An evaluation of two pastoral dairy production systems using automatic milking technology

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Abstract

The objective of this study was to evaluate the performance of two pastoral farming systems using automatic milking systems (AMS). Two farmlets were established at the DairyNZ Greenfield Farm and were evaluated over a single lactation. The GRASS farmlet (92 cows, 3.2 cows/ha) was self-contained except for 2% of the diet fed as supplement in the AMS. In the GRASS+ farmlet (72 cows, 3.6 cows/ha) 18% of the diet was from feed grown off the milking platform. Modelling the economic performance of the two systems showed a greater operating profit for the GRASS system at milk payouts ranging from $4.50 to $6.50/ kgMS. The field study showed that AMS can be successfully integrated into both all-pasture and higher supplementary feed pastoral dairy production systems. The design of profitable farming systems incorporating AMS technology should consider maximising milksolids per AMS through both milking frequency and ratio of cows per AMS.

Keywords: grazing, pasture management, economic evaluation

Introduction

Dairy production in New Zealand is based on low-cost, efficient farming systems that utilise intensive grazing to grow and harvest high quality pasture to produce milk. Automatic milking systems (AMS) are a technology that has the potential to reduce the labour cost associated with milking and improve the lifestyle and work environment for farm staff. The Greenfield Project was established in 2001 to test the viability of automatic milking in New Zealand pastoral farming systems. Following the successful development phase a herd of 180 cows was milked by two AMS on the 54 hectare, all-year grazing (Greenfield Farm) farm (Jago *et al*. 2004; Davis *et al*. 2005).

Two farmlets were established on the Greenfield Farm in 2008 to evaluate the performance of production systems typically found in New Zealand. DairyNZ uses a standard classification that categorises farms into one of five production systems based on the timing, purpose and amount of non home-grown feed used (Dairy Economic Survey 2008-2009; Hedley *et al.* 2006). The systems range from all grass, no supplement imported (10% of farms) to at least 30% of total feed imported and fed either in early and late lactation or all year round, and including grazing for dry cows (<5% of farms). The latter typically has a higher stocking rate, higher production per cow and per hectare and the herd tends to be larger than in the former system.

The capacity of an AMS is an important consideration in farm systems design. Practical utilisation of fully automated milking systems has been measured at around 80% (daily range 65-85%), allowing for connection failures, technical problems and cleaning down-times (Halachmi 1999). Field experience suggests that in systems where grazed pasture is the predominant diet, about 140 milkings can be carried out per AMS each day. These milkings can be achieved by milking fewer cows more often (more suited to higher input systems with higher yielding cows) or more cows less often (more suited to lower input systems with lower yielding cows) (Jago *et al.* 2007), with yield and milk harvest rate determining the total output of an AMS.

The objective of the study was to evaluate the performance of an all-grass system with a high number of cows per AMS, and a higher feed input system with a lower ratio of cows to AMS.

Methods

Animals and design of farmlets

The existing Greenfield cows were divided into two spring calving herds which were managed on adjacent farmlets from June 1st 2008 to 30th April 2009. Herds were balanced for age (mean 5.3 years, range 2-14 years), breed (84% Friesian, 4% Jersey, 12% Crossbred), genetic merit expressed as breeding worth ($BW, average = 135, 2007) and expected calving date. After calving, each herd had continuous access to one of the two Fullwood Merlin (Fullwood, UK) AMS throughout the lactation. The 28.8 ha GRASS farmlet ran 92 cows (3.2 cows/ha). A small quantity of concentrate (up to 0.5 kg per cow per day; wheat nuts) was fed in the AMS to assist with cow flow. With the exception of the concentrate (2% of the total diet) the diet was grazed pasture supplemented during periods of pasture deficits (daily offered pasture less than 13.5 kg/ cow/day) with silage made from within the farmlet and fed at pasture. The 20 ha GRASS+ farmlet ran 72 cows

