Colostrum replacer feeding regimen, addition of sodium bicarbonate, and milk replacer: The combined effects on absorptive efficiency of immunoglobulin G in neonatal calves

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ABSTRACT

Eighty Holstein and Holstein cross dairy calves were blocked by birth date and randomly assigned to 1 of 8 treatments within each block to examine the effect of a colostrum replacer (CR) feeding regimen, supplementation of CR with sodium bicarbonate (NaHCO_3), and provision of a milk replacer (MR) feeding on IgG absorption. Calves were offered a CR containing 184.5 g/L of IgG in either 1 feeding at 0 h (within 30 min of birth), with or without 30 g of NaHCO_3 , with or without a feeding of MR at 6 h of age, or 2 feedings of CR (123 g of IgG at 0 h with or without 20 g of NaHCO_3 and 61.5 g of IgG at 6 h with or without 10 g of NaHCO_3), with or without a MR feeding at 12 h. Therefore, treatments were (1) 1 feeding of CR; (2) 2 feedings of CR; (3) 1 feeding of CR + 30 g of NaHCO_3 ; (4) 2 feedings of CR + 30 g of NaHCO_3 ; (5) 1 feeding of CR + MR feeding; (6) 2 feedings of CR + MR feeding; (7) 1 feeding of CR + 30 g NaHCO_3 + MR feeding; and (8) 2 feedings of CR + 30 g NaHCO_3 + MR feeding. Blood samples were obtained at 0, 6, 12, 18, and 24 h after birth and were analyzed for IgG via radial immunoassay. Results indicated that CR feeding schedule, MR feeding, and the interactions CR $\times$ Na, CR $\times$ MR, and CR $\times$ Na $\times$ MR were similar for 24-h serum IgG, apparent efficiency of absorption, or area under the curve. Serum IgG at 24 h, apparent efficiency of absorption, and area under the curve were decreased with addition of NaHCO_3 compared with calves not supplemented with NaHCO_3 . These data indicate that supplementation of CR with NaHCO_3 is not beneficial to IgG absorption and feeding MR within 6 h of CR feeding does not affect IgG absorption.

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

INTRODUCTION

Whereas optimal feeding and management of the neonatal calf is an enigma, colostrum is undoubtedly critical to ensure neonatal calf survival. Quality, pathogen-free colostrum is needed to establish protective serum concentrations of IgG and to provide necessary fat and other nutrients for thermogenesis and digestive tract development. However, approximately 60% of colostrum produced on US dairy farms does not meet the suggested minimum standard of 50 g/L of IgG and <100,000 cfu/mL of bacteria (Morrill et al., 2012). Colostrum replacement (**CR**) products were developed to reduce disease transfer in calves and provide IgG and nutrients that may be lacking in poor quality or quantity colostrum.

As calves are often fed their entire mass of colostrum in a single feeding soon after birth, these animals need to receive a subsequent feeding of milk or milk replacer (**MR**) within a few hours of the colostrum ingestion. No studies exist demonstrating the effect of noncolostral feedings on the absorption of IgG when fed within the first day of life. However, concern that this may negatively affect IgG absorption exists, as Besser and Osborn (1993) observed that calves fed colostrum supplemented with additional colostral whey and BSA experienced a reduction in efficiency of IgG absorption. Davenport et al. (2000) conducted 2 experiments utilizing whey protein concentrate and casein as colostrum supplements. The authors concluded that addition of whey protein concentrate had little effect on IgG absorption in the calf; however, large amounts of casein may reduce IgG absorption from colostrum supplements. The effect of nonconcurrent feeding milk or MR in the first day of life has not been investigated in terms of effect on serum IgG concentrations.

Previous studies have demonstrated that feeding 30 g of sodium bicarbonate (NaHCO_3) with lacteal-based CR may increase 24-h serum IgG concentrations, apparent efficiency of absorption (**AEA**), area under the curve (**AUC**; Morrill et al., 2010; Cabral et al., 2012), and rates of IgG absorption (Cabral et al., 2012),

Received May 7, 2013.

Accepted January 5, 2014.

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whereas other studies have failed to support some or all of these findings (Cabral et al., 2011, 2012). The objective of the current study was to further investigate the merits of adding NaHCO_3 to CR, to examine the role of feeding regimen on that effect, and to determine if feeding MR within the first day of life affects IgG absorption from CR.

