Short communication: Serum immunoglobulin G and total protein concentrations in dairy calves fed a colostrum-replacement product

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ABSTRACT

Neonatal calf health is largely dependent on the ingestion and absorption of maternally derived antibodies via colostrum administration. The objective of this study was to evaluate the efficacy of a commercially available plasma-derived colostrum-replacement (CR) product as compared with bovine colostrum. Holstein calves were removed from the dam immediately after birth and randomly allocated to 1 of 3 groups. Group 1 calves ($n = 22$) were fed 1 package of the CR product; group 2 calves ($n = 22$) were fed 2 packages of the CR product; and group 3 calves ($n = 22$) were fed 3 L of bovine colostrum. Blood samples were collected from all calves 24 h after colostrum or CR feeding and analyzed for serum IgG and total protein concentrations. Calves fed bovine colostrum had significantly higher serum IgG and total protein concentration than calves in either group fed the CR product. Group 1 calves (1 package of CR product) had a significantly higher incidence of failure of transfer of passive immunity than calves in groups 2 or 3. The results of this study indicated that 2 packages of this CR product achieved adequate IgG concentrations in calves. However, calves fed 1 package of this CR product consistently had failure of transfer of passive immunity.

Key words: colostrum, immunoglobulin G, passive immunity

Short Communication

Administration of colostrum to newborn calves is recognized as an important component of dairy calf health maintenance, as colostral immunoglobulin absorption is required to establish passive immunity. Current recommendations are to feed 3 to 4 L of high-quality (>50 g/L IgG and $<100,000$ cfu/mL bacteria) colostrum to dairy calves within 6 h of birth to protect against failure of transfer of passive immunity (Weaver et al., 2000; McGuirk and Collins, 2004; Chigerwe et al., 2008).

When high-quality colostrum is not available, or when attempting to avoid transmission of certain pathogens via maternal colostrum, the use of colostrum replacement (CR) products is an alternative. Despite the importance of a good colostrum management program, over one-third (36.3%) of dairy operations still depend on the calf nursing the dam as the only method for colostrum delivery, and 19.2% of calves are estimated to have failure of transfer of passive immunity (FTPI; NAHMS, 2007). Failure of transfer of passive immunity is generally defined as a serum IgG concentration of $<1,000$ mg/dL in dairy calves between 1 and 7 d of age (Weaver et al., 2000; McGuirk and Collins, 2004), and has been associated with an increased risk of morbidity and mortality, decreased growth rates, and decreased first-lactation milk production (Robison et al., 1988; Tyler et al., 1999; Virtala et al., 1999; Faber et al., 2005).

The ingestion and absorption of an adequate mass of IgG are key principles of colostrum management. Ingestion of an adequate mass of IgG is controlled by the quantity and quality of the colostrum administered, and absorption of IgG is dependent on the time elapsed between birth and ingestion. Current recommendations are to administer 3 to 4 L of colostrum with >50 g/L of IgG and $<100,000$ cfu/mL of bacteria within 6 h of birth (McGuirk and Collins, 2004). Meeting these goals requires timely and hygienic collection and delivery of colostrum to newborn calves. In cases where only poor-quality colostrum is available, dairy managers may depend on CR or colostrum supplement products to avoid FTPI. Colostrum replacement products may also be used to avoid transmission of various pathogens via colostrum, including *Mycobacterium avium* ssp. *paratuberculosis* (MAP), *Salmonella dublin*, and *Mycoplasma bovis* (Wray and Callow, 1974; Streeter et al., 1995; Walz et al., 1997; Godden, 2008). As Smith and Foster (2007) described, studies evaluating CR products fail to show a consistent relationship between the IgG concentration of a product and the serum IgG of the subject calves. Each product should be independently evaluated for its ability to produce successful transfer of passive immunity by providing sufficient serum IgG concentration to calves. The purpose of this study was

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to compare serum IgG and total protein concentrations of newborn dairy calves receiving a commercially available plasma-derived CR product or bovine colostrum.

The study protocol was approved by the North Carolina State University institutional committee on the care and use of laboratory animals. Sixty-six Holstein calves were obtained from 2 separate dairy herds in North Carolina. Calves were separated from the dam following an observed parturition and were not allowed to nurse. Calves used in the study had to weigh at least 70 pounds (32 kg) and all animals born as twins were excluded. Calves were maintained on their farm of origin for the duration of the study.

