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An innovative farm system combining automated milking with grazing

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ABSTRACT

The harvesting of raw milk for the New Zealand dairy industry is a labour intensive process. Technology to completely automate the milk-harvesting process has been developed in Europe and is operating on an increasing number of commercial farms in several countries. A research programme has been established at Dexcel to develop innovative pasture-based farm systems utilising existing automated milking technology. A new farm layout was designed and implemented on a 10 ha farmlet. The land was radially subdivided into eight paddocks leading to a central collection area. A 200-m two-way race extended between the collection area and a small waiting yard adjoining a Fullwood Merlin automated milking system (AMS). Water was only available in the central collection area, the holding yard and as cows exited the AMS. Cows had access to the AMS for 24h/day where they received a maximum of 2kg concentrate/24h. A herd of 41 mixed-age cows was milked in the farm system. Data for a 14-day period in October when cows had settled into the system were analysed. Cows voluntarily visited the AMS 2.7 times/24h and were milked 2.3 times/24h. Visits were distributed over 24h with the lowest number of visits occurring between 0330 and 0600. Cows demonstrated remarkable adaptability in a distributed AMS and there appears to be considerable potential for AMS within New Zealand's pasture-based farming system.

Keywords: automatic milking systems; grazing; dairy cows; behaviour; milking frequency; milking interval.

INTRODUCTION

Harvesting the raw milk to supply the New Zealand dairy industry is a highly labour intensive process carried out on 13,892 dairy farms twice a day on average 270 days per year (LIC Dairy Statistics, 2000-2001). Approximately 1.8 billion individual manual cow-milkings take place each season costing the industry an estimated $240 million. Since the development of the first milking machine, there have been continual improvements in efficiency and cow throughput. A key New Zealand innovation in milk harvesting technology was the development of the rotary platform in the 1970s which, along with the earlier herringbone dairy design of the 1960's, significantly increased cow throughput and cows milked/labour unit (Dodd & Hall, 1992). Using these technologies, New Zealand producers have refined batch milking to extreme levels of efficiency with up to 360 cows/hr being milked in rotary systems plus time for cow retrieval and cleaning.

While the current systems of milk harvesting have achieved high levels of efficiency, the continuing shortage of labour within the dairy industry, driven by rapid expansion in the number and size of dairy farms particularly in the South Island, along with increasing lifestyle and career choices available in society (Gaul, 2000; Nolan, 2001) has created the need to re-think the way raw milk is harvested on New Zealand dairy farms. Fully automated milking systems (AMS) that require no human intervention during teat cup attachment were first developed in Europe in the late 1980s (Ipema *et al*., 1992) and have been operating on commercial farms since 1992 (Lind *et al*., 2000). There are now about 1000 commercial units on dairy farms in a growing number of countries including The Netherlands, Denmark, The United Kingdom, Ireland, Italy, Spain, Germany, Israel, Canada and most recently Australia.

Automated milking systems were primarily developed for use in indoor intensive housing facilities and the greatest uptake of this technology has been in countries characterised by high labour costs, high yielding cows, high milk prices and family run farms (Lind *et al*., 2000).

A research programme has been established at Dexcel to develop innovative pasture-based farm systems utilising an existing European AMS system. This paper describes the development of New Zealand's first farmlet in which milking has been successfully fully automated, thereby becoming a background operation within an extensive pasture-based farm management system.

MATERIALS AND METHODS

Farm layout

The prototype farmlet, depicted in Figures 1 and 2, consisted of 10 ha radially subdivided into eight paddocks, all of which lead to a central cow collection area. A 200-m dual-race system (1 lane in, 2 lanes out) extended between the collection area and a small waiting yard adjoining a Fullwood Merlin AMS. A series of cow-operated one-way gates positioned at the entrance to the central collection area and waiting yard along with AMS-controlled automatic gates at the exit from the AMS were used to control cow traffic. Water was only available in the central collection area, the holding yard and at the exit from the AMS.

It is envisaged that this farmlet represents a component of a larger scale farm with other identical blocks to be established around (and feed into) the centrally positioned AMS and waiting yard, thereby minimising walking distance for cows anywhere on the total area.

