NUTRITION, FEEDING, AND CALVES

Zinc Concentration and Distribution in Mammary Secretions of Peripartum Cows

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ABSTRACT

Mammary secretions were sampled from peripartum cows and analyzed for Zn concentrations. Subsamples of these secretions were fractionated into casein and whey, and the distribution of Zn was determined. Concentration of Zn was greater in the colostrum than in either prepartum mammary secretions or in milk. The high colostral Zn was reflected by high concentrations of Zn in both casein and whey fractions. Approximately 60% of the colostral Zn was in the casein fraction compared with nearly 90% in milk. Calcium, P, Fe, and Cu concentrations, but not Mn, also were elevated in colostrum. When milk was augmented with Zn, the added Zn was associated largely with casein. Although casein has a very large capacity for binding Zn, about half of the extra Zn in colostrum is found in the whey fraction.

(Key words: colostrum, zinc, calcium, bovine)

INTRODUCTION

Colostrum is a vital source of nutrients and passive immunity for neonatal calves. Survival of newborn calves is dependent on sufficient colostrum intake soon after birth. Colostrum contains greatly increased concentrations of Ig and vitamin A for transfer from dam to calf. These substances help reduce calfhood morbidity and death (14).

Colostrum and milk differ in several characteristics. Although casein is present in both colostrum and milk, the concentrations of Ig, fat, and minerals are much different. For example, bovine colostrum contains four times the concentration of protein found in milk. Most of this extra protein is Ig and not casein (20). Differences in protein transport and synthesis between prepartum and postpartum alveolar epithelial cells explain many compositional differences between colostrum and milk (3).

Species differences exist in the type and concentrations of proteins and in mineral concentrations of colostrum. Copper in sheep colostrum is greatly elevated compared with Cu in bovine colostrum (11). Bovine colostrum contains elevated concentrations of Zn (9). Human colostrum has been shown to have elevated Zn concentrations that do not correlate to changes in protein concentrations (4).

This trial was undertaken as part of a study on maternal transfer of Zn. The objectives were to determine the concentration of Zn in prepartum and postpartum mammary secretions and the fractional distribution of Zn between casein and whey.

MATERIALS AND METHODS

Mammary secretions were sampled from 10 cows at approximately 240, 192, 144, 96, and 48 h prepartum and at 1, 8, 25, 61, 144, and 288 h postpartum. The dry cow ration contained 33 ppm of Zn, and the postpartum ration contained 38 ppm of Zn. Samples were centrifuged at 2800 x g for 20 min to obtain fat-free secretions. Subsamples were dry ashed, and Zn, Ca, Cu, Mn, and Fe were determined by atomic absorption spectrophotometry. Phosphorus was determined colorimetrically (1). Casein fractions were obtained by centrifuging the fat-free secretions at 150,000 x g for 60 min. Crude protein was determined by the Kjeldahl method (1).

To determine whether casein has the capability to bind large amounts of Zn, subsamples of mammary secretions were obtained and augmented with Zn as ZnCl₂ (20 mg of Zn/dl). To
these augmented samples, 100 mg of MgCO₃/ml were added to precipitate excess Zn, and the samples were centrifuged at 2800 × g for 10 min. The samples were fractionated into casein and whey as described.

The general linear models procedure of SAS (16) was used to analyze the effects of cow and time of sampling on mineral concentrations of mammary secretions. Treatment means were tested for linear and quadratic contrasts. Significance was declared at $P < .05$ unless otherwise noted.

**RESULTS AND DISCUSSION**

The Zn concentrations in mammary secretions were sharply increased at parturition compared with Zn concentrations in both prepartum and postpartum secretions (Figure 1). They were nearly normal for milk by 25 h postpartum. Calcium, P, Cu, and Fe (Table 1) were all increased in mammary secretions at parturition and dropped to nearly normal concentrations by 25 h postpartum (Table 1). Manganese concentrations were not increased ($P > .05$) in mammary secretions at parturition. The DM percentage was doubled in colostrum (Table 1), largely because of increased Ig (20). However, the increased Zn in colostrum was not due to simultaneous passage of Zn and Ig into mammary secretions. A recent study has reported that concentrations of IgG in mammary secretions peak prepartum and that colostral IgG concentrations drop at parturition in Holstein cows (2). Thus, the reported pattern of IgG concentrations in mammary secretions of peripartum cows is different from that for Zn (Figure 1).

The colostrum contained an average of 66 mg (SD = 8) of casein proteins and 128 mg (SD = 10) of whey solids/g of fat-free colostrum. These concentrations are similar to previously reported ones (20). Multiplying the amounts of casein and whey in 1 ml of colostrum by their Zn concentrations yields the micrograms of Zn contained in these fractions (Table 2). Thus, there were 14.2 and 9.5 μg of Zn, respectively, in the casein and whey fractions in 1 ml of fat-free colostrum, or distributions of 60 and 40% of the total Zn in the casein and whey, respectively. The amount of Zn in both the casein and whey fractions declined rapidly after 1 h postpartum. Casein Zn represented nearly 90% of total Zn in milk sampled at 144 and 288 h postpartum. Reported estimates of the percentage of total bovine milk Zn in casein range from 48% (12) to 84% Zn (5).

