Comparison of passive immunoglobulin transfer to dairy calves fed colostrum or commercially available colostral-supplement products

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Objective—To compare the efficacy of 3 commercially available colostral-supplement products with that of natural bovine colostrum in providing immunoglobulins for passive transfer and disease protection.

Design—Prospective randomized control trial.

Animals—47 neonatal female Holstein calves from unassisted, observed births. Calves were vigorous, stood within 90 minutes of birth, and did not suckle their dams.

Procedure—Calves were fed 2 L of colostrum or a colostral-supplement product within 2 hours after birth and again prior to 12 hours of age. Serum IgG concentrations were measured at 24 and 48 hours after parturition, and apparent percentage absorption for the colostrum and for each product was calculated. Prevalence of disease in all 4 groups of calves during the first 30 days of life was compared.

Results—Calves fed natural bovine colostrum (group 1) had highest serum IgG concentrations (range, 12.4 to 31.6 mg/ml) at 24 hours after birth, whereas serum IgG concentrations in calves fed colostral products ranged from 1.9 to 8.6 mg/ml. Values for apparent percentage absorption of colostral IgG in group-1 calves was 3 times that of calves fed colostral products. Group-1 calves had significantly (P < 0.05) fewer episodes of disease during the first 30 days of life, compared with calves fed colostral-supplement products.

Clinical Implications—Commercially available colostral-supplement products are less efficient at providing immunoglobulin transfer and disease protection to newborn calves, compared with bovine colostrum, even when fed at equal volume and similar immunoglobulin concentration.

Passive maternal immunoglobulin transfer to newborn calves via colostrum is a critically important aspect of neonatal calf immunity and disease prevention. The newborn calf requires a sufficient volume of colostrum with high immunoglobulin concentration to ensure availability of a high immunoglobulin mass necessary to achieve adequate passive immunity. Inadequate passive transfer can result from deficiencies in colostrum production, colostrum consumption, or immunoglobulin absorption. Deficient intestinal immunoglobulin absorption is difficult to predict or to circumvent, but strategies have been devised for monitoring and managing colostrum quality, availability, and consumption.

Availability of an alternative source of high-quality colostrum is important for circumventing colostral deficiencies.

Commercially available products can provide immunoglobulins for passive transfer to newborn calves when the dam's colostrum is deficient. Such products can provide disease protection to newborn calves when fed as directed. The purpose of the study reported here was to compare 3 commercially available colostral products with that of natural bovine colostrum as a source of immunoglobulins for passive transfer and disease protection in neonatal dairy calves.

Materials and Methods

Sources of immunoglobulin—The study was conducted on a dairy of 600 lactating cows in northern Colorado. Colostrum obtained during first milking after parturition from several multiparous cows in the dairy was pooled and mixed thoroughly to provide a single source of natural bovine colostrum. A sample of the mixed colostrum was obtained for analysis of IgG content. After mixing, the pool of natural colostrum was divided into 1 L aliquots, placed in plastic freezer bags, and stored frozen at −20 C for later use. Immediately prior to feeding, the frozen colostrum was thawed and warmed to approximately 38 C.

Three commercially available colostral products were obtained: For each product, only packages with a single lot number were obtained to ensure uniform composition of each product. A package of each supplement was analyzed. The 3 colostral products were mixed according to manufacturer's directions. For 2 products, this involved mixing 1 package of dried product with 1 L of 38 C water. For the third product, the mixture of 1 package of dried product with 1 L of water was too thick to be administered through a nipple feeder; therefore, approximately 1 L of water was used with each package of this product.

Calves—Calves used in the study were females from unassisted, observed births. Calves were vigorous, stood within 90 minutes of birth, and were not allowed to suckle their dams. Calves were weighed, and physical examinations were performed to assess pulse rate, respiratory rate, and rectal temperature and to detect congenital defects. Throughout the 48-hour sampling period, calves were examined prior to each feeding to determine pulse rate, respiratory rate, rectal temperature, appetite, and fecal consistency. Subsequently, calves were cared for by dairy personnel, were housed with the rest of the herd's calves, and were not distinguished from their herdmates. Calves observed to be ill were evaluated by the resident veterinarian (MBC), and appropriate treatment was instituted as deemed necessary. Calf illness was recorded as enteric disease, respiratory disease, or joint inflammation. For the purpose of statistical evaluation, calves were recorded as healthy or as affected with illness that required treatment.

