Short communication: Correlation of on-site inspection and laboratory milk testing results for Wisconsin grade A dairy farms in 2007 and 2008

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ABSTRACT

This study examined whether regulatory on-site dairy farm inspection results correlated with reported laboratory somatic cell count (SCC), standard plate count (SPC), and β -lactam drug residue (DR) results for individual farms. Results were obtained for Wisconsin grade A dairy farms in 2007 and 2008 (>11,000 farms, >1.4 million data points). The proportion of farms failing an on-site inspection ranged from 12% for farms that had never failed an SCC test (>750,000 cells/mL), an SPC test (>100,000 cfu/mL), or a DR test (drug detected) to 55% for farms that had failed at least 1 of each type of test. Conditional probability analysis showed that the probability of a farm failing an on-site farm inspection was higher if the farm had failed a DR test and increased as the proportion of samples failing SCC or SPC or both increased. However, the statistical correlations were weak ($R \leq 0.22$) between on-site farm inspection result (pass/fail) and numerical or logarithmic SCC or SPC or pass/fail DR result. The weak correlation may reflect temporal and methodological differences between on-site farm inspection and laboratory testing and may indicate that they provide different but useful indices of milk safety and quality. Alternatively, the results suggest that examination of a different frequency and focus for on-site farm inspection is warranted.

Key words: dairy farm inspection, milk testing

In the United States, fluid dairy products can enter interstate commerce only if they are designated as grade A. Grade A fluid milk and milk product standards are specified in the FDA Pasteurized Milk Ordinance (PMO; United States Department of Health and Human Services, 2008). The PMO criteria for meeting grade A standards are adopted by states, either by reference or by incorporation into state statutes or regulations, so that each state has the legal authority to

allow the shipment of grade A dairy products to other states.

Grade A unpasteurized milk must be produced at grade A dairy farms. The PMO specifies twice-yearly on-site dairy farm inspection to meet grade A standards. Alternatively, the PMO allows a performance-based farm inspection program in which a farm is inspected 1 to 4 times/yr, with the inspection frequency based in part on the results of SCC, SPC, and drug residue (DR) analyses performed by the dairy processing plant that receives the farm's milk. Wisconsin uses the performance-based farm inspection program for scheduling inspections at its approximately 11,266 grade A dairy farms.

On-site dairy farm inspections include evaluation of the cows, milk house, and barn for cleanliness; examination of the farm's water supply, waste disposal, plumbing, and pest control; and observation of the condition and sanitary upkeep of the milking equipment, the temperature of unpasteurized milk in the bulk tank, and the proper storage and use of dairy cattle medications. A dairy farm fails an on-farm inspection when specified key deviations are observed or when certain deviations are observed on 2 consecutive inspections.

Wisconsin has more than 11,000 grade A dairy farms, so conducting on-site farm inspections represents a very large portion of the state's food safety regulatory budget. Yet, it could be argued that few of the items monitored in an on-farm inspection have a direct and significant effect on the safety and quality of milk produced at a given farm. Unclean conditions in the milk house, or barn, or both, and damaged, poorly maintained, or poorly cleaned equipment would be expected to result in lower milk quality, which could be detected by an increased SPC. However, unless the milk was grossly temperature-abused, any microbiological hazard introduced to the milk at the farm could be controlled by the pasteurization process at the dairy processing plant receiving the farm's milk. However, for milk that is made into cheese without first being pasteurized, on-farm sanitation may have an important effect on end product safety.

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It is possible that temperature abuse of unpasteurized milk at a dairy farm could result in growth and production of heat-stable enterotoxin by *Staphylococcus aureus*. The unpasteurized milk temperature is already measured by the bulk milk hauler whenever milk is collected from a farm (every 1–2 d at the majority of Wisconsin dairy farms). As currently conducted, on-site farm inspection might detect milk temperature abuse if the temperature abuse coincided with an inspection or if it was properly documented by the bulk milk hauler at the farm and these records were reviewed by the inspector. Compared with on-site farm inspection, use of electronic temperature data-capturing technology at the farm bulk tank would be a far more efficient and thorough way of detecting milk temperature abuse.

The presence of drug residues in milk is an important safety hazard for allergic consumers. On-site dairy farm inspection involves observation for indication of improper use and storage of dairy cattle medications. However, improper use of medications may not always be evident during an inspection. Misuse of dairy cattle medications can be detected at the processing plant when milk from each bulk load (which may include milk from several farms) is tested for drug residues. Milk from individual farms is tested for drug residues whenever a positive result is obtained for a bulk load and each time that milk from an individual farm is tested for SPC.

Although there is debate about whether mastitis in lactating cattle presents an important milk-related safety hazard, mastitis can cause economic and quality problems for the dairy farmer and processor. Mastitis in cows may result from poorly maintained or unclean milking equipment, which may be detected during an on-site farm inspection. Mastitis is also often detected when an increased SCC result is obtained in a laboratory test conducted by the dairy processing plant. High SCC levels in milk will decrease cheese yield if the milk is used for cheese-making (Kosikowski and Mistry, 1997).