MATERIALS AND METHODS

Experimental Design and Treatment Diets

The current experiment was reviewed and approved by the University of New Hampshire Institutional Animal Care and Use Committee (#120202). It was conducted at a commercial dairy in Lancaster, New Hampshire, using 80 Holstein and Holstein-cross calves born from multiparous and primiparous cows. Calves were assigned to 1 of 8 treatments: (1) 1 feeding of CR; (2) 2 feedings of CR; (3) 1 feeding of CR and 30 g of NaHCO_3 ; (4) 2 feedings of CR and 30 g of NaHCO_3 ; (5) 1 feeding of CR and MR feeding; (6) 2 feedings of CR and MR feeding; (7) 1 feeding of CR, 30 g NaHCO_3 , and MR feeding; and (8) 2 feedings of CR, 30 g NaHCO_3 , and MR feeding. Calves fed a single feeding of CR received the total dose at 0 h. Calves assigned to 2 feedings of CR received two-thirds of the total CR dose at 0 h and the remaining one-third of CR at 6 h. Calves receiving NaHCO_3 were dosed in the CR, with 30 g incorporated into the CR for calves on the single feeding of colostrum and 20 g of the NaHCO_3 mixed into the initial CR feeding and the remaining 10 g in the second CR feeding for calves receiving 2 feedings. Calves on treatments providing MR were fed MR at 6 h of age for the single-CR feeding groups or 12 h of age for the 2-CR feedings groups.

Calves were removed from dams within 15 min of birth, weighed, and had their navels dipped with a 7% tincture of iodine. Calves were initially group housed in a sawdust-bedded pen (2 × 3 m) then moved to individual sawdust-bedded calf pens (1 × 2.15 m) at 12 h of age for the remainder of the experiment. All calves received 3 sachets of Calf's Choice Total Gold CR containing a total IgG mass of 184.5 g reconstituted according to the manufacturer's instructions to a final volume of 3 L (The Saskatoon Colostrum Co., Saskatoon, Canada). One sachet of product contains 225 g of powder; therefore, calves received a total amount of 675 g of powder. Assuming 95% DM, each calf received 641 g of solids with a final volume of 3 L; total solids equals approximately 21%, which is similar to maternal colostrum. Osmolality of CR and CR + NaHCO_3 was measured using an osmometer (Advanced Instruments Model 3D3, Norwood, MA). The first feeding of CR

was given at 0 h (within 30 min). Calves receiving an MR feeding were provided nonmedicated all-milk MR (227 g; Blue Seal Feeds Inc., Londonderry, NH), which was reconstituted with 2 L of water. Calves were fed by nipple bottle. If the calf did not consume the entire volume of CR or MR, it was administered via esophageal tube to ensure the total dose was received.

Blood Collection for Hematocrit and IgG Assay

Blood samples obtained for IgG analysis were collected into 7-mL Vacutainer tubes (Kendall, Mansfield, MA) via jugular venipuncture using a 22-gauge needle. Blood samples were taken at 0, 6, 12, 18, and 24 h of age. Blood samples were taken immediately before CR or MR feeding. Blood samples for IgG analysis were refrigerated until centrifugation (CentraMP4R; International Equipment Company, Needham Heights, MA) at $1,310 \times g$ at 25°C for 20 min (within 2 d of collection). The serum was harvested and stored at -20°C until analyzed for IgG concentration by radial immunoassay (The Saskatoon Colostrum Co. Ltd.). A subsample was obtained for evaluation of packed cell volume. Capillary tubes were centrifuged (Haematokrit 210; Andreas Hettich GmbH and Co., Tuttlingen, Germany) at $16,800 \times g$ at 25°C for 5 min.

Apparent efficiency of absorption at 24 h of age was estimated using $[\text{plasma IgG (g/L)} \times \text{BW (kg)} \times 0.09 / \text{IgG mass consumed (g)}] \times 100\%$ (Quigley and Drewry, 1998). Area under the curve for plasma IgG was analyzed using the trapezoidal rule (Phillips and Taylor, 1973) by $0.5 \times \text{difference in time} \times \text{difference in IgG concentration}$.

