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An economic evaluation of automatic milking systems for New Zealand dairy farms

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ABSTRACT

An economic analysis for automatic milking for a medium sized farm set up to milk 450 cows and installing either a 40-bail rotary dairy with automated cup removal and drafting or a 5-unit Greenfield system is evaluated. The analysis used a model that incorporated findings from the previous 5 years of research and development at the Greenfield automatic milking project and used physical and financial data collected in Dexcel's 2003/04 Economic Farm Survey for the conventional milking system comparison. The model assumed a payout of \$4.25/kg milk solids (MS) and used current cost of technology. Once cows were established into the Greenfield System, the cost of producing 1 kg MS was 27% higher than for the conventional rotary system. This was due to higher interest, depreciation and service contract costs, despite the lower labour, cow health and dairy costs. Sensitivity analysis showed that when other factors were held constant a 70% decrease in capital cost or a more than two-fold increase in cow throughput was required for the Greenfield System to be as economic as the rotary system. Alternatively combining future improvements in AMS technology and farm system development including improved throughput to 112 cows/AMS, a 25% decrease in milk harvesting system capital cost, equivalent production and a 10% increase in the cost of labour produce a similar economic performance for the two systems.

Keywords: automatic milking, grazing, New Zealand, dairy farming, economics.

INTRODUCTION

Milk harvesting on New Zealand dairy farms has evolved substantially over the last 65 years, driven by the need for higher milking throughputs and improved labour productivity. Hand milking in small "walk-through" or "abreast" dairy sheds was the typical scenario on New Zealand dairy farms up until the 1940s when the use of milking machine technologies were progressively adopted. A significant development was the introduction of the herringbone dairy design during the 1950s and 1960s enabling a greater cow throughput. This was followed by the rotary platform design which has seen further efficiency gains, particularly for larger herds. Today herringbone dairies make up 80% of New Zealand dairies, with 18% rotary designs (Livestock Improvement Corporation, 2005). While relatively small in number, the proportion of the national herd milked through rotaries has increased from 18% to 34% from 1995 to 2005 (LIC Stats, 2005), reflecting the choice of the rotary design for larger herds.

Advances in milk harvesting methods, achieved through improved dairy design and cow flow rather than significantly enhanced milking machine technology, have yielded labour productivity gains through larger numbers of cows milked per full-time equivalent (FTE). In 1992/93 the Economic Farm Survey reported a ratio of 88

cows/labour unit (including paid and unpaid labour) and in 2003/04 this had increased to 119 cows/labour unit (Dexcel Economic Farm Survey 2003/04). Despite this gain in labour efficiency, growth in the dairy industry means that it continues to rely on a pool of approximately 25,000 people for milk harvesting.

The demographics of the typical New Zealand dairy farm have undergone rapid change in recent times. Since 1990 the number of owner-operated farms has decreased while the average size of farms has increased from 72 ha to 105 ha and from 166 cows to 286 cows (Dexcel Economic Farm Survey, 2003/04). As a result labour has increased on the average farm from 2.0 full time equivalents (FTE) to 2.25 FTE (Economic Farm Survey, 2003/04). Farm businesses are facing increasing labour constraints and the supply of labour to the dairy industry is unlikely to meet the future demand (Tipples *et al.*, 2004). A recent survey of shareholders and sharemilkers has shown that around 30% of farmers plan to have less involvement in milking in the near future (Woollett, 2005). At the same time 28% of shareholders and 44% of sharemilkers plan to increase their herd size in the next 5 years. The combination of increasing reliance on employed labour to harvest the raw milk from the national herd, increased herd sizes, a declining labour pool and work and lifestyle constraints imposed by current milk harvesting methods represents a major

problem for the industry.

