Effects of Method of Colostrum Feeding and Colostrum Supplementation on Concentrations of Immunoglobulin G in the Serum of Neonatal Calves

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ABSTRACT

Holstein heifer and bull calves (n = 52) at Ames Plantation (Grand Junction, TN) and Piedmont Research Station (Salisbury, NC) were blocked by sex and assigned randomly to receive 3.8 L of maternal colostrum in one feeding, 1.9 L in two feedings at a 10- to 12-h interval, or 1.9 L in two feedings at a 10- to 12-h interval plus 272 g of colostrum supplement at the first feeding. The colostrum supplement was mixed with 0.95 L of warm water and fed immediately following colostrum. Serum immunoglobulin G (IgG) concentrations were unaffected by the number of feedings and averaged 20.0 and 16.6 g/L at 24 and 48 h, respectively. Calves that were fed the colostrum supplement at the first feeding had lower serum IgG concentrations at 24 h (16.0 g/L) than did calves that were fed two colostrum feedings without supplementation (21.0 g/L); however, serum IgG concentrations at 48 h did not differ among treatments. Dry matter intake and body weight gain were unaffected by feeding method. Calves may be fed high quality colostrum in one or two feedings without affecting IgG absorption.
(**Key words**: calves, immunoglobulin, colostrum)

Abbreviation key: **1X** = 3.8 L of maternal colostrum in one feeding, **2X** = 3.8 L of maternal colostrum in two feedings at a 10- to 12-h interval, **2X+** = 2X plus 272 g of colostrum supplement at the first feeding, **NC** = Salisbury, North Carolina, **TN** = Grand Junction, Tennessee.

INTRODUCTION

Calves are born hypoglobulinemic or agammaglobulinemic (6); therefore, absorption of adequate amounts of Ig from colostrum prior to cessation of macromolecular transport by the intestine is essential for calves to acquire passive immunity. Factors that influence passive transfer of Ig include age of the calf at first feeding and the mass of Ig ingested (4, 6, 13, 14, 15, 16). When a fixed volume of colostrum is fed to neonatal calves, the concentration of Ig in colostrum markedly affects Ig absorption. Increased amounts of colostrum (up to 2 L) generally increased serum IgG concentration (15). However, Stott and Fellah (13) reported that the Ig in 1 L of colostrum was absorbed more efficiently than an equivalent mass of Ig in 2 L of colostrum when IgG concentration was >20 g/L. When IgG concentration was <20 g/L, efficiency of absorption of Ig was unaffected by Ig concentration in colostrum.

The concentration of Ig in colostrum that is obtained at the first milking may be inadequate to ensure transfer of an adequate mass of Ig when ≤2 L are fed. Besser et al. (3) suggested that failure of passive transfer in dairy herds could be minimized by artificially feeding calves large volumes (3 to 4 L) of fresh or refrigerated colostrum within the first 24 h of life. Whether absorption of Ig in calves is affected by offering a similar volume of colostrum in one or two feedings is not clear. Halliday and Williams (7) reported that one feeding of colostrum to lambs reduced efficiency of absorption compared with two feedings at 6 h apart. Increased serum IgG concentration was attributed to improved absorption of the first feeding of colostrum as a result of the second feeding (7). Increasing the Ig concentration in maternal colostrum may be possible by the addition of supplements containing Ig from colostrum, thereby alleviating the need to feed a large amount of colostrum.

The objectives of this study were to determine whether 3.8 L of colostrum in one feeding or divided into two equal feedings influenced serum IgG concentrations at 24 h of age and whether addition of colostrum supplement to maternal colostrum affected serum IgG concentration and efficiency of IgG absorption.

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MATERIALS AND METHODS

Twenty-nine Holstein heifer (n = 14) and bull calves at Ames Plantation [Grand Junction, Tennessee (**TN**) and 23 Holstein heifer (n = 11) and bull calves at Piedmont Research Station [Salisbury, North Carolina (**NC**)] were blocked by sex and assigned randomly to receive 3.8 L of maternal colostrum in one feeding (**1X**), 1.9 L in two feedings (10- to 12-h interval; **2X**), or 2X plus 272 g of colostrum supplement (First Milk™ Formula; Land O' Lakes®, Ft. Dodge, IA) fed at the first feeding (**2X+**). The colostrum supplement was mixed with 0.95 L of warm water and fed immediately following colostrum. Colostrum and colostrum supplement that had been refused were force-fed with an esophageal feeder in NC or were offered at an additional feeding approximately 1 h after feeding in TN.

Calving took place according to normal management at each farm, and parturition was monitored to ensure that calves did not nurse the dam. Calves were weighed shortly after birth and were moved to individual fiberglass hutches (NC and TN) or individual wooden pens in a calf barn (in NC only) after birth.

