The selenium status of dairy herds in Prince Edward Island

Jeffrey J. Wichtel, Gregory P. Keefe, John A. Van Leeuwen, Elizabeth Spangler, Mary A. McNiven, Timothy H. Ogilvie

Abstract — Bulk tank milk selenium (Se) concentration was compared with mean serum Se concentration in 15 herds and was found to be an accurate reflection of the herd Se status. The Se status of 109 Prince Edward Island (PEI) dairy herds was monitored for 1 year using bulk tank milk Se concentration. Fifty-nine percent of the herds surveyed were, at some point, found to be marginal or deficient in Se, putting them at risk of disease and suboptimal production. The periods of greatest risk of deficiency were fall and winter, at which time 5% and 4%, respectively, of herds sampled fell in the range considered truly deficient in Se. Herds in which Se supplementation was provided in the form of a commercial dairy concentrate were over 4 times more likely to be Se-adequate than herds not using this method, and adjusted average daily milk yield was 7.6% greater in herds determined to be Se-adequate when compared with Se-marginal herds. We conclude that many dairy producers in PEI are providing insufficient supplementary Se in the ration to meet the recommended Se intake for lactating cows.

Résumé — Bilan du sélénium des troupeaux laitiers de l'Île-du-Prince-Édouard. La concentration de sélénium (Se) dans les réservoirs de lait a été comparée à la concentration sérique moyenne de Se dans 15 troupeaux et s'est avérée être un reflet fidèle du bilan du Se dans ces troupeaux. Le bilan du Se de 109 troupeaux laitiers de l'Île-du-Prince-Édouard (Î.-P.-É.) a été contrôlé pendant 1 an en mesurant la concentration de Se dans le lait des réservoirs. Chez 59 % des troupeaux évalués, on a constaté une déficience en Se ou une concentration à la limite de la normale, avec pour résultats un risque accru de maladie et une production suboptimale. Les périodes à plus hauts risques de déficience se situaient en automne et en hiver, où respectivement 5 et 4 % des troupeaux contrôlés affichaient des taux de Se véritablement déficients. Les troupeaux recevant un supplément de Se sous forme de concentré commercial pour vaches laitières avaient une probabilité 4 fois plus grande d'avoir un taux de Se adéquat que les troupeaux n'en recevant pas et la production quotidienne moyenne ajustée de lait était de 7.6 % supérieure chez les troupeaux à taux de Se normal comparé aux troupeaux à taux situés à la limite des valeurs normales. Nous concluons que plusieurs producteurs laitiers de l'Î.-P.-É. ne supplémentent pas suffisamment la ration de leurs vaches laitières en Se pour fournir les apports recommandés.

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Introduction

The soils of the Maritime provinces are known to contain unusually low concentrations of selenium (Se). Adequate intake of Se in dairy cattle is important for ensuring optimal performance, especially with regard to udder health (1).

Department of Health Management, Atlantic Veterinary College, University of Prince Edward Island, 550 University Avenue, Charlottetown, Prince Edward Island C1A 4P3.

Address all correspondence to Dr. Jeff Wichtel.

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However, little is known about the current status of Se in dairy herds in Prince Edward Island (PEI). Studies during the 1970s highlighted the low concentrations of Se in both forages and grains grown in PEI (2). This work was extended to show that Se deficiency was to be expected throughout the Atlantic Provinces, if livestock were fed entirely on locally-grown feeds (3). More recently, data collected from beef farms on PEI showed that local forages provide inadequate Se for cattle (4). The average forage Se concentration in that study was 0.039 mg/kg, whereas the current recommendation for Se concentration is 0.1 or 0.3 mg/kg in the total ration (5) for beef and dairy cattle, respectively.

Although the addition of Se to dairy cattle rations is commonplace, its use and effectiveness in maintaining adequate Se intake has never been assessed in dairy herds on PEI. Inconsistencies in mineral supplementation may arise from fluctuation in the Se content of the base diet and variation in the amount or formulation of minerals fed during the different stages of lactation, during the dry period, and during heifer rearing.

The objectives of this study were as follows: (A) to evaluate the use of bulk tank milk for the monitoring of the Se status of dairy herds in PEI; (B) to obtain information on the Se status of lactating dairy cows in PEI in order to assess the adequacy of current Se supplementation practices; and (C) to examine the relationship between Se status and somatic cell counts, the prevalence of clinical mastitis, and other measures of herd productivity and disease in herds in PEI.

Materials and methods

Phase 1: Initial survey and validation of bulk tank milk Se as a measure of herd Se status

One hundred and nine herds were randomly selected from the list of the approximately 200 herds serviced by the Atlantic Dairy Livestock Improvement Corporation (ADLIC) dairy herd recording service. For each selected herd, the Se concentration of a sample of bulk tank milk was measured in May 1998. A random subsample of 15 herds with widely differing bulk tank milk Se concentrations was used for obtaining blood and milk from 14 cows per herd for individual serum and milk Se estimation. The cows within each herd were chosen by using a stratified random sampling procedure, with 7 cows chosen from cows less than 100 d in milk (DIM) and 7 cows chosen from cows more than 100 DIM.

