Farm Inspection Scores and Milk Quality Criteria as Indices of *Salmonella* in Bulk Milk

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**ABSTRACT**

The scores from routine dairy farm inspections, bulk milk standard plate bacteria counts, and somatic cell counts from dairy farms with *Salmonella*-positive milk filters (cases) were compared with those from dairy farms with *Salmonella*-negative milk filters (controls). Case and control farms showed no significant differences in their inspection scores based on general surroundings of the farm, milking area and cleanliness of milking cows, but differed in the higher mean score for milk houses of case farms. Additionally, there were no differences in the standard plate counts or somatic cell counts between case and control farms. Based on the results of this study, there is no evidence that poor dairy inspection scores, high standard plate counts or high somatic cell counts are useful indicators of the presence of *Salmonella* in bulk milk supplies from dairy farms.

The frequency of both small and large-scale outbreaks of illness attributed to milk borne *Salmonella* (3,23,40), *Campylobacter* (36), *Listeria* (12,20,24) and other microorganisms (13,31) underscores the importance of milk and milk products as vehicles of human infection. Although proper pasteurization is effective in reducing the health risk posed by these and other agents (2,6), recent outbreaks of human salmonellosis involving pasteurized milk products have demonstrated that faulty pasteurization or post-pasteurization contamination of milk products may lead to human infection (7,23,35). Coupled with this is the persistence of raw milk consumption by some groups, especially farm families, despite demonstrated hazards of the practice (42,44). For these reasons, the presence of *Salmonella* and other human pathogens in unpasteurized milk remains a public health hazard.

A number of surveys have demonstrated that various pathogens may be present in the bulk milk supplies at the farm (4,24,27), transport or processing level (1,19,28), and may or may not be associated with known incidents of human disease (44). Despite this, little is known of the factors that contribute to *Salmonella* contamination of bulk milk on dairy farms. Identification and quantification of these factors could be useful, both in terms of preventing the contamination of milk with these agents and in identifying farms that are at risk of *Salmonella* contamination.

The most frequent route of contamination of the bulk milk supplies is unresolved, although recently there have been several accounts of shedding of *Salmonella* from the mammary gland by infected cows (15,33,45). Another possible route is through environmental contamination of the milk supply, for example, it is known that a high percentage of clinically normal calves on dairy farms can be infected with *Salmonella* spp. (43). If environmental contamination of the milk supply were important, then farm level factors that reflect general hygiene, such as the degree of cleanliness of the facilities and animals, cleanliness of milking equipment, adequate cooling of milk and other factors might be important in limiting access of these agents to the milk. In Ontario, as in many other areas, the facilities and practices relating to general hygiene are subject to periodic inspection and scoring by regulatory personnel. The present study was undertaken to determine the association between dairy farm inspection scores, milk quality indices and the presence of *Salmonella* in the bulk milk supplies of Ontario dairy farms.

**MATERIALS AND METHODS**

**Dairy farm selection**

The dairy farms included in this study were participants in two recent surveys. Both surveys were designed to determine the prevalence of *Salmonella* in bulk milk filters from dairy farms in southwestern Ontario. The study period of the first survey was December 1985 - March 1986 (27), and the study period of the second was September 1986 - February 1987 (unpublished data). The details of the dairy farm selection process used in these surveys has been reported previously (27). For the purposes of the present study, cases were defined as dairy farms that had submitted one or more *Salmonella*-positive milk filters. *Salmonella*-negative (control) farms were obtained at random from the pool of dairy farms that had submitted *Salmonella*-negative milk filters for culture during the preceding surveys. Control farms were matched to cases on the basis of predominant breed of milking cow and on bulk milk transport company, as many of the *Salmonella*-positive farms that participated in
this study were determined to be clustered by transport company in a preceding study (27). It was not possible to match case and control farms on the basis of the fieldperson that conducted the farm inspection. Owners of study farms were asked permission to access their milk quality and production reports from the Dairy Inspection Branch (DIB) of the Ontario Ministry of Agriculture and Food (OMAF).

Dairy farm inspection scores

All participating dairy farms received an annual general inspection during the study period that was conducted by a fieldperson of the Dairy Inspection Branch (DIB) of the Ontario Ministry of Agriculture and Food (OMAF). Based on the subjective assessment of the fieldperson, the farms were assigned a score up to a maximum in each of 49 separate criteria. These criteria included a variety of characteristics, such as the cleanliness of milk house equipment, milking cows, stalls and parlours, quality of ventilation and animal housing facilities and many others. The various criteria were grouped under four summary headings (milking area, cows, general surroundings and milk house) that reflected the main areas of the farm operation being inspected. The inspection scores were recorded on a standard form (copy available upon request) and the individual criteria scores were subtotaled under the four summary headings previously mentioned. For the purposes of this study, each separate criterion and the summary headings of inspection were used as independent variables representing the inspection scores. A brief description of farm inspection and milk quality variables is given in Table 1. The fieldpersons were not aware of the Salmonella status of the milk filter culture before or after conducting the inspections.

