

NUTRITION, FEEDING, AND CALVES

Effect of Dietary IgG Source (Colostrum, Serum, or Milk-Derived Supplement) on the Efficiency of Ig Absorption in Newborn Holstein Calves¹

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ABSTRACT

This study was designed to compare the absorptive efficiency of IgG from a commercial bovine serum product (bovine serum), cow colostrum (positive control), and two commercial milk-derived IgG supplements (supplement 1 and supplement 2). Newborn Holstein calves, collected at birth and prior to the consumption of colostrum, were allotted to treatment by alternating birth order. Colostrum supplement treatments were fed according to manufacturer's recommendations at birth and again at 12 h. This strategy resulted in varying masses of total IgG being offered to the calves (200, 90, 50, and 60 g of IgG for colostrum, bovine serum, supplement 1, and supplement 2, respectively). Blood samples were collected at 0, 12, and 24 h after the end of treatment administration. Plasma volume was estimated as 9.10% of birth weight. Apparent efficiency of IgG absorption at 24 h was determined. Plasma IgG concentrations at 24 h differed for each treatment (12.1, 6.8, 2.2, and 3.5 g of IgG/L for colostrum, bovine serum, supplement 1, and supplement 2, respectively). Apparent efficiency of IgG absorption was greatest for bovine serum compared with colostrum and supplement 1. No treatment differences were detected on the occurrence of mortality. However, calves fed bovine serum tended to have fewer treatments for illness compared with calves fed colostrum and supplement 1. Calves receiving bovine serum-derived IgG had improved IgG absorption efficiency and a tendency toward fewer medical treatments compared with calves consuming colostrum or a dried colostrum product.

(Key words: immunoglobulin, colostrum, colostrum replacer, calves)

Abbreviation key: **AEA** = apparent efficiency of IgG absorption, **BS** = bovine serum based colostrum supplement, **PC** = pooled colostrum, **S-1** = commercial milk-derived colostrum supplement #1, **S-2** = commercial milk-derived colostrum supplement #2.

INTRODUCTION

Newborn calves are born agammaglobulinemic (22). Passive immune protection is achieved by the transport of macromolecules found in colostrum through the intestinal epithelium, which remains permeable for approximately 24 h after birth (24, 27). Absorbed Ig is then transferred through the lymphatic system into peripheral circulation; this remains an effective protective mechanism until the specific immune system of the calf matures (22). Therefore, to ensure adequate protection against disease exposure, calves rely entirely on the consumption of an adequate amount of quality maternal colostrum within a few hours of birth (3).

Attainment of passive immunity can be affected by many external factors including colostrum Ig concentration (13), colostrum volume, age at which colostrum is consumed (27), and calf stress (8, 9, 25). Low blood Ig concentrations are directly related to calf morbidity and mortality (1) as well as to long-term calf performance (28). The economic impacts of failure to achieve adequate passive immunity are substantial. A 1994 USDA survey (15) reported that preweaning morbidity of live-born dairy heifer calves exceeded 8%. Management procedures and products that improve passive immunity in calves are crucial for today's dairy industry.

The most common method of augmenting passive immunity to newborn calves has been the use of precollected frozen colostrum (5). Colostrum reserves may be collected, tested for quality, and stored frozen for later use. Although effective in most cases, this procedure requires careful attention to details to ensure the collection, storage, and delivery of a quality colostrum source. First, colostrum should only be collected from the first colostrum milking following parturition. Colostrum quality drops rapidly with subsequent milkings (26). Colos-

Received August 23, 1999.

Accepted February 2, 2000.

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¹Contribution No. R-06975 from the Florida Agricultural Experiment Station.

trum quality should be estimated before freezing; specific gravity is a common measure and, when done correctly, can adequately estimate overall quality (10, 11, 17, 20). Even when procedures are closely followed, obtaining an adequate amount of frozen colostrum may be difficult. In these instances, the use of an exogenous source of IgG to supplement colostrum may prove beneficial.