The mean herd serum Se concentration, weighted for the proportion of animals in each lactation group, was compared with the bulk tank milk Se concentration from a bulk tank milk sample obtained within 2 d of the time of the blood sample being taken. Linear and nonlinear regression models (SigmaPlot for Windows, version 5; SPSS, Chicago, Illinois, USA) were tested to assess the relationship between bulk tank milk Se concentration and herd mean serum Se concentration. The model with the highest R^2 value was used to generate reference values for bulk tank milk Se by calculating the point where the published reference values for serum Se (6) intersected the model regression line.

Phase 2: Descriptive analysis of the Se status of dairy cows in PEI

Bulk tank milk Se concentrations were obtained from the 109 study herds in July and November 1998, and in February 1999, in addition to the samples obtained in May 1998 during phase 1 of the study. These dates were chosen to represent typical spring, summer, fall, and winter management periods for dairy herds in PEI. Variations in bulk tank Se concentrations were analyzed by using repeated measures analysis of variance (ANOVA) (SAS, version 6.12; SAS Institute, Cary, North Carolina, USA) and presented graphically. The proportion of herds falling into the accepted adequate, high-marginal, low-marginal, and deficient ranges were calculated first for each season, and then for the entire year based on the mean of the 4 seasonal values.

Because seasonal variation in herd Se status might be subject to confounding by lactation number or stage of lactation, these factors were tested for their association with milk Se concentration using analysis of variance (SAS, version 6.12; SAS Institute) by using the individual cow data obtained during phase 1 of the study.

Phase 3: Relationship between Se status and measures of herd productivity and disease

The 109 producers were sent a questionnaire and asked to return it by mail. A follow-up telephone call was made to all nonrespondents. Information was requested on the timing and extent of Se supplementation, as was information on disease occurrence during the study period. After the telephone follow-up had been completed, a total of 84 questionnaires were returned with at least some sections completed and the ADLIC information release agreement signed by the producer (77% response rate). Descriptive statistics were compiled concerning the frequency of specific management practices.

Herd Se status was derived from the bulk tank milk Se concentrations averaged over the 4 sampling periods. Herds were classified as Se-adequate or Se-marginal, based on the reference values derived from phase 1 of the study. There were no herds with an average value in the deficient range. These data were merged with the survey data, and these, in turn, were merged with herd production and breeding data from ADLIC.

With respect to the data obtained from the ADLIC database, milk yield per cow per day was adjusted for average stage of lactation (150 DIM), herd demographics (35% first lactation heifers), and corrected to 3.5% milk fat according to the standard formula for adjusted corrected milk (ACM) production (7,8). Individual somatic cell counts were log-transformed before analysis. Milk yield and cell count data were averaged over the year of study and these variables were used in the analysis. The variable "services per conception" was based on the outcome of all recorded services for each herd during the year of survey. Average days open for pregnant cows and minimum projected average days open for all cows were calculated; the results of analysis were similar for both parameters, so only the former is presented.

Step-wise logistic regression was used to examine the relationships between management variables and average bulk tank milk Se status, dichotomized as Se-adequate or Se-marginal. Variables offered to the step-wise regression included the Se supplementation practices (see Table 1), feeding system variables (component feeding versus total mixed ration and pasture use), and herd size. The supplementation variables "inject during lactation" and "blanket herd treatment" (see Table 1) were combined because of problems with estimability due to low numbers of respondents using these methods. The milking cow ration supplementation variables "free choice mineral" and "mineral salt block" were similarly combined. Regression model goodness of fit was evaluated using the Pearson chi-squared test. Continuous variables, such as milk yield and days open, were analyzed using ANOVA, including the dichotomized variable for herd Se status and herd size in the initial model. A software package (Stata Statistical Software, Release 6; Stata Corporation, College Station, Texas, USA) was used.

Table 1. Results of a survey of dairy producers in Prince Edward Island concerning selenium (Se) supplementation practices used in their herds

Method of supplementation	*n*	Proportion of respondents answering "yes"
Inject with Se/vitamin E?	84	36%
At dry off	30[a]	40%
During dry period	30	43%
At calving	30	20%
During lactation	30	7%
Blanket herd treatment	30	7%
Bred heifers	30	43%
Include Se in milking cow ration?	75	89%
As a mineral premix	67[a]	60%
Commercial concentrate	67	40%
Free choice mineral	67	18%
Mineral salt block	67	7%
Include Se in dry cow/heifer ration?	77	69%
As a mineral premix	53[a]	49%
Commercial concentrate	53	28%
Free choice mineral	53	17%
Mineral salt block	53	21%

n — number of respondents answering the survey question
[a]Includes only those respondents who answered "yes" to the question immediately above

Milk and serum sample collection, handling, and analysis

Bulk tank milk samples for phases 1 and 2 were obtained with the assistance of the PEI Department of Agriculture and Forestry Dairy Laboratory, which processes all bulk tank milk samples for the province. For the phase 1 validation step, individual milk and serum samples were obtained, with producer permission, during herd visits scheduled for this purpose. Serum and milk samples were frozen at $-20°C$ and stored for up to 3 mo until they were sent to the Animal Health Laboratory, Ministry of Agriculture and Food, Abbotsford, British Columbia. After thawing, aliquots were digested, and Se was assayed using a fluorometric method (9).