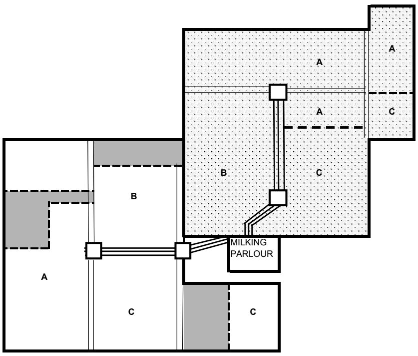


Figure 1 Farm layout for the GRASS (shaded with dots) and GRASS+ (unshaded) farmlets, the location of the milking parlour, the main grazing areas (A: morning, B: afternoon, and C: evening) in the respective farmlets, milking parlour housing two AMS, dual laneways and selection units (□). The area that was not part of the milking platform and was used to feed cows when not lactating and to grow non home-grown silage is shaded grey on the GRASS+ farmlet.

(3.6 cows/ha). Feed grown off the farmlet was 18% of the diet and consisted of a mixture of grass silage (fed at pasture) and concentrate (48% each of maize and barley, 4% molasses, fed in the AMS), ranging from 0.8-3.7 kg DM /cow/day.

Pasture management and farm configuration

Pasture species on both farmlets was mainly perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*). Farmlets were managed independently using standard best practice decision rules (Macdonald & Penno 1998) for a rotational grazing system, with 3 daily allocations of pasture using temporary fences with back fencing. Access to fresh areas of pasture was at 8 am, 2 pm and 11 pm daily via remote selection units located on dual raceways (Fig. 1) as detailed in Jago *et al*. (2004). Milking frequency targets were set within the herd management software, aiming to achieve an average of 1.5 and 2.0 milkings per day across the season for the GRASS and GRASS+ herds, respectively (Crystal 0.44, Fullwood Fusion, Holland). Upon entering a selection unit an electronic identification device was read and the cow drafted accordingly. All cows due for milking went to the milking parlour, while cows not due for milking were either directed back to the grazing area or to new pasture, depending on the time of the visit. Each farmlet received an annual total of 151 kg N/ha. An annual maintenance fertiliser dressing was applied to both farmlets at a rate of 685 kg/ha in March 2008 (76% Super Ten, 4% Calmag, 5% Durasul Sulphur, 7% salt bulk and 7% potash).

Measurements

Pasture cover (kg DM/ha) for each farmlet was estimated weekly using an electronic Rising Plate Meter (360 mm diameter, 315 g plate weight; Farmworks, Fielding, New Zealand). Total pasture grown and pasture eaten was estimated using the Pasture Eaten Calculator V1.4 July 2007 (http://www.dairynz.co.nz/page/pageid/2145836732/Production%20and%20 Feeding#PastureEatenCalculator). The energy requirements for grazing dairy cows used in the Pasture Eaten Calculator are based on measurements and assumptions described by Nicol & Brookes (2007).

Milk yield was recorded automatically by the herd management software (Crystal 0.44, Fullwood Fusion, Holland). Milk composition (fat and protein) was measured from samples collected during herd tests in mid October 2008, mid December 2008, mid February 2009 and early April 2009. Each herd test sampling period lasted for 48 h with samples being collected from every milking. A 24 h milk yield was calculated for individual cows using milking interval and milk yield data. Total fat and protein yield/cow/day or milksolids (MS) yield, was then estimated using the individual fat and protein percentages measured in the milk samples.

Table 1 Modelled Farm physical characteristics and MS yield for two farmlets (1 AMS) and two scaled up farm systems (4 AMS) based on actual field trial farmlet performance.

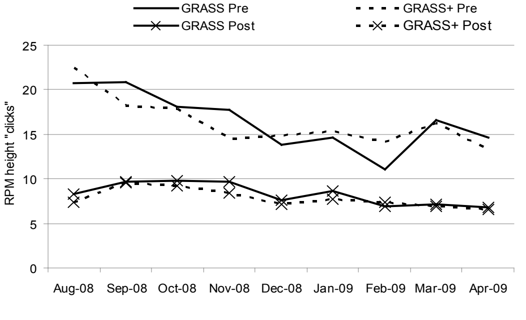
Physical Characteristics	GRASS	GRASS+	GRASS Large	GRASS+ Large
Peak cows	92	72	368	288
Effective ha	28	20	115.2	80.0
Cows/ha	3.2	3.6	3.2	3.6
Number of AMS	1	1	4	4
Total milksolids (fat+protein) (kg)	33572	30073	134286	120293
Milksolids/cow (kg)	365	418	365	418
Milksolids/ha (kg)	1168	1504	1168	1504
Milksolids/AMS (kg)	33572	30073	33572	30037
Milking frequency	1.5	1.8	1.5	1.8
Days in milk	262	267	262	267

Table 2 Model assumptions.

