ABSTRACT

The purpose of the present study was to estimate the effect of total blood plasma calcium (TBPCC) concentration at calving on milk yield in dairy cows. Data originated from 153 dairy cows in 27 herds from a single veterinary practice. For each cow, data included calcium concentration in a blood sample taken within 12 h postpartum, monthly test-day milk yield until 300 d in milk, calving date, parity, breed, and herd. The TBPCC ranged from 0.69 to 2.73 mmol/L, with a mean value of 1.80 mmol/L. The statistical analysis adjusted for the fixed effects of parity and lactation stage, random effects of herd and cow, and the correlation between repeated measures of test-day milk yield. The results showed that TBPCC at calving was not significantly related to fat- and protein-corrected milk yield at any lactation period. The present study indicates that hypocalcemia (low TBPCC) at calving is not an important risk factor for decreased milk yield.

(Key words: blood plasma concentration, hypocalcemia, milk yield)

Abbreviation key: FPCM = fat- and protein corrected milk, TBPCC = total blood plasma calcium concentration.

The early-lactation period poses high risks for common diseases in dairy cows (Rajala and Gröhn, 1998). Some of these health problems may be related directly to the abrupt physiological changes in the transition cow. Accordingly, the complex of calcium homeostasis is known to be crucial (Horst et al., 1997). During parturition, blood calcium drops to subnormal levels, and this decrease in available body calcium may eventually continue below levels for normal function, resulting in milk fever or parturient paresis.

The definition of boundaries between normocalcemic and hypocalcemic blood levels is arbitrary. Several boundaries have been proposed to discriminate between a normocalcemic level and hypocalcemia in the periparturient period. Total blood plasma calcium concentration (TBPCC) of 1.7 mmol/L (±0.2, 95% confidence limits) have been proposed as a boundary between severe to moderate and slight hypocalcemia (Kvart et al., 1982). More recently, however, a higher threshold has been used, i.e., 1.8 to 2.0 mmol/L (Bigras-Poulin and Tremblay, 1998; Daniel et al., 1990). If the latter blood level is accepted, huge fractions of transition cows will consequently be diagnosed as hypocalcemic. Reports available within the last decade (Bigras-Poulin and Tremblay, 1998; Daniel et al., 1990; Massey et al., 1993) group between 23 and 39% of periparturient animals within this group. The incidence of hypocalcemia will consequently be four to five times more frequent than clinically diagnosed milk fever when the incidence is reported to be between 0.05 and 0.10 (Beaudeau et al., 1994; Rajela and Gröhn, 1998).

Milk fever incidence is connected with reduced herd profit (Østergaard et al., 2000) because of decreased milk yield (Østergaard and Gröhn, 1999; Rajala-Schultz et al., 1999), increased risk of other diseases (Klerx and Smolders, 1997), and costly interventions following the syndrome (Kossaibati and Esslemont, 1997). Hypocalcemia, a subclinical milk fever, would consequently be categorized likewise regarding the effects. Under specific conditions, hypocalcemia has been associated with a negative effect on subsequent ovulation (Johnsson et al., 1999). In a study involving 510 Holstein cows (Massey et al., 1997), hypocalcemic cows were found to be at 4.8 times greater risk of developing left displaced abomasum compared with nonhypocalcemic cows. These effects, combined with the high incidence of hypocalcemia, suggest that TBPCC may be a valuable indicator of animal or herd status, and worth watching when considering animal welfare and herd profit. Milk yield is the single most important factor related to herd profit. However, associations between TBPCC and herd profit or milk yield have not been studied. The intention of this study was to estimate associations between TBPCC around calving and subsequent milk yield in dairy cows.
Data used in this study originated from 27 Danish dairy herds. The herds were randomly selected within herds from a single veterinary practice. The majority of the cows were Danish black and white breed; no herds of Jersey breed were included.

Blood was harvested from vena jugularis or vena coccgea by a veterinarian within 12 h of calving. Whole blood was collected in Li-heparinized tubes. Blood samples were kept on ice upon harvesting until centrifugation at 2000 × g. Plasma was frozen at −20°C pending chemical analysis.

