was quickly adopted by farmers and by the mid-1980s more than 80 percent of all herds were milked using this type of dairy (Figure 1).

The second development came 17 years later, when in 1969 Merv Hicks, a Taranaki farmer, constructed the first rotary abreast dairy (more commonly known as the external rotary) in New Zealand[2]. In contrast, the adoption of the rotary has been slower, likely due to the durability of the herringbone, the early rotary's higher capital and maintenance costs, and its lack of labour saving without automation (as a cups-off operator was required).

As the dairy industry has grown, investment in rotary dairies has accelerated, led mainly by operators of large herds. Between 1998 and 2008, 72 percent of new dairy installations were rotaries, up from 52 percent in the previous decade[3]. The average herd size for farms with rotaries is approximately 625, compared with 326 for herringbones[4].

Figure 2 shows that for herds larger than 500 cows, the rotary becomes the dairy of choice. Today, 23.6 percent of herds are milked through rotaries; the most common are between 50 and 60 bails (Figure 3).

The remainder of herds are milked in swing-over herringbones. Other dairy types, such as double-up herringbones, a few remaining walk-throughs and the first handful of fully automated robotic milking systems are in use, but these make up fewer than 1.5 percent of all dairies.

Milking potential

The herringbone and rotary dairy differ in design but how do they differ in their ability to milk cows?

The data presented in Figure 4 (pg 10) are from two sources: recent data manually entered by farmers on the Milksmart website (**milksmart.co.nz**) and electronic data obtained in the 2010/11 season from 80 high tech rotary dairies[5,6]. The number of cows milked per hour increases as the number of clusters increases (i.e. the larger the shed, the more cows per hour that can be milked). Looking at the Milksmart data, 40-aside herringbones and 40-bail rotaries, on average, achieved a similar number of cows milked per hour.

Accounting for the labour required to operate the dairy, the advantage of the larger dairies was reduced. The most labour efficient was the 60-bail rotary with automatic cluster removers (ACR) and, therefore, no cups-off operator.

Figure 1. The proportion of herds milked by dairy type from early 1960s through to 2012/13[4]

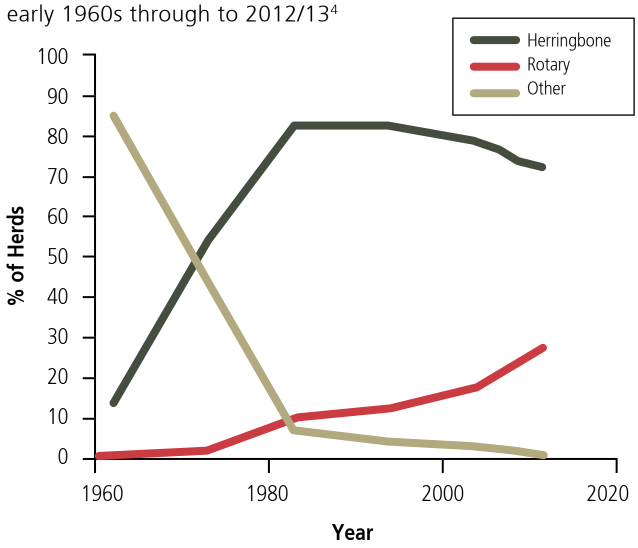

Figure 2. The proportion of herds milked through herringbone or rotary dairies by herd size[3]

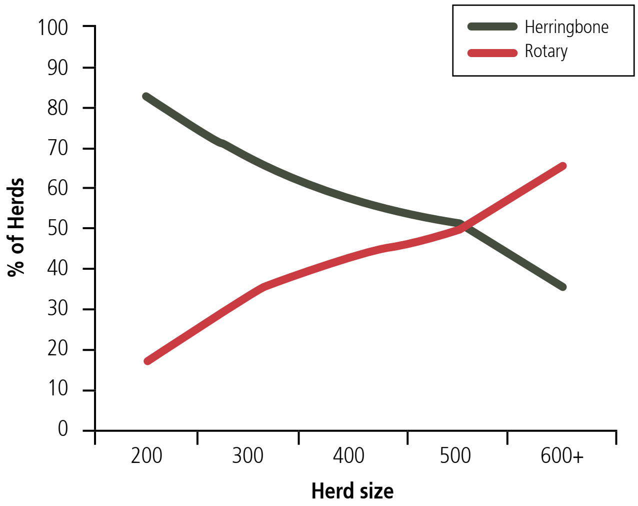

Figure 3. Number of herds milked through herringbone and rotary dairies by dairy size[4]