Treatments—Calves were allotted sequentially to 1 of 4 groups. Each group was fed a source of colostral immunoglobulin. Group-1 calves received pooled natural bovine colostrum with high IgG content and received only 1 source of colostrum. Group-2 calves received a colostral-supplement product and received only 1 source of colostrum. In group-3 calves, colostrum was fed as directed; calves were given a source of colostral immunoglobulin and a colostral-supplement product and were given the colostral-supplement product twice. In group-4 calves, colostrum was fed as directed; calves were given a colostral-supplement product and were given the colostral-supplement product twice.

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colostrum from cows of the farm, and calves in groups 2 through 4 each received 1 of the commercially available colostral products. After mixing each product accordingly, calves in each group were fed 2 meals (2 L of colostrum or colostral product/meal), such that each calf received 4 L of immunoglobulin-containing liquid. The first feeding was within 2 hours after birth, and the second meal was fed within 12 hours after birth.

After the initial 2 feedings, calves in all groups were fed in the same manner. Calves in all 4 groups were provided discarded milk or a milk replacer solution 2 times per day. Discarded milk was fed until calves were 3 days old. On day 4 and thereafter, calves received a solution of milk replacer at a rate of 4 L/d for 60 days. A starter ration was offered after the first week of life, and calves were offered water ad libitum throughout the 60-day milk feeding period.

Sample collection—Blood was obtained from the jugular vein of each calf at birth (prior to the initial colostrum feeding) and again at 24 and 48 hours after parturition. Blood was collected into plain glass tubes and was allowed to clot, and serum was received. Serum samples were stored frozen at −20°C for later analysis. Serum samples and samples from each of the immunoglobulin sources were analyzed for IgG content by use of a radial immunodiffusion method. The technician performing assays was not informed of calf group or treatment.

Statistical analysis—Data from analysis of the precostral blood sample were examined. Calves with serum IgG concentrations of >1.0 mg/ml were excluded from further analysis on the basis of believed in utero immune stimulation. Comparisons between groups of calves were performed for body weight (BW) at birth, serum IgG concentrations at 24 hours, serum IgG concentrations at 48 hours, and apparent percentage absorption of immunoglobulin received by the calves, using factorial ANOVA. An estimation of apparent percentage absorption of immunoglobulin was made by estimating the serum volume of each calf (4% of BW) and then determining the circulating immunoglobulin mass (serum volume × serum immunoglobulin concentration). The value determined for the circulating IgG mass then was divided by the value for the amount of IgG mass fed, and the resulting value was multiplied by 100 to yield a percentage. For each variable, homogeneity of variances between groups was evaluated, using Bartlett's test. For variables in which variances were not equal between groups, analysis was performed after log transformation of the data. When a significant difference was detected, the Bonferroni procedure was used to distinguish significant (P < 0.05) differences between groups.

Comparison of the prevalence of illness between groups was performed, using contingency table analysis. When a significant difference was detected, χ² analysis was used to distinguish differences between groups.

Results

Seven calves initially included in the study were excluded on the basis of a serum IgG concentration >1.0 mg/ml in the precostral blood sample. There were 10 calves in group 1, 12 calves in group 2, 14 calves in group 3, and 11 calves in group 4. Significant differences were not detected in mean BW among groups of calves (mean ± SD: 41.1 ± 3.9 kg, 40.7 ± 6.1 kg, 40.8 ± 3.1 kg, and 42.8 ± 4.9 kg, respectively, for calves in groups 1 to 4).