Statistical Analysis

Using the mixed procedure of SAS (Version 9.2; SAS Institute Inc., Cary, NC), 24-h serum IgG, hematocrit, AEA, and AUC data were analyzed as a randomized complete block design with a $2 \times 2 \times 2$ factorial arrangement of treatments according to

$$Y_{ijk} = \mu + B_i + C_j + S_k + M_l + CS_{jk} + CM_{jl} \\ + SM_{kl} + CSM_{jkl} + E_{ijkl},$$

where Y = the dependent variable; μ = the overall mean; B_i = the random effect of block i ($i = 1, \dots, 10$); C_j = the fixed effect of the j th CR feeding regimen ($j = 1, 2$); S_k = the fixed effect of the k th NaHCO_3 level ($k = 0, 30$); M_l = the fixed effect of the l th MR feeding ($l = 0, 1$); CS_{jk} = the fixed effect of the interaction between the j th CR feeding regimen and the k th NaHCO_3 level; CM_{jl} = the fixed effect of the interaction between the

Table 1. Mean BW, 24-h IgG, apparent efficiency of absorption (AEA), area under the curve (AUC), and hematocrit (HEM) across all treatments¹

Item	Treatment 1				Treatment 2				Contrast ($P =$)				
	0 g		30 g		0 g		30 g		SE	Colostrum replacer (CR)	Na	Milk replacer (MR)	CR $\times$ Na $\times$ MR
	0 L	2 L	0 L	2 L	0 L	2 L	0 L	2 L					
BW $\pm$ SD (kg)	37 $\pm$ 7	41 $\pm$ 6	40 $\pm$ 6	38 $\pm$ 5	39 $\pm$ 5	40 $\pm$ 9	40 $\pm$ 4	40 $\pm$ 5					
IgG (g/L)	15.9	16.2	12.9	12.7	16.5	15.8	11.9	13.0	0.9	0.84	<0.0001	0.84	0.38
AEA ² (%)	31.3	29.9	24.3	24.5	33.7	29.4	24.6	25.8	2.2	0.54	0.0002	0.48	0.53
AUC ³ (g/L·h)	326.9	296.6	215.1	247.1	340.7	293.9	243.4	241.1	22.1	0.56	<0.0001	0.44	0.78
HEM (%)	28.7	33.3	34.2	34.9	32.9	33.5	32.7	29.7	2.1	0.69	0.61	0.63	0.94

¹Treatment 1 = colostrum replacer fed all at the initial feeding; treatment 2 = two-thirds colostrum replacer fed at birth and one-third fed 6 h later; in each group, calves were fed either 0 or 30 g of sodium bicarbonate; and calves were fed either no milk replacer or 2 L of milk replacer at 6 h after the last feeding of colostrum replacer.

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

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

j th CR feeding regimen and the l th MR feeding; SM_{kl} = the fixed effect of the interaction between the k th NaHCO_3 level and the l th MR feeding; CSM_{jkl} = the fixed effect of the interaction between the j th CR feeding regimen, the k th NaHCO_3 level, and the l th MR feeding; and E_{ijkl} = the residual error $\sim N(0, \sigma^2_e)$.

Degrees of freedom were calculated using the kenward-rogers option of the MIXED procedure of SAS. Least squares means were determined for each treatment and the PDIF option of SAS was selected to differentiate least squares means between treatments. Calves were placed in blocks based on when they were born. Treatments administered to calves were randomized within each block of 8 calves. Significant treatment effects were noted at $P < 0.05$.

RESULTS

Body weight, IgG, and hematocrit data are presented in Table 1. The osmolality of the CR and the CR and NaHCO_3 was 301 and 516 mOsm, respectively. The osmolality of the CR was similar to blood, which has an osmolality of 300 mOsm. Mean precolostral serum IgG concentrations were not different among treatments, ranging from 0.41 to 0.74 g/L. Seven calves did not attain adequate passive transfer (defined as serum IgG < 10 g/L): 1 calf receiving 1 CR and MR (9.8 g/L); 2 calves receiving 1 CR and 30 g of NaHCO_3 (8.4 and 8.6 g/L); 1 calf receiving 1 CR, 30 g of NaHCO_3 , and 1 MR (7.2 g/L); 1 calf receiving 2 CR and 1 MR (9.7 g/L); and 2 calves receiving 2 CR and 30 g of NaHCO_3 (7.7 and 9.3 g/L). Several calves were fed some of the treatment(s) via esophageal tube (Table 2), though tube feeding did not affect IgG absorption in the calf. Colostrum replacer feeding regimen, MR treatments, and the interactions CR $\times$ Na, CR $\times$ MR, and CR $\times$

Na $\times$ MR were not different for 24-h serum IgG, AEA, or AUC. Serum IgG at 24 h was decreased ($P < 0.0001$) with addition of NaHCO_3 compared with calves not receiving NaHCO_3 (12.61 and 16.08 g/L, respectively; Figure 1). Addition of NaHCO_3 also decreased AEA ($P = 0.002$) compared with calves not receiving NaHCO_3 (31.1 and 24.8%, respectively) and AUC ($P < 0.0001$; 314.5 and 236.1 g/L·h, respectively) compared with calves not receiving NaHCO_3 . No effect of CR feeding, NaHCO_3 supplementation, or MR provision on hematocrit was observed.