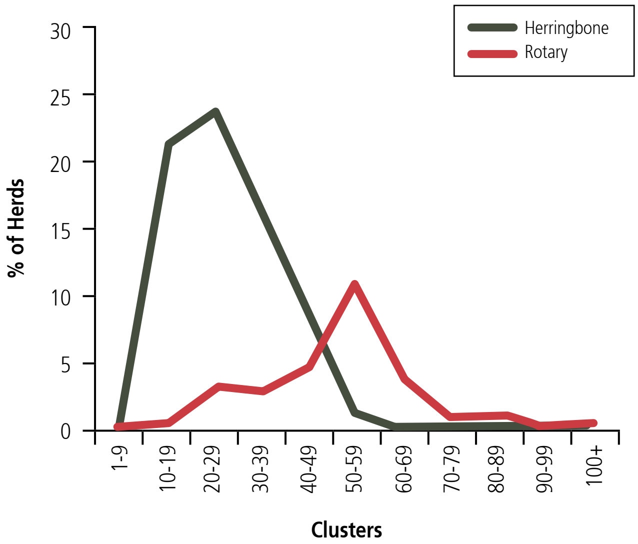

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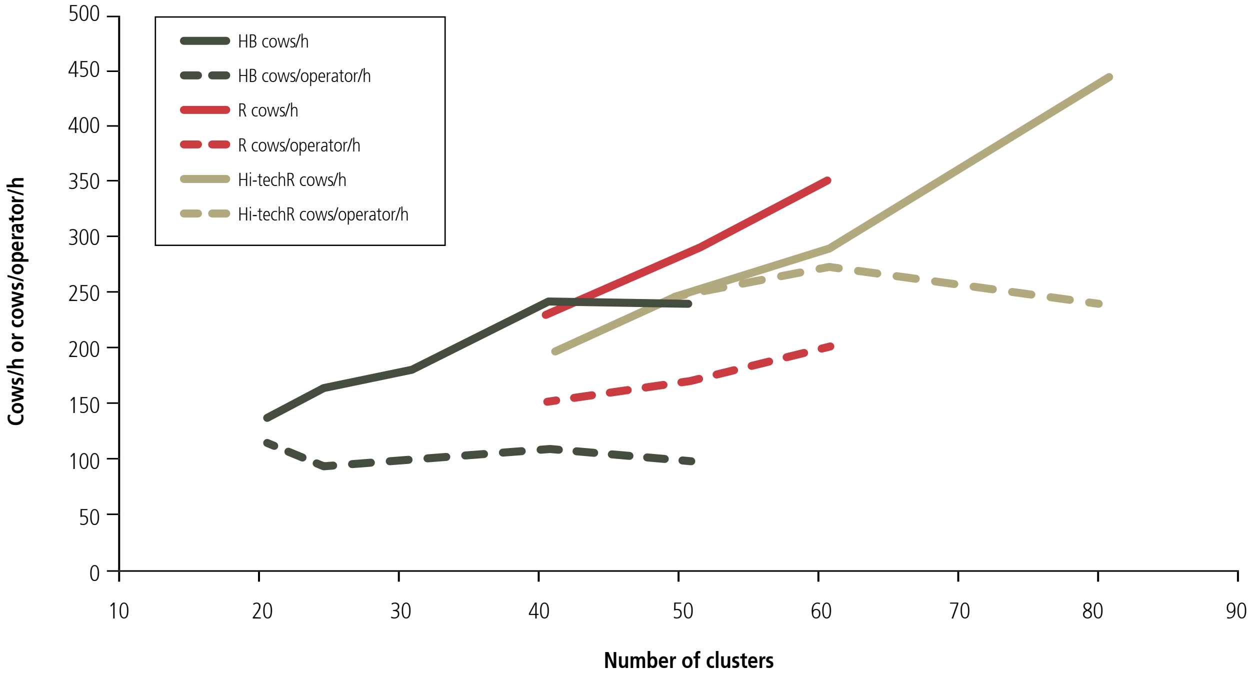
Figure 4. Cow throughput (cows/hour and cows/operator/hour) for herringbone (HB) and rotary (R) dairies by size (number of clusters) from data sourced from the DairyNZ Milksmart website and 80 rotaries with automation (Hi-techR).
Note, caution must be used when interpreting data from the large (>40 aside herringbones and >60 bail rotaries) as there were few dairies in these categories.