Results

Phase 1: Validation of bulk tank milk Se as a measure of herd Se status

There was a strong relationship between mean serum Se concentration and the bulk tank milk Se concentration (Figure 1). Although a linear relationship appeared to exist at lower concentrations, a plateau effect was noted in serum concentration when milk Se concentration exceeded 0.02 μg/mL. The relationship was best described by a sigmoidal curve that yielded an adjusted R^2 of 0.92 ($P < 0.0001$). These results suggest that bulk tank milk Se concentration is an accurate reflection of the herd Se status over the range of Se intakes typical of dairy herds in PEI.

Tentative reference values for bulk tank milk Se were generated: a milk Se concentration of less than 0.0096 μg/mL was taken to represent deficiency, and a milk Se concentration of greater than 0.0218 μg/mL was taken to represent adequacy. The Se concentration 0.0157 μg/mL divided the marginal range equally into high- and low-marginal categories. Herds were classified as deficient, marginal, or adequate, based on these bulk tank milk Se reference ranges. When compared with their classification based on established serum Se reference ranges, only 1 herd was not classified correctly by the bulk tank milk assay, this herd being classified as adequate rather than high-marginal. This result corresponded to a 93% agreement between diagnostic tests (Kappa statistic 0.89; $P < 0.0001$).

Phase 2: Descriptive analysis of the Se status of dairy cows in PEI

There was significant seasonal variation in Se concentration of bulk tank milk (Figure 2; $P < 0.001$). The lowest concentrations were in milk sampled in fall and winter, with the highest concentrations occurring in the spring and summer.

Fifty-six percent of the herds sampled were considered to be adequate for Se intake, based on bulk tank milk Se concentrations averaged over the 4 seasons (Figure 3). However, there was significant seasonal variation in the proportion of herds falling into each category ($\chi^2 = 9.4$, $P < 0.05$; Figure 3). Fall and winter appeared to be the time at which herds were most at risk for true deficiency, with 5 and 4 of the 109 herds classified as deficient in November and February, respectively, compared with none in May and July. The 4 herds found to be deficient in February were also deficient in November. For each season, a large proportion of herds fell into the marginal category, with a large proportion of these classified as high-marginal.

Because of their potentially confounding roles, the effects of lactation number and stage of lactation were examined by using individual cow data collected from the 15 herds in phase 1 of the study. Individual milk Se concentration was found to be associated with the stage of lactation ($P < 0.001$). Early lactation cows, on average, had a 12% lower milk Se concentration than did late lactation cows (0.016 μg/mL and 0.018 μg/mL, respectively). This effect of stage of lactation is likely mediated by a simple dilution effect of milk production, since stage of lactation more strongly influenced milk Se concentration ($P < 0.001$) than serum Se concentration ($P = 0.07$), and positive relationships between milk Se concentration and the protein test ($P < 0.01$) and the fat test ($P < 0.05$) were observed. A

