Effectiveness of Calcium Chloride in Increasing Blood Calcium Concentrations of Periparturient Dairy Cows¹,²,³

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ABSTRACT: Calcium chloride supplements such as gels and drench were studied to determine their effectiveness for increasing blood serum Ca concentrations in periparturient dairy cows. Multiparous, pregnant Holstein dairy cows (n = 36) were assigned to one of four treatments. After calving, cows in four treatments received basal diet and two doses of either control inert gel (CON), gel containing CaCl₂ and vitamins (CVG), gel containing CaCl₂ and minerals (CMG), or CaCl₂ as drench containing vitamins (CVD). The first dose was given within 2 h after calving and the second dose 12 h after the first dose. Each dose provided 0.07, 54.5, 56.0, and 33.2 g of elemental Ca in CON, CVG, CMG, and CVD treatments, respectively. Blood samples were collected at 0, 15, 30, 60, 180, and 360 min after each oral dose. The blood serum Ca concentrations were 6.26, 7.56, 6.20, and 5.96 mg/dL during the pretreatment period and deviated −13.5, 7.1, 9.3, and 18.1% from pretreatment levels at 18 h after the first dose in CON, CVG, CMG, and CVD treatments, respectively. The average changes in serum P from pretreatment levels were not different among treatments. Serum Mg concentrations remained below the pretreatment levels in all four treatments. Blood serum β-hydroxybutyrate during the first 2 wk and milk yields during the first 4 wk of lactation were the same in all treatments. Three cases of clinical milk fever were observed in CON treatment and one case in CVD treatment. The oral supplements of CaCl₂ as gel or drench increased the blood Ca levels in periparturient dairy cows. Increased supply of Ca through oral supplements of CaCl₂ may prevent milk fever in cows that are marginally hypocalcemic.

Key Words: Bovidae, Parturient Paresis, Calcium, Hypocalcemia, Lactation

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Introduction

Milk fever in dairy cows is caused by a temporary imbalance between Ca availability and high Ca demand following the onset of lactation (Oetzel, 1996a). Calcium leaves the extracellular fluid to enter the mammary gland faster than it can be replaced by intestinal Ca absorption or bone Ca resorption (Goff and Horst, 1993). Each case of milk fever leads to a loss of $334 to the producer by way of treatment charges and milk loss (Horst et al., 1997).

Increasing the supply of Ca to the cow can prevent milk fever (Goff et al., 1996). Calcium supply can be increased either by increasing intestinal absorption of Ca or through resorption of Ca from the bones or both. Practices such as dietary manipulations and hormone treatments can achieve this (Goff et al., 1986; Beede, 1996). Another alternative is to supplement Ca orally to cows near parturition.

Goff and Horst (1993) observed better absorption of Ca in cows from CaCl₂ compared with CaCO₃. The aqueous formulations of CaCl₂ are rapidly absorbed compared with gel formulations (Goff and Horst, 1993; Oetzel, 1996b). In addition to Ca, P and Mg are also associated with mineral imbalances in parturient cows (Oetzel, 1988). The objective of this study was to compare the effectiveness of CaCl₂ supplements such as gel and drench for increasing blood serum Ca concentrations and to assess the influence on blood P.

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³Trade names and the names of commercial companies are used in this report to provide specific information. Mention of a trade name or manufacturer does not constitute guarantee or warranty of the product by the University or an endorsement over products not mentioned.
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and Mg in periparturient dairy cows during the first 18 h after calving.

Materials and Methods

Animals and Experimental Procedures

The study was conducted from April to August 1997 at the George B. Caine Dairy Teaching and Research Center at the Utah State University. Multiparous (n = 36; 11, 9, 8, and 8 cows in 2, 3, 4, and > 4 lactations, respectively), pregnant Holstein dairy cows were blocked according to the expected date of calving. Cows within each block were randomly assigned to one of four treatment groups. There were nine cows in each treatment. Animal care and procedures were approved and conducted under established standards of the Utah State University Institutional Animal Care and Use Committee (Approval #862).

