

Effects of Spray-Dried Animal Plasma in Milk Replacers or Additives Containing Serum and Oligosaccharides on Growth and Health of Calves¹

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ABSTRACT

The effects of spray-dried animal plasma in milk replacer without or with the addition of additives containing fructooligosaccharides and spray-dried serum on health, growth, and intake of Holstein calves was measured in two 56-d experiments. In experiment 1, 120 calves were fed milk replacer containing 0 or 20% of crude protein as spray-dried bovine plasma for 42 d and 30 to 60 g/d of additives containing whey protein concentrate or bovine serum for the first 15 d. Commercial calf starter was available from d 29, and water was available at all times. In experiment 2, 120 calves were fed milk replacer containing 0 or 16% of crude protein as spray-dried bovine plasma with 0 or 30 to 60 g/d of additive containing bovine serum for the first 15 d. Additive containing bovine serum also contained fructooligosaccharides, whey, and vitamin/mineral premix. In experiment 1, calves fed additive containing bovine serum tended to have fewer days with diarrhea, lower use of electrolytes, and improved BW gain from d 29 to 56. The addition of spray-dried bovine plasma to milk replacer did not influence any parameter measured. In experiment 2, calves fed additive containing bovine serum or milk replacer containing spray-dried bovine plasma had lower mortality (4.4 vs. 20%) and tended to have improved fecal scores and fewer days with scours. Antibiotic use was lower when calves were fed the additive. Indices of enteric health (incidence of scours and treatment with antibiotics and electrolytes) were improved when plasma was added to milk replacer throughout the milk feeding period or as an additive during the first 15 d of the milk feeding period, when calves were most susceptible to enteric pathogens. The

addition of spray-dried animal plasma to milk replacer or the addition of additive containing spray-dried bovine serum and oligosaccharides may be a useful adjunct to animal management during periods of stress. (**Key words:** calf, immunoglobulin, oligosaccharide, milk replacer)

Abbreviation key: **CMR** = calf milk replacer, **CS** = calf starter, **FOS** = fructooligosaccharide, **GAM** = gammulin additive, **PLC** = placebo additive, **SDAP** = spray-dried bovine plasma.

INTRODUCTION

Calf milk replacers (**CMR**) are commonly used for replacement dairy calves. According to Heinrichs et al. (1995), much of the CMR fed in the United States contain antibiotics, typically neomycin and oxytetracycline. Antibiotics have been evaluated in several studies (Braidwood and Henry, 1990; Morrill et al., 1977; Quigley et al., 1997) and generally result in reduced shedding of enteropathogens (Losinger et al., 1995), reduced scours, and improved BW gain. On the other hand, recent evidence suggests that continued use of antimicrobials in animal agriculture may contribute to increased risk of antibiotic-resistant bacteria of medical importance (Fey et al., 2000; Tollefson et al., 1999).

Products have been evaluated as potential alternatives to antibiotics in CMR formulations. Some of these include yeast and yeast cultures (Quigley et al., 1992; Seymour et al., 1995), oligosaccharides (Kaufhold et al., 2000; Quigley et al., 1997), and animal plasma (Morrill et al., 1995; Quigley and Bernard, 1996). Animal plasma contains Ig and other compounds with antibacterial and antiviral activity and is used widely in diets of early-weaned pigs (Hansen et al., 1993). Due to the presence of protease inhibitors and protein conformation, Ig are relatively resistant to digestion and retain immunological activity in the gastrointestinal tract (Besser et al., 1988b; Roos et al., 1995). Besser et al. (1988a, 1988b) reported resecretion of absorbed colostrum Ig into the intestine, which imparted protection

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against an oral rotavirus challenge. Immunoglobulins administered orally to postclosure animals are protective against oral challenge with bacteria and viruses (Nollet et al., 1999a,b; Quigley and Drew, 2000; Yokoyama et al., 1997; Zuniga et al., 1997). Calves fed CMR containing animal plasma have performed similarly to (Quigley and Bernard, 1996) or better than (Morrill et al., 1995) calves fed CMR containing proteins derived from whey.

