Comparison of on-line measurements with conventional single-day herd tests

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Abstract

Previous theoretical studies have shown that frequent tests by on-line milk analysers (OMA) can provide better cow assessments than infrequent laboratory-based tests. This is because the higher test error associated with OMA averages to zero with multiple tests and the true means of traits with high day-to-day variation are better captured using tests taken over several days than with a single-day herd test (1DHT). This theory, however, assumes tests are not affected by cow specific bias (CSB). CSB is a systematic error that causes cows to be consistently under- or over-evaluated relative to the herd, which reduces the accuracy of between-cow comparisons. We compared the precision of data from OMA and 1DHT for milk volume, fat, protein, lactose and SCC, using the 10d average herd test as ground truth. The precision of OMA was better at a cow average level than at an individual test level, but this was dependent on the degree of CSB. CSB was negligible for protein, lactose and somatic cell count (SCC) ≥200 kcells/mL and not negligible for volume, fat and SCC <200 kcells/mL. The precision of the 1DHT estimate of the cow average was numerically similar to the within-cow day-to-day variation of each trait, which is consistent with the theory that day-to-day variation is the primary cause of 1DHT error. For traits with high day-to-day variation (milk volume, fat, SCC ≥200 kcells/mL), OMA provided a statistically equal or better estimate of the cow average than 1DHT. For traits with low day-to-day variation (protein, lactose, SCC <200 kcells/mL), 1DHT provided a significantly better estimate of the cow average than OMA, despite OMA protein and lactose exhibiting negligible CSB. For all milk production traits and for SCC in the range most useful for herd management purposes (≥200 kcells/mL), OMA estimated the cow average with precision and ranking accuracy suitable for herd management.

Keywords: on-line milk analysers, cow-specific bias, day-to-day variation.

Introduction

One argument in favour of on-line milk analysers (OMA), as opposed to laboratory-based herd testing, is that the average of repeated tests provides a good estimate of the true mean (Mein *et al.*, 2000; Clarke and Hannah, 2007). This theory, however, assumes tests are not affected by cow specific bias (CSB). CSB is a systematic error that causes cows to be consistently under- or over-estimated relative to their herd mates. CSB limits the usefulness of the data for between-cow comparisons (Anderson *et al.*, 2016). LIC Automation produces two OMA: *Saber™ Milk* and *Saber SCC*, which between them measure milk volume, fat, protein, lactose and somatic cell count (SCC). *Saber Milk* fat and protein measurement exhibits relatively high CSB. To address this problem, a new milk composition analyser is being developed by LIC Automation using a technology less susceptible to CSB.

While CSB limits the ability of OMA to average out errors over multiple tests, within-cow day-to-day variation limits the power of a single-day herd test (1DHT) to represent the cow average, no matter how accurate the test. Day-to-day variation for milk volume and fat is typically high (Mackle *et al.*, 1999; Andrée, 2008). Mackle (1999) reported within-cow day-to-day coefficients of variation (CVs) of 8.93% for volume and 5.17% for fat. The current trial compared the ability of OMA and 1DHT to estimate the short-term cow-average milk traits. The aim was to determine whether the advantage of frequent tests by OMA, limited by CSB, outweighed the advantage of the precise tests of the 1DHT, which does not capture within-cow day-to-day variation.

Materials and methods

Data were collected from a herd of 208 cows, milked twice per day in a 24-a-side swing-over herringbone milking system in Waikato, New Zealand. Milk analysers were manufactured by LIC Automation, Hamilton, New Zealand. Prototypes, incorporating a new milk composition analysis technology, were installed at 14 positions, testing milk volume, fat, protein, lactose and SCC. *Saber Milk* and *Saber SCC* were installed at the remaining 10 positions, testing milk volume and SCC. Herd tests were conducted at twenty consecutive milking sessions, from 11 to 21 June 2018. Only milkings with valid results from both the herd test and the OMA (paired milkings) were included in the analysis.