Maternal colostrum was collected from the dam as soon as possible after parturition and was frozen (−20°C) prior to analysis of IgG by single radial immunodiffusion (VMRD, Inc., Pullman, WA). Samples from dams in NC were placed on dry ice and transported to TN for analysis. The colostrum supplement was obtained from one lot per site and provided 25 g of IgG per dose.

Commercial calf starter was offered for ad libitum consumption from d 1 (NC) or from d 3 (TN). The amount offered was measured daily, and the amount of starter remaining was measured daily (TN) or weekly (NC). Commercial milk replacer (at TN) was reconstituted to 12.5% DM and was fed at 3.8 L/d in two equal feedings from 3 to 56 d. All milk replacer was consumed. Whole milk (at NC) was fed at 3.8 L/d in one feeding from 3 to 56 d. Water was available at all times. No hay was fed throughout the study.

Calves were weighed at birth and every 7 d thereafter to 56 d. Approximately 10 ml of jugular blood were taken immediately prior to first feeding and at 24 and 48 h of age. Blood was allowed to clot, and serum was separated by centrifugation (3000 × *g* for 15 min at 5°C) and frozen (−20°C) until transported to the laboratory for analysis of IgG. Samples of milk replacer (TN) and calf starter were taken weekly (NC) or monthly (TN) and pooled prior to analysis of DM and CP (2).

Data were analyzed as a randomized complete block by analysis of covariance using BW at birth as a covariable. Independent variables in the model included location, sex, treatment, and interactions among those variables. Sex of calf was not significant for any measurement and was removed from the final model. Intake of IgG in colostrum was also included as a covariable for serum IgG concentration and for the calculated efficiency of absorption. Growth and intake data were adjusted by covariance for BW at birth. Orthogonal contrasts were used to test differences between 1X and 2X and 2X and 2X+. Significance was declared at $P < 0.05$ unless otherwise noted.

RESULTS AND DISCUSSION

Intake of Colostrum

Calves at TN were not forced to ingest colostrum; remaining colostrum or supplement was offered at an additional feeding approximately 1 h after the initial feeding. However, no calf consumed a significant amount of colostrum during this additional feeding. Only 1 of the 10 calves at TN fed 1X consumed all colostrum. Mean consumption of colostrum by calves fed 1X was 3.0 L, which corresponded to 8% of BW. Calves fed 2X and 2X+ consumed 3.2 and 3.3 L, respectively, in 24 h. Calves at NC that refused colostrum were fed by an esophageal feeder; therefore, intake of colostrum was 3.8 L for all calves. Mean age at first feeding at TN was 1.3 h; age at first feeding at NC was not recorded precisely but was ≤3 h.

Serum IgG Concentrations

Serum IgG measured at 24 h was lower ($P < 0.01$) when calves were fed 2X+ than when calves were fed 2X; however, concentrations of serum IgG at 48 h did not differ among treatments (Table 1). Serum IgG concentrations at 48 h were lower than those at 24 h; the decline was probably due to expansion of plasma volume from 24 to 48 h. The lack of increase in serum IgG with supplementation has been observed previously (1, 11) and was probably due to the small amount of IgG (25 g) provided by the supplement and the low efficiency of absorption that has been observed with colostrum supplements (5). When high quality colostrum is fed, as in this study, calves consume ≥200 g of IgG from 3.8 L of colostrum; addition of 25 g of IgG from a supplement might have been insufficient to affect serum IgG concentration. Other researchers have reported no effect of colostrum supplements when added to pooled (11) or maternal (1) colostrum.

TABLE 1. Least squares means of serum IgG and apparent efficiency of IgG absorption (AEA) in calves fed colostrum in one or two feedings after birth and in calves fed colostrum in two feedings plus a colostrum supplement after birth.

	Treatment[1]						Constrast	
Item	1X		2X		2X+		1X vs. 2X	2X vs. 2X+
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	*P*	
Calves, no.	19	. . .	16	. . .	15	. . .		
Birth BW, kg	41.3	1.5	36.4	1.7	40.5	1.7	0.04	0.09
Serum IgG, g/L								
0[2,3] h	0.7	0.1	0.9	0.1	0.7	0.1	NS[4]	NS
24[3] h	19.1	1.1	21.0	1.3	16.0	1.3		0.009
48[3] h	16.5	1.2	16.7	1.4	15.3	1.4	NS	NS
AEA,[3,5] %	35	3	40	3	30	3	NS	0.06
Colostrum IgG,[3] g/L	68.5	6.1	52.8	7.0	61.4	7.1	0.10	NS
IgG Intake, g	237	22	187	26	243	26	NS	NS

[1]Treatments: 1X = 3.8 L of maternal colostrum in one feeding; 2X = 3.8 L of maternal colostrum in two feedings; 2X+ = 2X plus 272 g of commercial colostrum supplement at the first feeding (First Milk™ Formula; Land O'Lakes®, Ft. Dodge, IA).