While the current batch milking methods are extremely efficient the essential tasks required for milking have not changed. Cows are still manually herded to the dairy, usually twice daily, where cups are manually attached and often manually detached. An alternative method, commonly described as automatic or voluntary milking, that enables complete automation of the milk harvesting process, utilising distributed rather than batch milking, has been developed internationally and is in use on over 2500 commercial farms in over 20 countries worldwide (de Koning and Rodenburg, 2004). Automatic milking systems (AMS) are predominantly used with housed herds (concentrated in Europe) and aim to achieve a high milking frequency and high individual yield with minimal labour input.

Research and development has recently been undertaken to determine the practical viability of AMS for New Zealand farming conditions (Greenfield System, Jago *et al.*, 2002, 2004a, 2004b; Woolford & Jago, 2002; Davis *et al.*, 2005). These studies have demonstrated that AMS can be implemented on low-input pastoral dairying systems using rotational grazing and with cows walking up to 900m to the dairy for milking. The Greenfield System utilises a combination of remote selection of cows for milking (Jago *et al.*, 2004) and a reduced milking frequency (between 12 and 24 hour milking intervals, Jago *et al.*, 2005; Davis *et al.*, 2005) to achieve a higher ratio of cows to AMS than is typically reported for housed systems.

This paper considers the economics of AMS for one likely New Zealand dairy farm business situation. Other likely scenarios including small farms will be considered in a separate paper. The evaluation looks specifically at the impacts of changing key inputs, i.e. cost of farm dairy and milking equipment and milking capacity on the viability of automatic milking and makes projections for impact of likely future developments.

METHODS

Economic model

A model was developed to evaluate the financial performance of the Greenfield system as an option for a New Zealand dairy farm scenario. It was assumed the dairy would be constructed on a new site but there was some existing raceway infrastructure in place. The model included gross farm revenue (GFR = net milk + net stock sales + other), farm working expenses (FWE = labour (including the value of paid and unpaid labour and management) + service costs + herd health + dairy

costs + herd improvement + pasture + fertilizer + weed and pest + repair and maintenance + vehicle expenses + standing charges + administration) and the capital cost of the milk harvesting system. It was assumed there was no run-off with young stock being grazed off, and no change in feed or stock numbers between years. Financial indicators were derived from the model including: Economic Farm Surplus (EFS), a measure of farm profitability (Economic Survey of New Zealand Dairy Farmers 2003/04, $EFS = GFR - FWE$ (-depreciation)); Operating return on assets (ROA = $EFS/\text{total opening assets including land valued at } \$25,000/\text{ha}$); and cost of production (COP = $(FWE + \text{depreciation} + \text{interest})/\text{total milk solids, MS}$). A sensitivity analysis was carried out for AMS capacity and capital cost by changing one variable at a time until the cost of producing 1 kg MS was equivalent to the rotary system. The predicted impact of likely future developments and changing cost of labour was determined.

Farm profile and model inputs.

A 140 ha medium sized operation milking a herd of 450 cows (3.24 cows/ha) and needing to upgrade the dairy was assumed as a starting point. The two new milking systems compared were a 40-bail rotary batch milking system and a 5-unit Greenfield System. Table 1 outlines the physical profile of the virtual farm, key features of each milk harvesting system.

TABLE 1: Farm profile, milk harvesting system features, service and capital costs for a rotary dairy and 5 unit Greenfield System.

	Rotary	Greenfield
Farm profile	450 cows 140 ha 3.24 cows/ha	450 cows 140 ha 3.24 cows/ha
Milk harvesting system	40 bail rotary ACR ¹ & Automatic drafting No in-bail feeding	5 AMS units 6 selection units In-bail feeding
Service costs	\$100/cluster/yr	\$10,000/AMS unit/yr
Capital investment ²	\$577,000	\$1,217,000

¹Automatic cup removers

²Includes site development, installation, plumbing, electronic ID, automatic cup removers and two-way drafting. The automatic milking system includes 5 AMS units with in-bail feeding, electronic ID (ear tags), auxiliary equipment (compressors and driers), freight, locally sourced additional buffer vat and cooling system, site development, complete installation, 6 solar-powered selection units as described in Jago *et al.* (2004) and associated services, and fencing required for two-way traffic to the dairy.

