

Passive Immunoglobulin Transfer in Newborn Calves Fed Colostrum or Spray-Dried Serum Protein Alone or as a Supplement to Colostrum of Varying Quality¹

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ABSTRACT

Two experiments were conducted to investigate the effect of serum-derived immunoglobulin (Ig) source and the effect of colostrum supplementation with serum-derived Ig on the attainment of passive immunity in newborn colostrum-deprived calves. In experiment 1, colostrum-deprived Holstein bull calves were fed pooled colostrum (PC, n = 9), spray-dried bovine serum (BS, n = 11), or spray-dried porcine serum (PS, n = 9). All treatments were balanced to provide 45 g of IgG in a 2-L volume at birth and again 12 h later. Calves receiving BS had higher 24-h serum IgG concentrations than did calves receiving PC or PS (8.3, 5.7, and 4.2 g of IgG/L for BS, PC, and PS, respectively). In experiment 2, the effect of supplementing bovine colostrum of varying quality with BS on Ig absorption was assessed. Thirty-two colostrum-deprived Holstein bull calves and four freemartin heifer calves were allotted by birth order to receive one of three treatments. Treatments consisted of 1) 2 L of pooled high quality colostrum (95.8 g of IgG, 0% from BS), 2) 2 L of pooled medium quality colostrum mixed with BS (95.2 g of IgG, 47% from BS), or 3) 2 L of low quality colostrum mixed with BS (98.8 g of IgG, 70% from BS). Serum IgG concentrations at 24 h after treatment were greater for calves receiving medium and low quality colostrum supplemented with BS (6.2, 9.6, and 9.6 g of IgG/L for high, medium, and low quality colostrum, respectively). Similarly, apparent efficiency of IgG absorption was greater for calves receiving medium and low quality colostrum supplemented with BS (25, 37, and 38% for high, medium, and low quality

colostrum, respectively). The results of these studies suggest that dried BS contains a concentrated source of Ig, which is efficiently absorbed by newborn calves. Supplementation of marginal or low quality colostrum with dried BS is an effective means of improving passive transfer of IgG in newborn calves.

(Key words: immunoglobulin, colostrum, bovine serum, calves)

Abbreviation key: AEA = apparent efficiency of IgG absorption, BS = bovine serum, PC = pooled colostrum, PS = porcine serum.

INTRODUCTION

Attainment of passive immunity in newborn calves occurs through the oral consumption and subsequent absorption of Ig soon after birth (Bush and Staley, 1980). Low blood Ig concentrations are directly related to calf morbidity and mortality (Besser and Gay, 1994), as well as long-term calf performance (Wittum and Perino, 1995). As the interval following birth to colostrum consumption increases, the ability to absorb colostrum Ig decreases (Stott et al., 1979). As well, the concentration of colostrum Ig has a positive linear relationship with the amount of Ig absorbed by calves following consumption (Stott and Fella, 1983). Therefore, it is commonly recognized that both the time of colostrum feeding relative to birth and colostrum IgG concentration bear the greatest influence on subsequent attainment of passive immunity in newborn calves.

Many attempts have been made to artificially augment the ability of calves to attain passive immune support, such as, stored surplus colostrum (Foley and Otterby, 1978), injectable Ig solutions (Quigley and Welborn, 1996), dried colostrum (Morin et al., 1997; Garry et al., 1996), and concentrated milk whey (Mee et al., 1996). In general, these methods have proven inadequate, especially when compared to natural ma-

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ternal colostrum, to provide adequate passive immune support.

In a previous study by our group (Quigley et al., 1998b), apparent efficiency of IgG absorption (AEA) of bovine serum-derived Ig was found to be dependent upon the amount of product offered. In that experiment, attempts to increase the mass of IgG offered to the calves, by increasing the mass of serum powder, resulted in a decrease in AEA. However, at lower administration levels, the AEA of dried serum Ig exceeded maternal colostrum values when offered at equal Ig masses (Quigley et al., 1998b).