Increasing the number of clusters above 40 does not appear to increase cow throughput in herringbone dairies. This is likely to be due to the challenge of implementing an efficient milking routine at this size. It is important to note that for every dairy type and size, there was considerable variation in cow throughput.

Case study analysis of four of the top performing hi-tech rotary dairies identified key features of these farms as: excellent stock handling skills, staff training including efficient cupping techniques to allow fast platform speeds, regular repair and maintenance programmes and a culture of continually looking for small improvements.

Economics

Modern rotary dairies are more efficient at milking cows but how do they compare as an investment? To answer this question, two scenarios were considered.

Scenario 1

This represented a farm with 450 cows building a new dairy. The analysis compared investment in a 40-aside herringbone operated by two people, with a 44-bail rotary including sufficient automation to be operated by a single operator (i.e. ACR, auto teat sprayer). Both options had automatic drafting. Production and farm working expenses were calculated based on an analysis of the average 2010/11 Waikato farm[7]. Other assumptions included: milk price at $6.50/kg MS, twice daily milking, interest calculated at 7 percent, plant and machinery depreciated over 12.5 years, buildings and yards over 25 years.

Herd milking duration was calculated based on a 9 minute row or round and it was assumed that two operators were required for the herringbone and a single operator for the rotary. Labour to fetch herds and assist with other tasks associated with milking were the same for both farms.

The total labour saving was accounted for in the model using a rate of $25/hour, which included an accommodation allowance.

Scenario 2

This represented a 1000 cow dairy conversion with income and farm working expense data based on the average 2010/11 Canterbury-Marlborough farm[7]. Four options were considered: 40-aside herringbone, 50, 60 or 80-bail rotary.

It was assumed that two operators were required for the herringbone and the 80-bail rotary, and a single operator for the smaller 50 and 60-bail rotaries. All other assumptions were the same as for scenario one.

Table 1. Economic analysis for two case studies: (1) 450 cows comparing 40-aside herringbone and 44-bail rotary (2) 1000 cows comparing 40-aside herringbone and 50, 60 or 80-bail rotary.

	Scenario 1		Scenario 2			
	40 herringbone	**44 rotary**	**40 herringbone**	**50 rotary**	**60 rotary**	**80 rotary**
Physicals						
Cows	450	450	1000	1000	1000	1000
Milksolids (kg MS)	145,800	145,800	409,000	409,000	409,000	409,000
Rows/Rounds	12.0	10.2	25.0	20.0	16.7	12.5
Number operators	2	1	2	1	1	2
Milking duration* (h)	1.8	1.9	3.8	3.7	3.1	2.2
Total milking labour hours	2002	1078	4155	2067	1694	2490
Total FTE[¥]	3.1	2.7	6.5	5.4	5.2	5.6
Financials ($)						
Capital[#]	637,790	961,208	637,790	1,072,259	1,262,511	1,680,015
Revenue	1,005,750	1,005,750	2,726,500	2,726,500	2,726,500	2,726,500
Farm working expenses	650,623	630,306	1,695,500	1,647,221	1,639,821	1,663,562
Depreciation	47,177	69,454	67,177	95,796	106,780	131,706
EFS	307,950	305,990	963,823	983,483	979,900	931,231
Interest	44,645	67,285	44,645	75,058	88,376	117,601
Economic Indicators						
Return on Equity[‡] **(%)**	4.4	4.0	7.5	7.4	7.3	6.6
Net present value (NPV)[**]	3,108,426	2,978,626	10,323,217	10,377,430	10,258,950	9,562,785

[*] *Assuming peak yield of 23.4 kg milk/cow/day.*

[¥] *Full time equivalents from 2010/11 Economic Farm Survey[7] adjusted to account for the labour saving due to the milking system.*

[#] *Includes excavation, power supply lines, building and yards, effluent line to pond, leg spreaders (rotary only), water pumps, reticulation, water tank/s, electrical, vat wash (single vat), dung buster and cleaning channel, hot water cylinders, milk cooling.*

[‡] *Year 1, only liabilities are those borrowed for the new dairy.*

[**] *Over 25 years.*

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The analysis indicates that for the smaller 450 cow herd, the herringbone dairy is the better investment ($130,000 higher net present value [NPV], the value of the investment in today's money, over 25 years). This is despite the rotary needing just 54 percent of the labour requirement of the herringbone for milking.