Fructooligosaccharide (**FOS**) compounds reportedly stimulate growth of beneficial bacteria in the gastrointestinal tract and inhibit colonization by pathogens (Grizard and Barthomeuf, 1999; Menne et al., 2000; Seymour et al., 1995). These carbohydrates may reduce the adhesion of certain bacterial species to the intestinal epithelium, most notably *Escherichia coli* (K99+) and salmonella (Martin, 1994; Oyofe et al., 1989a,b). Further, oligosaccharides may also increase the growth of beneficial intestinal bacteria, including *Lactobacilli* and *Bifidobacterium* (Menne et al., 2000). Oligosaccharides containing mannose (Quigley et al., 1997) and fructose (Kawaguchi et al., 1993) have been used in diets of calves and pigs to improve intestinal health and reduce the incidence of disease. Conversely, Mathew et al. (1997) reported no effect of oligosaccharides on nutrient digestibility or ileal VFA and lactate concentrations in early-weaned pigs.

Our objective was to determine the response of calves to the inclusion of spray-dried animal plasma (**SDAP**) or a combination of spray-dried bovine serum and FOS added to CMR.

MATERIALS AND METHODS

Experiment 1

Holstein bull calves (n = 120) were purchased from area farms and shipped to the APC Calf Research Unit in Ames, Iowa. Calves were received in two groups of 60 calves on May 26, 2000, and June 2, 2000, and the study was initiated the next day. Calves were approximately 9 d of age on arrival (based on date of birth provided by the producer). Jugular blood was collected from each calf on arrival into evacuated tubes containing EDTA, and a subsample collected for measurement of hematocrit by microhematocrit centrifuge. Tubes were then centrifuged, and plasma was separated and frozen (-20°C) until analyzed for IgG by turbidimetric immunoassay (Etzel et al., 1997).

On arrival, calves were unloaded from the truck, moved to individual fiberglass hutches, and fed 454 g of a colostrum supplement product (Lifeline Calf Nutritional Colostrum Supplement, APC, Inc.) reconstituted in 1.9 L of water. Calves were then assigned randomly

to receive experimental nonmedicated CMR (Table 1) containing 0 or 20% of CP from SDAP (NutraPro B, APC, Inc.). This amount of SDAP provided approximately 3 to 4 g of IgG per day. All CMR were formulated to contain 22% CP, 20% fat, 0.8% Ca, 0.7% P (air-dry basis) and to meet or exceed NRC requirements (NRC, 1989) for vitamins and minerals.

Calves were fed CMR twice daily at approximately 0700 and 1600 h using individual nipple bottles. Calves were offered 454, 545, 654, 726, 545, 272, 0, and 0 g of CMR/d reconstituted to 12% DM during wk 1 to 8, respectively. The CMR were mixed in hot water (approximately 50°C) to disperse fat. Cool water was then added to bring temperature to approximately 39°C and the appropriate DM content before feeding. Calves were also assigned to receive oral supplement (**GAM**; Gamulin, APC, Inc.) or a placebo additive (**PLC**). The GAM contained spray-dried bovine serum, FOS, dried whey, and vitamin/mineral premix; and the PLC contained dried whey, vitamin/mineral premix, and whey protein concentrate to approximate the nutrient content of GAM. Additives were fed at rates of 60, 45, and 30 g/d for d 1 to 5, 6 to 10, and 11 to 15, respectively.

Commercial textured calf starter (**CS**; Cargill Herd Builder, Cargill, Inc., Minnetonka, MN) was offered once daily for ad libitum consumption, and feed refusals were measured daily. Water was offered once daily for ad libitum consumption. Refusals of water were measured, and water intake was assumed to equal water offered minus water refused. No hay was fed. Hutches were bedded with straw throughout the study. Samples of CMR and CS were collected weekly and stored (-20°C) before analysis for CP, ether extract (Mojonnier assay), ADF (CS only), ash, and selected minerals (AOAC, 1990) by a commercial laboratory (Silliker Laboratories of Iowa, Cedar Rapids, IA).

Calves were weighed once weekly starting on d 0. Fecal consistency was qualitatively scored once daily using a scale of 1 = normal fecal consistency, 2 = slightly liquid consistency, 3 = moderately liquid consistency, and 4 = primarily liquid consistency (severe scours). When fecal material was unavailable for scoring, calves were assigned a missing value. A scour day was defined when calves had a fecal score >2. Rectal temperatures were determined on calves with fecal score >1. Treatment with antibiotics was initiated when an animal had a rectal temperature >39.4°C. Electrolyte therapy was initiated when calves had fecal score >2, or were visibly dehydrated, and continued until signs of disease abated. Daily mean high and low ambient temperature, relative humidity, and solar radiation were obtained from ISU Campbell Network (Iowa State University, Ames, IA).