Cost of capital for each of the milking systems was sourced from the Lincoln Farm Manual (03/04), local milking system manufacturers and international suppliers of

automatic milking technology as appropriate. The total cost of the rotary dairy installation included site development, complete installation and plumbing, electronic ID, automatic cup removers and two-way drafting. The total capital cost of the Greenfield system included 5 AMS units with in-bail feeding, electronic ID (assumes use of ear tags rather than pedometers), auxiliary equipment (compressors and driers), freight, locally sourced additional vat and milk cooling system, site development, complete installation, 6 solar-powered selection units as described in Jago *et al.* (2004) and associated services and fencing required for two-way traffic to the dairy. All costs of imported equipment were converted from Euros using an exchange rate of 0.570NZD/Euro.

The average farm revenue and farm working expenses data used as inputs into the model for the rotary dairy system were obtained from a sample of 9 owner-operator farms with a herd ranging in size from 420-500 cows (Economic Farm Survey, 2003/04). The revenue and farm working expense data used as inputs into the model for the Greenfield system were based on the performance of the Greenfield Project research farm and scaled for the 5-unit Greenfield system. Farm revenue was calculated using a payout of \$4.25/kg MS (average real payout 1991-2004) and a Fonterra milk transport charge of 3.9c/L (2003/04 Fonterra data).

Production is based on experience and performance of the Greenfield project farm, assuming a seasonal calving pattern, achievement of an 18 hour average milking interval at peak lactation (Jago *et al.*, 2004) and a 7 week dry period for individuals achieved through staggering dry off. In year one of operation, production was 90% of year two due to cow training and system optimisation requirements in the commissioning year (GF unpublished data). In the second and subsequent years per cow production in the GF system was 95% of those in the rotary system, due to the training and adaption requirements of the 20% heifer replacements. Average milk solids composition was 8.5% (2003/04 LIC stats, average 4000 South Auckland herds) for the rotary system and 8.6% for the AMS system due to the effect of the longer milk interval on milk solids percentage (Clark *et al.*, 2006; Woolford *et al.*, 1980) which will affect dairy payout due to differing milk volumes.

Labour audits undertaken during the 2004/05 season at the Greenfield research farm indicated a 50% reduction in labour associated with milk harvesting. It is assumed 50% of the total farm labour is milking related and that the reduced labour for milking tasks in the Greenfield system

equates to a 25% reduction in overall farm labour. Labour was costed at \$18.85/hour (2003/04 Dexcel Economic Survey for the average 450 cow farm). The model assumed an annual service & maintenance contract of \$10,000/unit including all rubberware, parts and full service and technical support.

Animal health expenses included a small saving due to a lower incidence of lame cows (3% treated, Davis and Jago, 2004). Dairy building & yards were depreciated at 4%. Milking systems and automation capital investment were depreciated at 10%. An interest rate of 9.0% was applied to the additional capital required for upgrade. The full capital cost of each milk harvesting systems was used to calculate annual interest costs.

RESULTS AND DISCUSSION

The physical and financial performance of the two milking systems is presented in Table 2. Overall the cost of producing 1 kg of milk solids (MS) including interest and depreciation on the full cost of the milking system capital, was 42% and 27 % higher for the Greenfield System than for the rotary system in the commissioning year and second year of operation, respectively. Farm working expenses were 6.7 % higher in year two (driven by service contract costs). As a result of a lower EFS and increased capital the operating ROA was 2.7 % for the Greenfield system compared with 4.4 % for the rotary system.

The major differences between the costs associated with the two milk harvesting methods were the substantially higher service and maintenance contract costs for the AMS, lower labour costs as a result of less time required for milking related tasks and higher depreciation costs due to the higher capital investment required for the automation of milking. Lower dairy expenses for the Greenfield System were offset by higher electricity costs while savings in labour costs were offset by the extra service contract costs.