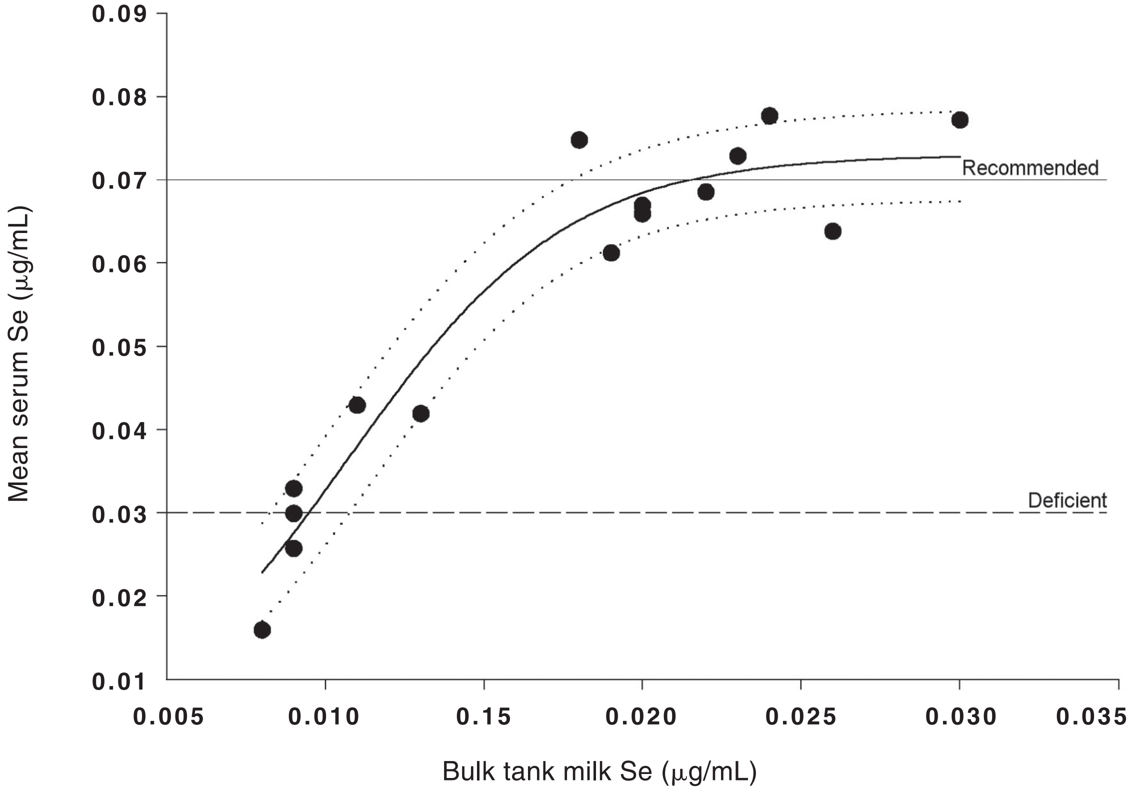

Figure 1. The relationship between mean herd serum selenium (Se) concentration and the bulk tank milk Se concentration obtained from the same herd (n = 15 herds). The regression line is shown with upper and lower 95% confidence intervals. The regression line is given by the equation serum Se = 0.071/(1 + exp(-(BTMilkSe-0.0107)/0.0035)); adjusted $R^2 = 0.92$, $P < 0.0001$.

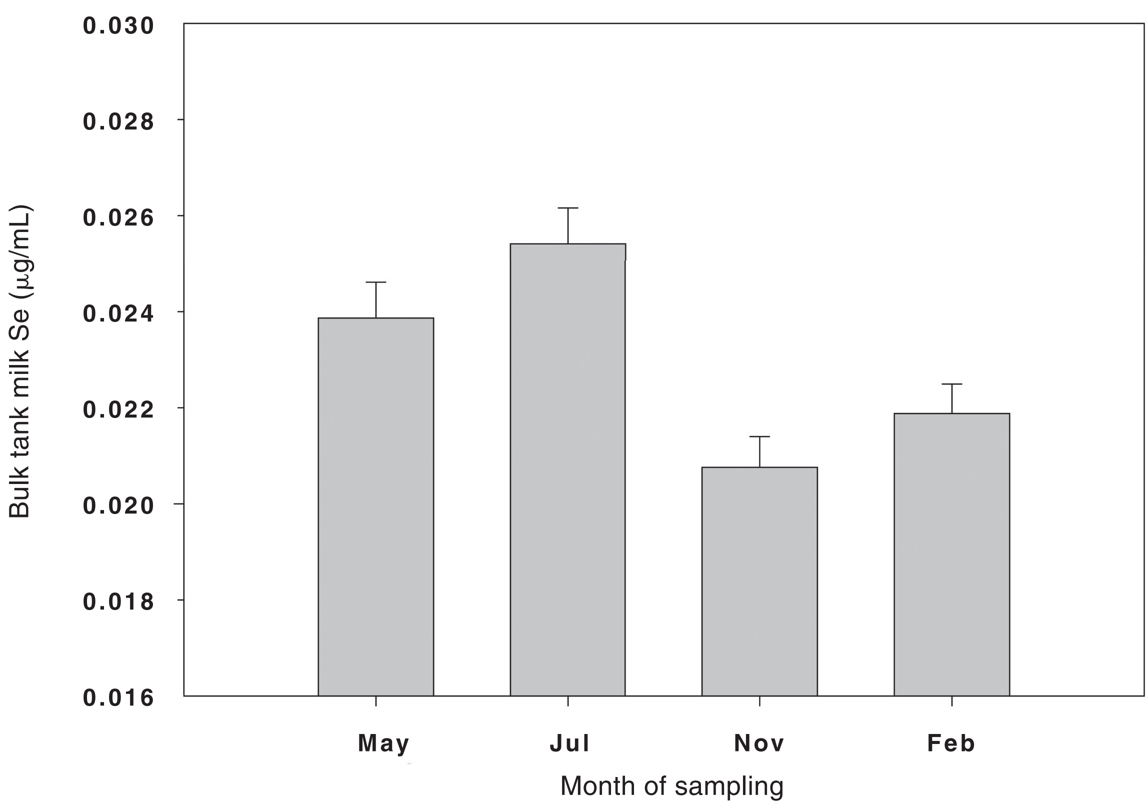

Figure 2. Seasonal variation in the concentration of selenium (Se) in bulk tank milk (n = 109 herds). Error bars represent standard errors of the means.