DISCUSSION

Colostrum replacer feeding regimen (delivery of the colostrum in 1 vs. 2 feedings) did not affect 24-h serum IgG, AEA, or AUC, which is in agreement with Hopkins and Quigley (1997) but in disagreement with Jaster (2005), who reported higher ($P < 0.05$) 24-h serum IgG concentrations in calves fed a split feeding of colostrum at 0 and 12 h postpartum. The discrepancy between the results may be due to the breed differences, as the current study and that of Hopkins and Quigley (1997) used Holstein and Holstein crosses (only in the current study), whereas Jaster (2005) used the lower-BW Jersey calves. Milk replacer needed to be fed via esophageal feeder to many calves assigned to those respective treatments, which may have been an effect of the large volume of CR fed previously.

Results have been inconsistent in relation to the effect of supplementation of NaHCO_3 in CR. Morrill et al. (2010) fed CR in 2 feedings, providing 132 g of IgG $\pm$ 20 g of NaHCO_3 at the first feeding and 66 g of IgG $\pm$ 10 g of NaHCO_3 at the second feeding. Serum IgG concentrations were higher ($P < 0.05$) for calves receiving supplemental NaHCO_3 in CR compared with

Table 2. Number of calves provided treatment(s) via esophageal tube

Treatment ¹	Feeding ²		
	1 ³	2 ³	MR ³
C ₁	2	—	—
C ₁ MR	0	—	7
Na ₁	1	—	—
Na ₁ MR	2	—	7
C ₂	1	5	—
C ₂ MR	3	4	6
Na ₂	2	3	—
Na ₂ MR	3	7	8

¹C₁ = 1 feeding of colostrum replacer (CR); C₁MR = 1 feeding of CR + milk replacer (MR) feeding; Na₁ = 1 feeding of CR + 30 g of NaHCO₃; Na₁MR = 1 feeding of CR + 30 g NaHCO₃ + MR feeding; C₂ = 2 feedings of CR; C₂MR = 2 feedings of CR + MR feeding; Na₂ = 2 feedings of CR + 30 g of NaHCO₃; Na₂MR = 2 feedings of CR + 30 g NaHCO₃ + MR feeding.

²Assigned treatment feedings.

³1 = first feeding of colostrum replacer; 2 = second feeding of colostrum replacer; MR = milk replacer feeding.

control calves (16.3 vs. 13.2 g/L). Cabral et al. (2011) studied graded doses of NaHCO₃ (0, 15, 30, or 45 g) in a single feeding of CR containing 200 g of IgG fed at 0 h. Though no effect of the 2 lower doses of NaHCO₃ was noted, a trend was observed for a negative response

among the highest dosage of NaHCO₃ with 24-h serum IgG concentrations of 16.9, 16.0, 17.2, and 14.5 g/L for the 0-, 15-, 30-, and 45-g treatments, respectively. Because the serum IgG concentrations were similar between the control and 30-g treatments, researchers suggested feeding the CR in a single dose and not a split feeding (Morrill et al. 2010) caused the absorptive capacity of the intestine to be saturated, therefore a benefit to the addition of NaHCO₃ could not be realized.

Mechanisms relating to changes in pH and osmolality may explain the discrepancies between the current and aforementioned studies. The Fc receptor (**FcRn**) has not been observed on the luminal side of the neonatal bovine intestine; however, in rats, the FcRn mediates the transport of IgG across fetal or neonatal tissues for the acquisition of passive immunity. The FcRn binds to IgG with nanomolar affinity at pH 6, but shows no detectable binding at 7.5. Vaughn and Bjorkman (1997) reported that the pH dependence of FcRn stability and affinity for IgG can be attributed to electrostatic interactions involving histidine residues, which are more favorable for the protonated form of histidine that predominates in an acidic state. The presence of FcRn on the basal side of the calf epithelium has been observed.

