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Factors influencing milk harvesting efficiency in an automatic milking system

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ABSTRACT

Maximising milk harvested per robot is an important goal of pasture-based automatic milking systems (AMS). Results are presented from an analysis of 2937 cow milkings in a year-round milking system during January 2003 at the Dexcel Automatic farm (average herd size = 75 cows). Each cow milking was classified as OK (yield > 80% of expected yield, EY), Yield Carry Over (YCO, 20% < yield < 80% EY), or Failed (F, yield < 20% EY). The time and duration (from entry to exit from crate) of each cow milking was determined, as well as milk yield, and from these milk harvesting rate was calculated. There were an average of 95.8 cow milkings/day, average milking frequency was 1.13 milkings/cow/day (range 0.9 – 1.9 milkings/cow/day). Eighty-four percent of milkings were classified as OK, 8.9% as YCO and 7.1% as F (after which the cow was returned to the yard for another attempt). Milking times ± SD (F = 3.76 ± 2.57, YCO = 7.63 ± 3.31, OK = 10.07 ± 4.09 minutes/event) and milk harvesting rate (F = 0.09, YCO = 0.76 and OK = 1.37 kg/minute) suggest that failed milkings were costly in terms of time. The data show potential for improving the 24 h milk harvest per AMS through cow selection, a more consistent flow of cows through the AMS and technological improvements.

Keywords: milk harvesting efficiency; automatic milking systems; grazing; dairy cows.

INTRODUCTION

Maximising the milk output per automatic milking system (AMS) for minimum labour input will be critical to the economic viability of automatic milking in New Zealand's low cost dairying environment. Recent work in New Zealand (NZ) indicates that in a pasture-based system cows can be milked once-a-day with a reduction in per cow production and a small reduction in per ha production (6% Jerseys and 17% Friesians), provided the stocking rate is increased, typically by 17% (Collis *et al.,* 2004). Work reported by Woolford *et al.* (1985) suggested that a milking frequency of 3 times per 2 days (variable interval) resulted in a milk fat loss of 6%. The philosophy of the Automatic Farm Project has not been to use automatic milking to increase milking frequency of individual cows (as is typical with AMS overseas), but instead to maximize the daily harvest of milk per AMS by reducing milking frequency and increasing the number of cows milked per AMS.

Milk harvested per AMS is dependent on many factors involving the cow, the machine and management practices. In an AMS, optimizing crate utilization is important in maximizing the potential achievable throughput (cow milkings/day) without detrimental effects on queue lengths and time off pasture.

Calculations of AMS capacity are often based on the assumption that cows almost continuously or evenly attend the AMS, as is the case in many indoor systems. The combination of automatic milking on a voluntary basis with grazing does not currently result in an even attendance (Jago *et al.*, 2002; Ketelaar-de Lauwere & Ipema, 2004) as fewer cows visit the AMS between 0200 h and 0600 h (Jago *et al.*, 2002).

It is not currently realistic to calculate AMS capacity on the basis of the continuous reporting of cows to the AMS throughout the 24-hour period. Within the current automatic farm system some group-wise behaviour is evident associated with pasture break changes causing peaks in AMS visits (Jago *et al.,* 2004) and some periods whereby the AMS is unoccupied for minutes or hours.

Attendance in the AMS crate can result in a successful milking and subsequent release of the cow to pasture or an unsuccessful (failed) attempted milking. Failed milkings are generally caused by a failure to attach the teat cups to the teats or a failure to detect milk flow subsequent to teat cup attachment. After a failed milking the cow is returned to the waiting yard for a further attempt at milking. Milkings can be unsuccessful (failed) for a number of cow or machine reasons. Cow reasons for failed milkings include poor udder conformation, cow behaviour in the AMS, standing position within the crate, and the physiological state of the cow. Machine factors most commonly include a dirty laser, tangled cups or a milk or pulsation hose detached from the teat cup.