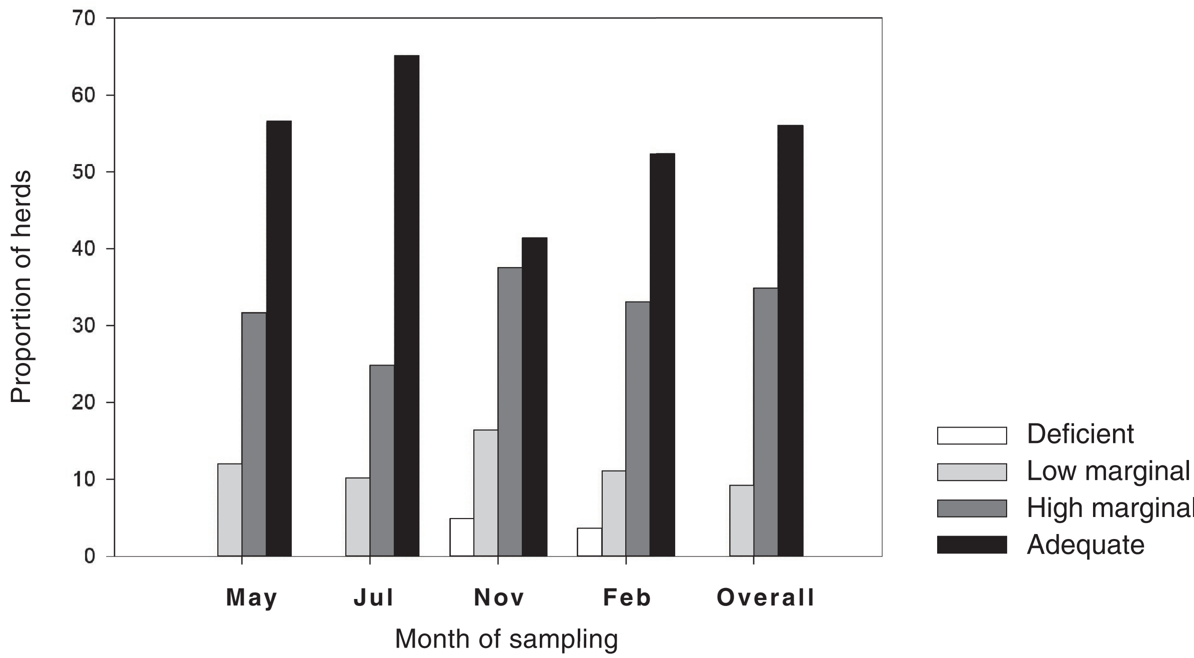

Figure 3. The selenium (Se) status of dairy herds in Prince Edward Island based on bulk tank milk selenium concentration.

seasonal pattern for average daily milk production was noted, with per cow milk production lowest and average DIM highest for herd tests conducted during the month of November.

Phase 3: The relationship to Se status to Se supplementation practices and measures of herd production and disease

Results of the survey of dairy producers concerning the Se supplementation practices used in their herds are presented in Table 1. The vast majority of producers (89%) included Se in the milking cow ration. Inclusion of Se in a commercial dairy concentrate (a complete concentrate prepared by a feed company) or as a mineral premix containing Se added to the concentrate ration were the most common methods, while free choice mineral and blocks were rarely used. Fewer producers (69%) provided additional Se for their dry cows and bred heifers, and use of a mineralized salt block was more common with this group of cattle. Injectable Se was used by only 36% of producers, in most cases at dry off or during the dry period. Of those producers who did not provide Se in the dry cow and heifer rations, only 25% used injectable Se at dry off or during the dry period (data not shown). A significant proportion of producers thus provided no additional Se for their dry cows and bred heifers.

Herds were classified as either Se-adequate or Se-marginal, based on their bulk tank milk Se concentrations over the entire year. The only supplementation practice significantly associated with Se status in the final regression model was the provision of Se in a commercial dairy concentrate ($P < 0.05$; Table 2). Herds supplemented in this way were 4 times more likely to be Se-adequate than herds not supplemented in this way. Injection of Se at calving and the use of a total mixed ration also showed a small but nonsignificant tendency to improve the odds of Se adequacy ($P < 0.2$), while use of free choice mineral in the dry cows and heifers tended to decrease the odds of Se adequacy ($P = 0.07$).

