Effects of colostrum replacer supplemented with lactoferrin on the blood plasma immunoglobulin G concentration and intestinal absorption of xylose in the neonatal calf

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ABSTRACT: The objective of this experiment was to determine the effect of lactoferrin (Lf) supplementation of colostrum replacer (CR) fed as 1 or 2 doses on apparent efficiency of IgG absorption, serum IgG concentrations, and xylose absorption/intestinal development in neonatal Holstein bull calves. Eighty bull calves were assigned to a 2 × 4 factorial arrangement of treatments in a randomized complete block design. Calves used were from the University of New Hampshire (n = 48) or a commercial dairy (n = 32). All calves were fed CR according to manufacturer’s recommendations ± Lf treatment within 90 min of birth. Lactoferrin treatments were 0 (control), 0.5, 1, and 2 g/d of supplemental Lf. At 12 h of age, calves were fed a second feeding of CR ± supplemental Lf or 2 L of milk replacer ± supplemental Lf. Calves continued to be fed milk replacer ± supplemental Lf every 12 h for the duration of study. Blood samples were collected for determination of IgG and total serum protein at 0, 6, 12, 18, 24, and 48 h. Calves, except those fed 1 dose of CR plus 1 or 2 g of Lf, had serum IgG concentrations ≥10 g/L at 24 h. Lactoferrin supplementation had no effect on serum IgG or total serum protein concentrations. Calves fed 2 doses of CR had greater serum IgG concentrations compared with calves fed 1 dose of CR. Apparent efficiency of absorption of IgG was less in calves fed 2 doses of CR compared with calves fed 1 dose of CR. Lactoferrin supplementation (up to 1 g/d) resulted in decreased apparent efficiency of absorption of IgG. At the sixth feeding (60 ± 2 h of age), d-xylose (0.5 g/kg BW) was mixed with milk replacer ± supplemental Lf (n = 48) to determine xylose absorption by the small intestine. Blood was collected at 0, 2, 4, 6, 8, and 12 h after feeding xylose for determination of plasma glucose and xylose concentrations. Xylose means and area under the curve resulted in quadratic effects. Feeding calves 0.5 or 1 g/d supplemental Lf resulted in decreased plasma xylose concentrations compared with calves fed 0 or 2 g/d of supplemental Lf. Colostrum replacer or supplemental Lf did not affect plasma glucose concentrations. This study indicates that supplementing Lf at 0.5 or 1 g/d to calves fed CR has a negative effect on apparent efficiency of IgG absorption and xylose absorption.

Key words: calf, colostrum replacer, immunoglobulin G, lactoferrin, xylose

INTRODUCTION

The neonatal calf is born hypogammaglobulinemic. Passive immunity is dependent upon adequate con-
vine milk that has a concentration of 0.01 to 1 mg/mL (Molenaar et al., 1996). Lactoferrin has been shown to be important for intestinal development and development of the immune system in species such as mice and humans (Shah, 2000; Zhang et al., 2001). It has 3 functions, which may be beneficial to the development of a neonatal calf: inhibiting bacterial growth (Terauchi et al., 1998), increasing intestinal cell growth (Zhang et al., 2001), and stimulating glucose absorption (Terauchi et al., 1998). The ability of Lf to inhibit bacterial growth may protect the intestine of the newborn calf from infection, whereas increasing intestinal cell growth may increase IgG and nutrient absorption by the intestine (Robblee et al., 2003). The objective of this experiment was to determine the effect of Lf supplementation of colostrum replacer (CR) fed as 1 or 2 doses on apparent efficiency of IgG absorption, serum CR supplementation of colostrum replacer (CR) reconstituted in 1 L of water) containing 105 g of IgG (Saskatoon Colostrum Co., Ltd., Saskatoon, Saskatchewan, Canada) ± supplemental Lf every 12 h for the duration of the study. Calves received 1.2% of their initial BW in MR powder daily. The MR powder was divided into 2 equal portions daily, and each portion was reconstituted in 2 L of warm water immediately before feeding. Calves were fed using a nipple bottle; any CR or MR remaining after 30 min was fed via an esophageal feeder. At the sixth feeding in which calves were 60 ± 2 h of age, a xylose challenge was conducted (university calves only) to determine xylose absorption by the small intestine. Calves from the commercial dairy were removed from the study at 48 h, whereas calves born at the university were removed at 72 h.

