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Estimating 24-hour milk, fat and protein yields and somatic cell count for automatically milked cows in pastoral production systems

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Abstract

Currently, there are no accepted methods for conducting herd tests on farms using fully automated milking systems in New Zealand. This study used data from the DairyNZ Greenfield pasture-based automatic milking research farm to evaluate six milk sampling protocols to estimate daily milk, fat and protein yield and somatic cell count (SCC). Total milk, fat and protein yield, and SCC were estimated using all samples collected within 12, 16, 18, 24 and 36 hours from the start of the herd test and for a single test-day sample and compared with values calculated from a 48-hour gold standard herd test day. The correlation coefficient for milk and protein yields were relatively consistent when the sampling interval was shortened to 12 hours (r = 0.95, r = 0.94 for 12 hour milk yield and 12 hour protein yield). However, for fat yield it reduced from 0.96 for a 36 hour sampling interval to 0.88 for a 12 hour interval. The number of cows without a milking increased from 6.7% to 27.8% when the sampling interval decreased from 36 to 12 hour. A 24 hour sampling interval provided high correlations for milk, fat and protein yields, and SCC, with a 48 hour gold standard and minimised the number of missed cows.

Keywords: automatic milking; 24-hour production; milk; fat; protein; somatic cell count

Introduction

Herd testing enables farmers to collect information about individual cows in their herd. The information gained from herd testing is important for effective herd management and decision making. Furthermore, individual milk, fat and protein yields and somatic cell count (SCC) data are central to national animal genetic evaluation schemes. In 1996/97 87.2% of New Zealand dairy herds, equivalent to 89.6% of the cows in the national herd, were herd tested and contributed data to the national herd testing scheme (DairyNZ 2012). This declined to a low of 67.3% of herds or 64.0% of the cows in 2009/10 and then increased slightly to 73.5% of herds and 72.6% of the cows in 2010/11 (DairyNZ 2012). Herds milked by an automatic milking system (AMS) present a new challenge for existing herd test sample collection protocols and the estimation of 24-hour milk, fat and protein yields, and SCC. In AMS, milking is distributed throughout the day and milking intervals vary between and within individual cows (de Koning 2010). In the future it is likely that in-line sensors will be used to collect data continuously from every milking from which suitable estimates for daily milk yield and composition can be derived. However, at present a means of adapting the established conventional herd testing methods to AMS is required.

Acquiring milk samples for laboratory analysis is both costly and time consuming on AMS farms. An automated sampling device is required for each AMS, and samples must be transferred from the device to a storage facility up to three times during a 24-hour sample collection due to limited capacity of these devices. This creates potential opportunities for mishandling and mislabelling of samples. Additionally, if the test day (TD) is a fixed period, more than one sample may be collected per cow, increasing processing costs.

International herd improvement organisations have sought to develop appropriate protocols for herd testing on AMS farms (Dutch cattle improvement organization, Peeters & Galesloot 2002; Canadian milk recording system, Hand et al. 2010). However, these have been for housed cows, and achieve a higher milking frequency than is typical of grazed cows. Suggestions that a 14 to 16 hour TD is sufficient to obtain the necessary samples are unlikely to be appropriate for all grazing systems where milking frequency can range from 1 to >2 milkings per day (Ketelaar-de Lauwere et al. 2000; Jago and Burke 2010). Alternatively, the proposal of a single milking sample (Peeters & Galesloot 2002) would reduce cost and time.

The objective of this study was to estimate daily milk, fat and protein yield, and SCC using a range of protocols that differed according to duration and frequency of milk sampling within a TD. The aim was to identify the minimum number of samples and TD duration that would give a reasonable estimate of 24-hour milk, fat and protein yield, and SCC.