Bovine and porcine plasma protein are natural sources of concentrated IgG. As well, the availability of both protein sources is substantial if sourced from the commercial meat packing industry. Therefore, our objective was to determine whether differences existed between bovine or porcine-derived Ig in providing passive immunity to newborn calves. In building on our previous findings (Quigley et al., 1998b), we hypothesized that serum-derived Ig may be a beneficial supplement to low quality colostrum when attempting to successfully fortify Ig concentrations offered to newborn calves.

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 (1988).

After treatment administration and throughout the course of each study, all calves were individually housed. In experiment 1, all calves were fed 2 L twice daily of a complete (20% fat and 20% protein) commercial milk replacer. In experiment 2, calves were fed whole milk at a rate of 5% of birth weight, twice daily.

Experiment 1. Over a 4-wk period, 36 Holstein bull calves were collected immediately after birth and deprived of maternal colostrum consumption. All calves were collected from a single commercial dairy (Loveland, CO) and housed on-site for the duration of the study. Three treatments were allocated to calves in alternating birth order, as follows; pooled, first-milking, Holstein colostrum (PC), bovine serum (BS), and porcine serum (PS).

Bovine and porcine serum treatments originated from whole abattoir blood. Serum was harvested from blood and then spray-dried into a fine powder. Each treatment was administered via nipple bottle feeder in 2-L volumes within 2 h of birth and again at 12 h after birth. Any treatment volume refused was force-fed using an esophageal feeder. Treatments provided 45 g of

IgG from their respective source in each 2-L volume resulting in a total IgG intake of 90 g/calf.

To ensure that calves had no initial circulating immunoglobulin, blood samples were collected from all calves prior to treatment administration. Calves with initial blood IgG concentrations >1 g of IgG/L were removed from further analysis. Passive transfer of IgG was determined by analysis of calf serum IgG concentrations at 24 and 72 h after treatment administration.

Experiment 2. First milking colostrum was collected from dairy cows at the University of Illinois Dairy herd (Urbana-Champaign, IL) and pooled to provide a high quality (48 g of IgG/L) colostrum source. Second and third milkings were pooled to provide marginal (29 g of IgG/L) and low quality (17 g of IgG/L) colostrum sources. Colostrum sources were pooled and refrozen at -20°C in individual bags until later use. To balance the IgG concentration of all colostrum sources, medium and low quality colostrum was mixed with BS (28.8% IgG) immediately before feeding. Thirty-six colostrum-deprived Holstein calves (32 bull calves and four freemartins) were allotted by birth order to receive one of three treatments. All calves were collected from the University of Illinois Dairy Herd and were housed on site for the duration of the study. Treatments were 2 L of pooled high quality colostrum (95.8 g IgG, 0% of IgG from BS), 2 L of pooled medium quality colostrum mixed with 183 g of dried BS (95.2 g of IgG, 47% of IgG from BS), or 2 L of low quality colostrum mixed with 267 g of dried BS (98.8 g of IgG, 70% of IgG from BS). Each treatment was administered via nipple bottle feeder. Five calves received treatment after 3, but within 4 h of birth (1, 2, and 2 calves for high, marginal, and low quality colostrum treatments, respectively). All other calves received treatment within 3 h of birth. Any treatment volume refused was force fed with an esophageal feeder. Passive transfer of IgG was determined by analysis of calf serum IgG concentrations at 12 and 24 h after treatment administration.

Blood collection and IgG analysis. Blood samples for both experiments were collected by jugular venipuncture into evacuated tubes containing no anticoagulant. Serum was harvested from blood via centrifugation and frozen at -20°C until later analysis. Total IgG of serum samples from Experiment 1 was determined by a turbidimetric technique (Etzel et al., 1997). The IgG content of colostrum samples, and serum samples from experiment 2, was determined by radial immunodiffusion technique (Triple J Farms, Redmond, WA).