**MATERIALS AND METHODS**

This experiment was reviewed and approved by the University of New Hampshire Institutional Animal Care and Use Committee.

**Calves, Feeding, and Treatments**

Eighty Holstein bull calves born between March 2006 and November 2006 at 2 different dairies were used. Calves were assigned randomly at birth by location to a 2 × 4 factorial arrangement of treatments in a randomized complete block design; the first factor was CR fed in 1 or 2 meals, and the second factor was Lf supplementation at 4 quantities. Calves were blocked in groups of 8 at birth by location. Randomization of treatments occurred within blocks. Forty-eight calves assigned to the experiment were born at the University of New Hampshire, Fairchild Dairy Teaching and Research Center (initial BW of 43.8 ± 4.9 kg). Thirty-two calves were from a local dairy farm. All calves were removed from their dam at birth and not allowed to suckle. Calves born at the university were weighed at birth and placed in a naturally ventilated, enclosed calf room in individual pens. Pens were bedded with kiln-dried sawdust. Calves born at the commercial dairy were not weighed at birth because a scale was unavailable. Calves from the commercial dairy were placed in a naturally ventilated maternity pen and bedded with wheat straw. The treatment groups consisted of 1 dose of CR versus 2 doses of CR ± supplemental Lf (Immunell, Portland ME). The amounts of supplemental Lf were 0, 0.5, 1, or 2 g/d. The amounts of Lf were selected based on previous research conducted in our laboratory (Robblee et al., 2003; White, 2005; Cowles et al., 2006). All calves received 1 dose of CR (470 g of CR reconstituted in 1 L of water) containing 105 g of IgG (Saskatoon Colostrum Co., Ltd., Saskatoon, Saskatchewan, Canada) ± supplemental Lf within 90 min of birth. The source of Lf was bovine milk; iron saturation was 13.2 g/100 g. The second feeding was at 12 h in which the calves received either a second dose of CR or 2 L of nonmedicated milk replacer (MR; 20% CP and 20% fat) with each containing the varying amounts of supplemental Lf. Calves were fed MR ± supplemental Lf every 12 h for the duration of the study. Calves received 1.2% of their initial BW in MR powder daily. The MR powder was divided into 2 equal portions daily, and each portion was reconstituted in 2 L of warm water immediately before feeding. Calves were fed using a nipple bottle; any CR or MR remaining after 30 min was fed via an esophageal feeder. At the sixth feeding in which calves were 60 ± 2 h of age, a xylose challenge was conducted (university calves only) to determine xylose absorption by the small intestine. Calves from the commercial dairy were removed from the study at 48 h, whereas calves born at the university were removed at 72 h.

**Feed Analysis**

The DM of the CR and MR was determined by drying samples in a forced-air convection oven at 60°C for 24 h (VWR Scientific Inc., West Chester, PA). Samples from each bag of CR and MR were saved and stored at −20°C. Once the experiment was completed, samples were composited for nutrient analysis. The CR and MR were analyzed for CP (method 976.06, AOAC, 1995). The total fatty acid content of the CR and MR were determined by saponification with KOH in ethyl alcohol. The fatty acids were liberated from the soaps with HCl, followed by extraction with petroleum ether (AOAC, 1995). Calcium, P, Mg, and Fe were determined using method 985.01 (AOAC, 1995). Milk replacer Lf concentration was determined by reconstituting the powder to 15% DM, then analyzing using radial immunodiffusion (Cardiotech Services Inc., Louisville, KY). Chemical analyses of CR and MR are shown in Table 1.

**Blood Collections for IgG and Serum Protein**

Blood samples were collected via jugular venipuncture before the first feeding of CR (within 90 min of birth, referred to as 0 h) and at 6, 12, 18, 24, 48 h after birth. Samples were collected in 5-mL tubes (Monoject Blood Tubes, Tyco Healthcare, Mansfield, MA). Samples were allowed to clot at room temperature for at least 1 h and then centrifuged at 3,300 × g at 25°C for 20 min. Serum samples were stored at −20°C until analyzed for IgG by radial immunodiffusion (University of Saskatchewan, Saskatoon, Saskatchewan, Canada) and total serum proteins with a digital refractometer (model 300027, SPER Scientific, Scottsdale, AZ). Area under the curve (AUC) was determined for IgG. Apparent efficiency of IgG absorption at 24 h of age was estimated using the equation: [(serum IgG, g/L × BW, kg × 0.09/IgG intake, g) × 100%] (Quigley and Drewry, 1998).
Blood Collections for Xylose Challenge