Materials and methods

Data and milk sample collection

Data from 19 herd tests and 7,181 cow milkings between November 2002 and April 2009 from the Greenfield Research Farm (Jago et al. 2004) were available. Of these data, fat and protein percentage, and SCC were available for 6,472 cow milkings. Data from samples for which the preceding milking was incomplete in that the yield was between 20%

Table 1 Correlation coefficients and standard deviation of the difference between predicted herd test results measured during test days of different lengths and actual ‘gold standard’ values measured over 48 hours, and the proportion of missed cows from which a sample was not collected during the test day, within an automated milking system.

Statistic	Length of test day (Hours)	Herd test measurement						Proportion of missed cows (%)
		24 hour milk yield	Fat yield	Fat percentage	Protein yield	Protein percentage	Log_{10} Somatic cell count	
Correlation	36	0.99	0.96	0.96	0.99	0.99	0.98	0.6
	24	0.96	0.87	0.87	0.96	0.98	0.93	6.7
	18	0.96	0.85	0.85	0.95	0.97	0.92	12.7
	16	0.96	0.85	0.85	0.95	0.97	0.91	15.7
	12	0.95	0.83	0.83	0.94	0.97	0.90	27.8
	One sample	0.94	0.82	0.82	0.93	0.97	0.90	-
Standard deviation of difference	36	6.0	8.1	5.1	6.0	1.0	5.1	
	24	11.1	15.4	10.2	11.1	2.1	8.7	
	18	12.2	17.2	11.3	12.2	2.3	9.7	
	16	12.3	17.5	11.6	12.4	2.4	10.0	
	12	13.7	19.2	12.3	13.8	2.6	10.5	
	One sample	14.1	19.9	12.5	14.2	2.6	10.6	

and 80% of the expected yield were excluded. Expected yield was calculated from the individual’s average milk production rate (kg milk/hour) and the number of hours since her last successful milking. Also omitted were samples where the estimated daily yield was >40 kg. This left a total of 6,458 cow milkings with samples.

Milk samples for fat and protein analysis were collected using an automated sampling device (Lely Holdings, Maassluis, The Netherlands). For each herd test the sampling device was set to collect a milk sample from every cow-milking over 48 hours, with the exception of milkings where the yield was <20% of the expected yield. As the sampling device only holds 60 milk samples, samples were collected in 50 mL vials preloaded with 200 µL of 10% Bronopol solution for milk preservation. Samples were removed from the device a minimum of three times every 24 hours and refrigerated at 4°C. For each sample, the herd management software recorded cow identity number, time of milking, time since last milking, and milk yield. Milk fat and protein concentrations were determined using an infrared milk analyser (Milko Scan 133B Analyser, FOSS Electric, Hillerød, Denmark). Somatic cell count was determined using an automated cell counter (Fossomatic 500, FOSS Electric, Hillerød, Denmark).

Analysis

Total milk, fat and protein yields, and SCC were calculated for TD at 12, 16, 18, 24, 36 and 48 hours from the start of the herd test period. For each milking for each cow the interval from the previous milking was calculated and recorded as milking interval in days. For each cow for each milking with herd test data during the TD, fat and protein yields were calculated using the composition data and milk yield from this milking. Total milk yield, fat yield, protein yield and milking interval were then calculated for TD from these milkings. The 24 hour standardised yields were then calculated by dividing the total milk, fat and protein yields by the total milking interval. Fat percentage and protein percentage were calculated from these 24-hour yields. The same process was used to calculate TD SCC. Data from the first sample in the herd test period were used as the data for the one-sample protocol. The 48 hour TD was used as the ‘gold standard’.

Correlation coefficients were calculated for each TD at 12, 16, 18, 24, and 36 hours and one-sample protocol with the gold standard measure. For the one-sample protocol, only cows with multiple samples within the gold standard TD at 48 hours were included in this analysis. Differences between each protocol and the gold standard for each variable were calculated for each cow herd test. Means and standard deviations of these differences were calculated for each variable for each protocol. The standard deviation was standardised by expressing it as a percentage of the mean of the gold standard to enable the accuracy of the protocols to be compared.