Apparent efficiency of IgG absorption. Apparent efficiency of IgG absorption was estimated using an assumed plasma volume in calves of 9.10% of BW as previously reported in Holstein bull calves (Quigley et al., 1998a). Apparent efficiency of IgG absorption at 24

Table 1. Serum IgG concentrations at 24 and 72 h after first feeding in colostrum-deprived calves receiving IgG from pooled colostrum (PC), bovine serum (BS), or porcine serum (PS) sources (experiment 1).

Treatment	Serum IgG concentration, g/L			
	24 h	SE	72 h	SE
PC	5.7 ^a	0.85	5.7 ^{ab}	0.91
BS	8.3 ^b	0.85	7.4 ^b	0.85
PS	4.2 ^a	0.85	3.5 ^a	0.85

^{ab}Means within column with different superscripts differ ($P < 0.01$).

h was calculated as [plasma IgG (g/L) \times plasma volume (L) \times 100]/IgG intake (g) (Quigley et al., 1998a).

Statistical analysis. Analysis of variance was performed using the general linear model procedures of SAS (1988) using a completely randomized model. For IgG concentrations over time, a split-plot design was used with calf as the whole plot and time and time \times treatment interactions in the subplot. When time \times treatment interactions were significant ($P < 0.05$), treatment means within times were compared using least significant differences.

RESULTS

Experiment 1. Six calves had initial pretreatment IgG serum concentrations >1 g/L. This indicated the potential for prior colostrum consumption. These calves were removed from further analysis resulting in 9, 12, and 9 calves/treatment for PC, BS, and PS, respectively.

Solution treatments were balanced to provide 45 g of IgG in a 2-L feeding. Calves were fed their individual 2-L treatment within 2 h of birth and again 12 h later. Calves receiving IgG from BS had higher ($P < 0.01$) 24-h serum IgG concentrations compared with calves receiving IgG from PC or PS treatments, and higher ($P < 0.01$) 72-h IgG concentrations compared to calves receiving PS (Table 1).

Experiment 2. The consumption of total IgG did not differ between colostrum treatments (95.8, 95.2, and 98.8 g of IgG for high quality, medium quality supplemented with BS, and low quality supplemented with BS, respectively). Calf birth weight did not differ among treatments. Serum IgG concentrations before treatment administration were <1 g/L for all calves, indicating that no nontreatment, maternal colostrum was consumed.

Apparent efficiency of IgG absorption at 24 h and mean serum IgG concentrations at 12 and 24 h were greater ($P < 0.05$) for calves receiving medium and low quality colostrum supplemented with BS compared with calves receiving the same Ig mass from high quality colostrum (Table 2).

DISCUSSION

Dried BS is a concentrated source of IgG that is efficiently absorbed by newborn calves. Supplementation of marginal or low quality colostrum with dried BS is an effective means of increasing Ig absorption in newborn calves.

Like calves, newborn pigs rely entirely on colostrum ingestion to attain passive immune support (Owen et al., 1961). Porcine blood is also a concentrated source of IgG. Porcine-serum derived IgG failed to be absorbed at the efficiency of bovine-serum derived IgG (Table 1). This may suggest a preferential selection for the absorption of species-specific Ig in the neonate. Research with foals suggests that heterologous Ig is not absorbed as efficiently as Ig from mares (Holmes and Lunn, 1991).

Alternatives to natural colostrum have been investigated. Currently, there are several commercial products available for the supplementation of colostrum. In general, these products have failed to improve passive transfer of IgG when added to maternal colostrum (Francisco and Quigley, 1993; Mee et al., 1996; Morin et al., 1997). This is often attributed to the low concentration of IgG offered in most commercial supplements and poor absorption kinetics (Haines et al., 1990). Our initial experiment investigating the AEA of BS (Quigley et al., 1998b) indicated that IgG derived from BS is absorbed well when offered to calves in solutions with low percent solids. When attempting to increase total IgG mass by increasing the amount of supplement powder offered, the absorption efficiency is greatly reduced (Garry et al., 1996).