Alternative sources of IgG supplementation to newborn calves, such as injectable Ig solutions (21), dried colostrum (6, 13), and concentrated whey (12) have been investigated. In general, these methods have proven inadequate, especially when compared with natural maternal colostrum, to provide adequate passive immunity. The most important factor for poor performance of colostrum supplements is poorly absorbed Ig, especially when compared with natural colostrum (6). Efficiency of Ig absorption is a method of balancing variability in actual blood Ig concentrations by accounting for differences in plasma volume as related to BW. Knowing the mass of Ig ingested, the plasma Ig concentration following Ig absorption, and the plasma volume, workers can calculate the efficiency of IgG absorption. In a previous study (19) apparent efficiency of IgG absorption (AEA) of bovine serum-derived Ig was found to depend on the amount of product offered. In that experiment, increases in the mass of serum powder offered to the calves resulted in a decrease in AEA. Other researchers have reported considerable decreases in the AEA of milk-derived colostrum replacers when fed at high Ig concentrations (6). As in our previous experiment (19), these authors used large masses of powder to achieve the desired mass of Ig. However, when administered at lower levels, the AEA of dried serum Ig exceeded maternal colostrum values when offered at equal Ig masses (19). Therefore, we hypothesized that serum-derived Ig would have a greater AEA compared with milk-derived Ig supplements when offered to newborn, colostrum-deprived calves. Increasing the mass of supplement offered is not an effective means of increasing the amount of Ig absorbed by the calf (6, 19). Therefore, producers are restricted to the mass of IgG offered in a supplement's individual feeding. Considering these options, we chose to compare a commercial bovine serum-derived product with two commercial milk-derived Ig supplements using manufacturer's label recommendations.

MATERIALS AND METHODS

The animals utilized in these experiments were cared for by acceptable practices as outlined in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (7).

Over a 4-wk period, 40 Holstein bull calves, obtained from a single-source dairy, were collected immediately after birth and deprived of maternal colostrum. Four treatments were allocated to calves in alternating birth order, as follows; pooled colostrum control (PC; n = 10), commercial milk-derived colostrum supplement (S-1; n = 10; First Milk Formula, Procor Technologies Inc. Arden Hills, MN), commercial milk-derived colostrum supplement from another manufacturer (S-2; n = 10; Colostrx, Protein Technology Inc. Santa Rosa, CA), and bovine serum-based colostrum supplement (BS; n = 10; LifeLine, American Protein Corporation, Ames, IA). Each treatment was administered via nipple bottle feeder in 2-L volumes within 2 h of birth and again 12 h later. Any treatment volume refused was force-fed using an esophageal feeder. The supplements were offered in concentrations prescribed by the manufacturer, resulting in different total IgG masses offered to the calves (90, 50, and 60 g of IgG for BS, S-1, and S-2, respectively). Immunoglobulin concentrations of S-1 and S-2 treatments were taken from the manufacturer's label guarantee. The IgG concentration of BS was measured by a turbidimetric technique (4). The colostrum fed calves received a high quality (50 g of IgG/L), pooled colostrum, previously collected and frozen, that provided 100 g of IgG at birth and again at 12 h. The total IgG concentration of PC was determined by radial immunodiffusion technique (Triple J Farms, Redmond, WA).

Blood samples were collected from all calves before treatment. Serum was harvested from blood via centrifugation and frozen at -20°C until analysis for total IgG by using a turbidimetric method (4). Calves with initial blood IgG concentrations >1 g/L were removed from further analysis, resulting in 7, 9, 9, and 8 calves per treatment for PC, S-1, S-2 and BS, respectively.

To estimate the influence of dystocia on subsequent absorption of IgG, calving ease scores were collected on all births using a 1 to 3 scale (1 = unassisted, 2 = moderate assistance, 3 = difficult delivery). Prevalence of illness and calf death was monitored daily by visual inspection, from the time of treatment administration until 28 d of age. An incidence of illness was defined as any condition requiring at least one intervention with medical therapy.

Following treatment administration and throughout the study, all calves were individually housed and fed 2 L of a complete (20% fat and 20% protein) commercial milk replacer twice daily.

To assess the effect of treatment on subsequent passive immunity, IgG concentration was measured in blood samples collected at 12 and 24 h after the end of treatment administration. Serum was harvested from

Table 1. Initial treatment means for calf birth weight, calving ease score, and estimated plasma volume.

Treatment ¹	Birth weight, kg	Calving ease score ²	Plasma volume, L ³
PC	41.4	1.6	3.77
S-1	41.5	1.1	3.78
S-2	44.8	1.1	4.08
BS	42.1	1.5	3.83

¹Treatments consisted of PC = pooled colostrum, S-1 = milk-derived supplement 1, S-2 = milk-derived supplement 2, and BS = bovine serum supplement.

²Calving ease scores were collected on all calves, by a single technician, using a 1 to 3 scale (1 = unassisted, 2 = moderate assistance, 3 = difficult delivery).