Table 1. Ingredient composition of experimental milk replacers.

Ingredient, % as fed	Treatments ¹			
	Experiment 1		Experiment 2	
	WPC	SDAP	SPC	SDAP
Dry fat blend (20% CP/40% fat)	50.1	50.1	0.0	0.0
Dry fat blend (7% CP/60% fat)	0.0	0.0	33.0	32.7
WPC, 34%	31.9	15.7	27.5	16.1
Bovine plasma, 78% CP	0.0	5.0	0.0	4.0
Dried whey	13.0	24.7	21.7	30.5
Soy protein concentrate, 67% CP	0.0	0.0	13.4	12.8
Vitamin/mineral premix	2.5	2.5	2.5	2.5
Dicalcium phosphate, 18.5%	2.5	2.0	1.7	1.2
L-lysine HCl	0.0	0.0	0.1	0.1
DL-methionine	0.0	0.0	0.1	0.1

¹Treatments: WPC = Milk replacer containing whey protein concentrate as primary protein ingredient; SDAP = milk replacer containing spray-dried animal plasma; SPC = milk replacer containing whey protein concentrate plus soy protein concentrate as primary protein ingredients.

Data were analyzed by ANOVA using SAS (1990). Data were summarized over the 56-d study and within period (d 0 to 15, 16 to 28, 29 to 42, and 43 to 56) and analyzed using a completely randomized experimental design. Daily intake of CS, CMR, water, fecal scores, and weekly BW and feed efficiency were pooled by week and analyzed as repeated measures ANOVA using the Mixed procedure of SAS. Mortality was analyzed by chi-square analysis using the Mixed procedure of SAS. Significance was declared at $P < 0.05$.

Experiment 2

Holstein bull calves ($n = 120$) were transported to the APC Calf Research Unit in Ames, Iowa. Calves were received in two groups on August 11, 2000, and August 18, 2000, and the study was initiated on the next day. Calves were managed as in experiment 1, except that all calves were purchased from sale barns instead of farms, CS was formulated to contain 16% of CP as SDAP (Table 1), and calves were fed 454 g/d of CMR powder reconstituted to 12% DM throughout the 56-d trial. The CMR was formulated to contain soy protein concentrate to replace a portion of the whey protein concentrate in the formula. Differences in formulation were required because the fat blend was unavailable when experiment 2 was started. The placebo (PLC) was not fed in experiment 2, so the control would more closely resemble conditions on dairy farms. On arrival, plasma total protein was determined using a refractometer in addition to measurement of hematocrit.

RESULTS

Chemical composition of experimental ingredients (Table 2) was typical for bovine plasma and serum and

did not differ between experiments. The composition of diets was similar between CMR containing whey protein concentrate or SDAP (Table 3). The amount of CP in CMR was higher than formulated but did not differ markedly between treatments. The amount of CP in PLC was lower than in GAM (68.5 vs. 74.6%) and other nutrient specifications differed slightly. Amount of CP in CS was markedly higher than anticipated (nearly 28% of DM) and markedly influenced CP intake later in the study. Inclusion of SDAP in CMR had no effect on solubility, handling, mixability, or palatability of the CMR.

Experiment 1

Calves were generally healthy throughout the trial, and only one calf died. At the start of the trial, calves were 9 d of age and mean plasma IgG concentration and hematocrit were 9.7 g/L and 35.3%, respectively (Table 4). Calves assigned to receive GAM tended to have higher initial plasma IgG concentration ($P < 0.06$);

Table 2. Chemical composition of spray-dried bovine plasma (SDAP), spray-dried bovine serum (SDBS), and experimental soy protein concentrate (SPC) used in milk replacer and additives.

Nutrient ¹	Experiment 1		Experiment 2		
	SDAP	SDBS	SDAP	SDBS	SPC
Moisture, %	6.90	5.40	7.46	5.25	3.87
CP, %	78.12	85.23	78.05	84.51	70.32
Fat, %	3.75	4.09	4.13	5.11	1.10
Ca, %	0.11	0.15	0.10	0.21	0.36
P, %	0.99	0.11	1.43	0.13	0.85
K, %	0.09	0.10	0.17	0.08	2.07
Mg, %	0.02	0.01	0.03	0.01	0.33

¹Data from Silliker Laboratories (Cedar Rapids, IA). Analyses are on an air-dry basis.