The xylose challenge was performed on calves born at the university. D-Xylose (0.5 g/kg BW) was mixed with MR and fed at the sixth feeding (60 ± 2 h of age). D-Xylose is used as an indirect marker for glucose absorption across the small intestine (Hammon and Blum, 1997; Kuhne et al., 2000; Rauprich et al., 2000). Calves were fasted throughout the sampling period but allowed ad libitum access to water. Blood samples were taken before d-xylose treatment (0 h) and at 2, 4, 6, 8, and 12 h after feeding. Blood samples (5 mL) were collected via jugular venipuncture into evacuated tubes containing tripotassium EDTA to measure d-xylose and glucose concentrations in the plasma. Blood samples were immediately centrifuged at 3,300 x g at 5°C for 20 min to harvest plasma. Two 1-mL aliquots of plasma were stored in 5-mL polypropylene tubes at −20°C and later analyzed for d-xylose and glucose concentrations. D-Xylose was measured as described by Merritt and Duelly (1983). Plasma glucose concentrations were determined using a kit based on glucose oxidase (Wako, Richmond, VA). Area under the curve was determined for plasma xylose and glucose.

Statistical Analysis

The UNIVARIATE procedure (SAS Inst. Inc., Cary, NC) was used to determine outlier calves. An observation greater than 2.5 SD from the mean for each item analyzed was considered an outlier. The results of the outlier analysis indicated that 2 calves were outliers; therefore, these calves were removed from the final statistical analyses.

A randomized complete block design with a 2 × 4 factorial arrangement of treatments was used, and calves were randomly assigned to treatments in blocks of 8 based on birth order and location. Glucose, xylose, IgG, AEA, AUC, and the serum protein data were analyzed using the MIXED procedure of SAS according to the following model:

\[
Y_{ijk} = \mu + b_i + L_j + R_k + T_l + LR_{jk} + R_kT_l + KC_{ijk} + E_{ijklm}
\]

where \(Y\) = the dependent variable; \(\mu\) = the overall mean; \(b_i\) = the random effect of block \(i\) (\(i = 1,...,10\)); \(L_j\) = the fixed effect of the jth Lf level (\(j = 0, 0.5, 1, 2\)); \(R_k\) = the fixed effect of kth CR feeding (\(k = 1, 2\)); \(T_l\) = the fixed effect of the lth time point (\(l = 0, 2, 4, 6, 8, 12, 18, 24, 48\)); \(LR_{jk}\) = the fixed effect of the interaction between the jth Lf level and the kth CR feeding; \(R_kT_l\) = the fixed effect of the interaction between the kth CR feeding and the lth time point; \(KC_{ijk}\) = the covariate variable used and was significant for IgG and AEA and remained in the model statement. Residual errors, which are errors within calf across time and represent errors from repeated measurements from the experimental unit (calf), were modeled using the first-order autoregressive covariance structure because it resulted in the best fit according to Sawa’s Bayesian information criterion. Data were tested for linear, quadratic, and cubic response to amount of Lf supplementation. Results were expressed as least squares means with the largest SEM. Degrees of freedom were determined using the Satterwaite option of the MIXED procedure of SAS. Significance was determined as \(P \leq 0.05\). The MIXED procedure of SAS was used to compare the IgG concentration at 24 h with 10 g/L (the threshold value indicating successful passive transfer). Partial efficiency of absorption was determined using only the calves that were fed 2 doses of CR. The equation used to calculate partial efficiency was \([(\text{concentration of IgG at 24 h} - \text{concentration of IgG at 12 h})/\text{concentration of IgG at 24 h}] \times 100\%\).

RESULTS

Chemical analysis of CR and MR are presented in Table 1. Lactoferrin concentration was less in the CR than in colostrum (Molenaar et al., 1996).