³Plasma volume (liters) = birth weight (kg) × 0.091.

blood via centrifugation and frozen at -20°C until analysis for total IgG by using a turbidimetric method (4).

Apparent efficiency of IgG absorption was estimated with a standard plasma volume in calves (9.10% of BW) as previously reported in Holstein bull calves (19). Apparent efficiency of IgG absorption at 24 h was calculated as [plasma IgG (grams per liter) × plasma volume (liters) × 100]/IgG intake (grams) (18).

Analysis of variance was performed using the general linear model procedures of SAS (23). For analyses involving multiple measurements over time, a split-plot design was used with the effect of calf in the whole plot and time and time × treatment interactions in the subplot. When time × treatment interactions were significant ($P < 0.05$), treatment means within times were compared using least significant difference test. The prevalence of illness and the occurrence of mortality were compared using Proc FREQ of SAS. Differences in percent mortality or percentage of calves treated for illness were compared with Fisher's Exact Test.

RESULTS

There were no differences in birth weight and calving ease score (Table 1). Calves receiving PC had the greatest increase in 12 and 24 h blood IgG concentrations, followed by BS, S-2, and S-1 (Table 2). Blood IgG concen-

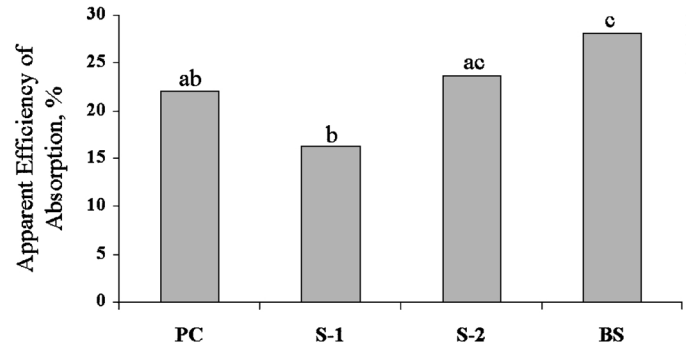


Figure 1. Apparent efficiency of IgG absorption in colostrum-deprived calves receiving IgG from pooled colostrum (PC), supplement 1 (S-1), supplement 2 (S-2), or bovine serum (BS). Pooled standard error of the means were 2.0, 1.9, 1.8, and 1.9% for PC, S-1, S-2, and BS, respectively. ^{a,b,c}Values with different superscripts differ ($P < 0.05$).

trations at 24 h (12.1, 6.8, 3.5, and 2.2 g of IgG/L) followed the order of total mass of IgG offered initially (100, 90, 60, and 50 g of IgG offered), for PC, BS, S-2, and S-1, respectively.

Apparent efficiency of IgG absorption was greatest for calves receiving BS (Figure 1). Calves receiving S-2, but not S-1, had AEA values similar to BS; however, 24-h blood IgG concentrations were greater ($P < 0.05$) for BS calves compared with both milk-derived colostrum supplements. This is related to the actual concentration of IgG in each supplement powder (10.0, 5.5, and 6.6% IgG for BS, S-1, and S-2, respectively).

No differences were detected in percent mortality across treatments (Table 3).

DISCUSSION

Birth weight affects estimates of plasma volume (18). Also, stress conditions on both the cow and calf may directly impair the ability of calves to acquire adequate passive immune transfer (8, 9, 14, 16). In this study, there were no differences in calf birth weight, calving difficulty, or plasma volume. Calves receiving bovine

Table 2. Effect of IgG treatment on subsequent serum IgG concentrations at 0, 12, and 24 h in colostrum-deprived calves.

Treatment ¹	Total plasma IgG, g/L					
	0 h	SE	12 h	SE	24 h	SE
PC	<1.0	...	7.7 ^a	0.3	12.1 ^a	0.3
S-1	<1.0	...	1.7 ^b	0.3	2.2 ^b	0.3
S-2	<1.0	...	2.5 ^c	0.3	3.5 ^c	0.3
BS	<1.0	...	4.1 ^d	0.3	6.8 ^d	0.3

^{a,b,c,d}Means within column with different superscripts differ ($P < 0.05$).

¹Treatments consisted of PC = pooled colostrum, S-1 = milk-derived supplement 1, S-2 = milk-derived supplement 2, and BS = bovine serum supplement.