Item	Assumption
Milk payout ($/kg MS)	$5.50
Capital (milking facilities)	Includes AMS, compressors, milk line, buffer vat and cooling, building based on Greenfield Farm design ($1200/m^2), selection units, EID, silo
Labour	Includes paid and unpaid labour. Manager ($75000/yr) and assistant ($45000/yr). Labour ratios (/cow) based on Hedley *et al*. (2006) and adjusted to account for a 50% reduction in milking duties, and no change for non-milking duties (Jago *et al*. 2006).
Service cost/AMS	$10000
Animal health[1]	$71/cow
Breeding[1]	$42/cow
Dairy[1]	$21/cow for GRASS+ as close to twice daily milking then add 5% for additional milkings in GRASS
Electricity[1]	$32/cow adjusted up 4.3% for additional milkings in GRASS
Silage conserved on milking platform	$0.20/kgDM
Bought in silage	$0.25/kgDM
Meal	$500/t as fed
Fertiliser (including N) [1]	$611/ha
Stock grazing	Young stock $7.8/head/wk 52 weeks, 25% of herd, assume calves on platform, + 6 weeks winter grazing for whole herd at $15/head/wk
Regrassing[1]	$65/ha
Weed and pest[1]	$30/ha
Vehicle and fuel[1]	$180/ha
Repairs and maintenance[1]	$308/ha
Freight and general[1]	$49/ha
Standing charges and administration[1]	$94/cow
Depreciation	25 years (4%) for buildings and yards, 10 years (10%) for milking equipment, resale value of $70000/AMS
Interest	9% cost of capital
Capital for ROA calculation	Includes $38000/ha land value, dairy plant and buildings (capital listed above), other machinery, livestock ($1500/head), shares at $4.52 ea.

[1]DairyNZ Economic Farm Survey 2008/2009

Figure 2 Rising plate meter height readings for pre- and post-grazing pasture covers for the GRASS and GRASS+ farmlets.



Economic evaluation

The physical results of the farm systems trial were used as model inputs to determine the economic performance of the two production systems (see Jago *et al.* 2006). Farm physical characteristics for the two

Table 3 Feed and performance measures for the GRASS and GRASS+ farmlets.

	GRASS	GRASS+
Number of cows	92	72
Meal (kg DM/cow)	116	743
Silage (not grown on milking platform, kg DM/cow)	0	284
Total non home-grown feed (kg DM/cow)[1]	116	1027
Total non home-grown feed (% of diet)[1]	2	18
Milksolids (fat + protein)/cow(kg)	365	418
Milksolids/ha (kg)	1166	1504
Milksolids/AMS (kg)	33572	30073
Total milk yield/cow (kg/cow)	4420	5092
Average milking frequency (milkings per day)	1.5	1.8
AMS utilisation at peak (% time occupied/day, Nov)	81	74
Days in milk	262	267

[1]Feed not grown on the milking platform

Table 4 Model outputs assuming a milk price of $5.50/ kg MS.