Grazing and feeding management

The eight paddocks within the farmlet were divided such that paddocks 1-4 were located on Side A and paddocks 5-8 on Side B (Figure 1). A grazing system was used in which two paddocks, one on each of Sides A and B, were grazed at any one time. Cows began in Side A, and once entering the central collection area, were prevented from returning to Side A by one-way gates. They were then required to walk along the central race to the waiting yard and pass through the AMS. On presentation at the AMS, a cow was either milked (if • 6h since last milking), returned to the waiting yard (if • 5 and < 6h since last milking) or released to pasture (if <5h since last milking) via AMS-controlled gates (Figure 2). If teat cup attachment was unsuccessful (i.e., a failed milking) the cow was sent back to the waiting yard. After the fourth consecutive failed attempt to attach the teat cups the cow was automatically sent to the holding yard (Figure 2). The minimum milking interval of 6h was set using production rate and expected yield criteria. When released from the AMS, cows walked along an external return race to a paddock on Side B. The direction of cow flow (to Side A or to Side B) was reversed twice in 24h at 10:00 and 21:00. At 21:00 any cows remaining in the paddock on Side A were moved into the central collection area and the position of the manually-operated gates at the exit from the AMS changed so that cows leaving the AMS now flowed from Side B to Side A. Similarly, at 10:00, any cows remaining in the paddock on Side B were moved to the central collection area and the gates changed so that cows now flowed to Side A after visiting the AMS. This system ensured that cows were milked at least once in each 24h period.

FIGURE 1. The farm layout indicating radial paddock design separated into Side A and Side B, central collecting area, water placement and two-way race system.

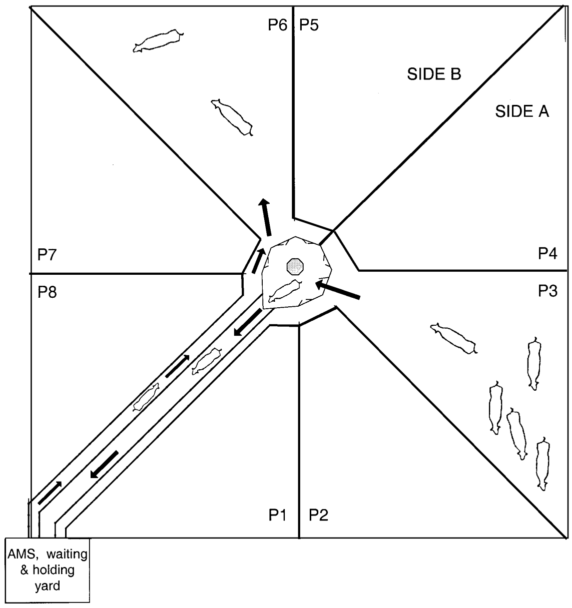
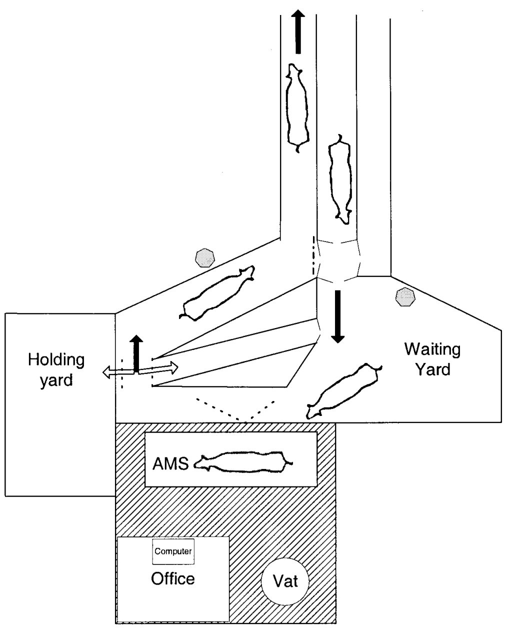


FIGURE 2. Layout and positioning of the Fullwood Merlin Automatic Milking System adjoining a waiting yard, and showing direction of cow flow via one-way and automatic gate system.



Cows received a maximum of 2 kg concentrate (80% crushed barley, 20% Moozlee®)/24h in the AMS during milking. The amount received at each visit was proportionate to the time since last milking visit (e.g. if 12h since last milking 1 kg dispensed).