Table 3. Effect of IgG treatment on subsequent incidence of illness and calf mortality.¹

Treatment ²	Incidence of illness, % ³	Mortality, %
PC	57.1% (4/7)	0% (0/7)
S-1	55.6% (5/9)	11.1% (1/9)
S-2	22.2% (2/9)	22.2% (2/9)
BS	12.5% (1/8)	12.5% (1/8)

¹No effect of treatment ($P > 0.05$).

²Treatments consisted of PC = pooled colostrum, S-1 = supplement 1, S-2 = supplement 2, and BS = bovine serum supplement.

³Incidence of illness indicated by any condition requiring at least one intervention with medical therapy.

serum-derived IgG had greater efficiency of IgG absorption than did calves receiving PC. However, 24-h blood IgG concentrations were higher for calves consuming PC. This is in direct relation to the initial amount of IgG fed to the calves (90 vs. 200 g, for BS and PC, respectively). The initial concentration of IgG in powdered supplements has been shown to be an important factor when considering the use of these products in a calf management program. Attempts to increase the amount of IgG administered by increasing the mass of powder offered to an individual calf, results in marked decreases in IgG absorption efficiency for both serum-based (20) and milk-based (6) colostrum supplements. The colostrum used in this treatment was specifically chosen because it was high quality (50 g of IgG/L). Colostrum quality directly affects subsequent adequate passive immune protection. However, in many instances high quality colostrum is not available. Calf management programs that utilize colostrum with IgG concentrations below 50 g/L experience increased calf morbidity and mortality (2).

No statistical differences were detected in measures of calf mortality or illness (Table 3) possibly because of the small number of experimental units enrolled in this study. Calves receiving BS tended to have fewer incidences of illness when compared with PC ($P = 0.119$) and S-1 ($P = 0.131$) treatments. Actual diagnosis of illness was not determined; however, all treatments were allotted to calves by alternating birth order within a 30-d enrollment period, ensuring uniform access to environmental and disease challenges. A larger sample size would have increased the statistical power of these categorical data comparisons (morbidity and mortality).

Commercial IgG supplements are commonly used when quality natural colostrum is unavailable. The results of this study indicate that, in the absence of quality colostrum, serum-derived IgG may be used to supply calves with a concentrated source of Ig, which is readily absorbed. The serum-based supplement used in this study provided calves with the greatest 24-h blood Ig

concentration when compared with the milk-derived supplements. In this experiment, supplements were fed according to manufacturer's recommendations. Simply increasing the mass of powder offered does not improve the attainment of passive immunity (7, 19). None of the supplements provided calves with adequate 24-h blood Ig concentrations (>10 g of IgG/L). Further research is necessary to examine the influence of supplementing varying qualities of maternal colostrum with serum-derived Ig.

ACKNOWLEDGMENTS

Appreciation is extended to American Protein Corporation for their partial financial support of this research. Appreciation is also extended to Lisa Etzel for her laboratory technical assistance.

REFERENCES

- Besser, T. E., and C. C. Gay. 1994. The importance of colostrum to the health of the neonatal calf. *Vet. Clinics North Am.* 10:107-117.
- Besser, T. E., C. C. Gay, and L. Pritchett. 1991. Comparison of three methods of feeding colostrum to dairy calves. *JAVMA* 98:419-422.
- Bush, L. J., and T. E. Staley. 1980. Absorption of colostrum immunoglobulins in newborn calves. *J. Dairy Sci.* 63:672-680.
- Etzel, L. R., R. E. Strohbahn, and J. K. McVicker. 1997. Development of an automated turbidimetric immunoassay for quantification of bovine serum immunoglobulin G. *Am. J. Vet. Res.* 58:1201-1205.
- Foley, J. A., and D. E. Otterby. 1978. Availability, storage, treatment, composition, and feeding value of surplus colostrum: A review. *J. Dairy Sci.* 61:1033-1060.
- Garry, F. B., R. Adams, M. B. Cattell, and R. P. Dinsmore. 1996. Comparison of passive immunoglobulin transfer to dairy calves fed colostrum or commercially available colostrum-supplement products. *JAVMA* 1:107-110.
- Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching. 1988. Consortium for Developing a Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching. Champaign, IL.
- Hough, R. L., F. D. McCarthy, C. D. Thatcher, H. D. Kent, and D. E. Eversole. 1990. Influence of glucocorticoid on macromolecular absorption and passive immunity in neonatal lambs. *J. Anim. Sci.* 68:2459-2464.
- Johnston, N. E., and J. A. Stewart. 1986. The effect of glucocorticoids and prematurity on absorption of colostrum immunoglobulins in the calf. *Aust. Vet. J.* 63:191-192.
- Mechor, G. D., Y. T. Grohn, L. R. McDowell, and R. J. Van Saun. 1992. Specific gravity of bovine colostrum immunoglobulins as affected by temperature and colostrum components. *J. Dairy Sci.* 75:3131-3135.
- Mechor, G. D., Y. T. Grohn, and R. J. Van Saun. 1991. Effect of temperature on colostrometer readings for estimation of immunoglobulin concentration in bovine colostrum. *J. Dairy Sci.* 74:3940-3943.
- Mee, J. F., K. J. O'Farrell, P. Reitsma, and R. Mehra. 1996. Effect of a whey protein concentrate used as a colostrum substitute or supplement on calf immunity, weight gain, and health. *J. Dairy Sci.* 79:886-894.
- Morin, D. E., G. C. McCoy, and W. L. Hurley. 1997. Effects of quality, quantity, and timing of colostrum feeding and addition of a dried colostrum supplement on immunoglobulin G1 absorption in Holstein bull calves. *J. Dairy Sci.* 80:747-753.