[2]Serum IgG concentration taken at 0 to 4 h after birth.

[3]Significant effect ($P < 0.05$) of location (Salisbury, NC vs. Grand Junction, TN).

[4]$P > 0.10$.

[5]AEA = Serum IgG (grams per liter) × 0.10 × BW (kilograms) ÷ IgG consumed (grams) × 100.

Serum IgG concentration at 24 h increased linearly as IgG intake increased. Regression analysis indicated that treatment ($P < 0.05$; Figure 1) and location ($P < 0.01$; Figure 2) also affected serum IgG concentration. Calves at NC attained lower serum IgG concentration at a similar IgG intake.

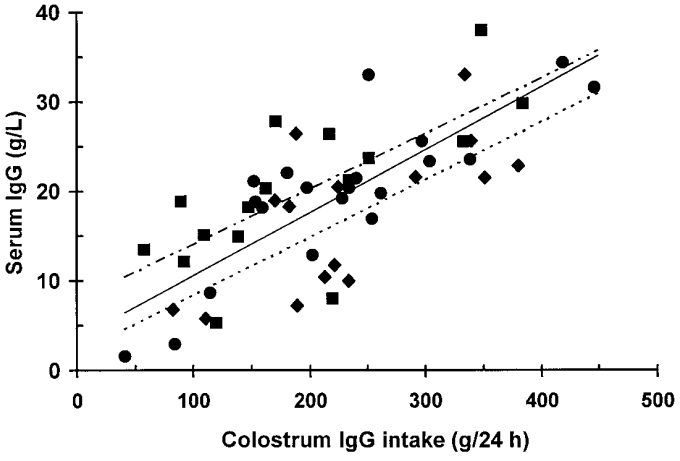

Figure 1. Regression of serum IgG concentration at 24 h on IgG intake. Solid line and circles = 3.8 L of colostrum in one feeding, dashed line and squares = 3.8 L of colostrum in two feedings at a 10- to 12-h interval (2X), and dotted line and diamonds = 2X plus 272 g of colostrum supplement at the first feeding (2X+). Regression equation was Y = 4.46 + 0.066 × IgG intake (grams per 24 h) + 2.58 × 2X − 2.93 × 2X+; R^2 = 0.59.

The lack of effect of 1X versus 2X suggests that successful transfer of passive immunity, as measured by serum IgG concentrations, can be achieved if calves are fed in one or two feedings. McCoy et al. (11) also reported no effect of feeding 2 L of marginal quality colostrum in two feedings or 4 L in one feeding. Larger amounts of colostrum at the first feeding via an esophageal feeder may affect acquisition of passive immunity. Colostrum administered via an esophageal feeder does not pass directly to the abomasum, but is deposited in the reticulorumen, although outflow into the abomasum occurs within 3 h (9). Serum IgG_1 concentrations were somewhat lower in calves fed colostrum by an esophageal feeder than in calves fed by bottle (10, 11).

The calculated efficiency of IgG absorption at 24 h, based on an assumed blood volume of 10% of BW, was 35% (SE = 2), indicating that higher concentrations of serum IgG were probably affected by a higher intake of IgG in colostrum. These data also suggest that the second feeding of colostrum at 12 h of age was absorbed with an efficiency similar to that of colostrum consumed at the first feeding. Although efficiency of IgG absorption decreased during the first 24 h after birth (8), absorption of a larger amount of IgG at the first feeding might have been reduced somewhat, possibly by saturating absorptive sites in the intestine. Stott and Fellah (13) reported that a mass of Ig in 1 L of colostrum was absorbed more efficiently than an equivalent mass of Ig in 2 L of

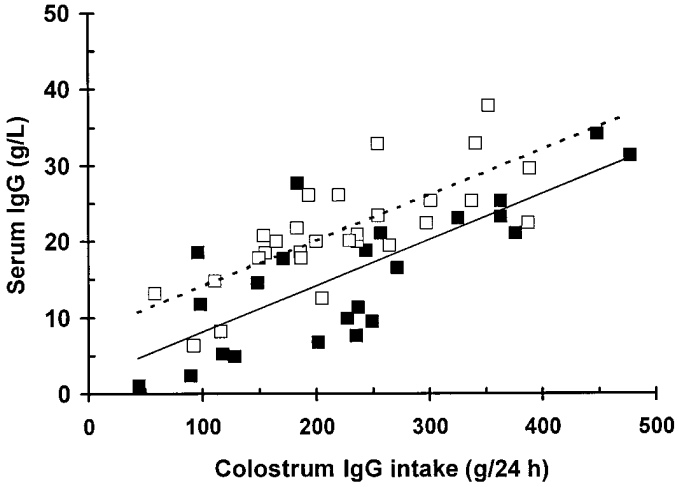

Figure 2. Regression of serum IgG concentration at 24 h on IgG intake. Dashed line and open squares = calves at Grand Junction, Tennessee (TN); solid line and closed squares = calves at Salisbury, North Carolina (NC). Regression equation was Y = 7.38 + 0.064 × grams of IgG intake – 5.738 × location (NC vs. TN) + 2.053 × 2X – 3.05 × 2X+; where 2X = 3.8 L of colostrum in two feedings at a 10- to 12-h interval, and 2X+ = 2X plus 272 g of colostrum supplement at the first feeding; R^2 = 0.68.