Data from cows that had eight or more paired milkings in the trial period, and at least one day of the middle five days (14-18 June) with both AM and PM paired milkings, were included. The final dataset for volume analysis included 178 cows with data from 2224 milkings, and for SCC included 177 cows and 2209 milkings. The final dataset for milk composition analysis was smaller because the milk composition analysers were only installed at 14 of 24 milking positions, resulting in fewer paired milkings, and included 50 cows with data from 473 milkings. The distribution of tests per cow for these three datasets is illustrated in figure 1.

The final datasets were a mixture of AM and PM results for each cow, depending on which milking positions the cow visited during the trial. It was therefore difficult to determine a ground truth cow average with balanced AM and PM contributions without discarding excessive amounts of data. This problem was addressed by scaling individual AM and PM results to a 24h equivalent result by multiplying by a coefficient derived from the whole herd data. If a cow had both AM and PM results on a day, two 24h values were inferred and both were included in the cow average.

Statistics for SCC were calculated for two ranges using a cut-point of 200 kcells/mL. Precision was quantified using SD of error (SDE) for fat, protein, lactose and SCC (<200 kcells/mL), and SD of relative error (SDRE) for milk volume and SCC ($\geq$200 kcells/mL). Three tests were evaluated: OMA at an individual milking level, OMA at the cow average level, and 1DHT (adjusted for herd day-to-day variation). The 1DHT for each cow was the day closest to the middle day with two herd test results. The ground truth for individual milkings was the herd test, and the ground truth for cow average OMA and 1DHT was the 10-day cow average herd test. Cow averages for SCC were calculated by geometric mean.

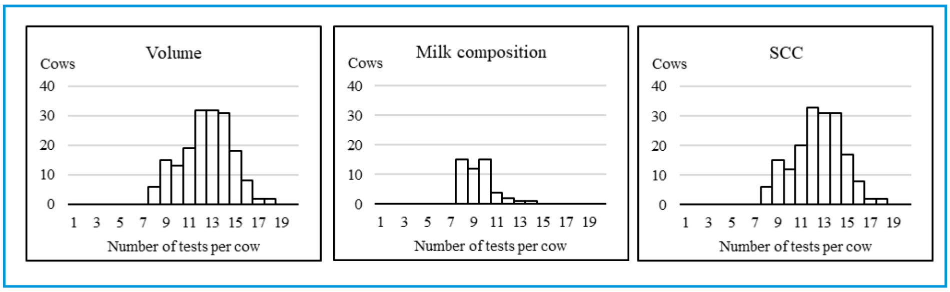

Figure 1. Distribution of tests per cow in the final datasets for evaluating measurement performance.

Within-cow day-to-day variation in the milk traits was quantified as the herd-mean of the cow-SD or cow-CV of 24h herd test results, from cows with at least five 24h values (168 cows). Spearman correlation was used to quantify the ability of a test to correctly rank animals according to milk volume, fat yield, protein yield, lactose yield, SCC less than 200 kcells/mL and SCC greater than or equal to 200 kcells/mL.

Results and discussion

The results of the trial are illustrated in figure 2, where the three types of estimate are plotted against their respective ground truth for each trait. The performance statistics from the trial are shown in table 1. The SDE or SDRE for individual tests and the OMA cow-average, respectively, was 10.6% and 6.0% for volume; 0.36 and 0.18 g/100mL for fat; 0.29 and 0.12 g/100mL for protein; 0.18 and 0.09 g/100mL for lactose; 66 and 42 kcells/mL for SCC <200 kcells/mL; and 52% and 21% for SCC ≥200 kcells/mL. Therefore, OMA had better precision (SDE or SDRE) at the cow-average level than at the individual milking level for all traits, indicating that some of the test error averaged-out with repeated tests. The degree of improvement for protein, lactose and SCC (≥200 kcells/mL) suggests that for these traits, CSB was negligible. For example, the SDE for protein improved from 0.29 to 0.12 g/100mL, whereas the cow average SDE

Table 1. Summary of results.