In the first year of operation the herd and staff must undergo a period of adaptation to a new milking system. This is likely to be greater for the Greenfield system as cows must learn tasks on the farm as well as at the dairy. Experience at the Greenfield farm has shown that the impact of the adaptation period on production can be reduced through training cows in late lactation prior to calving into the system the following season. Cows have demonstrated considerable learning ability and typically milk unassisted within 7 days of introduction to the Greenfield System, however it appears to take longer for cows to be fully competent and confident within the AMS

TABLE 2: Economic indicators (farm working expenses, cost of production, EFS and operating ROA for a 40 bail rotary and 5-unit Greenfield milk harvesting system (including likely future improvements) for a 450-cow herd.

	Rotary	Greenfield		Future Impact	
		Year 1	Year 2	Rotary ⁴	Greenfield ⁵
Production					
MS/cow	347	295 ¹	330	347	347
MS/ha	1,115	948	1,061	1,115	1,115
Revenue (/kgMS)					
Milk	4.25	4.34	4.28	4.25	4.26
Other	0.26	0.30	0.27	0.26	0.25
Total	4.51	4.64	4.55	4.51	4.51
Farm Working Expenses					
Service costs	0.03	0.38	0.34	0.03	0.26
Health	0.14	0.14	0.12	0.14	0.12
Dairy (including power)	0.12	0.15	0.13	0.12	0.12
Labour ²	0.96	0.84	0.75	1.05	0.68
All other	1.42	1.68	1.51	1.44	1.43
Total	2.67	3.19	2.85	2.76	2.61
Revenue Less Working Expenses	1.84	1.45	1.70	1.74	1.90
Non Cash Adjustments					
Depreciation	0.31	0.69	0.62	0.31	0.42
EFS (\$/kgMS)	1.52	0.76	1.08	1.44	1.48
Interest	0.33	0.83	0.74	0.33	0.44
EFS less interest (cost/kgMS)	1.20	-0.07	0.34	1.10	1.04
Total cost of production (\$/kgMS)	3.31	4.70	4.21	3.40	3.47
Operating ROA (%)	4.4	1.7	2.7	4.2	4.1
Capital investment (\$/kgMS)³	3.70	9.17	8.19	3.70	4.66

¹ Assume 90% of second year production due to cow adaptation requirements; ² Including paid and unpaid labour; ³ Total capital cost of harvesting, automation, drafting and feeding systems, excludes land and other assets; ⁴ 10% increase in labour rates ⁵ Including an increase in AMS capacity from 90 to 112 cows/AMS unit, 10% increase in labour rates, 25% reduction in capital, further labour saving of 10% and equivalent production through improved cow adaptation.

environment. During this period milking intervals are extended resulting in lower yields.

Following the commissioning year the production for the experienced cows is expected to be equivalent to that of the rotary system, based on Greenfield herd production. However current knowledge indicates that the performance of new heifers will be less than in the rotary system which results in the lower overall per cow production. While the impact of once-a-day milking has been well documented in New Zealand there has been little study of variable milking intervals. Studies by Woolford *et al.*, (1980) reported a 6% decrease in per cow yield with less loss for milkfat when mature cows were milked three times in two days (approximately an 18 hour interval). Heifers recorded greater losses than cows. The situation is more complex in automatic milking as milking intervals will vary from day to day for individuals. Milking is also more frequent than the 18 hour interval during the first few weeks of the season as the ratio of cows to AMS is lower. It is only when the ratio of cows to AMS approaches 90:1 that milking intervals are extended to 18 hours (mean).