For the larger herd, the greatest NPV was calculated for the 50-bail rotary, followed by the herringbone, 60-bail rotary and finally the 80-bail rotary. This result supports the trend for more rotaries, particularly among larger herds.

The analysis shows that the higher capital cost of single operator rotaries is off-set by the labour savings over the term of the investment. However, larger rotaries (>60 bails) require two operators to improve throughput above medium sized rotaries and are, therefore, less labour efficient, making it difficult to justify the additional capital cost.

However, dairy choice is not made purely on economic grounds, as shown by the adoption of rotaries across all herd sizes, and investment in large rotaries. Other factors, such as the complexity of automation in herringbone dairies, are important.

For example, if a farmer wants to install in-bail feeding to take advantage of the high feed utilisation and knowledge of what each cow is being offered, then a single drop point is required in the rotary. This compares with 80 drop points for a 40 aside herringbone, adding significantly to the cost. This may become more important in the future, as new technologies are developed.

The strongest argument in favour of the rotary is from a labour perspective. In comparison with the single operator in rotary dairies of up to about 60 bails, the larger herringbones require two operators and, therefore, significantly more man hours to operate, which can be problematic for labour flexibility.

For example, in the 1000 cow farm scenario, two people are needed for milking for more than 7.5 hours per day, effectively leaving only four people to run the farm (assuming that the additional 0.5 full-time equivalent [FTE] is for leave cover, calf rearing etc). This becomes even more logistically challenging when attempting to limit the amount of time each operator spends in the dairy to the recommended two hours per milking, as four of the six people will be involved with any one milking.

How the rotary stacks up

In comparison, the 50 bail rotary requires half the amount of staff time and one less person to be employed on the farm (with associated cost of housing), which can be highly valuable if the farm is located where it is difficult to employ suitable staff.

Other labour considerations not taken into account by the economic analysis include operator skill and comfort. Compared with the herringbone with limited automation, many components of the work routine are automated in the rotary e.g. cow loading and exiting, leaving only the major component of attaching clusters.

Arguably, this means a lower skill level is required to operate a rotary, and it is easier to create a standard operating procedure for new staff, whereas a high level of stockmanship is required to operate a herringbone efficiently. This may be of importance in areas where it is difficult to attract experienced and/or skilled labour. Operator comfort can also be higher in the rotary, due to the main task being only to attach clusters, there is more space and less walking. However, attaching clusters is a repetitive motion and it is recommended to cup for no longer than two hours, impacting on labour flexibility, as discussed above.

A final consideration may be the total time taken to milk the herd. The majority of New Zealand farmers have elected to operate their dairies for only a few hours each day, which has suited the pastoral grazing system as it allows cows to be managed in large herds, affording savings in other aspects of the business. This leads to low capital utilisation. However, recently there has been a move by some farmers to use smaller dairies to milk very large herds, thus expanding the total milking time well beyond the traditional two hour milking window.

Current Fonterra milk collection guidelines leave a 2.5 hour milking window in the morning and two hours in the evening. To meet these requirements on the large farm scenario, two vats would be required on all but the 80 bail rotary.

The decision to invest in a herringbone, rotary dairy or other dairy type is one that will be faced by an increasing number of farmers, if the size of herds continues to increase and as original herringbone dairies come to the end of their useful life. Each farm is different and careful consideration must be given to the financial implications of an investment. Equally, the implications for people and the overall management of the farming operation must be evaluated.

Pros and cons

Advantages and disadvantages of herringbone dairies[8]

Advantages	Disadvantages
Cheaper to build and maintain	Requires a lot of walking and swivelling for milkers
Highest cows per cluster per hour rate – cows exit and enter while other side is milking	An efficient milking routine is important to achieve maximum throughput
Cows are in full view of the milker while in the dairy	Installation of automatic cup removers (ACR) can be complicated; can complicate the milking routine; and may not offer any efficiency advantages
Easier to drench	Loading and unloading can be slow in large herringbones
Can increase capacity (by lengthening the pit if starting from a small dairy size)	Slower milking cows can slow down the whole row if MaxT (**milksmart.co.nz**) is not used
More sociable.	In-shed feeding system not as simple as for a rotary.

Advantages and disadvantages of rotary dairies[8]

Advantages	Disadvantages
Quick entry and exit times, if working well	Expensive to build
Cow flow less affected by cow/people interactions	Difficult to expand
Usually a low milk line, so lower vacuum	Without automation, it requires at least two milkers
Little walking required of the milker	Awkward for drenching
Slower milking cows do not hold up more than one set of cups	Difficult for the milkers to see the cows for at least some of the milking
Platform speed can be varied with the stage of lactation and yield of the herd	Cows frequently milked out before they get to the cluster removal station (only an issue if no ACR)
Automation often easier to install	More moving parts than a herringbone, requiring more maintenance.
Generally brighter and airy working environment.	