There are two potential areas for improvements in AMS crate utilisation. The first is to improve the harvesting rate by reducing the proportion of failed milkings, increasing the speed of cup attachment and improving the milking machine flow rates. The other area is that involving cow traffic which would focus on improving the uniformity of cow flow to the dairy and reducing the lag-time between one cow exiting the crate and another entering. The aim of this study was to quantify the milking capacity and harvesting efficiency of an AMS with a high ratio of cows to AMS within an extensive grazing farming system.

MATERIALS AND METHODS

Farm layout

The basic farm layout was described in detail in Jago *et al*. (2004). Briefly the farm consisted of two pasture blocks of 9.7 and 12.7 ha, respectively, joined together and to the dairy with dual one-directional cow-ways.

A selection unit that remotely pre-selected cows for milking was located in the centre of each block. Cows entered the selection units through one-way gates and exited via computer controlled gates that drafted cows either back to pasture if they had recently been milked or into the laneway to the dairy if they had exceeded their current minimum milking interval. Drinking water was available in both selection units and at the exit from the dairy, not at pasture.

Animals and grazing management

The herd was managed as a year-round milk production system and was in the process of changing from seasonal to split calving. The herd comprised a total of 83 mixed-age (range 2 to 11 years old) and mixed-breed (Jersey, Jersey x Friesian, Friesian) cows (average days in milk = 123, range 2 to 526 days). The average herd size for the 31 day period was 75 cows. Each cow was fitted with a leg-mounted transponder (left front leg) for electronic identification and drafting at the selection units and the AMS.

A rotational grazing system was used in which two paddocks, one on each side of a selection unit were grazed at any one time (a night and a day paddock). A fresh break of grass was made available twice a day at 0800 h and 2000 h. At these times any cows remaining in the old pasture break that had not voluntarily moved across to the new break of pasture were manually moved into the selection unit.

Milking management

A minimum milking interval (MMI) of 9 hours was set for all cows using expected yield and production rate criteria (Jago *et al.,* 2004). Individuals that entered the selection unit within 9 hours of a previous successful milking were drafted to a fresh break of pasture as outlined in Jago *et al.* (2004). If the 9 hour MMI was exceeded the cow was drafted onto the laneway to the dairy.

All cows were milked through one Fullwood Merlin AMS, which consisted of a crate and an integrated robotic arm. Upon entering the crate the cows' identification transponder was electronically read and an expected milk yield (EY) calculated. The EY was calculated from the individual's average milk production rate (kg milk/hour) and the number of hours since her last successful milking. The EY was used to determine the destination of the cow at the conclusion of milking. If > 80% of EY was harvested the milking was termed 'OK' and the cow was released to return to pasture. If 20-80% of the EY was harvested then the milking was termed 'Yield Carry-Over – YCO' and the cow was also released to pasture. A YCO was used to correct the EY calculation of the following milking and the cow was allowed to return to the dairy sooner. If < 20% of the EY was harvested the milking was termed 'Failed – F' and the cow was returned to the waiting yard before re-entering the AMS for a further attempt at milking. After four successive failed milkings the cow was automatically drafted to a holding yard with access to pasture to await attention from the herd manager.

Data collection

All data including time of entry into and exit from the AMS crate, milk yield (kg milk), and milking outcomes (OK, YCO or F), were automatically collected by the system support software (Crystal® 1.40, Fullwood Fusion, Holland and Logview).

The month of January 2003 was chosen as the data collection period as it was the period of highest ratio of cows to AMS for the prototype system. It was also a period of minimal disruption due to technical and design development.

Data analyses

Average milking frequency for each cow was calculated as the total number of milkings (classified as OK or YCO) divided by the number of days in milk for the data collection period. The time of entry to the AMS crate and the time of exit from the crate (collected by Logview®) were used to determine the duration of crate occupancy (minutes). Harvesting rate (kg/minute) was calculated using the yield of milk and the duration of crate occupancy.

RESULTS

There were 2937 cow milkings from 1 to 31 January 2003. There were 81 cows milked during this period (average 75 cows/day). During the data collection period 11 fresh cows were added and 3 late lactation cows were dried off. There was an average of 95.8 cow milkings/day (range 65 to 119 milkings/day).