All the animals received a far-off dry cow diet for 6 wk and then close-up dry cow diet during the last 2 to 3 wk of gestation. Cows were offered a fresh cow diet immediately after calving. The ingredient and chemical composition of far-off dry, close-up, and fresh cow diets are given in Table 1. Diets were fed as a total mixed ration. The cows were moved into maternity pens 2 to 3 d prior to the expected date of calving and housed in individual stalls (4.5 × 10.2 m) on concrete floor. Sand was used as a bedding material during the study.

Immediately after calving, in addition to the basal fresh cow diet, cows received two doses of either control inert gel (CON), gel containing CaCl₂ and vitamins (CVG; Cal-C-Fresh), gel containing CaCl₂ and minerals (CMG; CMPK Gel Plus), or CaCl₂ in the form of drench containing vitamins (CVD; Calcium drench). Calcium gels and drench were manufactured by Vets Plus Inc. (Knapp, WI). The first dose was given within 2 h after calving and the second dose 12 h after the first dose. The amounts of each dose given were 400 g for gels and 200 mL for drench. A drenching gun with 200 mL capacity was used for administering drench in the CVD treatment. Routine herd management practices were followed during the experiment. Animals were given ad libitum access to

Table 1. Composition of diets

<table>
<thead>
<tr>
<th>Item</th>
<th>Far-off dry cow</th>
<th>Close-up dry cow</th>
<th>Fresh cow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingredient</td>
<td>% on DM basis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>20.73</td>
<td>29.23</td>
<td>28.05</td>
</tr>
<tr>
<td>Alfalfa silage</td>
<td>7.91</td>
<td>13.01</td>
<td>9.37</td>
</tr>
<tr>
<td>Corn silage</td>
<td>26.52</td>
<td>14.96</td>
<td>10.10</td>
</tr>
<tr>
<td>Rolled corn</td>
<td>2.80</td>
<td>8.30</td>
<td>16.60</td>
</tr>
<tr>
<td>Soy-best</td>
<td>2.93</td>
<td>2.89</td>
<td>3.48</td>
</tr>
<tr>
<td>Grass hay</td>
<td>20.70</td>
<td>20.43</td>
<td>—</td>
</tr>
<tr>
<td>Oat hay</td>
<td>17.61</td>
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<td>—</td>
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<tr>
<td>Cottonseed</td>
<td>—</td>
<td>—</td>
<td>7.97</td>
</tr>
<tr>
<td>Concentrateb</td>
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<td>8.70</td>
<td>19.14</td>
</tr>
<tr>
<td>Ener G IIc</td>
<td>—</td>
<td>—</td>
<td>1.86</td>
</tr>
<tr>
<td>Molasses</td>
<td>—</td>
<td>1.87</td>
<td>1.40</td>
</tr>
<tr>
<td>Mineral mix</td>
<td>.80d</td>
<td>.61d</td>
<td>2.03e</td>
</tr>
<tr>
<td>Chemical</td>
<td></td>
<td></td>
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<tr>
<td>CP</td>
<td>13.4</td>
<td>16.4</td>
<td>19.5</td>
</tr>
<tr>
<td>NDF</td>
<td>52.0</td>
<td>40.4</td>
<td>30.3</td>
</tr>
<tr>
<td>ADF</td>
<td>35.4</td>
<td>28.4</td>
<td>20.8</td>
</tr>
<tr>
<td>NE₄, Mcal/kg of DM</td>
<td>1.39</td>
<td>1.50</td>
<td>1.83</td>
</tr>
<tr>
<td>DCADf, mEq/100 g of DM</td>
<td>37.2</td>
<td>49.5</td>
<td>ND³</td>
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<tr>
<td>Mineral</td>
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<tr>
<td>Ca</td>
<td>.77</td>
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<tr>
<td>P</td>
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<td>.57</td>
</tr>
<tr>
<td>Mg</td>
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<td>.32</td>
<td>.39</td>
</tr>
<tr>
<td>K</td>
<td>2.37</td>
<td>2.34</td>
<td>1.86</td>
</tr>
<tr>
<td>Na</td>
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<td>.32</td>
<td>.76</td>
</tr>
<tr>
<td>S</td>
<td>.21</td>
<td>.22</td>
<td>.20</td>
</tr>
</tbody>
</table>