Animals

A herd of 41 mixed-age, mixed-breed cows was milked in the novel farm system. Each cow was fitted with a small transponder on her left front leg for automatic identification within the AMS. Cows had access to the AMS for 24h/day, with the exception of three 7-min periods at 06:00, 11:30, and 19:30 when the unit was automatically washed. The AMS back-flushed with cold water between cow milkings.

Data collection

Data was analysed for a 14-day period in October (8th-14th & 17th -23rd inclusive) when cows had settled into the system and the herd size was stable. Data including time of entry to the AMS, the type of visit to the AMS (milk, return to yard to wait, return to pasture without milking), percentage of successful attempts at attaching teat cups, milking duration and yield, were automatically collected via a computing system (Crystal 0.44, Fullwood Fusion, Holland). The number of cows remaining in the "old" paddock was recorded at 10:00 and 21:00 when the gates and direction of cow flow were changed for reverse transition across the farm.

Data analyses

The mean yield, number and type of visit to the AMS and percentage of successful attempts to attach the teat cups was calculated for individual cows over the 14 days during which data was collected. These values (n = 41) were then used to calculate the mean, minimum and maximum value for the herd. The median number of cows remaining in each paddock at 10:00 and 21:00 is presented, as the data was not normally distributed. To determine the percentage of successful cup attachments, the number of times a cow entered the AMS and was milked was divided by the total number of times a cow entered the AMS and either a failed attempt to attach the teat cups or a successful milking occurred.

RESULTS

Cows readily learned to operate the one-way gates and negotiate their way independently to and from the AMS. On average, cows voluntarily visited the AMS a total of 2.7 times/24h (Table 1). The average number of visits to the AMS for individual cows varied from a low of 1.3 visits/24h to 4.5 visits/24h over the 14 days of data collection. The average milking frequency was 2.3 times/24h while the average interval between milkings was (mean ± se) 10.5h ± 0.13h.

Figure 3a shows the averaged distribution of successful milkings over the 24h period. Cows were milked within each hour with the highest number of milkings occurring between 07:00 and 08:00 and the lowest number of milkings between 03:00 and 06:00. The average was 3.9 milkings/h (range: 1-6). Mean milking time (from entry to exit of AMS) was (mean ± se) 9min 3s ± 57s. Non-milking visits, when cows attended the AMS <5 h since their last successful milking, were on average never greater than 2/hour and were most frequent from 09:00 to 12:00 and from 18:00 to 21:00 (Figure 3b).

TABLE 1. Milk production, visiting frequency to the AMS, cup attachment rate and cows remaining in paddocks at 10:00 and 21:00 hrs for a herd of 41 mixed-age and mixed-breed cows milked in a pasture-based AMS.

	Mean	Minimum	Maximum
Yield (kg/24 hr)	18.2	10.2	27.3
Total number of visits to AMS	2.7	1.3	4.5
Milking visits	2.3	1.3	3.1
Return to Paddock visits	0.4	0	1.4
Successful cup attachment rate (%)	84.9	50.7	100
% cows remaining in paddock			
10:00 h	9.8*	0.0	41.5
21:00 h	2.4*	0.0	29.3