The IgG concentration in the 4 immunoglobulin sources were pooled natural bovine colostrum (group 1), 43.5 mg/ml; colostral product a (group 2), 39.2 g/

Figure 1—Serum IgG concentrations (mean ± SD) at 24 and 48 hours in calves fed pooled natural bovine colostrum or a colostral supplement within 12 hours of birth. a,b,c, Within each time period, values with different superscripts differ significantly (P < 0.05). Group 1 (n = 10), pooled natural bovine colostrum; group 2 (n = 13), colostral product 1; group 3 (n = 14), colostral product 2; group 4 (n = 11), colostral product 3.

package; colostral product a² (group 3), 35.9 g/package; and colostral product b² (group 4), 31.5 g/package. The IgG mass fed to calves in each group ranged from 164.7, 156.8, 107.7, and 126.0 g, respectively, for groups 1 to 4.

Values for serum IgG concentrations at 24 and 48 hours for calves fed pooled natural bovine colostrum ranged from 12.4 to 31.6 mg/ml (Fig 1). Calves fed colostral products had values ranging from 1.9 to 8.6 mg/ml. Coefficients of variation were similar among groups for both sampling times, but variance for group 1 was much larger than for the other groups at both sample times because of the markedly higher values for calves in group 1.

Serum IgG concentration at 24 hours for calves in group 1 was significantly (P < 0.0001) higher than those for any other group. Comparisons between the other 3 groups revealed a significant (P < 0.05) difference in values for calves in group 2 versus group 4, but other group values were not significantly different. Serum IgG concentrations from the sample at 48 hours again revealed that values for calves in group 1 were significantly (P < 0.001) different from those of the other groups. At 48 hours, comparisons among the 3 colostral-product groups revealed a significant (P < 0.05) difference between calves in group 3 versus group 4, but other group values were not significantly different.

Values of the apparent percentage absorption of consumed IgG for group-1 calves ranged from 14.5 to 35.9%, and values for calves from the 3 groups fed colostral products ranged from 3.6 to 12.1% (Fig 2). Values for calves in group 1 were significantly (P < 0.0001) different from those for the other groups. Comparison of the 3 colostral-product groups revealed a difference (P < 0.05) between group-3 calves and those in groups 2 and 4, but other differences were not detected between group-2 and group-4 calves.

Enteritis, including undifferentiated neonatal scour and presumptive clostridial enteritis, was the most
commonly identified illness (Table 1). Enteritis was diagnosed in 8 calves in group 2, 1 of which died at 13 days of age. There were 9 calves with enteritis in group 3 and 6 calves with enteritis in group 4. Respiratory disease was diagnosed in 3 calves in group 3. Joint inflammation was diagnosed in 1 calf in group 2. Evaluation of contingency table analysis revealed significant ($P = 0.0003$) differences in prevalence of illness between groups of calves. Evaluation by means of $\chi^2$ analysis revealed that the major differences among groups was the number of healthy calves (10/10) in group 1. The other major contributor to the differences among groups was the large number of calves (12/14) in group 3 that became ill.

**Discussion**

Colostral supplements for calves are commercially available and designed to provide newborn calves with measurable quantities of immunoglobulin for passive transfer.\(^{11}\) To be sold as licensed products, manufacturers of such products are required to provide information about the efficacy of their product for passive transfer of immunoglobulin to the newborn calf and protection against disease challenge, compared with calves deprived of a colostral source. Because the products are not sold as substitutes for colostrum, licensing agencies do not require that a comparison with naturally derived bovine colostrum be performed.

Evaluations of colostral-supplement products have been published previously.\(^{12-14,16,18}\) In 1 such report, an extremely low content of immunoglobulin was detected in some of the products.\(^{18}\) In another report, minimal immunoglobulin was transferred to newborn calves, but the product was efficacious in preventing neonatal losses from septicemia *Escherichia coli* challenge, compared with colostrum-deprived calves.\(^{9}\) In another study, the addition of a colostral supplement to natural bovine colostrum did not increase calf serum immunoglobulin concentration or apparent disease resistance.\(^{14}\) From such studies, we concluded that there is variation between some products and that some products do have value for colostrum-deprived calves, but that an enhancement of the value of natural bovine colostrum was unlikely.