*Product of Grain States Soya, Inc., West Point, NE.
*Contained 22.5% canola meal, 40% barley, 12.5% corn, 16% soybean meal, 3% hydrolyzed animal fat, 1% salt, 1.5% sodium bicarbonate, and 3.5% trace mineral and vitamin mixture.
*Rumen-inert calcium salts of long-chain fatty acids (Bioproducts, Inc., Fairlawn, OH).
*Contained 11.91% Ca, 8.19% P, 7.95% Mg, .70% Na, .95% K, and 1.47% S.
*Dietary cation-anion difference was calculated using the equation as described by Beede (1996).
*Not determined.
fresh water. After freshening, cows in all groups received a probiotic supplement (Fastrack, Conklin Co. Inc., Shakopee, MN) in the feed at the rate of 35 g-cow\(^{-1}\)d\(^{-1}\).

**Feed Sampling and Analysis**

Once a month, samples of individual dietary ingredients were collected. The feed samples were dried at 60°C for 48 h. The dried samples were ground through a Willey mill (Arthur H. Thomas, Philadelphia, PA) using a 1-mm screen. One gram of ground sample of each ingredient was further dried in crucibles at 105°C for 24 h and ashed at 500°C in a furnace for 9 h. The ash was dissolved in 10 mL of 2 N HCl (AOAC, 1990). The supernatant was analyzed for minerals (Ca, P, Mg, K, Na, and S) using an ICAP Plasma Spectrometer (Model ICAP-9000; Therma Jarrell-Ash Corp., Franklin, MA). Final mineral composition of each ingredient was expressed on absolute DM basis determined at 105°C. The CaCl\(_2\) supplements were analyzed for minerals using the procedures as described above except the mineral contents were expressed on an as-is basis. Chloride analysis in feed samples was performed using the procedure as described by Adriano and Doner (1982).

Dietary cation-anion difference (DCAD) in far-off dry and close-up dry cow diets was calculated using the equation described by Beede (1996).

The inert gel in CON treatment contained .07 g of Ca; .05 g of P; .03 g of Mg; .62 g of Na; and .62 g of K per dose on an as-is basis. The gel in CVG treatment contained 54.52 g of Ca; 6.99 g of P; 100 mg of niacin; 100 mg of thiamin; 50 IU of vitamin E; 10 mg pantothenic acid; 5 mg riboflavin; 5 mg ascorbic acid; and 100 \(\mu\)g vitamin B12 per dose on an as-is basis. The gel in CVG treatment had no detectable Mg, Na, and K. The gel in CMG treatment contained 55.95 g of Ca; 9.69 g of P; 2.93 g of Mg; 1.64 g of Na; and .11 g of S per dose on an as-is basis. The gel in CMG treatment had no detectable K. The drench in CVD treatment contained 33.24 g of Ca; .43 g of Na; 1.81 g of K; and vitamins similar to CVG treatment per dose. The drench in CVD treatment had no detectable P and Mg. The CMG treatment compared with CVG supplied an additional 2.7 g of P and 2.93 g of Mg per dose. The mineral contents in the CaCl\(_2\) supplements matched the claims on the label. The vitamin values for Ca supplements mentioned above are manufacturer’s specifications.