colostrum. However, regression of efficiency of absorption on IgG intake at 24 h did not indicate a significant slope of efficiency as Ig intake increased.

Location affected efficiency of absorption of IgG at 24 h. Mean efficiencies of IgG absorption at 24 h at NC and TN were 31 and 39% (SE = 3), respectively. Lower efficiency of IgG absorption at NC might have been due to differences in IgG concentration in colostrum, method of feeding, or age at first feeding. Calves at TN consumed less colostrum (3.2 vs. 3.8 L) containing more IgG (68.4 vs. 53.4 g/L), although cumulative consumption of IgG at 24 h was similar (222 vs. 221 g) between locations. In addition, some calves at NC were fed by an esophageal feeder, which might have further reduced the efficiency of IgG absorption (10, 12).

Two calves at TN died during the trial at 17 and 18 d of age. Serum IgG concentration at 24 h was ≥10 g/L for both calves that died. Necropsy indicated that calves died from complications associated with rotavirus infections; one calf was also infected with bovine viral diarrhea.

BW Gain, Intake, and Efficiency

Calf BW at birth was somewhat lower for calves assigned to the 2X treatment (Table 1); differences in BW at birth were used as a covariable in analyses of intake, BW, and feed efficiency data. However, this

TABLE 2. Least squares means of BW, BW gain, intake, and feed efficiency in calves at Salisbury, North Carolina (NC) and Grand Junction, Tennessee (TN).

Item[1]	Location				*P*
	NC		TN		
	$\bar{X}$	SE	$\bar{X}$	SE	
Calves, no.	23	. . .	27	. . .	. . .
BW at Birth, kg	39.9	1.4	38.8	1.2	NS[2]
BW at 28 d, kg	47.4	0.6	45.4	0.6	0.02
BW at 56 d, kg	68.9	1.5	64.7	1.4	0.04
BW Gain, 0 to 28 d, g/d	263	23	190	21	0.02
BW Gain, 29 to 56 d, g/d	767	42	689	38	NS
BW Gain, 0 to 56 d, g/d	514	27	439	25	0.04
Intake, g/d					
DM[3]	878	33	953	30	0.10
CP[4]	210	7	220	6	NS
Starter	423	33	518	30	0.04
Milk or milk replacer	454	0	435	1	0.01
Feed efficiency, g/kg					
BW Gain:DMI	588	23	468	21	0.01
BW Gain:CP intake	2454	99	2022	92	0.01

[1]Means are covariately adjusted for BW at birth, except BW at birth.

[2]$P > 0.10$.

[3]Feed DM content was 90.0, 86.6, and 95.7% for calf starter at TN, calf starter at NC, and milk replacer at TN, respectively.

[4]Protein content in feeds was 21.3, 20.6, and 25.2% for calf starter at TN, calf starter at NC, and milk replacer at TN, respectively.

covariable was not significant in analyses of serum IgG at 24 or 48 h.

No differences in BW or BW gain were observed among calves for any of the treatments at 28 or 56 d. Gain in BW from 0 to 28 d was low (222 g/d; SE = 15) but increased as starter intake increased after 28 d. Mean BW gain from 29 to 56 d was 731 g/d (SE = 28). Location was significant for BW at 28 and 56 d, for BW gain from 0 to 28 and 0 to 56 d, and for feed efficiency from 0 to 56 d (Table 2). These differences in BW gain according to location might have been due to the milk replacer used in TN and the whole milk used in NC. Intake of milk or milk replacer DM (454 g/d), starter DM (474 g/d), total DMI (917 g/d), and BW gain per DMI (525 g/kg) were unaffected by method of colostrum feeding.

CONCLUSIONS

In this study, 3.8 L of colostrum in one or two feedings was equally effective in providing passive immunity (as measured by serum IgG concentration) and did not affect efficiency of IgG absorption, intake, or BW gain. Several calves offered 1X did not voluntarily consume all liquid offered; 1X might necessitate the use of an esophageal feeder.

The colostrum supplement increased intake of IgG in this study by 11% without affecting serum IgG concentration at 24 or 48 h. When high quality colostrum (large amount of Ig) is fed, addition of colostrum supplements appears unnecessary.

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