Results and discussion

The means and standard deviations of the 24-hour estimates of milk yield and fat and protein percentage, calculated using the gold standard (48 hour TD), were: milk yield 15 ± 6 kg, fat percentage 4.7 ± 0.8%, protein percentage 3.8 ± 0.4%, log_{10}SCC 2.00 ± 0.5 and milking interval 19 ± 2 h. The average milking interval was longer than reported for housed systems (de Koning 2010) but was not surprising as others have reported a lower milking frequency when cows are grazing pasture (Ketelaar-de Lauwere et al. 2000). In New Zealand it is common for farmers to milk cows once daily for either part of the season or the whole season, therefore any sampling protocol must allow for this range in milking frequency.

The correlation coefficients and the standard deviation of the difference between the actual and estimated values, as a percentage of the 48 hour TD mean, for each milk variable are presented in Table 1. The correlation coefficient for estimates of milk and protein yields were high and relatively consistent when the sampling interval was reduced to 12 hours, however, fat yield correlation was <0.90 for the 16 hour, 12 hour and one sample TD. The results indicate increased error in estimating milk variables as the sampling duration decreased. This was most apparent for estimating fat percentages. It is well known that milk fat concentration is more variable than protein concentration. A similar result has been reported by other authors (Lazenby et al. 2002; Hand et al. 2010). Protein percentage estimates were least affected and stayed within 3% of the 48 hour mean for all TD durations and for the one-sample protocol. The error in estimating $\log_{10}$SCC increased by 4.6% when the sampling interval was shortened from 36 hours to 18 hours then remained relatively stable as the herd test duration reduced.

Previous authors have suggested that a TD of between 14 hour and 16 hour results in a minimal loss in accuracy in estimates for 24 hour milk, fat and protein yields in AMS herds (Lazenby et al. 2002; Hand et al. 2010). However this analysis shows that decreasing the sampling duration also increased the risk of a proportion of the herd not being sampled (Table 1). Even at a 24 hour TD, 7% of cows that would have been sampled at least once within a 48 hour period were not sampled. Therefore, although a shorter TD may be more practical, and sufficient on some farms to achieve a satisfactory daily yield estimate, at least for protein, it may not be acceptable because of the numbers of cows that would not be sampled.

The management of the Greenfield research herd was deliberately targeting a milking frequency of less than twice daily. Although this is lower than that achieved on some commercial farms, experience to date suggests that a wide range of milking frequencies are occurring on the small number of commercial AMS farms in New Zealand (JG Jago, Unpublished data). For the purpose of developing a suitable herd testing protocol, the reported data show that if the herd test period is to be less than 48 hours, then a 36 hour TD will be optimal in terms of accuracy. However, there is only a small loss in accuracy if the TD is reduced to 24 hours, although farmers would need to ensure that all cows were milked and sampled in that time.

An alternative protocol is to estimate daily yields from one sampled milking per cow per TD. Estimates based on a single sample were similar to those for a 12 hour sampling period in terms of accuracy and precision but had the advantage of no cows being missed. These results concur with those of Peeters and Galesloot (2002) who reported a similar correlation between predicted and actual fat yield (r = 0.92), fat percentage (r = 0.84), protein yield (r = 0.997) and protein percentage (r = 0.98) when a single milking was sampled. The authors suggested that one sampled milking was sufficient for a satisfactory estimate for TD fat yield. In contrast, Buenger et al. 2002) concluded that it was possible to estimate daily protein content with a single sample, but not fat content.

Conclusion

This analysis has highlighted the issues for achieving satisfactory 24 hour milk, fat and protein yield and SCC estimates when cows are milked in an AMS. The herd testing protocol is a compromise between prediction accuracy and the cost of collecting the samples including labour and laboratory analysis. Satisfactory estimates for milk and protein yield were achieved when the sampling interval was reduced to 12 hours. However, the number of cows without a sample exceeded a quarter of the herd. The estimates for fat yield and fat percentage were poorer for all test day protocols than for both milk and protein yields. In conclusion, the analysis has shown that a 24 hour sampling interval achieves a satisfactory milk, fat, and protein yield, and SCC estimate, minimising the number of missed cows.

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