The levels of Ca, P, Mg, and K in the dry cow diet were .77, .34, .31, 2.37% on a DM basis (Table 1). The levels of Ca and K in the far-off dry cow diet were higher than the recommended levels (NRC, 1989). This was because the Ca and K contents in the forages that were used in the diet were high. Beede (1996) has suggested a low or negative DCAD in prepartum dairy cow diets as a means to reduce the incidence of periparturient hypocalcemia. In the present study, the far-off dry and close-up dry cow diets had a DCAD of 37.2 and 49.5 mEq/100 g of DM, respectively. As a routine management practice on the farm where the study was conducted, the dry cow diets are supplemented with commercial anionic salts 2 to 3 wk prior to calving to maintain a low DCAD. To simulate field conditions and to prevent any confounding effects, the anionic salts were not fed to the cows in this experiment.

**Blood Collection and Analysis**

Blood samples from individual cows were collected from a coccygeal vein or artery at 0, 15, 30, 60, 180, and 360 min after each oral dose of Ca supplement including control inert gel. The blood samples were collected in serum separation tubes (Vacutainer brand SST Gel and clot activator; Becton Dickinson and Co., Franklin Lakes, NJ). The blood samples were allowed to clot for a minimum of 30 min at room temperature and then centrifuged at 1,200 \(\times\) g for 10 min to separate serum. The serum samples were stored at \(-20°C\) until further analysis.

Serum samples were analyzed for Ca, P, and Mg at the Marshfield Laboratories (Marshfield Laboratories, Veterinary Division, Marshfield, WI). Calcium was measured based on the principle that it reacts with ortho-cresolphthalein complexone in the presence of 8-hydroxyquinoline to form a purple chromophore (Sarkar and Chauhan, 1967). Phosphorus was measured using the procedure as described by Weissman and Pileggi (1974). Magnesium was measured based on the principle that it reacts with calmagite in the presence of potassium cyanide and ethylenebis(oxyethylene-nitrito)-tetraacetic acid to form a reddish violet chromophore (Gindler and Heth, 1971). The color intensities in Ca, P, and Mg analysis were measured using Hitachi 911 Chemistry Analyzer (Boehringer Mannheim Corp., Indianapolis, IN).

Blood samples were also collected during d 7 and 14 after calving, and serum was separated as described previously. A composite serum sample made by taking equal amounts of sample from the first 12 samples following oral dose of Ca supplement, and samples collected on d 7 and 14 were analyzed for \(\beta\)-hydroxybutyrate (BHB). The BHB analysis was performed using the procedure as described by Gibbard and Watkins (1968).

Milk production data were collected until cows completed wk 4 of lactation. Cows were observed for clinical milk fever, retained fetal membranes, metritis, mastitis, and displaced abomasum for a period of 4 wk after calving. Animals showing signs of clinical milk fever before the administration of the first dose of Ca supplement were eliminated from the study. Using this criterion, a cow in the CVG treatment was substituted by another cow. The health data were based on the observations of the attending veterinarian. The animals showing clear symptoms of milk
fever were treated immediately by administering Ca intravenously. When a cow did not shed her placenta within 24 h after calving, it was considered as a case of retained fetal membranes. A cow was considered to have mastitis when clinical signs of mastitis such as inflamed udder and changes in the color and consistency of the milk were observed. Any fetid vaginal discharge following calving was designated as a case of metritis. Abomasal displacement was diagnosed based on the typical clinical signs of the disorder.

Statistical Analysis

The data were analyzed using the General Linear Models procedure in SAS (1989). An initial analysis was run with actual serum mineral concentrations to determine the effects of treatment, lactation, treatment × lactation interaction, time, and treatment × time interaction. Because there was a considerable difference in pretreatment serum mineral concentrations among the treatment groups, a subsequent statistical analysis was done using the difference between the actual serum mineral concentrations and pretreatment concentrations for dose 1 and 2 separately. The data for differences in mineral concentrations from pretreatment levels were also analyzed separately for each dose with time within treatment as a regression variable. In all the analyses, cows were nested within treatment and lactation.