Holstein calves were randomly assigned to 1 of 3 groups with 22 calves per group. Calves in group 1 were fed a single package of a commercially available plasma-derived CR product (Colostrx 130; AgriLabs, St. Joseph, MO) within 2 h of birth, which provides 130 g of globulin protein, mixed in 1.5 quarts (1.42 L) of warm water (67 g of IgG/L). Calves in group 2 were fed 2 packages of the same CR product within 2 h of birth, providing 260 g of globulin protein, mixed in 3 quarts (2.84 L) of warm water (67 g of IgG/L). Calves in group 3 were fed 3 L of bovine colostrum within 2 h of birth. Samples of the colostrum fed to each calf were analyzed by radial immunodiffusion to determine IgG concentration. Calves in all groups were fed the entire volume of colostrum or CR product with an esophageal feeder within 2 h of birth. The CR product was mixed individually for each calf immediately before feeding according to label directions, which indicate to mix 1.5 quarts (1.42 L) of warm (no hotter than 110°F) water with a package of the product using a wire whisk. Water for mixing the CR was always between 100 and 110°F.

A blood sample was collected from the jugular vein of each calf 24 h after colostrum or CR feeding. Samples were collected into plain glass tubes and allowed to clot. Serum was removed and stored at -4°C until analyzed. Serum and colostrum samples were submitted to an independent laboratory for measurement of serum IgG and total protein concentrations. Laboratory personnel were blinded to treatment group of samples. Serum total protein concentration was determined with a digi-

tal temperature-compensating refractometer (model 300027; Sper Scientific Ltd., Scottsdale, AZ).

Serum and colostrum IgG concentrations were determined by radial immunodiffusion. A bovine IgG sample obtained from the USDA Center for Veterinary Biologics was used as the reference sample. The IgG of the reference sample had been measured by turbidometric assay (Etzel et al., 1997) and was reported to be 3,204 mg/dL. The reference sample was diluted 1:3 with PBS before use in the assay. The radial immunodiffusion assay incorporates an antiserum that is both heavy- and light-chain reactive, detecting both IgG₁ and IgG₂. The assay has been validated for use in calves (Chelack et al., 1993).

Data are presented as mean $\pm$ SD. Mean serum IgG and total protein concentrations for each group were compared using one-way ANOVA followed by unpaired *t* tests. Values of *P* < 0.05 were considered significant. The proportion of calves in each group with serum IgG concentration less than 1,000 g/dL (to determine FTPI incidence) was compared with other groups using Fisher's exact test.

Group 1 had significantly lower mean serum IgG and total protein concentrations and a significantly (*P* < 0.001) higher percentage of calves with FTPI than calves in groups 2 and 3 (Table 1). Group 2 calves had significantly (*P* < 0.001) lower mean serum IgG and total protein concentrations than calves in group 3, although the incidence of FTPI in group 2 calves was not significantly different (*P* = 0.25) than group 3 (Table 1). As in other studies (Swan et al., 2007; Poulsen et al., 2010), the results reported here indicate that calves fed maternal colostrum had significantly higher serum IgG and TP than calves fed the plasma-derived CR.

It is currently recommended that Holstein calves ingest 150 to 200 g of IgG within 24 h of birth to avoid FTPI (Quigley et al., 2002; Chigerwe et al., 2008). Colostrum quality varies greatly, as one study representing 239 colostrum samples from 12 dairy herds in Wisconsin and Minnesota found IgG concentration from Holstein cows to average 76.7 ± 30.0 g/L and range from 9.4 to 185.7 g/L (Swan et al., 2007). The present study found the colostrum IgG concentration to average 70.3 ± 4.9

Table 1. Mean $\pm$ standard deviation values for serum IgG and total protein concentrations and the percentage of failure of transfer of passive immunity (FTPI) in calves fed colostrum or a colostrum replacer (CR)

Group	Serum IgG (mg/dL)	Total Protein (g/dL)	FTPI ¹ (%)
Group 1 (1 package of CR)	738 $\pm$ 45 ^a	4.73 $\pm$ 0.06 ^a	86.3 ^a (19/22)
Group 2 (2 packages of CR)	1,059 $\pm$ 23 ^b	5.19 $\pm$ 0.05 ^b	13.6 ^b (3/22)
Group 3 (maternal colostrum)	2,135 $\pm$ 205 ^c	6.07 $\pm$ 0.12 ^c	4.5 ^b (1/22)

^{a-c}Values within a column followed by different superscript letters are significantly different (*P* < 0.05).

¹FTPI was defined as a serum IgG concentration less than 1,000 mg/dL.

g/L and range from 35.8 to 124.2 g/L in the 22 samples tested. Variability in colostrum quality is the basis for the recommendation to feed 3 L of maternal colostrum as soon as possible after birth to ensure adequate IgG intake early in life. With the average colostral IgG concentration reported in this study, this would result in an average ingestion of 211 g of IgG.