Table 3. Chemical composition¹ of experimental milk replacers containing whey protein concentrate (WPC) or soy protein concentrate (SPC), spray-dried bovine plasma (SDAP), or additive containing bovine serum (GAM) or placebo (PLC) and calf starter (CS).

	Experiment 1					Experiment 2			
	WPC	SDAP	GAM	PLC	CS	SPC	SDAP	GAM	CS
DM, %	97.92	97.94	95.58	96.46	86.43	97.62	97.96	95.18	86.46
CP, %	23.05	23.25	74.61	68.53	27.80	28.48	23.36	73.23	28.44
Fat, %	20.31	20.48	3.87	0.74	3.93	18.71	22.15	4.43	4.38
Ash, %	8.65	8.42	5.62	6.14	5.90	ND ²	ND	ND	ND
Ca, %	1.44	1.03	0.69	1.21	0.77	1.45	1.03	0.75	0.59
P, %	0.97	0.85	0.15	0.42	0.79	1.13	0.90	0.20	0.68
K, %	1.45	1.24	0.15	0.82	0.99	1.73	1.65	0.26	0.91
Mg, %	0.18	0.15	0.09	0.28	0.29	0.16	0.15	0.13	0.25
ADF, %	...	...	...	...	6.49	...	...	...	5.62

¹Data from Silliker Laboratories (Cedar Rapids, IA). All analyses are on a 100% DM basis, except DM.

²Ash data were not reported in experiment 2.

however, plasma IgG concentration did not contribute significantly to any model when included as a covariate. Therefore, unadjusted means are presented.

Daily high and low ambient temperatures ranged from 15.6 to 33.5°C and 8.7 to 23.1°C, respectively. Mean high and low ambient temperatures over the study were 26.3 and 15.5°C, respectively. Ambient temperatures were generally within the thermoneutral zone for calves (National Research Council, 1981) throughout the study, indicating that little additional dietary energy was used to support thermoregulation. Mean humidity and solar radiation during the trial were 79.9% and 499.8 kcal/cm², respectively.

Mean BW at 0, 28, and 56 were unaffected by treatment (Table 4) and were 46.8, 54.1, and 71.7 kg, respectively. Mean daily BW gain from 0 to 28 d was unaffected by treatment and was 262 g/d. Body weight gains from 29 to 56 d and 0 to 56 tended ($P < 0.10$) to be greater when calves were fed GAM versus PLC. Calves fed GAM gained 12.9% more BW (665 vs. 589 g/d) during the d 29 to 56 period compared with calves fed PLC. Increase in BW gain with feeding GAM was measured even though feeding GAM and PLC had terminated on d 15.

Intake of CMR (Table 4) was affected by inclusion of SDAP ($P < 0.01$), but differences were only 2 g/d. The biological significance of this difference is probably minimal. Intake of CS averaged 511 g/d and was unaffected by treatment (Table 4). Intake of total DM and CS intake increased rapidly with day from d 29 when CS was offered; by 8 wk calves were consuming nearly 2 kg/d of CS. Intake of additive was similar among treatments, and difference ($P < 0.01$) between GAM and PLC were due to differences in DM composition of the respective products.

Intakes of CP, fat, and water increased with increasing age but were not affected by treatment. Increased

CP intake compared with fat intake was caused by high CP in CS and increasing intake of CS from d 29. Water intake averaged 2.3 L/d but increased dramatically when CS was offered beginning at 29 d. The correlation between daily CS intake and water intake was high ($r = 0.79$, $P < 0.001$, $n = 6689$), indicating the highly significant relationship between intake of water and CS. Efficiency of BW gain tended ($P = 0.12$) to be improved when calves were fed GAM and was increased by 8.3% compared with PLC.

