Addition of sodium bicarbonate to either 1 or 2 feedings of colostrum replacer: Effect on uptake and rate of absorption of immunoglobulin G in neonatal calves¹

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ABSTRACT

Forty Holstein dairy calves were blocked by birth date and sex, and randomly assigned to 1 of 4 treatments within each block to elucidate the effect of feeding regimen and sodium bicarbonate (NaHCO_3) supplementation on absorption of IgG from colostrum replacer (CR). Calves received CR containing 191.4 g of IgG fed either in 1 feeding at 0 h (within 45 min of birth), with or without 30 g of NaHCO_3 , or in 2 feedings (127.6 g of IgG at 0 h, with or without 20 g of NaHCO_3 , and 63.8 g of IgG at 6 h, with or without 10 g of NaHCO_3). The treatments were (1) 1 feeding of CR + 0 g of NaHCO_3 ; (2) 1 feeding of CR + 30 g of NaHCO_3 ; (3) 2 feedings of CR + 0 g of NaHCO_3 ; and (4) 2 feedings of CR + 30 g total of NaHCO_3 . Only calves born with no dystocia were used on this study. Blood samples were taken at 0, 6, 12, 18, and 24 h postpartum and were analyzed for IgG using a radial immunoassay. Results indicated that, individually, feeding regimen and NaHCO_3 treatments had no effect. However, the interaction was significant for 24-h IgG and area under the curve, and showed a trend for apparent efficiency of absorption. Absorption rate data indicated that, for calves fed within 45 min of birth, most IgG absorption occurred in the first 6 h after birth. From 6 to 12 h postpartum, IgG absorption started to decrease; however, IgG absorption remained higher for calves fed in a single feeding than in 2 feedings. These data indicated that NaHCO_3 may increase IgG absorption when calves are fed colostrum in a single feeding but is not beneficial when colostrum is fed in 2 feedings.

Key words: calf, colostrum replacer, immunoglobulin G, sodium bicarbonate

INTRODUCTION

The synepithelialchorial placenta in cattle prevents maternal Ig transfer to the fetus, resulting in hypogammaglobulinemia in the newborn calf. Calves receive the necessary Ig through the feeding of colostrum, which contains high concentrations of Ig, especially the IgG₁ subclass. The Ig is absorbed from the nutrient-dense colostrum through passive transfer, the success of which can affect the health and vitality of the calf (Butler, 1969). Macromolecular absorption in the neonate occurs within the first 24 h of life, after which the intestine is unable to passively absorb the large Ig molecule. It is, therefore, critical that the calf receive adequate colostrum before this process ceases. Maximizing the absorption of Ig during this time period may help to increase the health and longevity of the animal. Inadequate transfer of Ig has resulted in decreased gains, higher incidence of disease, and decreased milk production in the subsequent lactations (Smith and Foster, 2007; Beam et al., 2009). Morrill et al. (2010) successfully increased serum IgG concentrations in neonatal calves fed colostrum replacer (CR) through the supplementation of approximately 30 g of NaHCO_3 . However, Cabral et al. (2011) saw no benefit to NaHCO_3 supplementation at this level and a negative response in serum IgG concentration when 45 g of NaHCO_3 was added to CR. These researchers hypothesized that the discrepancies between the findings of the 2 studies was due to the feeding schedule. Morrill et al. (2010) fed the CR in 2 feedings at 0 and 6 h postpartum. Cabral et al. (2011) fed CR in a single feeding at 0 h. This experiment was designed as a hybrid of the 2 aforementioned studies. The objective of this study was to determine the effect of single versus split feeding of CR with or without supplemental NaHCO_3 on serum IgG concentrations, apparent efficiency of absorption,

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area under the curve (**AUC**), and rate of absorption of IgG.

MATERIALS AND METHODS

Experimental Design and Treatment Diets

This experiment was reviewed and approved by the University of New Hampshire Institutional Animal Care and Use Committee (Approval # 100906).