In cases where sufficient quantities of good quality colostrum are not available, or as part of a disease control program, CR products are an alternative. As Smith and Foster (2007) described, IgG mass in a CR product has not been shown to be predictive of its success in providing adequate transfer of passive immunity, and various other factors have been identified to contribute to efficiency of IgG absorption, including IgG source and amount and type of non-IgG protein (Arthington et al., 2000; Davenport et al., 2000; Quigley et al., 2001). Some studies have reported the apparent efficiency of absorption (AEA) of CR and colostrum supplement products, as well as maternal colostrum, to describe the perceived difference in absorption of IgG. The present study did not include accurate birth weight records, but assuming a birth weight of 35 kg and a calf serum volume of 10% of BW, an estimated AEA can be calculated for each of the 3 groups, according to the formula described by Quigley et al. (2002). Calves receiving 1 or 2 package(s) of the CR had an average estimated AEA of $19.9 \pm 5.7\%$ and $14.3 \pm 1.5\%$, respectively. Calves receiving 3 L of bovine colostrum had an average estimated AEA of $35.7 \pm 12\%$. The results of all 3 groups were statistically significantly different ($P < 0.05$). These results differ from the 28 to 30% AEA previously reported for plasma-derived CR products (Quigley et al., 2002; Place et al., 2010). The bovine colostrum-fed group results were comparable to those of a previous study that found an AEA of $31.8 \pm 11.7\%$ in calves fed 3.8 L of maternal colostrum, assuming a plasma volume of 9.9% birth weight (Godden et al., 2009a). The differences in AEA of the CR in this study compared with others can only be speculated, and further studies would need to be pursued to investigate the absorptive efficiency of different CR products head-to-head.

One possible explanation for the lower absorption efficiency observed in this study is the use of the esophageal feeder. A recent study demonstrated that calves fed 1.5 L of a CR via nipple bottle had higher IgG concentrations and higher AEA values as compared with feeding an equivalent volume via esophageal feeder (Godden et al., 2009b). Calves fed 3 L of a CR, however, had no difference in IgG concentrations or AEA values whether they were fed with a nipple bottle or esophageal feeder. An esophageal feeder was chosen in this study to ensure consistent delivery of the total volume of colostrum or CR to calves. In addition, the

use of an esophageal feeder to administer colostrum was standard protocol on both dairy farms used in this trial. Although bottle feeding of colostrum may result in slightly higher IgG concentrations, several studies have shown that calves are often reluctant to drink more than 2 L in a single feeding (Urday et al., 2008; Godden et al., 2009b). Another study examined the prevalence of FTPI in dairy calves based on different feeding methods (Besser et al., 1991). Across 3 different dairy herds, 61.4% of calves that were allowed to nurse the dam had FTPI as compared with 19.3% of calves that were bottle fed colostrum and 10.8% of calves that were fed with an esophageal tube. Many herds, therefore, still rely on an esophageal feeder to ensure delivery of an adequate volume of colostrum or CR in a timely manner.

Colostrum replacers have been shown to be an effective alternative to maternal colostrum. In a study involving 497 animals from 12 Midwestern dairy herds, calves fed a CR were followed for approximately 54 mo and compared with herdmates fed colostrum (Pithua et al., 2010). Cows that had been fed CR as calves were no different than cows fed maternal colostrum with respect to lifetime milk yield, breeding performance, and overall risk of culling or death. In addition, calves that had received CR had a decreased risk of developing *Mycobacterium avium* ssp. *paratuberculosis* infection as compared with herdmates fed colostrum (Pithua et al., 2009). In another study, calves that received a plasma-derived CR product had no difference in growth rates, health, or fecal scores through 5 wk as compared with calves that received colostrum (Jones et al., 2004). Although the data evaluating long-term success of calves that receive CR products at birth is limited, several other studies have documented satisfactory transfer of passive immunity with CR products (Foster et al., 2006; Godden et al., 2009a; Poulsen et al., 2010). It is important to use a CR product that has been proven to be effective because many products have failed to establish adequate transfer of passive immunity. Producers should choose a product that has specifically been evaluated for its ability to achieve adequate IgG concentrations in calves.

One package of the CR product used in this study did not provide adequate protection from FTPI. Feeding 2 packages of the CR resulted in an incidence of FTPI not significantly different than calves fed 3 L of bovine colostrum in this study.

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