Fecal scores were unaffected by treatment, and mean score was 1.6 (Table 3). The incidence of scours and use of electrolytes tended ($P < 0.10$) to be reduced when GAM was fed compared with calves fed PLC. The overall use of antibiotics was low (0.9 d), and differences did not approach significance. The 22% reduction in the incidence of scours (5.5 vs. 7.0 d) in calves was consistent with lower use of electrolytes and antibiotics. Calves fed GAM were treated with electrolytes and antibiotics for 1.5 and 0.7 d, respectively, whereas calves fed PLC were treated for 2.5 and 1.2 d, respectively.

Least squares means of fecal scores, days with scours, and use of antibiotics and electrolytes during the first two periods of the experiment (Table 5) generally did not show statistical significance, although the number of days with scours was reduced ($P < 0.01$) in calves fed GAM. No differences were apparent during the last two periods of the study (data not shown).

Experiment 2

Chemical composition of SPC and SDAP used in experimental CMR and bovine serum used in GAM are in Table 2. The SPC contained less CP and fat than the SDAP. Concentration of CP and fat in experimental CMR varied significantly; the amount of CP was higher and fat lower in CMR containing SPC than formulated (Table 3).

Table 4. Least squares means of animal performance, experiment 1.

	Treatment ¹				SE	Contrasts ²		
	P-A-	P-A+	P+A-	P+A+		P	A	I
N								
Begin	30	30	30	30	...	...	...	...
End	29	30	30	30	...	...	...	...
Mortality, %	3.3	0	0	0	0	...	...	...
IgG, g/L	9.0	10.3	8.5	11.1	1.0	NS	0.06	NS
Hematocrit, %	35.0	35.3	36.0	34.9	1.4	NS	NS	NS
Age, d	8.8	8.9	9.1	9.0	0.8	NS	NS	NS
BW, kg								
D 0	47.1	46.1	47.4	46.5	0.7	NS	NS	NS
D 28	54.6	54.0	54.7	53.3	0.6	NS	NS	NS
D 56	70.8	72.0	71.5	72.5	1.4	NS	NS	NS
ADG, g/d								
D 0 to 28	267	281	260	242	18	NS	NS	NS
D 29 to 56	577	643	601	686	40	NS	0.07	NS
D 0 to 56 ²	422	462	430	464	22	NS	0.10	NS
DMI, g/d								
CMR ^{3,4}	389	390	391	391	1	0.01	NS	NS
Starter ³	492	514	502	535	24	NS	NS	NS
Additive	12	12	12	12	1	NS	0.01	NS
Total ³	893	915	905	937	24	NS	NS	NS
Protein intake, g/d ³	234	241	238	248	7	NS	NS	NS
Fat intake, g/d ³	98	100	100	102	1	NS	NS	NS
Water intake, L/d ³	2.3	2.3	2.4	2.3	0.2	NS	NS	NS
ADG:DMI, g/kg ³	420	474	428	444	23	NS	0.12	NS
Fecal scores ³	1.6	1.6	1.6	1.6	0.03	NS	NS	NS
Scours, d ³	6.6	4.9	7.3	6.1	0.9	NS	0.09	NS
Electrolytes, d ³	2.0	1.6	3.0	1.4	0.6	NS	0.10	NS
Antibiotics, d ⁵	1.1	0.9	1.3	0.4	0.4	NS	NS	NS

¹Treatment: P = Calf milk replacer (CMR) containing 0 (-) or 20% (+) of CP as spray-dried bovine plasma; A = addition of placebo (-) or supplement (+) containing bovine Ig and fructooligosaccharide.

²Contrasts: P = main effects of P- vs. P+; A = main effects of A- vs. A+; I = interaction of P and A.

³Significant effect of week ($P < 0.01$).

⁴Significant week × treatment interaction ($P < 0.01$).

⁵Significant effect of week ($P < 0.05$).

Calves were obtained from sale barns, and the incidence of failure of passive transfer of immunity was significant. Plasma IgG concentrations were <10 g/L in 79 of 120 calves (66%), and 26 calves (22%) had plasma IgG concentration less than 4 g/L. Total plasma protein on arrival was highly correlated with plasma IgG ($r^2 = 0.73$). Initial blood hematocrit, plasma IgG, and total protein did not differ by treatment, although total protein tended ($P < 0.11$) to be higher in calves assigned to receive GAM (Table 6); this was primarily due to higher total protein in calves fed SDAP and GAM compared with other calves. Mean blood hematocrit was 33.2%. Plasma IgG and total protein were 8.9 and 56 g/L, respectively. Calf mortality was reduced when calves were fed GAM or SDAP (Table 6).