The model used for mineral, milk yield, and BHB analysis was

\[ Y_{ikm} = \mu + t_i + l_j + t_l_{ij} + c_{tl_{ijk}} + h_m + t_{him} + e_{ijkm} \]

where

- \( Y_{ikm} \) = dependent variable for kth cow in ith treatment and jth lactation during time m;
- \( \mu \) = population mean;
- \( t_i \) = treatment effect;
- \( l_j \) = lactation effect;
- \( t_{lij} \) = treatment by lactation interaction;
- \( c_{tl_{ijk}} \) = effect of cow nested within treatment and lactation;
- \( h_m \) = effect of time (in minutes for mineral analysis and in weeks for milk and BHB analysis);
- \( t_{him} \) = treatment by time interaction;
- \( e_{ijkm} \) = random error.

The error term used for testing time effect was \( e_{ijkm} \). Least squares means were compared using a protected least significant difference test. Significance was declared at \( P < .05 \), unless otherwise noted. The mean values were used to plot the figures.

Results and Discussion

Average blood serum Ca concentrations following an oral dose of inert gel or CaCl\(_2\) supplements are shown in Figure 1. The average pretreatment blood serum Ca concentrations were 6.26, 7.56, 6.20, and 5.96 mg/dL for cows in CON, CVG, CMG, and CVD treatments, respectively. Goff et al. (1996) suggested that cows with serum Ca concentrations of ≤ 7.50 mg/dL are generally in subclinical hypocalcemia. Using this criterion, 78% of the cows in this study were in some state of subclinical hypocalcemia. In another study by Goff et al. (1996), 44 out of 46 cows in the study (96%) were subclinically hypocalcemic. Immediately after the first dose there was a decline in serum Ca concentrations of cows in CON group (Figures 1 and 2). At 6 h after the first dose, the average serum Ca concentration was 6.11 mg/dL in CON group, and this was 3.32% less than the pretreatment serum Ca concentrations. In contrast to the CON group, cows in other treatment groups showed an increase in serum Ca concentration after the treatment (\( P < .05 \)). At 6 h after the first dose, the serum Ca concentrations were 5.0, 5.8, and 11.1% higher than pretreatment Ca concentrations in CVG, CMG, and CVD treatments, respectively.

Following the second dose, the serum Ca concentrations in CON group continued to decline further (Figure 2) and were lower (\( P < .05 \)) than CVG, CMG, and CVD treatments. At 18 h after the first dose, the average serum Ca concentration of cows in CON group was 5.58 mg/dL, and this was 13.5% less than the pretreatment serum Ca concentration. Unlike the CON group, cows in the other three treatment groups showed increased serum Ca concentrations after the second dose. The serum Ca concentrations at 18 h after the first dose were 8.01, 6.72, and 6.87 mg/dL for CVG, CMG, and CVD treatments, respectively. The increase in serum Ca concentration from pretreatment level was 7.1, 9.3, and 18.1% for CVG, CMG, and CVD treatments, respectively.

The data for average difference in serum concentrations of Ca from pretreatment levels following oral supplementation for dose 1 and 2 are given in Table 2. The effects of lactation, treatment × lactation, time, and time × treatment interaction were not significant following first dose. The lactation × treatment and time × treatment interaction effects were significant (\( P = .01 \)) for the second dose. During the first dose, there was a tendency for increase in serum Ca concentrations from pretreatment levels in CVG, CMG, and CVD treatments compared with CON.
Figure 1. Blood serum Ca, P, and Mg concentrations in periparturient dairy cows following oral dose of control inert gel (CON, ●), gel containing CaCl₂ and vitamins (CVG, ■), gel containing CaCl₂ and minerals (CMG, ▲), and CaCl₂ in the form of drench with vitamin (CVD, ○). The cows were given two doses. The first dose was given within 2 h after calving and the second dose 12 h after the first dose. Blood samples were collected at 0, 15, 30, 60, 180, and 360 min after each dose.
Figure 2. Percentage increase in blood serum Ca, P, and Mg concentrations in periparturient dairy cows following oral dose of control inert gel (CON, ♦), gel containing CaCl₂ and vitamins (CVG, □), gel containing CaCl₂ and minerals (CMG, ▲), and CaCl₂ in the form of drench with vitamin (CVD, ●). The cows were given two doses. The first dose was given within 2 h after calving and the second dose 12 h after the first dose. Blood samples were collected at 0, 15, 30, 60, 180, and 360 min after each dose.