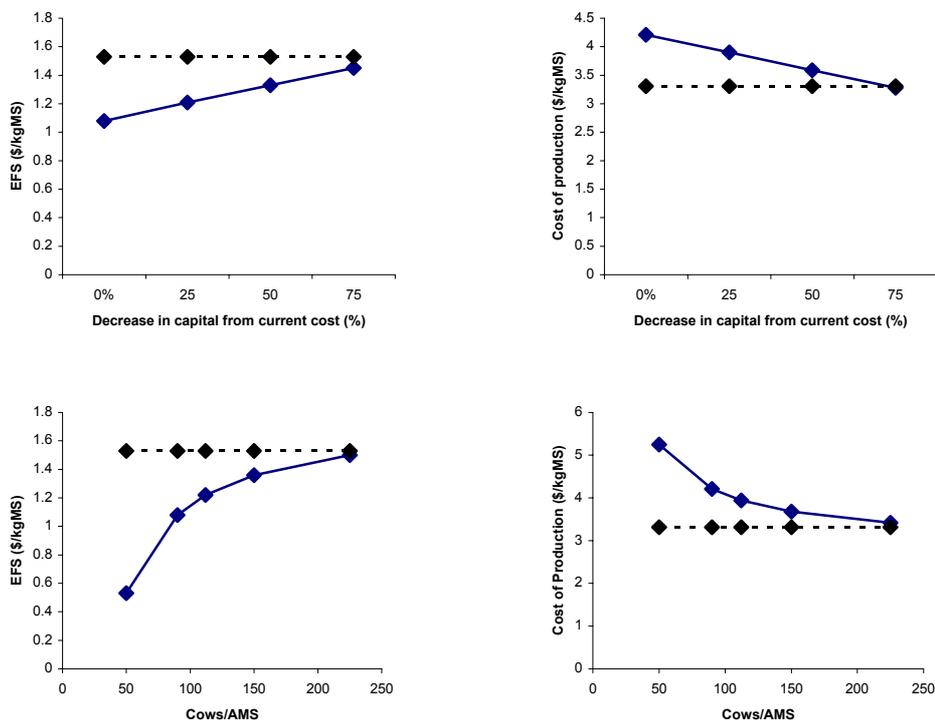
Although automatic milking removes the need for manual milking (with the exception of periods of cow training and difficult attachment

cows) there is still a requirement for visual monitoring and checking cow health, production and movement via computer generated reports, inspection and treatment of unwell cows, fetching of cows not reporting to the dairy in the required time interval, cleaning of external surfaces and waiting yard area and filling of chemical reservoirs. There is potential for further labour efficiency as these remaining tasks and cow training are streamlined.

Sensitivity Analysis

The impact of milk harvesting technology cost and cow throughput on the cost of production and EFS was determined by only changing the cost of the milk harvesting capital and keeping all other inputs stable (Figure 1). As expected a decrease in the cost of the AMS infrastructure had a major impact on each of the economic indicators. The graph illustrates the substantial gain that has already been made by achieving a higher ratio of cows to AMS than is typically practiced internationally. Without changing any other revenue or cost factor a 70% decrease in the cost of capital would be required to realise equivalent economic performance to the rotary system based on cost of production, EFS and operating ROA

FIGURE 1: The impact of changing total cost of capital or ratio of cows to AMS on Economic Farm Surplus (EFS, \$/ha) and Cost of Production (\$/kg MS) for the Greenfield System in second year of operation (—), assuming current performance compared with rotary system (- - - -).



figures. The reliance on an imported technology which contributes a major proportion of the total capital cost means that in addition to freight charges these costs will also be dependent on exchange rates.