At birth, serum protein concentrations were approximately 4.5 g/dL. Calves fed 2 doses of CR had greater \((P < 0.001)\) mean serum IgG concentrations and greater \((P < 0.001)\) serum protein concentrations compared with calves fed 1 dose of CR (Table 2). Calves fed a second dose of CR at 12 h had greater serum IgG and serum protein concentrations at 18, 24, and 48 h, resulting in a significant CR × time interaction \((P < 0.05; \text{Figures 1 and 2})\). Supplemental Lf had no effect on mean serum IgG concentrations or mean serum protein concentrations for any time point in which samples

Table 1. Nutrient analysis (DM basis) of colostrum replacer (CR) and milk replacer (MR)

<table>
<thead>
<tr>
<th>Item</th>
<th>CR</th>
<th>MR</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM, %</td>
<td>93.5</td>
<td>89.5</td>
</tr>
<tr>
<td>CP, %</td>
<td>54.9</td>
<td>20.6</td>
</tr>
<tr>
<td>Fat (acid hydrolysis), %</td>
<td>22.6</td>
<td>18.9</td>
</tr>
<tr>
<td>Ca, %</td>
<td>1.10</td>
<td>0.97</td>
</tr>
<tr>
<td>P, %</td>
<td>0.99</td>
<td>0.64</td>
</tr>
<tr>
<td>Mg, %</td>
<td>0.16</td>
<td>0.15</td>
</tr>
<tr>
<td>Fe, mg/kg</td>
<td>4.5</td>
<td>102</td>
</tr>
<tr>
<td>Lactoferrin, mg/g</td>
<td>1.66</td>
<td>0.45</td>
</tr>
</tbody>
</table>

1Land O'Lakes colostrum replacer, manufactured by Saskatoon Colostrum, Saskatoon, Saskatchewan, Canada.
2Blue Seal Feeds nonmedicated milk replacer, Londonderry, NH.

For AUC and AEA there was no fixed effect of time because these samples were single values. For glucose, xylose, IgG, and serum protein data, repeated measures analysis was performed. The data were run through 3 covariance structures: unstructured, compound symmetry, and first-order autoregressive. Initial BW was the covariate variable used and was significant for IgG and AEA and remained in the model statement. Residual errors, which are errors within calf across time and represent errors from repeated measurements from the experimental unit (calf), were modeled using the first-order autoregressive covariance structure because it resulted in the best fit according to Sawa’s Bayesian information criterion. Data were tested for linear, quadratic, and cubic response to amount of Lf supplementation. Results were expressed as least squares means with the largest SEM. Degrees of freedom were determined using the Satterwaite option of the MIXED procedure of SAS. Significance was determined as \(P \leq 0.05\). The MIXED procedure of SAS was used to compare the IgG concentration at 24 h with 10 g/L (the threshold value indicating successful passive transfer). Partial efficiency of absorption was determined using only the calves that were fed 2 doses of CR. The equation used to calculate partial efficiency was \([(\text{concentration of IgG at 24 h} - \text{concentration of IgG at 12 h})/\text{concentration of IgG at 24 h}] \times 100\%\).
were collected (Figures 1 and 2). Most of the calves attained blood serum IgG concentration ≥10 mg/mL by 24 h, resulting in successful passive transfer. The calves that did not attain blood serum IgG concentration ≥10 mg/mL by 24 h were calves fed 1 dose of CR with 1 or 2 g/d of supplemental Lf. In comparing the serum 24-h IgG concentration with the target of 10 g/L, all groups of calves fed 1 dose of CR had values similar to the target value (i.e., not different from 10 g/L) except those calves fed 1 dose of CR and 2 g of supplemental Lf. Calves fed 2 doses of CR, regardless of supplemental Lf, averaged greater than 10 g/L (P < 0.02). The range of IgG concentrations at 24 h indicated that at least 1 calf on each treatment did not attain passive transfer. Area under the curve of IgG was greater for the calves fed 2 doses CR compared with the calves fed 1 dose CR (P = 0.005). Lactoferrin supplementation had no effect on the results for AUC of IgG.

There was a decrease (P < 0.0001) in AEA of IgG when 2 doses of CR were fed vs. 1 dose of CR (Table 2). Although the AEA of IgG decreased when calves were fed 2 doses of CR, the percentage of calves that attained successful passive transfer was greater for calves fed 2 doses of CR (P = 0.03). Apparent efficiency of absorption of IgG decreased quadratically to the 1-g/d Lf dose (P = 0.03). However, the percentage of calves that attained successful passive transfer was not different among Lf treatments. Partial efficiency of absorption of IgG was 31% for calves that received 2 doses of CR.