Adjusted average daily milk yield was significantly associated with Se status ($P < 0.01$; Table 3), with Se-adequate herds producing 7.6% more milk than Se-marginal herds. In the final ANOVA model for milk yield, the term for pasture use and the covariate representing average DIM both remained significant ($P < 0.01$). Herds utilizing pasture as a major source of forage for at least 2 mo/y produced less milk than those not making use of pasture, but there was no significant interaction between pasture use and Se status.

Measures of mammary gland health (individual and bulk tank somatic cell counts and the rate of clinical mastitis), reproductive efficiency (services per conception and days open), and the rate of reproductive disease (retained placenta and uterine infection) did not significantly differ with Se status (Table 3).

Discussion

When serum Se concentration was used as the gold standard, bulk tank milk Se concentration was an accurate reflection of the herd Se status over the range of Se intakes typical of dairy herds in PEI ($R^2 = 0.92$). This is in agreement with other studies comparing Se concentrations in plasma and milk (10). The regression coefficient in the present study was considerably higher than that observed when milk Se concentration was compared with whole blood Se concentration ($R^2 = 0.57$) (11) and with whole blood glutathione peroxidase activity ($R^2 = 0.82$) (12). This is to be expected, as serum, plasma, and milk Se concentrations respond rapidly to daily variation in intake, whereas there is a considerable lag period before changes in dietary

Table 2. The relationship between herd management variables and selenium (Se) status

Management variable	OR	$s_{\bar{x}}$	P-value[a]	CI	
Provide Se in a commercial ration	4.1	2.5	0.023	[1.21	13.85]
Inject Se at calving	6.3	9.0	0.197	[0.39	102.76]
Use total mixed ration	3.9	3.7	0.144	[0.63	24.55]
Provide Se in free choice mineral for dry cows and heifers	0.18	0.17	0.071	[0.03	1.15]

OR — Odds ratio. Indicates how much greater were the odds of Se-adequacy for herds in which this management practice was employed, when compared with herds in which this management practice was not employed; $s_{\bar{x}}$ — Standard error of the OR; CI — 95% confidence interval for the OR
[a]Step-wise logistic regression with variables retained in the model if $P < 0.2$; $n = 68$ and model pseudo $R^2 = 0.123$

Table 3. The relationship between selenium (Se) status and herd measures of production and disease

	Se-marginal herds			Se-adequate herds			
Herd measure	n	Mean	s	n	Mean	s	P-value
Milk Se concentration (μg/mL)	32	0.0182	0.003	49	0.027	0.004	<0.00
Herd size (mean cows on test)	31	39	16	47	40	22	0.63
Average DIM	31	182	16	47	178	10	0.26
Average daily milk yield (kg)[a]	28	27.67	5.12	45	29.77	3.53	<0.01
Milk fat (%)	31	3.82	0.18	47	3.81	0.32	0.88
Protein (%)	31	3.29	0.10	47	3.33	0.12	0.33
Somatic cell count[b]	31	232	105	47	250	102	0.28
Bulk tank somatic cell count[b]	28	208	88	46	228	89	0.18
Clinical mastitis[c]	30	17.5	15.0	46	17.3	12.8	0.84
Services per conception	31	1.82	0.35	47	1.93	0.36	0.21
Average days open	31	152.5	31.0	47	147.3	20.5	0.39
Retained placenta[c]	30	14.9	10.8	47	13.4	8.6	0.89
Uterine infection[c]	30	3.3	5.2	45	4.5	6.6	0.37

n — number of herds; s — standard deviation; DIM — days in milk
[a]Adjusted corrected milk
[b]Somatic cells × 1000/mL
[c]Cases/100 lactating cows/year, as reported by the farmer

intake have an effect on red blood cell Se content and glutathione peroxidase activity (13). The plateau effect in serum Se at higher intakes has been observed by others (10,14). The sample size for the validation step was limited by study constraints and was considered marginal for validation of a diagnostic test. Nonetheless the high regression coefficient, together with a acceptable Kappa value for agreement between tests, strongly suggest that bulk tank milk Se is a satisfactory herd screening test for Se adequacy. Complete validation of the test would best be performed by using herds from different regions and by using a greater sample size than was possible in this study.

Interestingly, 4 of the 5 herds that were determined to be deficient in November remained in the deficient range in February, suggesting a high degree of repeatability in identifying individual herds with low Se intake. This is a useful attribute if bulk tank milk is to be used routinely as a test for monitoring herd Se status.

The prevalence of Se deficiency was greater in fall and winter than during the warmer months. This was unexpected, because other studies have found that Se status increased during the winter feeding period (15,16). One explanation might have been that in high-producing cows during the fall and winter, milk Se concentration was affected through dilution of Se. This "dilution effect" seemed plausible, as early lactation cows had a 12% lower milk Se concentration than did late lactation cows. However, this explanation is unlikely, because milk production per cow was lowest, and DIM highest, during the month of November. This is in agreement with an earlier study of daily milk production in PEI (17). The seasonal variation in milk Se concentration is thus unlikely to be due to a confounding effect of average daily milk production, and more likely to be related to actual Se intake.