The use of blood-derived IgG has been investigated previously (Crowley et al., 1994). These researchers studied the use of bovine-plasma-derived IgG as a supplement to commercial milk replacer. In that experi-

Table 2. Serum IgG concentrations at 12 and 24 h after first feeding, calf birth weight, and apparent efficiency of IgG absorption (AEA) in colostrum-deprived calves receiving IgG from colostrum sources of varying quality (experiment 2).

Colostrum treatment ¹	Serum IgG concentration, g/L		BW, kg	AEA, %
	12 h ²	24 h		
High quality	6.7 ^a	6.2 ^a	42.5	25 ^a
Medium quality + BS	10.3 ^b	9.6 ^b	40.0	37 ^b
Low quality + BS	10.7 ^b	9.6 ^b	42.8	38 ^b

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

¹IgG concentrations of treatments were 95.8 (0% from bovine serum, BS), 95.2 (47% from BS), and 98.8 (70% from BS) g of IgG/2L feeding for high, medium, and low quality colostrum, respectively).

²Pooled SEM were 0.49, and 0.50 g of IgG/L for 12 and 24 h means and 1.4% for AEA, respectively.

ment, the authors reported similar increases in 24-h serum IgG concentrations to the current study; however, control calves also had increased 24-h serum IgG despite colostrum deprivation. The use of blood-derived Ig in milk replacer does hold promise, however, especially in providing immune support against enteric pathogen challenges (Castrucci et al., 1984; Davidson et al., 1989).

Although IgG from BS was well absorbed, the resulting 24 h serum IgG concentrations were below 10 g/L, a concentration commonly considered minimal for providing adequate passive immune protection in newborn calves. The 24-h blood IgG concentrations were higher in calves from experiment 2 versus 1, when fed BS. Although calves in experiment 1 received a greater total mass of Ig, it was provided in two separate feedings, 12 h apart. This is in support of previous findings suggesting the importance of offering Ig to calves as soon after birth as possible (Stott et al., 1979).

In experiment 2, the total mass of IgG offered to calves did not differ. However, the inclusion of BS resulted in an increase in passive IgG transfer. The authors are uncertain as to the reason for this difference. Serum-derived Ig may be absorbed through mechanisms different than colostrum derived Ig. This supposition derives support from the differences in IgG isotypes existing between serum and colostrum. Immunoglobulin-G in colostrum is largely of the IgG1 isotype (75% IgG1 and 5% IgG2), whereas IgG in serum is almost evenly split between the IgG1 and IgG2 isotypes (42% IgG1 and 46% IgG2) (Butler, 1983). It is possible that the uniform distribution of IgG isotypes in BS contributes to a more efficient absorption mechanism.

Alternatively, a number of studies have suggested the presence of a factor or factors in colostrum, which may enhance Ig absorption (Bush and Staley, 1980). This absorption may occur by accelerating the rate of pinocytotic transport of Ig across the intestinal cells, leading to a more rapid closure of transport. The nature of this colostrum factor(s) has not been identified, but seems to be of low molecular weight (Bush and Staley, 1980) and may not be present in milk (Michanek et al., 1990). Our previous studies evaluating low quality colostrum supplemented with dried colostrum indicated that absorption efficiency was reduced in the supplemented calves (Morin et al., 1997). Ingestion of a large total amount of the colostrum factor may have hastened the closure process and lowered the efficiency of Ig absorption. In that case, the amount of Ig consumed by calves was directly confounded with the amount of total colostrum solids consumed. If the level of colostrum factor decreases with each milking of the cow, then the amount of the colostrum factor consumed by calves in the present study (experiment 2) would be decreased

in the marginal and low quality pooled colostrums compared with the amount in the high quality colostrum. The amount of Ig consumed was held constant among treatment groups in experiment 2. The smaller amount of colostrum factor consumed may have allowed for greater Ig absorption efficiency in calves receiving dried BS. This also would suggest that the colostrum factor is not present in dried BS.

The use of BS as a supplement to marginal and poor quality colostrum appears to be an effective tool for improving colostrum IgG content and subsequent transfer of passive immunity in newborn calves.

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