The TBPCG was determined spectrophotometrically using the ortho-creosol-phtaline-complexing method (Gittelma, 1967). Analyses were performed on an OpeRA autoanalyzer (Bayer-Technicon, Tarrytown, NY). Analytical precisions were within 1% (CV, intraassay) and 1.5% (CV, interassay).

Dairy managers were supposed to call the veterinarian at each individual calving regardless of health status; however, the study was biased toward cows with clinical milk fever. A total 153 multiparous dairy cows were blood tested, and according to parity, numbers were 8, 53, and 92 for parities 2, 3, and ≥4, respectively. Individual cow data included TBPCG within 12 h postpartum, monthly test-day milk yield until 300 DIM, calving date, parity, breed, and herd. Table 1 summarizes characteristics of the herds.

The TBPCG was modeled statistically to study both short- and long-term effects on fat- and protein-corrected milk (FPCM) during lactation. FPCM was calculated as:

\[ \text{kg of milk yield} \times (0.383 \times \% \text{ fat} + 0.242 \times \% \text{ protein} + 0.7832) \div 3.140. \]

To test the H₀-hypothesis of no effect of TBPCG on milk yield during lactation the following initial model was used:

\[ y_{ijklm} = \beta_0 + \beta_{1,i} + \beta_{2,i}x_1 + \beta_{3,i}x_1^2 + \beta_{4,i}x_1^3 + \beta_5 x_2 + \beta_6 x_2 + A_k + B_l + \epsilon_{ijklm} \]

where; \( y_{ijklm} = \) daily FPCM from mth lactation period \((m = 1,..,16; 16 \text{ periods of } 10, 20 \text{ and finally } 30 \text{ d})\) from lth cow \((l = 1,..,153)\); \( \beta_0 = \) overall intercept; \( \beta_{1,i} = \) fixed effect of ith parity \((i = 2, 3, 4+)\); \( x_1 = \) regression variable on DIM; \( \beta_{2,i} = \) fixed linear regression coefficients of DIM within ith parity; \( \beta_3 = \) fixed quadratic regression coefficient of DIM; \( \beta_4 = \) fixed cubic regression coefficient of DIM; \( x_2 = \) regression variable TBPCG; \( \beta_5 = \) fixed linear regression coefficients of TBPCG; \( \beta_6 = \) fixed linear regression coefficients of TBPCG within jth lactation period \((j = 1,..,40 \text{ DIM})\), 2 (41,..,100), 3 (101,..,180), 4 (181,..,300)); \( A_k = \) random effect of kth herd \((k = 1,..,27)\); \( B_l = \) random effect of lth cow; \( \epsilon_{ijklm} = \) residual effect.

By test statistics the initial model was stepwise reduced to the following final model without nonsignificant terms except TBPCG:

\[ y_{ijklm} = \beta_0 + \beta_{1,i} + \beta_{2,i}x_1 + \beta_5 x_2 + A_k + B_l + \epsilon_{ijklm} \]

where; \( y_{ijklm} = \) daily FPCM from mth lactation period \((m = 1,..,16; 16 \text{ periods of } 10, 20 \text{ and finally } 30 \text{ d})\) from lth cow \((l = 1,..,153)\); \( \beta_0 = \) overall intercept; \( \beta_{1,i} = \) fixed effect of ith parity \((i = 2, 3, 4+)\); \( x_1 = \) regression variable DIM; \( \beta_{2,i} = \) fixed linear regression coefficients of DIM within ith parity; \( x_2 = \) regression variable TBPCG; \( \beta_5 = \) fixed linear regression coefficients of TBPCG; \( A_k = \) random effect of kth herd \((k = 1,..,27)\); \( B_l = \) random effect of lth cow; \( \epsilon_{ijklm} = \) residual effect.

In both models \( \{A_k\} \) and \( \{B_l\} \) were assumed to be independent and tested by Shapiro-Wilk test to be distributed \( N(0,\sigma_\Lambda^2) \) and \( N(0,\sigma_\Sigma^2) \), respectively. \( \{\epsilon_{ijklm}\} \) and \( \{\epsilon_{ijklm}\} \), respectively, were assumed autoregressive of order one, i.e., to be correlated within lth cow with covariance \( \sigma^2 \rho^w \) (\( \rho^w \) is the correlation between two mth lactation stages with w number of periods in between). Homogeneity of \( \sigma^2 \) across mth lactation periods was tested by Brown-Forsythe test.