	Indiv. test		Cow average							
				SDE or SDRE[1]			Spearman correlation[2]			
	Milkings	SDE or SDRE[1]	Cows	OMA	1DHT	p-value	OMA	1DHT	p-value	Within-cow SD[3] or CV
Milk vol.	2224	10.6%	178	6.0%	6.1%	0.855	0.969	0.976	0.226	7.0%
Fat	473	0.36	50	0.18	0.26	0.001	0.957	0.940	0.407	0.31
Protein	473	0.29	50	0.12	0.09	0.028	0.934	0.973	0.027	0.10
Lactose	473	0.18	50	0.09	0.05	0.000	0.935	0.957	0.303	0.07
SCC <200k	1951	66	157	42	26	0.000	0.309	0.948	0.000	21
SCC >200k	258	52%	20	21%	68%	0.000	0.825	0.796	0.430	61%

[1] SDE has units of g/100mL for fat, protein and lactose, and kcells/mL for SCC.
[2] Spearman correlation for fat, protein and lactose was based on kg yield.
[3] Within-cow SD has units of g/100mL for fat, protein and lactose, and kcells/mL for SCC.

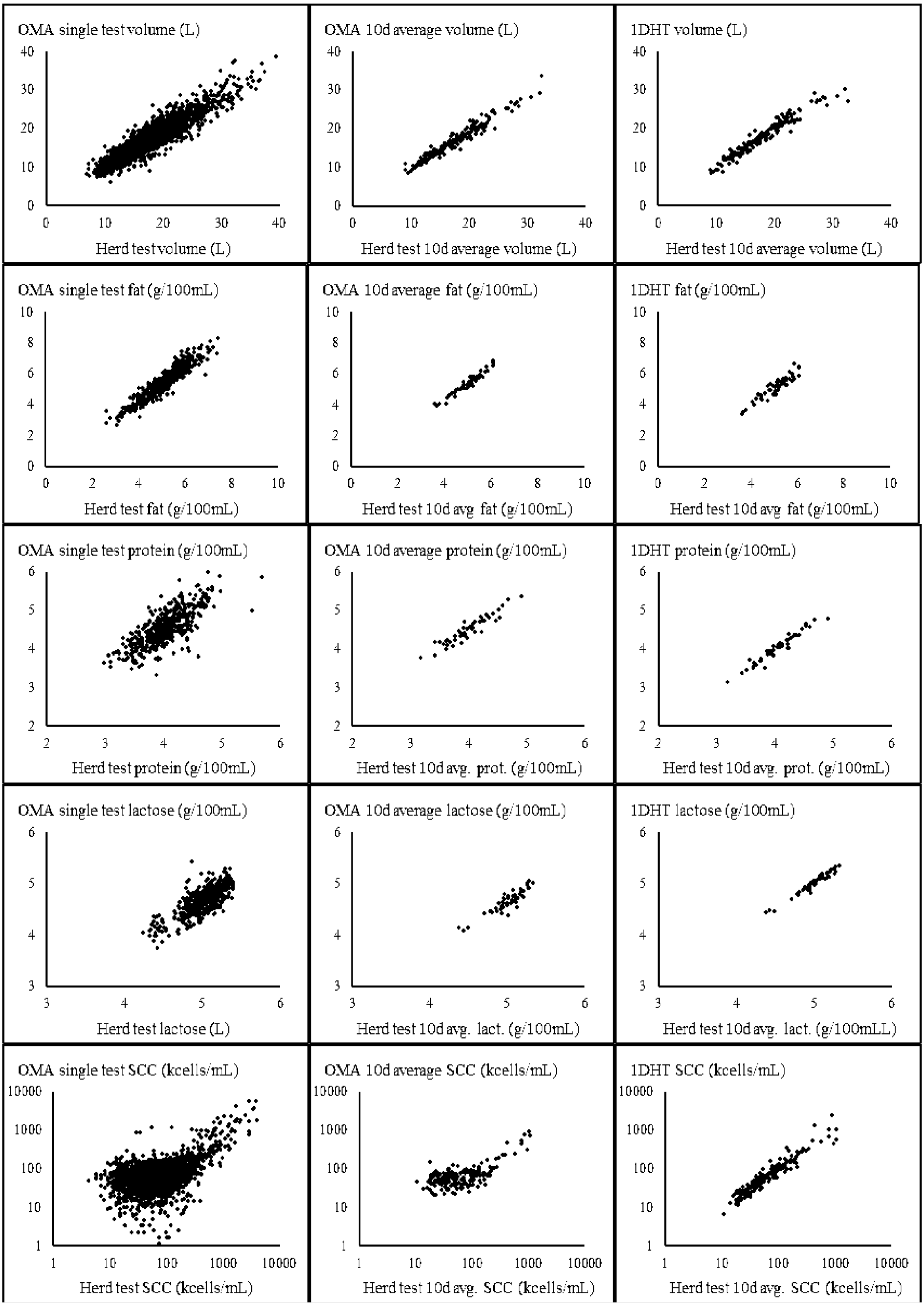

Figure 2. Correlation between the estimate and the ground truth for volume, fat, protein, lactose and SCC; for OMA single tests (left), OMA 10-day average (centre) and 1DHT (left).

expected in the absence of CSB, assuming eight tests per cow, would be 0.10 g/100mL ($0.29/\sqrt{8}$) However, for milk volume, fat and SCC (<200 kcells/mL) the improvement was less than would be expected if there were no CSB.

Day-to-day variation in the production traits was consistent with published work (Mackle 1999, Andrée 2008): relatively high for volume (7.0%) and fat (0.31 g/100mL); and relatively low for protein (0.10 g/100mL) and lactose (0.07 g/100mL). The SDE or SDREs for the 1DHT, compared with the cow average herd test as ground truth, were 6.1% for volume, and 0.26, 0.09 and 0.05 g/100mL for fat, protein and lactose, respectively, which were numerically similar to the within-cow day-to-day SD for these traits. This supports the idea that day-to-day variability inhibits the ability of the 1DHT to provide a result representative of the short term average for a cow. As a result, the OMA provided an equivalent or better estimate of the short term cow average for milk volume, fat and SCC (≥200 kcells/mL) – the traits with high day-to-day