Table 1 shows the average yield, crate time and milk harvesting rate of each classification of milking. The average daily milk yield was 14.46 kg/cow/day (range 4.78 to 27.6 kg/cow/day). The average total yield harvested/day was 1087 kg milk. The range in harvest rate for OK milkings was 0.02 to 8.43 kg milk/minute, for YCO milkings was 0.05 to 2.63 kg/minute and for F milkings was 0.00 to 0.88 kg/minute.

TABLE 1: Average yield (kg milk), crate occupancy time/milking (minutes) and milk harvesting rate (kg/minute) for milkings classified as OK (yield > 80% expected yield), YCO (20% < yield > 80% expected yield) or F (yield < 20% expected yield).

	Milking classification			
	OK	YCO	Failed	Overall
Proportion of all cow milkings (%)	84.0	8.9	7.1	100
Average yield (kg milk/event)	13.04 ± 5.19	5.58 ± 3.38	0.41 ± 0.73	11.48
Average crate time (minutes /event ± SD)	10.07 ± 4.09	7.63 ± 3.31	3.76 ± 2.57	9.12
Average milk harvesting rate (kg milk/minute ± SD)	1.56 ± 0.95	0.70 ± 0.44	0.07 ± 0.12	1.39

The average milking frequency for the herd during the data collection period was 1.13 milkings/cow/day (range 0.9 to 1.9). This equates to an average milking interval of 21 hours (range 12.6 to 26.6 h). Of the 2937 cow milkings, 84.0% were classified as OK, 8.9% as YCO and 7.1% as F. Of the 208 failed milkings, individual cows contributed with a range of 0-13 failed milkings/cow (0-6% of the 208 failed milkings). Four cows had greater than 30% failed milkings and 25 cows had no failed milkings. Cows that had failed milkings on a regular basis generally have poor conformation. Occasional failed milkings are more likely to be attributed to cow behaviour and AMS performance.

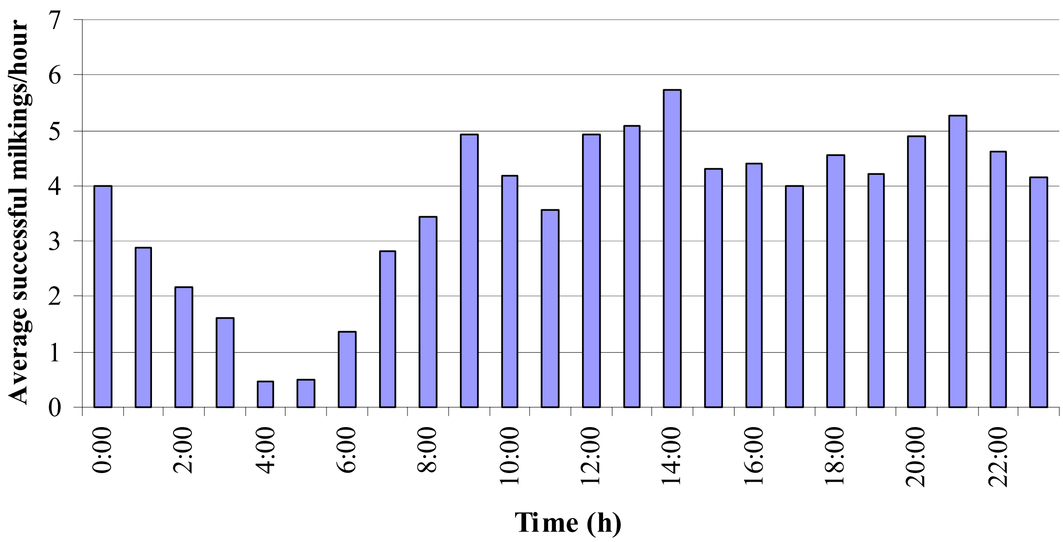
The AMS was occupied by cows for an average of 14.25 hours per day (range 9.84 to 17.06 hours/day) equating to an overall occupancy of 60% (range 41% to 71.1%). The 14.25 hours/day of occupancy were apportioned into 12.43 hours/day associated with OK milkings, 1.15 hour/day with YCO milkings and 0.68 hours/day with F milkings.