The 16 lactation periods indexed by m, and the covariance structure of the residual effects, were chosen according to Rajala-Schultz et al. (1999). The procedure MIXED in SAS/STAT (SAS Institute Inc., 1996) was applied to fit all models.

The model assumptions were all confirmed, except that homogeneity of \( \sigma^2 \) was confirmed for \( m > 1 \), only. Running the models without this lactation period (1 to 10 DIM) showed that violation of the respective model assumption did not change the estimates significantly.

Table 1. Characteristics of the 27 herds during February 1998 to October 1998 calculated from average herd figures.

<table>
<thead>
<tr>
<th>Herd characteristics</th>
<th>Mean</th>
<th>Lower</th>
<th>Medium</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual cows</td>
<td>81</td>
<td>49</td>
<td>70</td>
<td>105</td>
</tr>
<tr>
<td>FPCM/annual cow</td>
<td>6924</td>
<td>6540</td>
<td>6909</td>
<td>7262</td>
</tr>
<tr>
<td>Number of calvings</td>
<td>37</td>
<td>22</td>
<td>35</td>
<td>55</td>
</tr>
<tr>
<td>Number of blood test</td>
<td>5.7</td>
<td>2</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Milk fever incidence</td>
<td>0.13</td>
<td>0.02</td>
<td>0.08</td>
<td>0.25</td>
</tr>
<tr>
<td>Milk fever incidence</td>
<td>0.29</td>
<td>0.00</td>
<td>0.16</td>
<td>0.55</td>
</tr>
</tbody>
</table>

1. Lower, medium, and upper quartiles refer to 25, 50, and 75 percentiles, respectively. The lower quartile is the data value a quarter up through the ordered data set of the 27 average herd figures.


3. FPCL = Fat- and protein-corrected milk.

4. Only multiparous cows.
The statistical analysis showed that the effect of TBPC (cyan) did not interact with the effect of lactation stage, and that effect of lactation stage could be modeled by two linear regression curves for parities 2 and 3+, respectively. In the final model, those were estimated as $-0.028 \times \text{DIM} + 27.1$ (SE = 2.6) and $-0.057 \times \text{DIM} + 34.6$ (SE = 1.6), respectively. The linear effect of TBPC was estimated as $-1.16 \text{mmol/L}$; however, this effect was not statistically significant ($P = 0.18$). TBPC ranged within 0.69 to 2.73 mmol/L with mean of 1.80 mmol/L. The autoregressive correlation coefficient $\rho$ and the variance components $\sigma_A^2$, $\sigma_B^2$, and $\sigma^2$ were estimated as 0.69 (SE = 0.03), 5.6 (SE = 2.9), 12.2 (SE = 2.7), and 21.1 (SE = 1.8), respectively.

The results of this study showed that TBPC at calving was not significantly related to FPCM during lactation. No disease conditions were corrected for, consequently, possible indirect effects of an increase in diseases were included. It has been suggested (Østergaard and Grøhn, 1999; Rajala-Schultz et al., 1999) to use the cows’ own milk yield in late lactation as reference for estimating short-term milk yield reduction caused by milk fever to control the effect of higher yielding cows being more exposed to milk fever. The result of no interaction between TBPC and lactation stage showed no similar short-term effect of TBPC on FPCM in this study.

Because dairy managers sometimes failed to call the veterinarian at each individual calving during the study period, data were biased towards a distribution of cows diagnosed with milk fever. This makes it impossible to compare the TBPC distribution in the present study to a typical distribution (Bigras-Poulin and Tremblay, 1998). However, the skewed distribution makes the present data more powerful in estimation of an association between TBPC and subsequent milk yield according to the main interest in hypocalcemic conditions.

The size of the standard error of the linear effect of TBPC (SE = 0.87) indicates the power of the available data to test hypotheses of the effect of TBPC on FPCM. However, the fact that the linear effect of TBPC was negative ($-1.16$) strengthens the interpretation that hypocalcemia (low TBPC) at calving is not an important risk factor for decreased milk yield.

**REFERENCES**