*median value expressed as a %

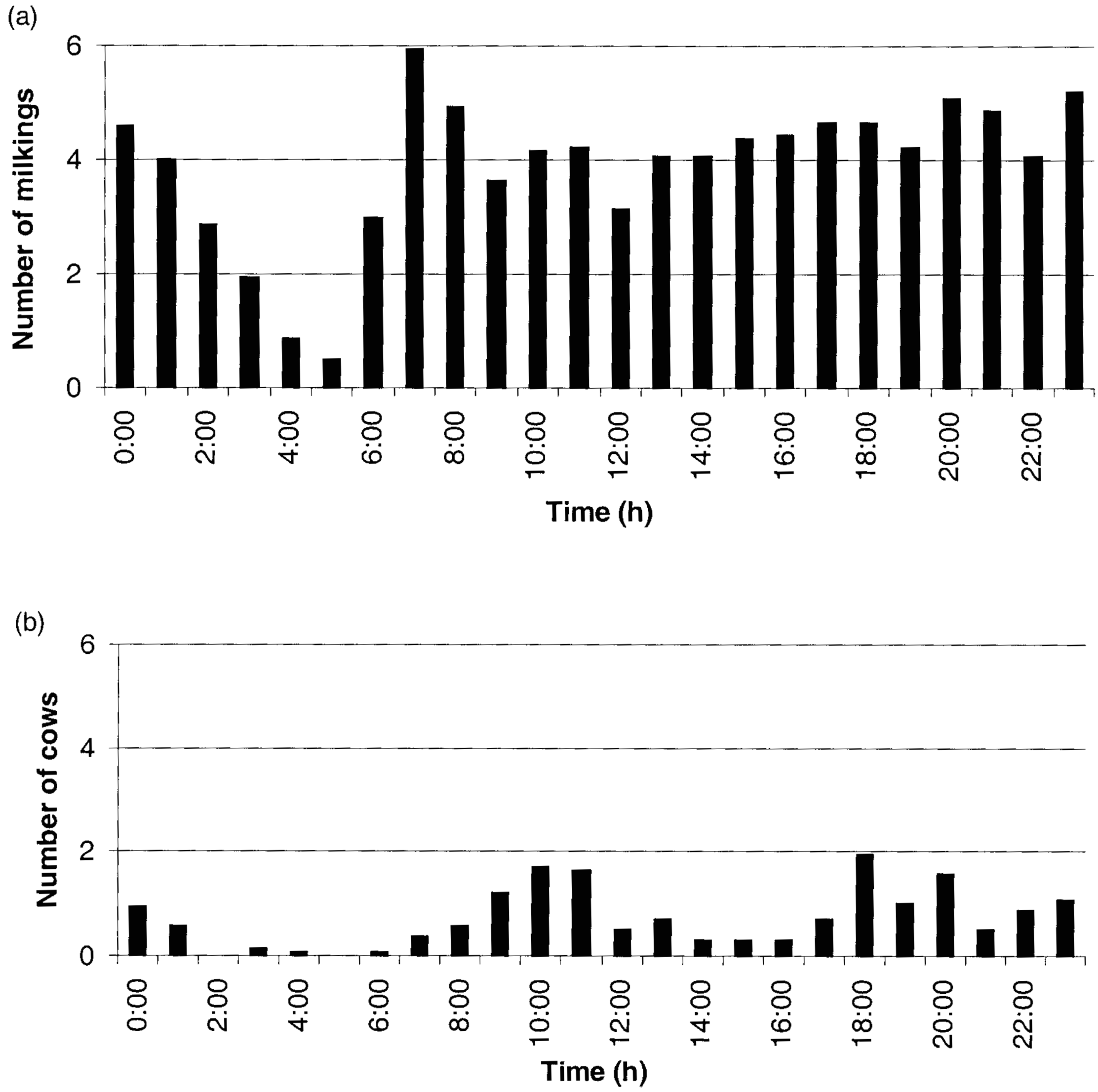
There was considerable individual variation in rates of successful teat cup attachments (Table 1). For some cows two or three attempts were necessary before the teat cups were successfully attached. There were no instances when a cow was sent to the holding yard as a result of four successive failed attempts to attach the teat cups. Those cows with low success rates tended to have udders of poor conformation and rear teats that were close together, making it difficult for the AMS to detect individual teats. There was also large daily variation in the proportion of cows that had to be moved from the paddock at 10:00h and 21:00h. There tended to be fewer cows remaining in the paddock in the evening than in the morning.

DISCUSSION

This research has demonstrated that New Zealand dairy cows will learn to walk from pasture and voluntarily attend an AMS stall with minimal additional feed as an inducement. The combination of incentives incorporated into the farm layout, including water placement, access to fresh pasture and provision of crushed barley within the AMS, were sufficient to generate voluntary cow movement to and from the AMS. Previous studies have shown that intra-mammary pressure is unlikely to have contributed significantly to the cows motivation to visit the AMS (Prescott, 1996), however, social facilitation of behaviour, whereby the behaviour of one cow is influenced by that of another, or larger groups within the herd, is likely to be of importance (Ketelaar-de Lauwere & Ipema, 2000).

The frequency of visits to the AMS ensured that the average milking frequency was above 2 milkings/cow/day. This is consistent with the milking frequency of 2.3 reported by Ketelaar-de Lauwere and Ipema (2000) for cows on an unrestricted grazing treatment. However, in that study, cows also received forage *ad libitum* within the milking barn in addition to 1-1.5 kg concentrate per milking. Salomonsson & Sporndly, (2000) also reported a similar milking frequency (2.2) when cows were grazed at pasture and received an allowance of concentrate during milking in the AMS.