treatment (P = .08). During the second dose, cows in the CVG, CMG, and CVD treatment groups showed increased serum Ca concentrations, whereas CON cows showed a decrease in serum Ca levels compared with pretreatment concentrations (Table 2). This suggests that oral administration of Ca supplements increased the blood serum Ca concentrations compared with no Ca supplement in the CON group.

The average increase in serum Ca concentration from pretreatment level was .4 mg/dL with oral supplementation of Ca as gel and .6 mg/dL as drench. Oetzel (1996b) reported an average increase in blood...
Table 2. Average pretreatment concentrations and change in blood serum Ca, P, and Mg concentrations following oral dose of Ca supplements to cows during the periparturient period\textsuperscript{a,b}

<table>
<thead>
<tr>
<th>Item</th>
<th>CON</th>
<th>CVG</th>
<th>CMG</th>
<th>CVD</th>
<th>SEM\textsuperscript{f}</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mg/dL</td>
<td></td>
<td></td>
<td></td>
<td>f</td>
<td>Trt</td>
</tr>
<tr>
<td>Ca</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretreatment</td>
<td>6.26</td>
<td>7.56</td>
<td>6.20</td>
<td>5.96</td>
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<td>Change</td>
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<td></td>
<td></td>
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<td>—</td>
<td></td>
</tr>
<tr>
<td>Dose 1</td>
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<td>.278</td>
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<tr>
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<td>.651\textsuperscript{c}</td>
<td>.519\textsuperscript{c}</td>
<td>.930\textsuperscript{f}</td>
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<td>P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Pretreatment</td>
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<tr>
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<td>1.836</td>
<td>1.339</td>
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<td>.54</td>
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<td>Mg</td>
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<tr>
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<tr>
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<td>−.047</td>
<td>−.069</td>
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<td>.64</td>
</tr>
<tr>
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<td>−.235</td>
<td>−.148</td>
<td>−.285</td>
<td>.05</td>
<td>.12</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Means with different superscripts in a row differ with P as indicated. The P-values ≤ .01 are indicated as .01. The lactation effects were not significant and lactation × treatment effects were significant (P ≤ .03) for changes in serum Ca and Mg following the second dose.

\textsuperscript{b}The change in blood serum Ca, P, and Mg concentrations after dose 1 and 2 was calculated as an average of difference between pretreatment concentration and concentrations at 15, 30, 60, 180, and 360 min after the administration of each oral dose of inert gel and Ca supplements. First dose of Ca supplement was given within 2 h of calving and second dose 12 h after the first dose.

\textsuperscript{c}In addition to the basal diet, cows received two doses of either control inert gel (CON), gel containing CaCl\textsubscript{2} + vitamin (CVG), gel containing CaCl\textsubscript{2} + mineral (CMG), or drench containing CaCl\textsubscript{2} and vitamin (CVD).

\textsuperscript{f}SE of treatment mean.

Ca levels of .72 mg/dL on the first day after calving by administering four doses of CaCl\textsubscript{2} gels. In the present study, even though drench had a lower amount of elemental Ca compared with gel (33.2 vs 55.2 g per dose), there was a trend toward higher uptake of Ca when CaCl\textsubscript{2} was supplied as drench compared with the gel form. Higher absorption rates with drench compared with gel form were also observed by Goff and Horst (1993). The drench has disadvantages in that it increases risks for tissue irritation and aspiration pneumonia (Goff and Horst, 1993; Oetzel, 1996b). Administration of CaCl\textsubscript{2} products generally reduces blood pH. The change in blood pH has been suggested to benefit periparturient cows, because reducing the alkalinity of the blood will increase the amount of ionized Ca. Reducing the alkalinity of the blood will also increase the sensitivity of the tissues to parathyroid hormone, resulting in increased mobilization of Ca from bone (Goff et al., 1991; Horst et al., 1997).