Forty Holstein calves born from multiparous and primiparous cows were used in this study. Calves were blocked by sex and birth date, and within each block, randomly assigned to 1 of 4 treatments. The treatments were (1) 1 feeding of CR + 0 g of NaHCO₃ (**C₁**); (2) 1 feeding of CR + 30 g of NaHCO₃ (**Na₁**); (3) 2 feedings of CR + 0 g of NaHCO₃ (**C₂**); and (4) 2 feedings of CR + 30 g total of NaHCO₃ (**Na₂**). Calves fed in a single feeding received CR containing 191.4 g of IgG at 0 h. Calves fed in 2 feedings of CR received 127.6 g of IgG, with or without 20 g of NaHCO₃, at 0 h and 63.8 g of IgG, with or without 10 g of NaHCO₃, at 6 h.

Within 30 min of birth, calves were removed from their dams, weighed, and their navels dipped in 7% iodine. Calves were then placed in a naturally ventilated, enclosed calf room and individually housed in pens bedded with kiln-dried sawdust where they remained for the duration of the study (24 h). Calves were assigned a dystocia score of 1 to 3 based on the difficulty of calving: 1 = unassisted calving, 2 = assisted easy calving, and 3 = assisted difficult calving. Only calves with a calving score of 1 or 2 were used in this study. All calves received a total of 3 sachets of Calf's Choice Total Gold (Saskatoon Colostrum Co., Saskatoon, Saskatchewan, Canada). The first feeding was fed at 0 h (within 45 min). If calves did not consume the CR, it was kept warm and reintroduced 1 h later. If the remaining colostrum was not consumed at this time, it was fed via esophageal tube to the calf.

Blood Collection for IgG Assay

Blood samples were collected into 7-mL Vacutainer tubes (Kendall International Inc., Mansfield, MA) via jugular venipuncture using a 22-gauge needle. Blood samples were taken at 0, 6, 12, 18, and 24 h of age. Samples at 0 h for all calves and 6 h for C₂ and Na₂ were collected before CR feeding. The blood was allowed to clot at room temperature (25°C) and then was centrifuged (CentraMP4R; International Equipment Co., Needham Heights, MA) at 1,310 × *g* at 25°C for 20 min. The serum was collected and stored at -20°C until analyzed for concentration of IgG by radial im-

munoassay (The Saskatoon Colostrum Co. Ltd., Saskatoon, SK, Canada).

The apparent efficiency of absorption (**AEA**) at 24 h of age was estimated using the equation [plasma IgG (g/L) × BW (kg) × 0.09/IgG intake] × 100% (Quigley and Drewry, 1998). The AUC was analyzed using the trapezoidal rule (Phillips and Taylor, 1973) with the equation 0.5 × difference in time × difference in IgG concentration. Rate of absorption was calculated using the slope equation $\Delta y/\Delta x$, where *y* = the difference in plasma IgG and *x* = the difference in time between sampling.

Statistical Analysis

Calf IgG was analyzed using the MIXED procedure of SAS (SAS Institute, 2004). The 24-h calf IgG, AEA, and AUC data were analyzed as a randomized complete block design using the MIXED procedure of SAS according to the following model:

$$Y_{ijk} = \mu + B_i + S_j + F_k + SF_{jk} + E_{ijk},$$

where Y_{ijk} = the dependent variable; μ = the overall mean; B_i = the random effect of block *i* (*i* = 1, . . . , 13); S_j = the fixed effect of the *j*th NaHCO₃ level (*j* = 0, 30); F_k = the fixed effect of the *k*th feeding method (*k* = 1 or 2); SF_{jk} = the fixed effect of the interaction between the *j*th NaHCO₃ level and *k*th feeding method; and E_{ijk} = the residual error, $\sim N(0, \sigma_e^2)$.

Degrees of freedom were calculated using the Satterthwaite option of the MIXED procedure of SAS. Least squares means were determined for each treatment and the PDIF option of SAS (SAS Institute, 2004) was selected to differentiate least squares means between treatments. Significant treatment effects were noted at $P \leq 0.05$ and trends were noted at $0.05 \leq P \leq 0.10$.

RESULTS

The initial BW of calves was similar among all treatments: 42.9 ± 6.3 kg for C₁, 42.4 ± 4.0 kg for Na₁, 40.9 ± 5.5 kg for C₂, and 40.9 ± 5.7 kg for Na₂ (Table 1). The mean initial IgG concentration was 0.03 g/L. Two of the 40 calves in the study did not attain adequate passive transfer: 1 on the C₁ treatment and the other on the Na₁ treatment. The calf on the Na₁ treatment was found to be an outlier and was removed from use in statistical analyses.