The study reported here was designed to compare the efficacy of 3 colostral-supplement products with that of pooled natural bovine colostrum in affording passive immunoglobulin transfer and disease protection to the newborn calf. The products used were licensed as colostral supplements and derived from bovine colostrum or cheese whey. Evaluation of immunoglobulin content revealed that all 3 products exceeded minimum immunoglobulin content indicated on the label. Recommendations commonly made to producers about colostrum feeding to newborn calves are made on the basis of a volume rate of feeding.\(^{1,2}\) For this reason, the 4 colostral sources were compared with equal rates of feeding on a volume basis. Because of variation in the immunoglobulin concentration among products, each group of calves received different masses of immunoglobulin; however, the immunoglobulin mass administered to all calves was $> 100$ g, which is the minimal amount commonly recommended to producers.\(^{2}\) Each of the colostral supplements was reconstituted according to manufacturer’s recommendations, but the volume fed was 3 to 4 times greater than that recommended on the label. Colostrum-deprived calves were not included for comparison, because such comparisons have been performed to obtain licensure, and such treatment would result in an abnormally high risk of disease and death in newborn calves.\(^{b}\)

Our original intent was to administer an equal volume of each of the 4 sources of colostral immunoglobulins and to provide the 3 colostral-supplement products at the same dilution rate (1 L of water/package). This proved impractical with the product fed to calves in group 3.\(^{4}\) Although 1.3 L of water/package of powder was used for that product, this was still within the manufacturer’s recommended guidelines for mixing and provided a liquid that could be administered satisfactorily via nipple feeder.

The calculation of apparent percentage absorption was made on the basis of an estimate of the serum volume in which the measured IgG concentration was circulating.\(^{16,17}\) Measurement of the circulating plasma volume by a dye dilution technique\(^{11}\) would have made the calculation more accurate. Plasma volume was not measured in this study, because we did not anticipate the poor efficacy of absorption of immunoglobulin from the colostral supplements. Differences in the amount of immunoglobulin ingested, however, could only account for a small percentage of the differences in serum IgG concentration seen among calves in the various groups. Whether determined by estimating or
by measuring circulating serum volume, the calculation of percentage immunoglobulin absorbed from the mass ingested will underestimate actual absorption, because some of the immunoglobulin will localize in extravascular pools. For this reason, the calculation of absorption was termed "apparent," and we assumed that the proportions of immunoglobulin in intravascular and extravascular pools would be similar irrespective of immunoglobulin source. If these assumptions were correct, then there was an approximate threefold difference in the efficacy of absorption of immunoglobulin from natural colostrum, compared with the colostral-supplement products used.

The increased number of ill calves fed the colostral products was notable, compared with calves fed pooled natural bovine colostrum. It was likely that a decrease in passive immunoglobulin transfer in the calves fed colostral supplements contributed to the increase in prevalence of disease. It also was likely that immunoglobulin derived from cows in the same herd was more specific for the pathogens encountered by the newborn calves in the study than was immunoglobulin contained in the commercially available products. The findings in our study supported the recommendation that calves are protected best against disease when they receive colostrum from cows in the herd of origin in sufficient quantity to achieve a high degree of passive immunoglobulin transfer.

Significant differences were found among serum IgG concentrations at 24 and 48 hours and apparent percentage of immunoglobulin absorbed in calves of colostral supplement groups (groups 2 through 4); however, the physiologic importance of these differences was questionable. The highest values obtained for IgG concentration from any of the calves fed colostral supplements were still lower than the minimum value obtained from calves fed pooled natural bovine colostrum. Comparing the measured IgG concentrations with those in published recommendations revealed that calves fed pooled natural bovine colostrum had acceptable serum IgG concentrations. Even though colostral supplements were fed in amounts that were 2 to 4 times the label recommendations, the calves in groups 2 through 4 all had circulating serum IgG concentrations suggestive of poor passive immunoglobulin transfer. It appeared that newborn calves absorbed immunoglobulin less well from commercially available colostral-supplement products than from natural bovine colostrum. Pooled natural bovine colostrum fed at a volume equal to that of 3 colostral products provided calves in our study with better protection against disease.

References


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