The average pretreatment blood serum P concentrations of cows in CON, CVG, CMG, and CVD treatments were 2.83, 4.36, 3.46, and 3.19 mg/dL, respectively (Figure 1). The normal range for serum P concentration in dairy cows is 4 to 8 mg/dL (NRC, 1989). The pretreatment blood serum concentrations of P in this study immediately after calving were below the reference range except in CVG treatment. Percentage change in serum P concentration after the oral dose of control gel or Ca supplements is shown in Figure 2. There was a gradual increase in serum P concentrations during the first 6 h after the first dose. At 6 h after the first dose, the serum P concentrations were 4.48, 6.13, 4.88, and 4.32 mg/dL for cows in CON, CVG, CMG, and CVD treatments, respectively. The increase in serum P from the pretreatment level was 58, 41, 41, and 35% for CON, CVG, CMG, and CVD, respectively. After the second dose, the serum P concentrations did not show any change, except for a transient increase in CMG and CVD groups. At 18 h after the first dose, the serum P concentrations remained above pretreatment levels in all four treatments.

The average changes in serum P concentrations are given in Table 2. There was a time effect on serum P concentrations, but the time × treatment interaction was not significant. The average change and rate of change in blood serum P concentrations after the oral dose of inert gel or Ca supplements were not different among treatments (Table 2 and Figure 2). In another study, Gregory et al. (1993) reported increased blood serum P from baseline only in cows treated with CaCl\textsubscript{2} gels and not in control cows. In the present study, only CVG and CVD treatments supplied 6.99 and 9.69 g of P per dose, respectively. The increase in serum P in all treatments suggests that during the periparturient
The serum Mg concentrations at 18 h after the first dose were 2.38, 2.26, 2.41, and 2.31 mEq/L for cows in CON, CVG, CMG, and CVD treatments, respectively. These Mg concentrations were 3.4, 9.4, 7.4, and 6.7% lower than the pretreatment serum Mg concentrations for CON, CVG, CMG, and CVD group of cows, respectively. These Mg concentrations were 2.31, 2.10, 2.28, and 2.14 mEq/L for cows in CON, CVG, CMG, and CVD treatments, respectively. The decline in serum Mg concentrations was lower (P < .05) in CON cows than in cows supplemented orally with Ca.

Changes in serum Mg concentrations from pretreatment levels were affected by time (Table 2). However, there was a weak effect of time × treatment and lactation × treatment interaction during dose 2. An average decrease in serum Mg concentrations from pretreatment levels following doses 1 and 2 were not different among treatments. However, regression analysis revealed that the rate of decrease in blood serum Mg levels following doses 1 and 2 was more in CVG, CMG, and CVD treatment groups compared with the CON group (P < .05). This may be because of high Ca intake in Ca-supplemented treatments. Feeding diets high in Ca has been shown to increase fecal excretion of Mg in sheep (Chicco et al., 1973). Also, an increased supply of Ca would decrease the parathyroid hormone level and increase the urinary excretion of Mg (Goff et al., 1986). The fecal and urinary excretions of Mg were not measured in this study. Failure to show any increase in serum Mg concentrations among the treatment groups may be because none of the Ca supplements had Mg in them, except CMG (2.93 g of Mg per dose). The final serum Mg concentrations in all four treatments were below the pretreatment levels and reference limits. This shows the enormous drain of Mg from the body during onset of lactation and failure to mobilize Mg from the bones to maintain Mg homeostasis. Further studies are needed to explore the interrelationship between minerals and the benefits to the animal's health of maintaining the serum Mg concentration at the onset of lactation.