Sodium bicarbonate alone did not affect any parameters measured in this experiment. Feeding regimen alone did not affect any parameters measured, except

Table 1. Mean initial BW, 24-h serum IgG concentrations, apparent efficiency of absorption (AEA), area under the curve (AUC), and rates of absorption

Item	Treatment				SE	Contrast (<i>P</i> -value)		
	1 feeding		2 feedings			Feeding	NaHCO ₃	Interaction
	0 ¹	30 ¹	0	30				
BW (kg)	42.9	42.4	40.9	40.9				
24-h IgG (g/L)	15.8	16.9	16.8	15.0	0.85	0.29	0.11	0.02
Highest	19.6	20.4	18.4	18.4				
Lowest	8.3	11.4	14.2	11.7				
AEA ² (%)	32.1	35.5	32.8	29.4	1.9	0.13	0.99	0.06
AUC ³ (g/L·h)	295.4	309.0	313.4	261.5	15.2	0.29	0.18	0.02
Hourly rate (g/L)								
0–6	1.37	1.46	1.67	1.27	0.16	0.73	0.31	0.11
6–12	1.30	1.21	1.04	0.94	0.13	0.05	0.47	0.97
12–18	0.04	0.05	0.08	0.21	0.10	0.31	0.46	0.53
18–24	−0.11	0.00	−0.03	0.05	0.07	0.33	0.15	0.80

¹Refers to calves receiving either 0 or 30 g of NaHCO₃.

²AEA = [plasma IgG (g/L) × BW (kg) × 0.09/IgG intake] × 100% (Quigley and Drewry, 1998).

³AUC = 0.5 × difference in time × difference in IgG concentration (Phillips and Taylor, 1973).

for rate of absorption between 6 and 12 h where the rate of absorption for the single feeding was greater than that of the 2 × feeding ($P = 0.05$; Table 1). The rate of IgG absorption data indicated that the greatest amount of absorption occurred from 0 to 6 h, decreased slightly from 6 to 12 h, almost ceased from 12 to 18 h, and became insignificant from 18 to 24 h (Table 1).

Though, individually, NaHCO₃ and feeding treatments were similar, the NaHCO₃ × feeding interaction was significant for 24-h serum IgG concentration and AUC ($P = 0.02$) and showed a trend for AEA ($P = 0.06$; Table 1 and Figure 1). The AUC and 24-h serum IgG concentrations were highest for calves on the Na₁ treatment and lowest for calves on the Na₂ treatment ($P = 0.2$). The AEA tended to be higher for the Na₁ treatment compared with the Na₂ treatment ($P = 0.06$).

DISCUSSION

The rate of IgG absorption data in this study agree with data published by Stott et al. (1979), which indicated that the rate of absorption is highest during the first 4 h after feeding. These researchers hypothesized that macromolecular transport of IgG from the lumen to circulation is affected by timing and amount of colostrum fed. Their data indicates that it is the timing after colostrum ingestion and not necessarily age of the calf that has the greatest effect on absorption and by 12 h after initial feeding, absorption was negligible. Our data are in agreement, as greatest IgG absorption occurred after the first feeding of colostrum, decreased slightly from 6 to 12 h, and decreased substantially thereafter. Stott et al. (1979) attributed the decreased rate of absorption post-ingestion of colostrum to the

pinocytotic activity having been exhausted after contact with the colostral nutrients. This could explain the decreased rate of absorption for the 6-h feeding of colostrum seen in the C₂ and Na₂ treatments ($P = 0.05$; Table 1).

This experiment was designed as a hybrid of 2 studies previously completed in this laboratory, performed by Morrill et al. (2010) and Cabral et al. (2011). The results of the aforementioned studies differed and it was hypothesized that the discrepancy was due to differences in feeding schedule (1 vs. 2 feedings of CR). Consequentially, this study was developed to test the effect of NaHCO₃ on IgG uptake from CR in calves fed in either 1 or 2 feedings.