Two hours after xylose challenge, plasma xylose concentrations were greater in calves fed 2 doses of CR compared with 1 dose of CR (P < 0.01), although at 8 and 12 h after the xylose challenge plasma xylose concentrations were greater in the calves fed 1 dose of CR (P < 0.05; Figure 3). However, the overall mean for plasma xylose concentrations of all the time points were not different between calves fed 1 dose vs. calves fed 2 doses of CR (Table 2). Plasma xylose concentration (P = 0.002) and AUC for plasma xylose concentration (P = 0.004) reacted in a quadratic manner where the xylose concentration and xylose AUC were least for the 0.5-g/d Lf treatment and then increased with 1- or 2-g/d Lf supplementation approaching the 0-g/d treatment.

There was a trend (P = 0.07) for greater plasma glucose concentrations for calves fed 2 doses of CR compared with 1 dose of CR. Two hours after xylose challenge, plasma glucose concentrations were greater in calves fed 2 doses of CR compared with calves fed 1 dose of CR (P < 0.05; Figure 4). There was a trend (P = 0.09) for a linear decrease in plasma glucose concentrations as Lf increased. Neither CR nor Lf affected glucose AUC (Table 2).

**DISCUSSION**

Lactoferrin concentration in the CR was less than typically observed in colostrum. Possibly some Lf was lost from the colostrum as the material was dried. A
previous study showed that heating Lf from 60 to 100°C resulted in 10 to 100% being denatured (Paulsson et al., 1993).

Serum protein concentration and serum IgG concentration increased with 2 doses of CR within 24 h of birth. The initial serum protein concentrations were similar to those obtained by Nocek et al. (1984). These authors did not observe any correlation with serum IgG concentration and serum protein concentration at birth ($r = −0.02$), but observed a positive correlation

**Figure 1.** Serum IgG concentrations (g/L) of calves fed 1 (closed symbol) or 2 (open symbol) doses of colostrum replacer with varying amounts of lactoferrin over the first 48 h of life. L0 = 0 g of lactoferrin, L0.5 = 0.5 g of lactoferrin, L1 = 1 g of lactoferrin, L2 = 2 g of lactoferrin. The largest SEM was 0.87 and occurred for all time points in calves fed 1 dose of colostrum replacer with L2. *Calves fed 2 doses of colostrum replacer had greater ($P < 0.05$) plasma IgG than those fed 1 dose of colostrum replacer.

**Figure 2.** Serum protein concentration (g/dL) of calves fed 1 (closed symbol) or 2 (open symbol) doses of colostrum replacer with varying amounts of lactoferrin over the first 48 h of life. L0 = 0 g of lactoferrin, L0.5 = 0.5 g of lactoferrin, L1 = 1 g of lactoferrin, L2 = 2 g of lactoferrin. The largest SEM was 0.13 and occurred for all time points in calves fed 1 dose of colostrum replacer with L2. *Calves fed 2 doses of colostrum replacer had greater ($P < 0.05$) serum protein than those fed 1 dose of colostrum replacer.
between serum protein concentration and serum IgG concentration at 12 to 24 h after being fed colostrum (r = 0.84).

In the present study, most calves attained blood serum IgG concentration ≥10 g/L resulting in successful passive transfer by 24 h, except for calves fed 1 dose of CR with 1 or 2 g/d of supplemental Lf. This is different from other studies in which lacteal secretion-based CR did not consistently provide successful passive transfer (Zaremba et al., 1993; Garry et al., 1996; Mee et al., 1996; Hopkins and Quigley, 1997; Arthington et al., 2000). It is likely that the differences observed in our study compared with those experiments were due to the decreased concentrations of IgG used in the previ-
ous studies (17.7 g, Mee et al., 1996; 60 g, Arthington et al., 2000). However, in those studies, there was no improvement in serum IgG concentration in calves fed colostral-based supplement at amounts of IgG > 100 g compared with calves fed colostrum (Garry et al., 1996). The production of an effective replacer from bovine colostrum is dependent upon processing only colostrum containing elevated immunoglobulin concentrations and upon having an efficient method of dehydration, which preserves immunoglobulin function (Chelack et al., 1993).