Grass and legume forages grown at certain times during the spring and summer are likely to contain less Se, due to the diluting effect of rapid plant growth (18), offering a plausible explanation for the seasonal variation in milk Se concentration. It could be that the more mature forage provided to grazing cows during the summer contains higher concentrations of Se when compared with ensiled or dried forages harvested in spring and fed during the winter months. Profiling the Se content of forages at different stages of the season could be a worthy topic of further studies. Including Se in a commercial dairy concentrate was the only supplementation practice that was significantly related to Se status (Table 2).

Eighty-nine percent of producers included Se in the milking cow ration (Table 1) compared with only 60% in a Californian survey (11). However, how Se was incorporated into the ration varied greatly, and the relationships between herd management variables and Se status (Table 2) suggest that not all methods are equally efficacious. One important problem is that the amount of concentrate fed to dairy cows is dependent on a number of factors, including forage quality, body size and condition, milk production, stage of lactation, and age. Mineral premixes incorporated into concentrates at a set ratio will provide insufficient Se if concentrate allowance is limited, as often occurs in late lactation cows, low-producing cows, dry cows and heifers. The use of total mixed rations tended to reduce this effect, as suggested by the results in Table 2, probably because the mineral premix is fed at a fixed ratio to total ration rather than to the concentrate component of the ration.

The use of commercial dairy concentrates was highly protective against marginal Se status in this study. It seems likely that commercial dairy concentrates are being formulated with higher concentrations of Se, compared with grain rations prepared on-farm. This may point to a lack of understanding among producers preparing concentrates on-farm of the importance of minerals in the dairy cow diet. The choice of mineral and the rate at which it is incorporated into the ration may not be optimal. It is clear that those who advise dairy farmers on nutrition should look more closely at Se intake of cows that are fed concentrates prepared on-farm.

It was surprising that 31% of producers did not supply additional Se in the dry cow and heifer rations. Although Se injection is a reasonable alternative form of supplementation for producers not feeding additional Se, only 25% of these producers reported injecting Se. Selenium adequacy during the period leading up to calving is considered critical, because most disorders thought to be Se-responsive (retained placenta, mastitis, neonatal mortality, reduced milk production, and impaired reproductive efficiency) occur in the early lactation period (1).

A large number of herds were found to have marginal Se status. The implications of this finding need to be examined in the context of the historical development of Se reference ranges. The reference range for deficiency in cattle is well established and is usually quoted as a serum Se concentration of less than 0.03 to 0.04 μg/mL (1,19). This reflects the Se intake below which white muscle disease is seen in calves, or retained placenta is seen in cows, and resolution of clinical signs is expected if supplementation is initiated. On the other hand, the range for adequacy is somewhat arbitrary and varies between laboratories and publications. A serum Se concentration of 0.07 to 0.08 μg/mL is seen as reflecting adequacy by most laboratories (6), but historically, this has been based on the average serum Se concentrations in populations of healthy cows without clear documentation of responses to supplementation (6). Recently, the validity of this threshold has been reinforced by results of studies showing improved mammary gland health at serum Se concentrations greater than 0.07 μg/mL (20). Currently, the range of values between deficiency and adequacy has been termed the marginal range, where responses to Se supplementation are unpredictable but, if they occur, are likely to be seen as improved milk production, reproductive efficiency, growth rates, and udder health (21).

Of all the measures of production and disease evaluated in this study, only milk yield was found to be significantly related to Se status. The effect of Se on milk yield is often ignored in the scientific literature in favor of its more obvious effects on clinical disease and somatic cell counts. Unfortunately, many studies that have investigated the effects of Se status on dairy cattle have failed to record milk yield. However, there is considerable evidence in the literature to suggest that milk yield may be the most sensitive indicator of Se status in dairy cattle and that reduced milk yield may be the most important economic consequence of marginal Se status. Researchers found a positive relationship between milk fat yield and bulk tank milk Se concentration in 60 herds in the San Joaquin Valley, even though no significant relationship was found with measures of mammary health and reproductive efficiency (11). Similarly, improved milk yield and increased growth in heifers have been the most repeatable responses found during controlled Se-response trials in dairy herds in New Zealand in which no clinical Se-responsive disease was apparent (22).

There is a possibility that the enhanced milk yield noted in the Se-adequate herds may be artifactual; sound nutritional management practices could lead to both increased milk production and enhanced Se intake, with no causal association between Se status and milk yield. However, the difference observed in milk production is large, and it would seem unlikely that the entire effect could be attributable to general nutritional management.