This study was undertaken as part of efforts to evaluate whether mandated on-site dairy farm inspections provide useful milk safety and quality information that is distinct from information gained in laboratory SCC, SPC, and DR testing. The hypothesis tested was that the results of SPC, SCC, and DR testing performed on each producer's milk at the dairy processing plant do not correlate with on-site farm inspection results, and therefore on-site farm inspection results provide information with an unclear link to objective measures of milk safety and quality.

To test this hypothesis, a data set was created from Wisconsin Department of Agriculture, Trade and Consumer Protection dairy program records. The data

set comprised on-site farm inspection and laboratory test results for all Wisconsin grade A licensed dairy producers for 2007 and 2008. For each unique license identification number (dairy farm), the results included SCC expressed numerically as cells per milliliter, SPC expressed numerically as colony-forming units per milliliter, pass/fail β -lactam DR test results, and the results of 2 to 8 on-site farm inspections. The SPC and SCC test results were also converted to $\log_{10}$ per milliliter. Results of the on-site farm inspection were binary, defined as whether (= 0) or not (= 1) a farm had failed a Wisconsin Department of Agriculture, Trade and Consumer Protection on-site farm inspection during 2007 and 2008. Failure was defined as follows: at least 1 reinspection of the farm necessitated by key deviations such as, but not limited to, 1) unclean milk contact surfaces, 2) filthy conditions in the cow yard, milking barn, or milk house, 3) unclean milking animals, 4) improper milk cooling, or 5) observed improper animal drug use or storage; at least 1 repeat violation observed on consecutive inspections; or at least 1 suspension of the farm's grade A permit for failure to correct significant noted violations. For each year's data, analysis was done for all dairy farm license identification numbers having no missing SCC, SPC, DR, and on-site farm inspection results (>1.4 million data points for the 2 yr combined).

Modeling of the data set was attempted using simple SAS tools such as PROC REG, MIXED, AUTOREG, and CORR (version 9.1, SAS Institute, Cary, NC), and R functions such as lm and glm (<http://www.r-project.org/>), but no strong correlations between failure of an on-site farm inspection and numerical SCC or SPC results or binary DR testing results were observed. No strong correlations were observed when the SCC and SPC data were $\log_{10}$ transformed.

The SCC, SPC, and DR data were also converted to a binary pass/fail format to indicate whether a farm had ever failed SCC testing (>750,000 somatic cells/mL), SPC testing (>100,000 cfu/mL), or a DR test. Correlations between pass/fail history of on-site farm inspections and pass/fail history of SCC, SPC, and DR were then examined. The proportion of farms failing on-site farm inspection was also determined for each combination of binary SCC, SPC, and DR results (Table 1).

In further analysis, SCC and SPC failure rates (number of failing samples divided by the number of total samples) were determined for each farm and individual farm results were grouped into interval classes. The failure rate interval width was 0.10. Using the gsummary function from the nlme package from R software, the probability of a farm failing an on-site farm inspection was then modeled as a function of the combination of

Table 1. Proportion of Wisconsin grade A dairy farms failing ≥ 1 on-site farm inspection during 2007 and 2008¹

SCC result	SPC result	DR result	Proportion with ≥ 1 on-site farm inspection failure
Pass	Pass	Pass	0.12
Pass	Pass	Fail	0.20
Fail	Pass	Pass	0.22
Pass	Fail	Pass	0.25
Fail	Pass	Fail	0.39
Fail	Fail	Pass	0.41
Pass	Fail	Fail	0.44
Fail	Fail	Fail	0.55

¹Results related to whether the farm's milk had failed ≥ 1 SCC test ($>750,000$ cells/mL), ≥ 1 SPC test ($>100,000$ cfu/mL), or ≥ 1 β -lactam drug residue (DR) test during 2007 and 2008.

SCC failure rate interval, SPC failure rate interval, and DR test result history.

The first question addressed by statistical analysis was whether the numerical or binary results of SPC or SCC or the binary results of DR testing correlated with the pass/fail on-site farm inspection results to such a degree that the farm inspection result could be considered overlapping or redundant. We concluded that none of these variables, or combinations thereof, was strongly correlated with on-site farm inspection result. The highest correlation ($R = 0.22$) was between the pass/fail history of an on-farm inspection and the pass/fail result for SPC. Even when an additional binary variable was created, indicating whether a particular farm had any failing SCC, SPC, DR, or on-site farm inspection result during 2007 and 2008, there was only a weak correlation ($R = 0.33$) between the pass/fail history of on-site farm inspection and this "all-tests" variable.