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Delving into DNA

DNA: a recipe for farm success

Rachel Boyle, DairyNZ Research Technician; Talia Grala, DairyNZ Post-graduate Student; Claire Phyn, DairyNZ Scientist; Jane Kay, DairyNZ Scientist.

Have you ever wondered what drives the udder to produce milk?

This new mini-series will define "what makes us" and every other living thing – genetics and DNA.

It will provide an overview and enough information to understand and explore genetics in a more informed way.

The series will explore the basic concepts of DNA structure and function, along with how DNA relates to milk synthesis and dairy breeding.

It will feature in future issues of the Technical Series.

This issue's DNA article looks at the basic concepts of DNA structure – how genetic code is the foundation of both people and cattle, and how a cow processes energy from grass.

What is DNA?

DNA (DeoxyriboNucleic Acid) is the recipe book for any living thing – it contains the genetic code for all body structures and is responsible for everything the body can do. It is also how characteristics are passed on from one generation to the next. When a sperm fertilises an egg, the embryo receives half its DNA from its mother and half from its father. The genome consists of all of this genetic material.

Like a recipe book, the genome is divided into chapters. These 'chapters' are called chromosomes, which are made up of two very long strands of DNA. The bovine genome consists of 30 pairs of chromosomes. In comparison, the human genome contains 23 pairs.

There are two complete copies of the genome in every cell (except for sperm and eggs, which have only one copy). To save space, this large amount of DNA is stored very compactly by being tightly coiled up.

Each chromosome contains many genes. These genes are like the recipes containing all the information (i.e. the DNA code) for particular components of the body, such as proteins or hormones.

These 'recipes' are three-letter words compiled from an alphabet of four letters, termed bases: Adenine (A), Thymine (T), Cytosine (C) and Guanine (G). These bases are attached to a backbone (or chain) of sugar and phosphate to form a single DNA strand. Each chromosome is made up of two DNA strands, which are joined together by the bases. The bases pair up (A always and only pairs with T, and G always and only pairs with C) to form the rungs of a ladder that is twisted into the characteristic double helix structure (Figure 1).

The bovine genome contains approximately 3 billion bases, encoding over 22,000 genes. Eighty percent of the genes in a cow are also present in humans, however cows have an additional group of genes, unique to ruminants, which allow them to process the energy from grass.

So what happens if there is an error in the 'recipe'?

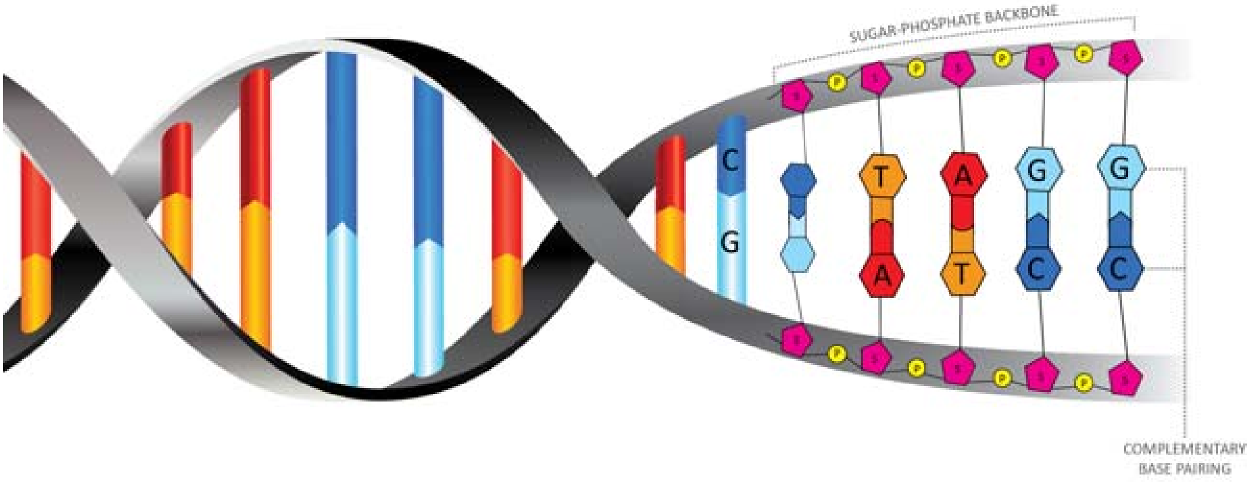
Variations in the genetic code (recipe) are caused when there are changes in the base pairs (ladder rungs) that are not normally found in that particular species. These changes are called mutations.