Increasing AMS capacity further from 90 cows to 112 cows per AMS unit would have a positive outcome on all economic indicators, however current throughput rates would have to more than double for the Greenfield System to approach the performance of the rotary system, assuming other factors remain constant (Figure 1). The number of cows milked per AMS is typically 50 to 65 on most international commercial farms operating indoor systems aiming for a milking frequency greater than twice daily. It is not uncommon for commercial installations to achieve an average of 150 milkings per single stall AMS unit over 24 hours (Rasmussen and Pedersen, 2004). The current maximum potential utilisation for a pastured-system has been calculated to be 83% or approximately 20 hours per day (Davis *et al.*, 2005). This is due to necessary automatic and manual plant cleaning and down time for maintenance, technical faults and a tendency for cows to not visit the dairy between 2 and 6am (Jago *et al.*, 2002; 2004b; Davis *et al.*, 2005). In practice crate utilisation of 65% during peak lactation has been achieved at the Greenfield

Project farm (Greenfield Internal report, 2005). Milking 112 cows at an 18 hour interval equates to 146 milkings per AMS unit per 24 hours so this ratio of cows to AMS is theoretically possible with existing technology. Utilising this spare capacity will require refinement of the cow traffic and management systems to ensure cows are present at the dairy throughout the 24 hours and enter the AMS crates without delay (Thumath, 2004). A significant advancement in AMS technology would be required to realise a ratio of 150 or more cows per AMS either through substantially quicker processing time (cow preparation, cup attachment and machine performance) or more cows being able to be milked at one time as a result of modified cup attachment technology and dairy configuration.

A more likely scenario is that a change in a number of key factors will lead to AMS becoming an alternative milk harvesting option for dairy farmers. A situation was modeled in which capital cost decreased 25%, labour hourly rates increased 10%, AMS capacity was expanded to 112 cows, overall farm labour requirements were reduced a further 10% and there was no negative impacts on production as a result of improved cow training methods and selection. In this scenario the cost of production and operating ROA was similar for the two systems (Table 2). Each of these changes are

considered achievable given the current rate of development of automatic milking technology and understanding of cow capabilities within voluntary pastoral milking systems.

It should be noted that these analyses have used a standard conventional rotary milking installation as a comparison. There are more expensive milking system installations that offer additional milk quality sensing and volume recording capabilities. These dairies would be at a 10-15% higher cost than standard installations. This analysis has not made any attempt to include the value of the additional information that comes standard with AMS such as milk volume recording and automatic milk diversion.

Automatic milking presents an opportunity for major changes to lifestyle and working conditions on farms. Evaluation of labour requirements of the Greenfield System have shown that automatic milking allows a more flexible work day, shorter working hours and arguably improved working conditions and less of the repetitive physical activities which are a common feature of current milk harvesting tasks. On the other hand AMS require that someone is able to attend the AMS units at any time of the day or night to resolve technical faults and this is likely to be a limiting factor to adoption for some people. The urgency of attendance to faults can be reduced with video surveillance and/or if the system is operating with spare capacity.

The economic analysis takes no account of the intangible or social aspects of automatic milking such as change in labour intensity and flexibility, ability to spend more time on other activities, to not have to milk anymore, improvements in physical and mental health, all of which have been found to be significant factors when people make milking system choices (Meskens & Mathijs, 2002; Hogeveen *et al.*, 2004; Mathijs, 2004). A recent qualitative study has found that farmers perceive that automatic milking may be able to alleviate problems they are currently facing with hired labour (Small *et al.*, 2005). Working environment, lifestyle, hours of work and retention of staff will also be important considerations in choosing milk harvesting systems for the future.

CONCLUSION

This analysis and the practical findings of the Greenfield Project (Jago *et al.*, 2004; Davis *et al.*, 2005) have shown that AMS could become a viable financial and practical option for low-input pastoral dairying farm systems in New Zealand, although investment in this technology currently

returns substantially less than investment in a conventional milk harvesting system. Significant changes in the cost of the technology and associated implementation costs and/or improved cow throughput capabilities will be required for this to be a viable proposition for a significant number of New Zealand farms. Research should focus on increasing AMS capacity given current technology performance, reducing the cost of milk harvesting capital and on-farm infrastructure, further reducing labour inputs for milking associated tasks and enhancing cow adaption. The importance of socio-economic factors in decision-making for New Zealand farmers considering investing in automatic milking technology remain unknown.

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