Figure 1. Serum IgG concentrations over 24 h for calves fed either 1 feeding of colostrum replacer (C₁); 2 feedings of colostrum replacer (C₂); 1 feeding of colostrum replacer + 30 g of NaHCO₃ (Na₁); 2 feedings of colostrum replacer + 30 g of NaHCO₃ (Na₂); 1 feeding of colostrum replacer + milk replacer feeding (C₁MR); 2 feedings of colostrum replacer + milk replacer feeding (C₂MR); 1 feedings of colostrum replacer + 30 g NaHCO₃ + milk replacer feeding (Na₁MR); or 2 feedings of colostrum replacer + 30 g NaHCO₃ + milk replacer feeding (Na₂MR). Color version available in the online PDF.

The FcRn is believed to play a role in the maintenance of circulating IgG. Though no data indicates that pH effects the FcRn on the basal portion, it is possible that its response is pH-dependent, as in the luminal FcRn. Cabral et al. (2011) reported increases in AUC for serum bicarbonate with increasing dosage of NaHCO₃; therefore, blood pH may have been affected by the NaHCO₃ treatment in the current study, affecting FcRn activity on the basal side. The IgG absorption may not have been affected by the NaHCO₃ treatment, but the maintenance of the IgG in the circulation may have been affected by treatment. Consequentially, a follow-up study was conducted to test the effect of feeding regimen on the effect of NaHCO₃ on IgG absorption. Calves were fed either a single feeding or 2 split feedings of CR $\pm$ 30 g of NaHCO₃. In contrast to previous findings, the results of that study indicated that when calves were fed a single feeding of CR, supplemental NaHCO₃ was beneficial to IgG absorption; however, if the CR was split into 2 feedings, NaHCO₃ was not beneficial (Cabral et al., 2012). One variable possibly affecting the disparity in these outcomes was whether a confounding effect was present due to the feeding of MR following the CR feeding(s) in the latter study (Cabral et al., 2012).

An in vitro study was conducted using CR and a CR with 30 g of NaHCO₃. Aliquots of each product were treated with a solution containing HCl and protease designed to be similar to the abomasal secretions of a neonate (pH 5.3). Addition of the acid solution to the CR and NaHCO₃ product caused rapid clot formation, whereas the CR solution was much slower to clot (no statistical analyses were conducted). The swift clot formation in the CR and NaHCO₃ suggested that adding NaHCO₃ to a CR enhanced clot development in the abomasum (P. S. Erickson, unpublished data). Cruywagen (1990) collected colostrum and divided it into coagulable (untreated) and noncoagulable (treated with oxalic acid and NaOH). Calves fed coagulable colostrum had 6-h plasma IgG concentrations almost twice that of noncoagulable colostrum-fed calves ($P < 0.05$). Results suggest that coagulation of colostrum in the abomasum aids in IgG absorption by the neonate. Coagulation of casein appears to improve IgG absorption in neonatal calves, as excessive amounts of casein added to a colostrum supplement decreased AEA of IgG (Davenport et al., 2000).

Whereas coagulation of casein as a result of added NaHCO₃ may be beneficial to IgG absorption, the changes in osmolality may have affected rate of passage out of the abomasum thus negating these possible benefits. Osmolality was increased by 215 mOsm/L with the addition of NaHCO₃. Increases in osmolality may slow abomasal emptying rate (Constable et al., 2009),

which could depress IgG absorption. Mokhber-Dezfooli et al. (2012) demonstrated that decreasing abomasal emptying rate resulted in a decrease in AEA, whereas increasing abomasal emptying rate resulted in an increase in AEA. Slowed emptying of the abomasum may delay IgG from reaching absorptive sites, leading to a decrease in uptake due to the finite period of time in which absorption occurs.

The current experiment was designed in response to the previous studies conducted by Morrill et al. (2010) and Cabral et al. (2011, 2012) to determine the effect of NaHCO₃ supplementation taking into account CR feeding regimen and the effect of feeding an MR 6 h after the final CR feeding. In the current experiment, addition of NaHCO₃ decreased 24-h serum IgG concentration, AEA, and AUC. The negative effect of NaHCO₃ on IgG absorption may have been caused by alkalosis. Though the calf care protocol was similar to the previous experiments, the current study was performed at a commercial dairy farm in New Hampshire and not the university facility.