Bovine milk contains α-casein (50 to 55%), β-casein (30 to 35%), κ-casein (15%), and γ-casein (5%) (13). Bovine casein is more phosphorylated than human casein and has greater

### Table 1. Changes postpartum in the concentrations of Ca, P, Cu, Fe, and Mn in milk with time.¹

<table>
<thead>
<tr>
<th>Time (h)</th>
<th>DM (%)</th>
<th>Ca (g/dl)</th>
<th>P (g/dl)</th>
<th>Cu (μg/ml)</th>
<th>Fe (μg/ml)</th>
<th>Mn (μg/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.18ᵃ</td>
<td>.16ᵃ</td>
<td>.17ᵃ</td>
<td>.35ᵃ</td>
<td>1.5ᵃ</td>
<td>.09</td>
</tr>
<tr>
<td>25</td>
<td>.09</td>
<td>.10</td>
<td>.10</td>
<td>.34</td>
<td>1.1</td>
<td>.06</td>
</tr>
<tr>
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<td>.09</td>
<td>.10</td>
<td>.09</td>
<td>.31</td>
<td>.9</td>
<td>.08</td>
</tr>
<tr>
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<td>.08</td>
<td>.09</td>
<td>.08</td>
<td>.27</td>
<td>.8</td>
<td>.08</td>
</tr>
<tr>
<td>288</td>
<td>.09</td>
<td>.09</td>
<td>.08</td>
<td>.29</td>
<td>.9</td>
<td>.07</td>
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<td>&lt;.01</td>
<td>.01</td>
<td>&lt;.01</td>
<td>.03</td>
<td>.1</td>
<td>.02</td>
</tr>
</tbody>
</table>

ᵃSignificant linear contrasts ($P < .05$).

¹ₙ = 19.
TABLE 2. Zinc distribution between the casein and whey of colostrum and milk.1

<table>
<thead>
<tr>
<th>Time postpartum (h)</th>
<th>Zn in milk (μg/ml)</th>
<th>Whey</th>
<th>SD</th>
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<tr>
<td>1</td>
<td>14.2a</td>
<td>9.5a</td>
<td>4</td>
</tr>
<tr>
<td>25</td>
<td>8.6</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>61</td>
<td>6.1</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>144</td>
<td>6.4</td>
<td>8.7</td>
<td></td>
</tr>
<tr>
<td>288</td>
<td>4.7</td>
<td>6.1</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>3.4</td>
<td>5.5</td>
<td></td>
</tr>
</tbody>
</table>

1Significant linear contrast (P < .05).  
In = 10 samples.

TABLE 3. Comparison of method of casein isolation and time postpartum on the concentration of Zn and Ca in the casein.1

<table>
<thead>
<tr>
<th>Time postpartum (h)</th>
<th>Acid2 Zn (μg/g)</th>
<th>Centrif3 Zn (μg/g)</th>
<th>Acid4 Ca (g/100 g)</th>
<th>Centrif Ca (g/100 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>64a</td>
<td>269a</td>
<td>.49a</td>
<td>.98</td>
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<tr>
<td>25</td>
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<td>18</td>
<td>142</td>
<td>.20</td>
<td>1.13</td>
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<tr>
<td>SD</td>
<td>4</td>
<td>16</td>
<td>.02</td>
<td>.09</td>
</tr>
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</table>

1Significant linear contrasts (P < .05).  
In = 10 per method.  
2Acid precipitation of casein.  
3Centrifugal precipitation of casein.  
4Acid precipitation of casein.
Lactoferrin, an Fe-binding protein in milk, normally has only about 10% of its Fe-binding capacity occupied by Fe and has the ability to bind Zn. Lactoferrin content of colostrum varies with parity and breed of cows (17). However, lactoferrin concentrations in bovine milk are much lower than for human milk (15).

The principal Fe-binding protein in milk is α-casein and not lactoferrin (7). The concentration of Fe in casein of Colostral samples in the current trial was 75 and 38 μg/g of casein in milk (SD = 7.9).

A hypothesis for elevated Colostral Zn concentrations is that an increase in corticosteroids at parturition causes an increased transfer of Zn from blood to the mammary gland. Glucocorticoids have been shown to increase Zn concentration in milk by mediating Zn transport into the mammary gland (18). Likewise, glucocorticoids are known to be elevated at parturition (19). The concentration of Zn in the Colostrum is, therefore, elevated; most of the extra Zn is nearly evenly distributed between casein and whey fractions.

Colostrum consumed by the neonatal calf forms a firm renin clot in the abomasum. The Zn that is bound to the casein is not released for absorption from this clot and, in fact, is not available for absorption until the breakup of the renin clot farther down the intestinal tract (21). The bioavailability of Zn in the whey fraction of Colostrum is not known.

Newborn calves have a highly efficient mechanism for intestinal absorption of Zn. When calves are fed diets with large amounts of Zn, resultant accumulations of Zn in the liver and kidney occur (8). Adult cattle largely are unaffected by excess dietary Zn and successfully limit intestinal Zn absorption to prevent excessive accumulations in tissues (10). Possibly, the relatively low bioavailability of Zn in milk necessitates a heightened ability of young calves to absorb it.

REFERENCES