	GRASS	GRASS+	GRASS Large	GRASS+ Large
DAIRY CASH INCOME				
Milk	184643	165403	738574	661613
Other	9844	7704	39376	30816
Total	194487	173107	777950	692429
Cash farm working expenses ($)				
Labour	29614	28421	101100	98400
Service costs	10000	10000	40000	40000
Animal health	6532	5112	15456	12096
Breeding	3864	3024	12512	9792
Dairy costs	1588	1512	6350	6048
Electricity	2404	2304	9615	9216
Feed made (silage)	7600	1600	15200	3200
Feed - bought in silage	0	5112	0	20448
Feed - bought in grain	5336	26748	21344	106992
Fertiliser (incl N)	17597	12220	70387	48880
Stock grazing	9329	13781	37315	55123
Regrassing	1872	1300	7488	5200
Weed and pest	864	600	3456	2400
Vehicles and fuel	5184	3600	20736	14400
Repairs and maintenance	8870	6160	35482	24640
Freight and general	1411	980	5645	3920
Standing charges	4784	3744	19136	14976
Administration	3864	3024	15456	12096
FARM WORKING EXPENSES ($)	120713	129242	450294	498483
(/kg MS)	3.60	4.30	3.35	4.14
Cash operating surplus	73775	43865	327656	193946
Depreciation	51242	51199	108065	107892
DAIRY OPERATING PROFIT ($)	22533	-7334	219591	86054
Capital ($)	420418	419985	1261000	1259000
Interest	37838	37799	113490	113310
Operating profit - interest	-15305	-45132	106101	-27256
Cost of production (/kg MS)[1]	6.25	7.26	5.00	5.98
Asset value[2]	1833000	1452000	6840000	5317000
Return on asset (%)	1.2	0.5	3.2	1.6

[1]Includes depreciation and interest costs
[2]Includes land ($38000/ha), stock ($1500/cow), plant and building and shares ($4.52)

Table 5 Sensitivity analyses for economic performance of the four farming systems with a milk price payout ranging from $4.50 to $6.50/ kg milksolids, assuming input costs remain constant.

	Milk Price ($/kgMS)	GRASS	GRASS+	GRASS Large	GRASS+ Large
Operating profit	$4.50	-11039	-37407	85304	-34239
	$5.50	22533	-7334	219591	86054
	$6.50	56104	22740	353877	206347
Return on assets (%)	$4.50	-0.6	-2.6	1.2	-0.6
	$5.50	1.2	-0.5	3.2	1.6
	$6.50	3.1	1.6	5.2	3.9

farmlets, two larger farms (based on farmlet production and physical characteristics scaled four-fold: GRASS Large and GRASS + Large) and the model assumptions are presented in Tables 1 and 2, respectively. The comparisons are based on the number of AMS installed as a constant (1 or 4 AMS), with land and cow numbers reflecting the different farming systems. The GRASS system is low input, with subsequently lower yields achieved per cow and longer durations between milkings. Based on each AMS performing 140 milkings per day, the GRASS system can therefore operate with more cows per AMS on a lower milking frequency. This requires additional land and cows compared with the GRASS+ system. The GRASS+ system is high input with higher yielding cows requiring more frequent milking. The higher milking frequency reduces the number of cows able to be milked per AMS to achieve the same number of daily milkings/AMS. Less land and cow numbers are therefore required for the GRASS+ system. Comparing economic performance of 4-AMS installations was selected based on obtaining a herd size similar to the national average of 360 cows (NZ Dairy Statistics 2008-09, http://www.dairynz.co.nz/page/pageid/2145848113/New_Zealand_Dairy_Statistics_2008-09).

Capital cost for the dairy has been calculated using a base price of $253 000 for a single AMS (GRASS, GRASS+) and $223 000 per AMS for the GRASS Large, and GRASS+ Large farms. The model assumes there are two remote selection units ($30 000/unit) for each of the GRASS and GRASS+ farms and four remote selection units for each of the GRASS Large and GRASS+ Large farms. Capital costs including land, livestock, plant and machinery have been included in the return on assets calculation (Table 2).

Feed volumes (silage conserved, concentrate fed etc) were based on the field trial data. With the exception of milk payout, labour, service costs, interest and depreciation all model input costs were based on the DairyNZ Economic Farm Survey 2008/09. For sensitivity analysis at differing payouts, input costs were assumed to have remained constant.

Results

Pasture and imported feed

The calculated values for annual pasture eaten were 13.2 and 13.5 t DM/ha for GRASS and GRASS+, respectively, assuming 80% utilisation of pasture (Macdonald *et al.* 2001). Making the assumption that pasture utilisation was similar for each farmlet is justified by similar post-grazing residual estimates throughout the season (Fig. 2). Post-grazing target residuals of 7 to 8 "clicks" were obtained on both farmlets for the majority of the season. However, during the spring when pre-grazing covers were higher, it was more difficult to reach target residual heights. Total harvested pasture silage was estimated at 38 t DM on the GRASS farmlet and 8 t DM harvested from the GRASS+ farmlet, using pre- and post- cutting pasture measurements.