For each combination of binary (pass/fail) results for SCC, SPC, and DR, we determined the observed proportion of farms failing on-site farm inspection (Table 1). Of farms with no failing SCC, SPC, and DR results, only 12% had ever failed an on-farm inspection, suggesting that producers of high-quality milk are relatively unlikely to fail a farm inspection. At the other extreme, 55% of farms that had failed at least 1 each of SCC, SPC, and DR tests also had failed at least 1 on-site farm inspection. We concluded that lower milk quality, as identified by SCC, SPC, and DR results, was only weakly linked to problems detected in an on-site dairy farm inspection.

The presence of DR is the major safety hazard that is addressed by both laboratory analysis and on-site farm inspection. Farms with a DR failure during 2007 and 2008 were generally more likely to fail an on-site farm inspection during that same period than were farms with no DR test failures. Conditional probability analysis showed that for a specific combination of SCC failure

rate and SPC failure rate, the probability of a farm failing on-site farm inspection was always lower for farms that had never failed a DR test than for farms that had failed ≥ 1 DR test. The proportion of farms that had failed at least 1 DR test and an on-site farm inspection was between 20% (farms that had never failed an SCC or SPC test) and 55% (farms that had failed at least 1 SCC test and at least 1 SPC test), again suggesting a weak link between lower quality milk and a failed on-site farm inspection. From a dairy processing plant's point of view, it would be beneficial if on-site dairy farm inspection results focused the processor's and farmers' attention on problems with handling and use of dairy cow medications to help prevent the financial loss associated with dumping a truckload of milk (often from multiple farms) that tests positive for DR.

Conditional probability analysis showed that the probability of a farm failing on-site farm inspection increased with increasing SCC failure rate or increasing SPC failure rate. The relationship was clearest when there were >100 farms sharing the same SCC failure rate interval and SPC failure rate interval (Table 2). These results suggest that failure of an on-site dairy farm inspection may be a useful warning of current or pending problems linked to increased likelihood of failing an SCC or SPC test. However, the probability of a failed on-site farm inspection accurately indicating an SCC or SPC failure is still low; the conditional probability analysis showed that there is a 12% chance that a farm with no SCC or SPC failures may fail an on-site farm inspection.

The overall results of our statistical analysis indicated that there was a weak but observable connection between the results of an on-site dairy farm inspection and the safety- and quality-related laboratory analytical results (SCC, SPC, DR) for milk produced at the farm. This weak connection could reflect the fact that the on-site farm inspection is not scheduled to coincide with SCC, SPC, or DR testing. Thus, the on-site farm

Table 2. Probability of a Wisconsin grade A dairy farm failing an on-site farm inspection¹

SCC failure rate	SPC failure rate			
	0	0.01–0.10	0.11–0.20	0.21–0.30
0.31–0.40	0.19	0.54	0.53	≤100 farms
0.21–0.30	0.21	0.48	0.51	≤100 farms
0.11–0.20	0.21	0.45	0.51	0.50
0.01–0.10	0.21	0.35	0.48	≤100 farms
0	0.12	0.26	0.21	≤100 farms

¹Probability as predicted by a model based on the failure rate (number of failing samples per number of samples tested) for SCC (>750,000 cells/mL) and SPC (>100,000 cfu/mL) during 2007 and 2008. Predicted probability values are shown for farms that never failed a β -lactam drug residue test. Results shown are for combinations of SCC failure rate interval and SPC failure rate interval shared by >100 farms.

inspection is providing a temporally and methodologically different view of milk safety and quality. The value of the on-site dairy farm inspection could be considerably increased if it addressed only the conditions that are most likely to result in either 1) safety hazards that would not be detected by the current laboratory tests or controlled by pasteurization, or 2) SCC, SPC, or DR failures. The main food safety hazard that would not be adequately controlled by subsequent pasteurization or detected by current mandatory laboratory testing is the growth and toxin production by *S. aureus* resulting from inadequate milk refrigeration. Under the Hazard Analysis Critical Control Point approach to ensuring food safety, the critical control point (CCP) for this hazard would be the bulk-tank storage of milk between milking and pick-up. The critical limit for this CCP would be a temperature low enough to prevent *S. aureus* growth (i.e., <10°C). For quality reasons and to prevent the growth and toxin production by psychrotrophic *Bacillus cereus*, a lower critical limit such as 5°C could be established. Obviously, the stricter (lower temperature) critical limit would result in higher quality milk. Monitoring of this CCP could most efficiently and comprehensively be performed by using electronic temperature-recording devices that capture

temperature data for real-time or future evaluation. Data logger results could be reviewed during an on-site farm inspection or at a distant location if data were transmitted electronically to the regulatory agency. It is possible that the frequency of on-site inspection at farms using electronic temperature-recording devices could be significantly decreased without negatively affecting milk safety or quality. Inspection of smaller dairy producers who are unable to afford data-logging equipment could be focused on proper milk refrigeration capacity, the proper use and storage of dairy cow medications, and only those sanitation issues proven to be closely related to SCC and SPC. Further data analysis should be conducted to determine what on-site farm inspection deviations are most closely linked to SCC, SPC, and DR failures.

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