The finding that Se status was unrelated to measures of mammary health contradicts a number of studies that suggest a role of Se in the immune response to mastitis pathogens. Several researchers (14,23,24) found that low Se status was associated with high somatic cell counts. Supplementation with Se both reduced the occurrence of clinical mastitis and sped the recovery of cows once they had become infected (20). In field trials in Ohio, a region with forage Se concentrations comparable with those of PEI, researchers found that the duration of clinical signs of mastitis was reduced by 46% in cows treated with Se (23).

Not all literature provides support for a role of Se in mastitis. A number of well conducted studies have found either no relationship (11,25,26) or an equivocal relationship (27) between Se status, somatic cell counts, and mastitis. Clearly, there are many interacting management and environmental factors that are potent determinants of the occurrence of mammary infection; in PEI herds, Se status does not appear to be one of the most important.

The methods used in this study to assess the effect of Se status on clinical reproductive disease (retained placenta and metritis) were not ideal; retrospective surveys that rely on the producers' recall of animal health events tend to be inaccurate. However, the measures of reproductive efficiency (days open and services per conception) were derived from the ADLIC database and should not have suffered from this potential source of bias. From the data available, it appears that Se status was related to neither reproductive disease nor measures of reproductive efficiency in this study. Overall, the incidence of retained placenta and uterine infection (Table 3) was not high in the surveyed herds, despite the high proportion of herds considered to be Se-marginal. Reproductive disease, specifically an increased incidence of retained placenta, is often quoted as a typical sign of Se deficiency (28). However, when the literature is examined closely, there have been conflicting reports concerning reduction in the incidence of retained placenta and improvement in reproductive performance associated with enhanced Se status (29). In agreement with the current study, measures of reproductive success were not related to bulk tank milk Se concentrations in 60 herds in the San Joaquin Valley (11).

Several options are available to Maritime producers who wish to increase the Se status of their herds. Mineral premixes should be incorporated into rations to ensure a final Se concentration that approaches 0.3 ppm on a dry matter basis, which is the maximum allowable daily Se intake for lactating and dry dairy cattle published by the Canadian Food Inspection Agency (30). However, late lactation cows, low-producing cows, dry cows, and heifers will still be at risk of Se deficiency unless separate concentrates are formulated for these groups. Use of a total mixed ration rather than component feeding will allow a more equitable provision of mineral to all groups, but this requires considerable investment for producers not equipped to provide such a ration. Use of organic Se in the form of selenium yeast may also result in increased Se status compared with the use of inorganic Se compounds (sodium selenate or selenite), which are typically included in dairy rations (31).

Methods are also available to improve the Se content of the base diet. Application of Se fertilizer to forage and cereal crops is an inexpensive and convenient method for improving the Se content of the diet. Selenium fertilizers are used widely in many countries (32) and have been shown to be effective in beef herds in PEI (4). A fertilizer additive containing Se (Selcote Ultra; Agro Pacific Industries, Chilliwack, British Columbia) has been approved for mixing with fertilizers in Canada. Trials should be initiated in Atlantic Canada to determine how such a fertilizer additive can best be incorporated into Se supplementation programs for dairy herds.

Strategic use of Se/vitamin E injections can be used to bridge small periods of inadequate Se intake. However, Se injections were not significantly associated with a greater odds of Se-adequacy in this study, except in the case of injection at calving, which showed a slight tendency to do so. This supports the conclusions drawn from other studies showing that Se injected at the labeled dose (0.055 mg/kg body weight) will result in serum Se concentrations in the adequate range for only a matter of days (33) and supplementary Se should always be provided in the diet.

Bulk tank milk Se concentration has been used rarely to monitor the Se status (11,12) and in only the San Joaquin Valley study has it been related to measures of herd health and productivity (11). In the latter study, bulk tank milk Se concentrations, measured only once, were related to individual milk and whole blood Se concentrations but were not related to measures of reproductive efficiency or to somatic cell counts. The Se status of herds in PEI in the current study is somewhat lower than, but similar to, that of herds in California. Bulk tank milk analysis holds considerable promise as a practical and inexpensive tool for on-going monitoring of Se status in dairy herds. This finding is especially timely with an increasing use of bulk tank milk for the monitoring herd health and management and in disease eradication programs. The measurement of milk urea nitrogen, the culturing of bulk tank milk for mastitis pathogens, and serologic testing for certain pathogens are currently some of the more widely used techniques.

Results of this study showed that bulk tank milk Se concentration was an accurate reflection of the herd Se status over the range of Se intakes typical of dairy herds in PEI. Fifty-nine percent of the herds surveyed were at some point found to be marginal for Se status, possibly putting them at risk of disease and suboptimal production. The period of greatest risk of deficiency was fall and winter. Herds providing Se supplementation in the form of a commercial dairy concentrate were over 4 times more likely to be Se-adequate when compared with herds not using this method, and average daily milk yield was 7.6% greater in herds determined to be Se-adequate than in Se-marginal herds. We conclude that many dairy producers in PEI are providing insufficient supplementary Se in the ration to meet the recommended Se intake for lactating cows. CVJ

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