Cows on this farm were possibly in an alkalotic state due to the observation that many of the dams of calves used in this study experienced hypocalcemia. An alkalotic diet fed prepartum can result in cows with hypocalcemia due to disruption of parathyroid hormone and vitamin D function. Because the maternal and fetal circulation is shared, both dam and fetus may have been in a metabolic alkalotic state. If this were the case, addition of NaHCO₃ to CR fed to the neonatal calf may have exacerbated the alkalosis, affecting the absorptive ability of the intestine for IgG. The calf may also have suffered from low blood calcium, as in the dam, which would affect smooth muscle contraction, possibly impairing peristalsis, therefore affecting IgG absorption via slowed progression of CR through the gastrointestinal tract.

Cabral et al. (2011) indicated that the AUC for serum bicarbonate increased linearly with increased dietary levels of NaHCO₃. Elevated serum bicarbonate concentrations can be associated with metabolic alkalosis or as a compensation for acidosis (Stockham and Scott, 2008). Though serum bicarbonate concentrations were not analyzed in the current experiment, it is possible that concentrations may have been elevated in these calves causing the negative effects associated with addition of NaHCO₃. In comparing the IgG levels attained in the calves in the control and 45-g NaHCO₃ treatment from Cabral et al. (2011) and in the 0- and 30-g NaHCO₃ treatments of the current study, some similarities are apparent. The control groups in the studies attained similar IgG levels (17 and 16 g/L, respectively); the 45-g treatment of Cabral et al. (2011) and the 30-g treatment of the current study had lower

values of 15 and 13 g/L, respectively. The decrease in IgG absorption associated with NaHCO_3 administration is similar in both studies and supports the theory that metabolic alkalosis may have been occurring in the calves used in the current experiment, as previously described (Cabral et al. 2011).

The effect of feeding MR following CR was added as a treatment due to the differences in 24-h serum IgG between the control calves in the Morrill et al. (2010) and the Cabral et al. (2012) studies. Despite delivery of a similar mass of IgG in a similar feeding program, the serum IgG concentrations were 3.8 g/L higher in the calves in the latter experiment. A difference in the treatment of these calves was the provision of MR at 12 h in the former study. Cabral et al. (2012) hypothesized that the lower serum IgG concentrations reported in the Morrill et al. (2010) study may have been a result of the provision of MR shortly after CR feeding. Besser and Osborn (1993) observed that addition of nonimmunoglobulin proteins to colostrum whey diminished IgG absorption by 23%. However, in the current study, feeding MR 6 h after the final feeding of CR did not affect serum IgG concentration, AEA, or AUC. The difference in outcome between the current study and that of Besser and Osborn (1993) may be due to the nonimmunoglobulin protein being incorporated at different times (6 h after CR feeding vs. concurrent feeding, respectively).

CONCLUSIONS

Supplementation of CR with NaHCO_3 decreased IgG absorption in the current study, which is in contrast to some previous work that indicated that NaHCO_3 may be beneficial under certain circumstances (Morrill et al., 2010; Cabral et al., 2011, 2012). Feeding relatively large volumes (3 L) of CR of standardized IgG mass (>180 g) in either 1 or 2 feedings had no effect on IgG absorption in Holstein and Holstein cross dairy calves. Feeding of MR 6 h after the final CR feeding did not affect IgG absorption. Whereas the present study did not demonstrate that the supplementation of CR with NaHCO_3 provided predictable or reliable benefits, it was useful to demonstrate that no effect of either split feeding of the CR or follow-up feeding with MR was observed. Future research on this subject should further examine the effect of osmolality on IgG absorption, and the effect of prepartum nutrition of the dam and the possibility that this affects the absorptive efficiency of IgG in the calf.

ACKNOWLEDGMENTS

Partial funding was provided by the New Hampshire Agricultural Experiment Station and the University

of Saskatchewan. This project was supported by the Multi-State Hatch NH00512-R (NC-1042). This is Scientific Contribution number 2510 of the New Hampshire Agricultural Experiment Station. The authors thank Saskatoon Colostrum Company Ltd. (Saskatoon, Canada) for the donation of colostrum replacer and conducting the IgG assays. We also thank the owners and farm crew of Forbes Dairy (Lancaster, New Hampshire) for allowing the use of their calves and for their assistance throughout the study, and Win Watson (Department of Biological Sciences, University of New Hampshire, Durham) for help with the osmometer.

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