Figure 1 shows the average 24-hour distribution of milkings/hour (excluding failed milkings) during the data collection period.

DISCUSSION

These are the first data reported on the practical milking capacity and milk harvesting efficiency of automated milking systems in an extensive grazing system. The ratio of 75 cows per AMS on the Dexcel Automatic farm is the highest reported in the literature and reflects the philosophy of maximising milk output per AMS by achieving a high cow to AMS ratio.

FIGURE 1: Twenty-four hour distribution of average number of cow milkings/hour (excluding failed milkings) for the period - January 1 to January 31, 2003.



The average occupancy rate of 60% for the AMS indicates that there is potential to increase the number of daily milkings through either increased cow numbers or increasing milking fequency/cow with a single AMS. Practical utilisation of fully automated milking systems has been measured at around 80% (daily range 65% to 85%), allowing for connection failures, technical problems and cleaning down times (Halachmi, 1999). This suggests that it is reasonable to expect that on an average day, 19 of the 24 hours are available for sucessful milkings. At the Automatic farm, given the current management practices, one hour per day is taken up with three automated washes (16 minutes each) and manual cleaning. A further 3.2 hours/day should be discounted to allow for the lack of voluntary visits to the AMS during a period of 4 hours in early morning, seen in Figure 1 and also reported in Jago *et al*. (2002). This reduces the potential utilisable time on the Automatic farm (with current management practices) to 19.8 per 24 hours (83%). At an average of 6 cow milkings/hour this equates to 119 cow milkings/day. During the data collection period, an average of 95.8 cow milkings were achieved per day which suggests that there is potential to increase the average daily number of cow milkings by 23 (increase by 24%).

In addition to the factors already mentioned there are others that prevent achievement of a 100% occupancy rate. These include technical failures, routine maintenance, cow behaviour and traffic. By nature there will be a lag time between each cow milking. It typically takes an average of 43 seconds for a cow to enter the crate after the departure of the previous cow, however this is highly variable (Thumath, 2004). This lag time can extend to minutes if a cow chooses, for whatever reason, to wait a period prior to entering the crate or even hours if there is no cow waiting in line to enter the crate. Jago *et al.* (2002) showed that grazing cows have a lower tendency to visit the AMS during the early hours of the morning than any other part of the day, a tendency which was repeated in these data. Unless some incentive could be given to encourage the cows to come to the dairy during this period it is likely that for a period of about 4 hours/day (0200 h – 0600 h) crate occupancy is reduced to less than 20%.

Regardless of cow behaviour and traffic factors, throughput has the potential to be increased by a number of means. One is to rely on improvements in cup attachment technology so that each milking would have a reduced associated crate time. In comparison with manual cup attachment, the process of automatic cup attachment is time-consuming, requiring between 45 and 100 seconds depending on cow and machine variables (de Koning *et al.,* 2002). This would likely also reduce the incidence and time associated with failed milkings. Another way to improve efficiency in this respect is to select cows that have suitable udder conformation for quick attachment. A final area for potential improvement is to improve AMS reliability. There are some aspects of machine performance that can reduce efficiency of utilisation through failed milkings or increased cup attachment time. For instance a dirty laser eye (used to identify the location of teats before cup attachment) will affect attachment performance, increasing crate time and thereby reducing harvesting rate.

Data presented indicate that close to 0.7 hours/day were associated with failed milkings. At an average rate of 6 cow milkings/hour, elimination of failed milkings would allow AMS crate utilisation to be improved by gaining an extra 4 cow milkings/day.

There was considerable variability in individual milk harvesting rates. The average milk harvesting rate of 1.37 kg milk/minute for OK milkings is lower than data published by Artmann (2004) who reported rates of 1.84 to 2.34 kg/minute and at the low end of rates reported by Ipema and Hogewerf (2004). The low harvesting rate for the failed and YCO milkings indicate that reduction of these milkings would improve efficiency of the AMS creating potential for more cow milkings/day. The range of milk harvesting rates will be indicative of different milking speeds and variable attachment times.

The data presented show that in an automatic milking system there is potential for improving the 24-hour milk harvest per AMS through cow selection, technological improvements and improved cow traffic.

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