The percentage of calves attaining passive transfer was greater when 2 doses of CR were fed as compared with calves fed 1 dose CR indicating that 2 doses, providing a minimum of 200 g of IgG, should be fed to provide serum IgG concentrations ≥10 mg/mL. Although calves fed 2 doses of CR had greater serum IgG concentrations compared with calves fed only 1 dose of CR, the AEA of IgG decreased with feeding increasing concentrations of IgG. This may be because more IgG was supplied than could be absorbed; thus the IgG absorption sites in the small intestine may have been saturated, preventing all of the supplied IgG from being absorbed. Also, the second dose of CR was not fed until 12 h after birth. By this time a significant amount of intestinal closure has occurred, resulting in a loss of absorption sites. The increased supply of IgG from the second dose of CR and the loss of absorption sites would have reduced the amount of IgG absorbed, resulting in a decreased AEA of IgG. This is also supported by the partial efficiency of absorption of IgG [(24 h IgG concentration – 12 h IgG concentration)/24 h IgG concentration] of 31%, supporting our contention that IgG absorption was less after the second CR feeding compared with the initial CR feeding. Therefore, the majority of the IgG observed in the 24 h sample was from the initial feeding of CR.

Unlike a previous study conducted in our lab (White, 2005), which showed Lf to have a trend for a positive effect on AEA of IgG, the present study showed Lf to have a negative quadratic effect on AEA of IgG. In the study by White (2005), Lf was supplemented at a rate of 1 g/d to maternal colostrum, which has an average Lf concentration of 2 mg/mL (Molenaar et al., 1996). This resulted in calves consuming approximately 9 g/d of Lf when fed 4 L of colostrum per day. In the present study, Lf was added to CR, which had an Lf concentration of 780 mg/L of CR. Therefore, calves fed the largest supplementation of Lf (2 g/d) and 2 doses of CR consumed 3.56 g/d of Lf. At the largest Lf supplementation of 2 g/d, calves on our study were receiving less Lf/d than the calves fed only maternal colostrum in the experiment of White (2005). However, this does not explain why, in the present study, the AEA of IgG was decreased by 0.5 and 1 g/d of supplemental Lf compared with control calves. Although it cannot be determined from the experiment of White (2005), it is possible that other components found in maternal colostrum complemented Lf, which resulted in the trend for the increase in AEA.

There was a quadratic effect with increasing Lf supplementation on xylose absorption and AUC with calves fed 0.5 and 1 g of Lf having decreased plasma xylose concentrations compared with calves fed 0 and 2 g of Lf. The xylose absorption test is used as an indirect measurement of glucose absorption and of intestinal epithelial size and function (Hammon and Blum, 1997; Kuhne et al., 2000; Rauprich et al., 2000). The results from this study indicate that Lf impaired xylose absorption and possibly intestinal development when supplemented at 0.5 and 1 g/d for the first 2.5 d of life. Cowles et al. (2006) performed a xylose challenge on calves fed MR supplemented with 1 g/d of Lf and found no effect of Lf. However, calves were 10 d old at the time of the xylose challenge and only fed 1 level of Lf (1 g/d) added to a nonmedicated conventional MR (20% CP and 20% fat) or a nonmedicated intensified MR (28% CP and 20% fat). They reported no effect of feeding Lf on xylose absorption, whereas in the present study both 0.5 and 1 g/d of Lf had a negative impact on xylose absorption. This is contradictory to other studies in which Lf was observed to increase intestinal development in other species (Zhang et al., 2001; Humphrey et al., 2002). Zhang et al. (2001) fed milk from transgenic mouse dams to neonatal mice for 10 d. The milk from these mice had an Lf concentration of 12 mg/mL. They fed Lf at a much greater concentration and for a longer period of time than in the current study. Humphrey et al. (2002) observed greater villous height, better nutrient absorption, and greater feed efficiency in chicks when Lf was fed in combination with lysozyme. There was no effect on intestinal development when Lf was fed alone. These studies would indicate that if the small intestines of neonatal calves responded in the same way as the small intestines of the neonatal mice and chicks, then Lf would have to be fed at a much greater concentration or in conjunction with another component of maternal colostrum such as lysozyme.

The percentage of calves that attained successful passive transfer was greater in calves fed 2 doses of CR compared with calves fed 1 dose of CR. The study indicates that feeding calves 2 doses of CR is recommended to provide a margin of safety due to factors affecting absorption. The AEA of IgG in CR was not improved by Lf supplementation at the quantities fed. Lactoferrin supplementation did not increase xylose absorption in the calves fed at the quantities in the current experiment, suggesting intestinal development is not improved by Lf supplementation.

**LITERATURE CITED**


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