Milk quality tests

Standard plate bacteria counts (SPC) and somatic cell counts (SCC) were performed routinely once per month on bulk milk samples from case and control farms throughout the period of the study. The samples were processed within 48h of collection at the farm, by the Central Milk Testing Laboratory (CMTL) of OMAF. Standard plate bacteria counts were performed using an automated version of the standard agar plate method (26). Somatic cell counts were performed with an automated somatic cell counter (Fossomatic 360, Foss Electric, Denmark). For each farm, an average of the monthly SPC and SCC was calculated for 1986 (Table 1).

Data handling and statistical analysis

The information obtained from OMAF was entered into computer files and validity of data entry was checked by direct comparison with record sheets. Statistical procedures were performed using the Statistical Analysis System (SAS) (34) and Biomedical Data Programs (BMDP) (9) and all tests of statistical significance were carried out at the p<.05 level. When appropriate, logarithmic transformation of data was performed to achieve normality (38). The means of farm inspection and milk quality (SPC, SCC) variables were compared using two-way analyses of variance (34), with classes of variables (Fieldperson and Status), representing the fieldperson conducting the inspection and the milk filter culture result, respectively (Table 1). The effects of the summary heading variables on the presence of Salmonella in bulk filters (Status) were assessed using multiple stepwise logistic regression (9). The effect of fieldperson conducting the interview was controlled by including the classification variable (Fieldperson) in the logistic regression model.

RESULTS

Of the 28 dairy farms from which Salmonella were isolated from milk filters during the preceding survey (27), 26 granted permission to utilize their information regarding dairy farm inspection scores and milk quality tests from OMAF. The 2 farmers that refused to participate in this part of the study did not state their reasons for doing so. The results of dairy farm inspection made during the study period were not available in OMAF files for 7/26 case farms, and these were excluded from the study. Permission to utilize information from milk quality records was granted by all control farms.

The farm inspections were conducted by 10 different fieldpersons, and the distribution of their participation between case and control farms is presented in Table 2. Two fieldpersons each conducted 10 of the inspections and in both instances these were evenly distributed between case and control farms. The remaining 8 fieldpersons conducted a variable number of inspections on study farms, each with an imbalance in distribution of one inspection between case and control farms.

### Table 1. Description of farm inspection and milk quality variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Maximum Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GENERAL SURROUNDINGS</td>
<td>8</td>
<td>Subtotal of scores for the general surroundings; the state of the buildings, manure handling and storage.</td>
</tr>
<tr>
<td>COWS</td>
<td>12</td>
<td>Subtotal of scores for the cleanliness of cows, for udder washing and teat dipping.</td>
</tr>
<tr>
<td>MILK AREA</td>
<td>22</td>
<td>Subtotal of scores for the cleanliness and physical condition of the milking stable or parlour.</td>
</tr>
<tr>
<td>MILK HOUSE</td>
<td>58</td>
<td>Subtotal of scores for the condition of equipment and procedures used in the milk house.</td>
</tr>
<tr>
<td>FIELDPERSON</td>
<td>N/A</td>
<td>Fieldperson that conducted dairy farm inspection.</td>
</tr>
<tr>
<td>SPC</td>
<td>N/A</td>
<td>Natural logarithm of the average monthly standard plate count for 1986.</td>
</tr>
<tr>
<td>SCC</td>
<td>N/A</td>
<td>Natural logarithm of the average monthly somatic cell count for 1986.</td>
</tr>
<tr>
<td>STATUS</td>
<td>N/A</td>
<td>Salmonella culture status of milk filters.</td>
</tr>
</tbody>
</table>

*Not applicable.*
There were no significant differences in the 49 individual criteria inspection scores between case and control farms (data not shown). The mean scores for case and control farms and corresponding levels of significance for each of the farm summary inspection variables (General Surroundings, Cows, Milkarea and Milkhouse) are summarized in Table 3. There were no significant differences in the means of the variables (General Surroundings, Cows or Milkarea) between case and control farms. Case farms had a significantly (p=.05) greater mean score for "Milkhouse" (53.08) than control farms (52.11).

Natural logarithmic transformations were performed on SPC and SCC test results to achieve normality. There was no significant difference in the mean SPC or SCC between case and control farms (Table 3).

In the final logistic regression model, with the variable "Fieldperson" included for control purposes, only the variable "Milkhouse" (coefficient=0.712, p=.009) was a significant predictor of Salmonella status of milk. Case farms had higher "Milkhouse" scores than control farms.