Immunoglobulin G concentration at 24 h and AUC data indicate that, individually, feeding and NaHCO₃ supplementation have no effect; however, there was an interaction ($P = 0.02$; Table 1). Serum IgG concentrations were highest for calves on treatments Na₁ and C₂ (16.8 and 16.9 g/L, respectively) and lowest for calves on the Na₂ and C₁ treatments (15.0 and 15.8 g/L, respectively). The AUC demonstrated the same result being highest in the Na₁ and C₂ calves and lowest in Na₂ and C₁ calves (Table 1 and Figure 1). These results indicate that calves fed CR in a single feeding may benefit from 30 g of supplemental NaHCO₃; however, if fed the same amount of CR in a split feeding, the NaHCO₃ is not beneficial. This outcome contrasts with previous work from our laboratory where varying doses of NaHCO₃ were fed in a single feeding of CR to neonatal calves (Cabral et al., 2011). Overall, a trend was observed for a linear decrease in IgG absorption and AUC, indicating a negative linear response for calves receiving increasing doses of NaHCO₃, and at 24 h,

Figure 1. Serum IgG concentrations for calves fed 1 feeding of colostrum replacer (CR; C₁), 1 feeding of CR with NaHCO₃ (NA₁), 2 feedings of CR (C₂), or 2 feedings of CR with NaHCO₃ (NA₂).

calves fed 30 g of NaHCO₃ in CR had serum IgG concentrations averaging 17.2 g/L, which was not different from control calves. In contrast, in the current study, the data indicates a benefit to adding NaHCO₃ to CR if a single feeding is administered. However, when the CR is fed divided into 2 feedings, addition of NaHCO₃ showed no benefit.

Serum IgG concentrations at 24 h for C₂ and NA₂ calves were 16.8 and 15.0, respectively (Table 1 and Figure 1). The AUC was 313.4 and 261.5 g/L × h for C₂ and NA₂ calves, respectively. Morrill et al. (2010) found that feeding calves CR in a split feeding with NaHCO₃ increased serum IgG concentrations at 24 h ($P = 0.01$) and the AUC ($P = 0.04$). The protocol for calf care between studies was identical except that Morrill et al. (2010) provided milk replacer (MR) to calves 6 h after final CR feeding and again at 24, 36, and 48 h after birth. Because of the short duration of our study, no MR was provided to calves until they exited the study at 24 h of age. Although the mechanism of the effect is unknown, the feeding of MR shortly after the final feeding of CR may be the cause for the discrepancies between studies. Overall, serum IgG concentrations reported by Morrill et al. (2010) were lower than concentrations seen in our study, which could also be an effect of the MR, as the nonimmunoglobulin milk proteins may have diminished IgG absorption (Besser

and Osborn, 1993). Addition of NaHCO₃ may have altered intestinal pH, therefore changing the functionality of enzyme proteins. The change in enzyme function could be the cause for the difference in IgG absorption between treatments.

The AEA showed a trend for an interaction and was highest in the NA₁ treatment and lowest in the NA₂ (35.5 and 29.4%, respectively; Table 1). Morrill et al. (2010) saw an increase in the AEA for calves receiving supplemental NaHCO₃ ($P = 0.02$); however, our data indicate no benefit of supplemental NaHCO₃ on the AEA of calves fed in a split feeding of CR. Cabral et al. (2011) observed a negative linear effect with increasing dosages of NaHCO₃ added to a single feeding of CR ($P = 0.05$). Discrepancies between the current study and the results reported by the aforementioned researchers may be due differences in feeding protocols including the feeding of MR.

CONCLUSIONS

The merits of feeding 1 versus 2 feedings of colostrum or CR and those of addition of NaHCO₃ to the CR are conflicting. Jaster (2005) suggests that feeding colostrum split into 2 feedings, especially for smaller breeds of dairy cattle, may improve the AEA. However, other studies report no difference in the AEA or 24-h serum

IgG concentrations when Holstein calves are fed either a single or split feeding of colostrum (Hopkins and Quigley, 1997). Calves fed a single feeding of CR benefitted from the addition of 30 g of NaHCO_3 ; however, calves fed the same amount of CR in a split feeding did not benefit. Future research should focus on the effects of MR fed in the first 24 h on absorption of IgG from colostrum and the effects that NaHCO_3 may have on the gastrointestinal tract of the neonate.

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