- 14 Nardone, A., N. Lacetera, U. Bernabucci, and B. Ronchi. 1997. Composition of colostrum from dairy heifers exposed to high air temperatures during late pregnancy and the early postpartum period. *J. Dairy Sci.* 80:838–844.
- 15 National Animal Health Monitoring Service. National Dairy Heifer Evaluation Project. Dairy Heifer Morbidity, Mortality, and Health Management Focusing on Preweaned Heifers. USDA-APHIS-VS. 1994.
- 16 Olson, D. P., and R. C. Ritter. 1980. The effects of cold stress on neonatal calves II. Absorption of colostrum immunoglobulins. *Can. J. Comp. Med.* 19–23.
- 17 Pritchett, L. C., C. C. Gay, D. D. Hancock, and T. E. Besser. 1994. Evaluation of the hydrometer for testing immunoglobulin G1 concentrations in Holstein colostrum. *J. Dairy Sci.* 77:1761–1767.
- 18 Quigley, J. D., III, J. J. Drewry, and K. R. Martin. 1998. Estimation of plasma volume in Holstein and Jersey calves. *J. Dairy Sci.* 81:1308–1312.
- 19 Quigley, J. D., III, D. L. Fike, M. N. Egerton, J. J. Drewry, and J. D. Arthington. 1998. Effects of a colostrum replacement product derived from serum on immunoglobulin G absorption by calves. *J. Dairy Sci.* 81:1936–1939.
- 20 Quigley, J. D., III, K. R. Martin, H. H. Dowlen, L. B. Wallis, and K. Lamar. 1994. Immunoglobulin concentration, specific gravity, and nitrogen fractions of colostrum from Jersey cattle. *J. Dairy Sci.* 77:264–269.
- 21 Quigley, J. D., III, and M. G. Welborn. 1996. Influence of injectable immunoglobulin on serum immunoglobulin concentrations in dairy calves. *J. Dairy Sci.* 79:2032–2037.
- 22 Redman, D. R. 1979. Prenatal influence on immunocompetence of the neonate. *J. Anim. Sci.* 49:258–267.
- 23 SAS. User's Guide: Statistics. Version 6 Edition. 1988. SAS Inst. Inc., Cary, NC.
- 24 Staley, T. E., and L. J. Bush. 1985. Receptor mechanisms of the neonatal intestine and their relationship to immunoglobulin absorption and disease. *J. Dairy Sci.* 68:184–205.
- 25 Stott, G. H. 1980. Immunoglobulin absorption in calf neonates with special considerations of stress. *J. Dairy Sci.* 63:681–688.
- 26 Stott, G. H., W. A. Fleenor, and W. C. Kleese. 1981. Colostral immunoglobulin concentration in two fractions of first milking postpartum and five additional milkings. *J. Dairy Sci.* 64:459–465.
- 27 Stott, G. H., D. B. Marx, B. E. Menefee, and G. T. Nightengale. 1979. Colostral immunoglobulin transfer in calves I. Period of absorption. *J. Dairy Sci.* 62:1632–1638.
- 28 Wittum, T. E., and L. J. Perino. 1995. Passive immune status at postpartum hour 24 and long-term health and performance of calves. *Am. J. Vet. Res.* 56:1149–1154.