FIGURE 3. Twenty-four hour distribution of (a) cow milkings and (b) non-milked visits over 24h for a herd of 41 mixed-age and mixed-breed cows milked in a pasture-based AMS.



There was a four-fold difference in the minimum and maximum average number of visits individual cows made to the AMS. It has been shown that age (younger animals are more willing to visit the AMS regularly) as well as position within the herds social hierarchy, influence the visiting patterns of cows milked within indoor AMS systems (Ketelaar-de Lauwere *et al.*, 1996).

Very few cows attended the AMS between 03:00 and 06:00. This is consistent with the results of Ketelaar-de Lauwere & Ipema (2000) who reported that cows made fewer visits between 23:30 and 5:30 than at other times of the day. This result is not surprising as cows typically rest during this time following a grazing bout near midnight (Kilgour & Dalton, 1984). The relatively even distribution of cow visits to the AMS throughout the remainder of the 24h was encouraging because to gain maximum efficiency from a distributed milking system it is essential that the AMS has as close to 100% utilisation as possible. Other studies have reported that visits to the AMS are not as uniform when cows are grazing pasture as when cows are in an indoor housing system (Ketelaar-de Lauwere & Ipema, 2000) and this has been acknowledged as one of the major limiting factors of successfully grazing with AMS.

In this study the AMS was not used to maximum efficiency, as the herd comprised only 41 cows. Typically a ratio of between 55 and 65 cows/AMS is common on European farms where cows are housed indoors and milked up to four times/day. The most appropriate number of cows/AMS in a grazing farm management system will be dependent upon the desired milking frequency and economic considerations. Further studies will seek to consider the costs and benefits of increasing cows/AMS and decreasing milking frequency. A potential risk of increasing cow numbers is increased cow waiting time before milking. Our observations indicate that the median waiting time (in the waiting yard before entering the AMS) for cows in the current farm set up and herd size was 22 minutes (Jago, unpublished data).

The number of cows remaining in the "old" paddock when the gates, and, therefore, direction of cow flow was changed, varied considerably from day to day. Casual observations suggest that the position of the paddock relative to the transit races and therefore the AMS is a likely causal factor. Previous studies have shown that environmental conditions and pasture length are also likely to influence cow movement patterns (Ketelaar-de Lauwere & Ipema, 2000; Salomonsson & Sporndly, 2000). While we observed similar effects, in general it was necessary to move very few cows out of the paddock to the central collection area, demonstrating a motivation to voluntarily transit to the AMS.

There are a number of key performance factors for AMS to work successfully under New Zealand farming conditions. Rapid and successful cup attachment as well as milking speed are limiting factors in any AMS. In order for the system to operate efficiently, a high success rate of "first attempts" needs to be achieved. While some animals recorded a 100% success rate at first attempt others were as low as 50.7%. Udder shape, cow size and behaviour during cup attachment are all important in achieving a high success rate. Cow behaviour is also a potential major limiting factor. The major difference from traditional milk harvesting systems is that within an AMS milking must be distributed over 24h, unlike the typical twice-daily batch milking seen on New Zealand farms. This relies entirely on cows voluntarily attending the AMS, and, most importantly, their visits must be evenly spread over the 24h. This has been achieved in an indoor housing management system but has proven to be more difficult in extensive pasture-based systems. The initial results of the prototype New Zealand farm layout indicate that cows visit sufficiently often and that these visits are adequately distributed to allow for efficient utilisation of the single stall AMS. Scale factors with larger numbers of cows and greater utilisation of the AMS need to be evaluated.

Cows demonstrated remarkable adaptability in a distributed AMS and there appears to be considerable potential for AMS within New Zealand's pasture-based farming system. The potential to save labour is apparent but also the AMS offers the opportunity to radically change the lifestyle and working conditions of dairy farm workers. No longer would it be necessary to be constrained to a twice-daily milk-harvesting ritual, work would become less physically demanding and the work environment much more hygienic and typical of a food production system. There would be more opportunity to focus on animal management, health and farm improvement, rather than the routine mechanics of milk harvesting. This prototype farmlet has shown, in a relatively short period of time, the potential to successfully fully automate the harvesting of raw milk for the New Zealand dairy industry.

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