Often a mutation has no effect, either harmful or beneficial. However, if bases are added to or deleted from the genetic code, this is more likely to have an effect. DNA has an in-built proof-reading mechanism, but like a computer's spell checker, it is not 100 percent effective. This is one source of natural genetic variation, which can result in desirable or undesirable traits. All the traits of a single animal are referred to as its phenotype – the physical result of their genetics. Both the phenotype and genetics can be used as tools in herd selection, for example, selecting traits that improve productivity or animal health.

Summary

- DNA (DeoxyriboNucleic Acid) is the recipe book for any living thing, containing the genetic code for all biological functions and structures.
- Each recipe book contains 'chapters' (chromosomes), which are made up of 'recipes' (genes) that contain all the information required for life.
- These 'recipes' are made up of three letter words. The gene 'alphabet' has only four letters called bases: Adenine (A), Thymine (T), Cytosine (C) and Guanine (G). The bases pair up (A with T and G with C) to form the rungs of a twisted ladder (i.e. the double helix structure of DNA).

Figure 1. Each chromosome is made up of two DNA strands, which are joined together by the bases. The bases pair up (A always and only pairs with T and G always and only pairs with C) to form the rungs of a ladder that is twisted into the characteristic double helix structure.



Focus on international research

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

Cerri, R.L.A. and others (2012). Effects of lactation and pregnancy on gene expression of endometrium of Holstein cows at day 17 of the estrous cycle or pregnancy.

Journal of Dairy Science 95: 5657-5675.

In this US study, researchers examined which genes in the uterine lining were up or down-regulated in pregnant and/or lactating cows. Of the 20,000 genes examined, about 1 percent were affected by lactation. In comparison, pregnancy resulted in changes to 3-4 percent of genes. These genes were involved in pregnancy recognition and immune function. Some of the genes important in reproductive success were affected by whether the cow was milking or not. The researchers suggest that these genes may be possible candidates for interventions to improve fertility of lactating dairy cows.

DairyNZ comment: DairyNZ research has also identified differences in gene expression in the uterine lining of pregnant and non-pregnant cows. This work found further differences between fertile and sub-fertile cows. This research has expanded our knowledge of the physiological pathways important for reproductive success. Ways that the expression of these genes could be altered to improve reproductive performance are being investigated.

Hohenbrink, S. and S. Meinecke-Tillmann (2012). Influence of social dominance on the secondary sex ratio and factors affecting hierarchy in Holstein dairy cows.

Journal of Dairy Science 95: 5694–5701.

German researchers assigned cows with a score based on observation of their ranking in the herd's social hierarchy. Dominant cows were less likely to be lame and more likely to have a higher BCS. Dominant cows were also more likely to have a heifer calf.

DairyNZ comment: The study should be viewed with caution as it only included 71 cows, however the relationship between lameness and BCS would be expected. The association between maternal dominance and the birth of female offspring is opposite to that reported in other species, nonetheless the results are interesting. DairyNZ researchers were the first to identify a link between cow BCS and offspring sex, with fatter cows at calving giving birth to more heifers the following year. This is the first paper identifying a link between social dominance and sex of the calf.

Barrier, A. C. and others (2012). Short communication: Survival, growth to weaning, and subsequent fertility of live-born dairy heifers after a difficult birth.

Journal of Dairy Science 95: 6750–6754.

The experience of a difficult birth (dystocia) is traumatic and has adverse effects on survival of the newborn. This Scottish study examined the effect of calving ease on heifer growth rates to weaning, reproduction results, and age at first calving, using a database of 2000 calves. Calves that experienced moderate calving difficulty had a higher mortality to weaning and first service, but pre-weaning growth rates and fertility performance did not differ from that of calves born without difficulty.

DairyNZ comment: There is no data from New Zealand on the effect of calving difficulty on the growth rate or productivity of surviving calves. This study indicates long-term effects of calving difficulty on calf survival, with affected calves being more likely to die in the first 15-18 months of life. These results highlight the importance of appropriate bull selection and nutrition to ensure that calving is easy for the benefit of both cow and calf.