**DISCUSSION**

The results of this study do not support the hypothesis that dairy farms with Salmonella contamination of the bulk milk supplies receive lower scores on farm inspection than do control farms. In contrast, case farms had significantly higher scores in the "Milkhouse" summary category than did control farms. If the latter finding is more than merely a chance association, then farms with good hygiene practices in the milkhouse are at increased risk of Salmonella contamination of milk. It is improbable that this association reflects the true state of nature and it is likely that farm inspection scores are poor predictors of Salmonella contamination of bulk milk. These findings support those of previous studies that found little correlation between dairy farm inspection scores and the total bacteria count of bulk milk (8,17,18). The evidence, however, does not necessarily lead to the conclusion that farm hygienic practices do not affect the degree of bacterial contamination of bulk milk. Indeed, the methods used to wash and dry udders and teats prior to milking have been shown to alter the bacterial contamination of milk (14,30). The results of the present and previous studies (17,18) do suggest, however, that factors responsible for the variability between farms in the type and numbers of bacteria present in milk are poorly estimated by inspection scores. The authors were concerned by the narrow range of inspection scores both within and between farms. To what extent this influenced the findings of this study is unknown, however, little variability between inspection scores would make it difficult to discriminate between farms based on these scores, and would tend to produce "no significant" findings.

The involvement of various fieldpersons in conducting the inspections of study farms was a potential source of bias, as the scores given in the various categories were largely dependent upon their subjective assessment. Although it was not possible to match case and control farms by the fieldperson conducting the inspection, the distribution of fieldpersons between case and control farms was quite equitable. In addition to this, the effect of fieldperson was controlled analytically in the analysis of variance procedures and the logistic regression model. By using these procedures, any confounding effect of fieldpersons on the observed association between "Status" and inspection score variables was removed.

No significant differences in the means of the milk quality variables SPC and SCC were present. The SPC has been reported to be associated with a variety of factors.

**TABLE 2. Frequency of inspection by different fieldpersons on case and control farms, in Ontario, 1986.**

<table>
<thead>
<tr>
<th>Fieldperson</th>
<th>Number of Inspections</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Case Farms</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
</tr>
</tbody>
</table>

**TABLE 3. Comparison of means and range of farm inspection and milk quality variables for case and control farms.**

<table>
<thead>
<tr>
<th>Variable†</th>
<th>Range (maximum-minimum)</th>
<th>Control mean (SE)</th>
<th>Case mean (SE)</th>
<th>Significance of difference‡</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n=19)</td>
<td>(n=19)</td>
<td>(n=19)</td>
<td></td>
</tr>
<tr>
<td>GENERAL SURROUNDINGS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COWS</td>
<td>(5-8)</td>
<td>6.79 (.20)</td>
<td>6.68 (.23)</td>
<td>.73</td>
</tr>
<tr>
<td>MILK AREA</td>
<td>(17-21.5)</td>
<td>19.71 (.26)</td>
<td>19.97 (.21)</td>
<td>.46</td>
</tr>
<tr>
<td>MILK HOUSE</td>
<td>(49.5-54.5)</td>
<td>52.11 (.35)</td>
<td>53.08 (.33)</td>
<td>.05</td>
</tr>
<tr>
<td>SPC</td>
<td>(9.0-10.5)</td>
<td>9.56 (.14)</td>
<td>9.62 (.10)</td>
<td>.69</td>
</tr>
<tr>
<td>SCC</td>
<td>(11.6-13.3)</td>
<td>12.49 (.10)</td>
<td>12.30 (.32)</td>
<td>.17</td>
</tr>
</tbody>
</table>

*See Table 1 for description and maximum score.

‡Standard error of mean.

†The observed level of significance after control of variation in scores among fieldpersons.
including the degree of environmental contamination (41), the methods used in washing of the udders and teats (14), the number of bacteria shed in the milk of infected cows (16,30) and other factors. If the isolation of Salmonella in milk was associated with environmental contamination, then a concurrent increase in the SPC might also be expected, however, this was not observed. This finding, therefore, does not support the view that Salmonella in milk is an environmental contaminant. Monitoring of fecal coliforms or _E. coli_ might have proven more discriminating between case and control farms.

Somatic cell counts have been shown to vary with mastitis, the stage of lactation, age, and with decreased production of milk (10,11,29,32,37). If _Salmonella_ were being shed in the milk of infected cows, a rise in SCC could result from mammary gland infection with this organism. Recently, it was reported that the somatic cell counts increased in quarters shedding _Salmonella_ in naturally infected cows (33,39). In another study, a single cow was found to be shedding _Salmonella_ from the mammary gland and milk samples from that animal had normal somatic cell counts (45). In the present study, there were no differences in the mean SCC between case and control herds. When shedding of _Salmonella_ directly into milk has been documented, usually only one infected cow in the herd had been detected (33,39,45). An attendant increase in somatic cells in the milk of a single _Salmonella_-infected cow probably would not be detected in a herd level sample (10).

Under the conditions of this study, dairy farm inspection scores, SPC and SCC were not predictive of the presence of _Salmonella_ in the bulk milk supplies of dairy farms. Although the general inspection of farms may be of value in the maintenance of overall quality of the milk production and marketing system (5,17,21,22), the achievement of high inspection scores should not be taken to imply that the raw milk supply from these farms is free from infectious agents like _Salmonella_.

### ACKNOWLEDGMENTS

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Bishop and Juan,-conit. from pg. 957