Production performance

The GRASS+ herd produced 53 kg MS/cow and 338 kg MS/ha more than from the higher feed input and stocking rate GRASS herd (Table 3). Despite lower per cow production, the low input GRASS herd produced more milk and MS per AMS as a result of the higher ratio of cows per AMS. The average milking frequency was higher for the GRASS+ herd, being close to twice daily milking, but the GRASS herd achieved a higher AMS utilisation.

Economic evaluation

Using the assumptions presented in Table 2, the model output (Table 4) shows that at a milk price of $5.50/kg MS, the lower input GRASS system has a higher operating profit and return on assets than the GRASS+ system because of higher milk income and lower feed costs (including winter grazing and fertiliser). These cost savings outweigh higher labour, animal health, breeding and other farm costs which result from the larger land area and more cows on the GRASS farmlet.

The increased scale resulted in an improved financial performance for both farm systems. A sensitivity analysis for milk price showed that at the lower milk price of $4.50/kg MS, all but the larger GRASS system have a negative operating profit (OP) (Table 5). At $6.50 all the systems have a positive operating profit, with the larger GRASS system providing 5.2% return on assets.

Discussion

This field study has shown that AMS can be successfully integrated into both all-pasture and high supplementary feed spring-calving dairy systems. The production performance of the two systems was consistent with farms managed to best-practice standards and conventional batch milking methods as described by Hedley *et al*. (2006). The GRASS+ farmlet produced more MS/ha, harvested similar pasture, and had less surplus pasture for conservation, while the GRASS system produced less MS/cow, had a shorter lactation and was able to produce sufficient surplus pasture to maintain the herd with feed from the milking platform.

Growing and utilising a large amount of pasture is necessary to maximise the profitability of pastoral dairy systems (Macdonald *et al.* 2008). Both farmlets grew over 15 t DM/ha which is comparable to well-managed farms in the region (Hedley *et al.* 2006) and similar to the net pasture accumulation of 16.2 t DM/

ha/yr reported for the Greenfield research farm in the 2004/2005 season (Davis *et al.* 2006). Key to achieving high pasture utilisation is the ability to achieve target grazing residuals. In a system where cows are able to leave the grazing area voluntarily this could present a problem, particularly when the incentive to leave is access to a fresh area of pasture. However, the data shown here, along with those described by Davis *et al.* (2006), indicates that voluntary milking through automatic milking systems need not be a barrier to harvesting large amounts of grazed grass.

Although cows in the GRASS+ system achieved a higher milking frequency and production per cow, less total MS were harvested per AMS. In grass-based systems where one of the major drivers of profitability is cost of production, it will be important to fully utilise each AMS and consideration should be given to how this can best be achieved. In this study, the economic evaluation showed that the scaled up all-pasture system with a high ratio of cows per AMS was more profitable than the more intensive system over a range of milk prices. This model did not account for increasing costs of inputs with higher payouts. However, it can be surmised that the input costs for the GRASS+ farm would have disproportionately increased compared to the GRASS system. For instance, at a payout of $6.50 operating profit increases from 1.7, with current assumption of no change in input costs, to 1.8 times greater for GRASS compared to GRASS+ (OP of $331 362 and $184 423, respectively) when a 5% increase in farm working expenses are included in the model for the 4-AMS farms.

Conclusions and Implications

Profitable pastoral dairy systems are based on a compromise between production per cow and per hectare. The cost of production imposes a limitation on yield per cow through imported feed costs. An additional consideration for an automatic milking farm is production per AMS. The field study has shown that AMS can be successfully integrated into both all-pasture and pastoral dairy production systems incorporating moderate levels of supplementary feed (within Production System 3). Increasing the number of cows milked and reducing the individual cow milking frequency can increase milk production per AMS. The implications of this study are that the fundamental requirements of profitable pastoral dairy systems, to produce high quantities of pasture and achieve high pasture consumption, are not compromised with the introduction of automatic milking systems, although with current costs profitability is marginal at a milk price below $5.50/kg MS.

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