There was no effect of lactation, lactation × treatment, week, or week × treatment for serum BHB concentrations (P = .07). The average serum BHB concentrations in a composite sample (composite of samples collected during the first 18 h after the first dose) and samples collected on d 7 and 14 were 7.25, 6.35, 9.61, and 7.92 mg/dL (SEM = 1.6) for cows receiving the CON, CVG, CMG, and CVD treatments, respectively. The BHB concentrations were not different among treatments. The serum BHB concentration has been used as an indicator of ketosis in dairy cows (Dhiman et al., 1991). Results suggest that supplementation of Ca orally through the CaCl2 preparations used in this study had no effect on serum BHB concentrations. In another study, administering Ca through calcium propionate had no effect on blood serum NEFA and BHB levels in Holstein cows (Goff et al., 1996).

The average milk yields during the first 4 wk of lactation were 36.8, 36.2, 37.2, and 33.2 kg/d (SD ± 1.6) for cows in CON, CVG, CMG, and CVD treatments, respectively. The week effect was significant for milk yield (P = .01). However, lactation × treatment and week × treatment interactions were not significant. The milk yields during the first 4 wk of lactation were not affected by oral supplementation of Ca through CaCl2 as gel or drench in this study (P = .6).

One case of retained fetal membranes was recorded in each of the CON, CVG, and CMG groups. One case of mastitis was recorded in the CON, CVG, and CVD groups. No case of metritis was observed in any of the treatment groups. One cow in the CMG group had displaced abomasum and was treated surgically. The observations on general health were not suggestive of any major effects of oral Ca supplementation. Similar observations were reported by Goff et al. (1996). However, the number of animals used per treatment was not adequate to accurately measure the treatment effects on health performance.

Three cases of clinical milk fever were observed in the CON (n = 9) and one case in the CVD (n = 9) group of cows. As mentioned earlier, the increase in serum concentrations of Ca from pretreatment level was higher in cows supplemented with Ca compared with cows in CON group (Table 2). Lower incidences of milk fever in treated cows suggest that the oral supplementation of Ca may have prevented the development of clinical milk fever in cows that were marginally hypocalcemic. Lower incidences of milk fever in cows supplemented orally with Ca have also been reported by others (Goff et al., 1996; Oetzel, 1996b). The average pretreatment blood serum Ca concentration in cows that developed milk fever was 5.5 mg/dL (range 4.9 to 6.0) and 3.2 mg/dL in CON and CVD treatments, respectively. The oral supplementation of Ca was probably not sufficient to bring the serum Ca concentrations high enough to
prevent milk fever. The oral Ca supplements may only prevent milk fever in cows that are marginally hypocalcemic. In cows that are in severe hypocalcemia, i.v. administration of Ca may be the only alternative to avoid milk fever. Oral supplementation of Ca can also prevent the relapse of milk fever in cows that initially responded to i.v. treatment (Oetzel, 1996b).

Long-term studies are needed to determine the economic impact of administering oral Ca supplements routinely on the farm to cows that are at high risk of milk fever, such as cows in second or greater lactation. Consider the costs associated with the treatment of cows in milk fever at the rate of $334 per case (Horst et al., 1997). Assuming that Ca supplements are used in cows in second or greater lactation and that this represents about 66% of the total milking animals on the farm, using the current prices of oral Ca gels at the rate of $6 per dose plus labor of $1.50 per cow, the producer will break even if the incidence of milk fever can be reduced by 3% through routine administration of Ca to cows in the second or greater lactation. The cost of using drench is about half that of gels. Therefore, the break-even point may be lower if drench is used instead of gel.

**Implications**

Supplementation of calcium orally should increase serum calcium concentrations and may prevent milk fever in cows with marginal hypocalcemia. In cows that are in severe hypocalcemia, intravenous administration may be the only alternative to treat or prevent milk fever. The costs of using oral calcium chloride supplements should be justifiable, if the incidences of milk fever can be reduced by 3% through routine administration of calcium to cows in the second or greater lactation.

**Literature Cited**