variation. For protein and lactose, which had low day-to-day variation, the estimate from 1DHT was significantly better than the OMA. Even so, low SDE and high Spearman correlations (>0.93) for all production traits at the cow average level indicate that the OMA used in this trial is a useful tool for identifying high and low producing cows.

The 1DHT SDE for SCC less than 200 kcells/mL (26 kcells/mL) was substantially smaller than observed in a previous trial (64 kcells/mL, Orchard *et al.*, 2018).The previous trial did not evaluate within-cow day-to-day SD, but the SDE results imply that day-to-day variation was substantially smaller in the current trial. Consequently, in contrast to the previous trial, the 1DHT provided a more precise estimate of the 10-day average than the OMA. The level of CSB exhibited by the OMA in the low SCC range was significant compared with the differences between cows. Accordingly, the OMA had a poor Spearman correlation for SCC <200 kcells/L. The primary uses for an SCC analyser are to detect high SCC animals and those with subclinical mastitis. Neither of these uses require accurate ranking of animals below 200 kcells/mL. In the more important high SCC range, the OMA provided a better estimate of cow average SCC than a 1DHT and had an equivalent Spearman correlation. Therefore, the OMA appears to be a valuable tool for monitoring individual cow SCC.

In summary, this trial has produced experimental data consistent with previous theoretical research that indicated that errors in individual tests from OMA can be averaged-out over multiple tests, but that CSB limits this; and that within-cow day-to-day variation limits the ability of 1DHT to estimate the short-term cow average. For milk volume, fat and SCC ≥200 kcells/mL, the OMA used in this trial provided an equivalent or better estimate of the short-term cow average than a 1DHT. For all traits, the data produced by the OMA provided useful estimates of the cow average for herd management purposes.

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