Mean BW at 0, 28, and 56 d were unaffected by treatment (Table 6) and were 46.8, 52.2, and 74.6 kg, respectively. Mean BW gains were also unaffected by treatment and were 194, 793, and 497 for d 0 to 28, 29 to

56, and 0 to 56, respectively. Weekly BW increased with advancing age but did not vary by treatment.

Intake of total DM and CS did not vary by treatment; however, intake of CMR was statistically different due to low variation and differences in chemical composition (Table 6). Consumption of CP and fat differed by treatment; calves fed CMR containing SDAP tended to consume less CP and consumed more ether extract than calves fed control CMR, due to differences in chemical composition of the CMR. Free water intake averaged 1.8 L/d and was not affected by treatment. Weekly water intake increased less rapidly than in experiment 1, peaked at 5 wk, and then declined during the week of weaning. Thereafter, water intake increased along with increasing CS intake. Efficiency of feed utilization was unaffected by treatment, and mean feed efficiency was 331 g of BW gain/kg of DMI. Efficiency of feed utilization increased with advancing age to 4 wk, and then was variable to the end of the study. Weekly mean efficien-

Table 5. Least squares means of animal performance during periods 1 and 2, experiment 2.

	Treatment ¹				SE	Contrasts ²		
	P-A-	P-A+	P+A-	P+A+		P	A	I
Experiment 1								
Period 1 (d 1 to 15)								
Fecal scores	2.02	1.96	2.02	1.98	0.04	NS	NS	NS
Scours, d	3.8	2.5	4.0	3.2	0.4	NS	0.01	NS
Electrolytes, d	1.2	1.0	1.3	1.0	0.3	NS	NS	NS
Antibiotics, d	0.3	0.2	0.3	0.2	0.2	NS	NS	NS
Period 2 (d 16 to 28)								
Fecal scores	1.83	1.82	1.81	1.81	0.05	NS	NS	NS
Scours, d	2.2	1.8	1.8	2.1	0.4	NS	NS	NS
Electrolytes, d	0.6	0.5	0.8	0.3	0.2	NS	NS	NS
Antibiotics, d	0.6	0.4	0.3	0.0	0.2	NS	NS	NS
Experiment 2								
Period 1 (d 1 to 15)								
Fecal scores	2.05	1.88	1.99	1.94	0.05	NS	0.04	NS
Scours, d	4.3	2.8	3.8	3.2	0.5	NS	0.03	NS
Electrolytes, d	1.9	1.0	1.4	1.2	0.3	NS	0.08	NS
Antibiotics, d	2.4	0.7	1.1	1.1	0.4	NS	0.02	0.02
Period 2 (d 16 to 28)								
Fecal scores	1.49	1.46	1.47	1.50	0.05	NS	NS	NS
Scours, d	0.6	0.6	0.5	0.6	0.2	NS	NS	NS
Electrolytes, d	0.0	0.1	0.7	0.6	0.3	NS	0.10	NS
Antibiotics, d	0.4	0.1	0.7	0.6	0.3	NS	NS	NS

¹Treatments: Calf milk replacer containing 0% (P-) or 4% (P+) spray-dried bovine plasma; A = addition of 0 (-) or 30 to 60 (+) g of additive/d for the first 15 d.

²Contrasts: P = main effect of P; A = main effect of A; I = interaction of P and A.

cies ranged from -117 to 749 g of BW gain/kg of DMI during wk 1 and 7, respectively.

Calves fed GAM and SDAP tended ($P < 0.10$) to have lower fecal scores compared with calves fed control CMR without added GAM (Table 6). The number of days that calves had scours (fecal score >2) was lower when calves were fed GAM, and a trend ($P < 0.07$) for a significant CMR \times GAM interaction indicated that calves fed control CMR without added GAM had greater incidence of scours than other calves. The use of electrolytes was not significantly affected, although the number of days that calves were treated with antibiotics was numerically lower when calves were fed GAM (Table 6).

Differences in health parameters were particularly significant during the first 15 d of the study (Table 5). During the first 15 d, calves fed GAM had lower fecal scores and reduced incidence of scours, reduced use of electrolytes, and antibiotics (Table 5). Additionally, antibiotic use was lower in calves fed SDAP with or without GAM during the first 15 d of the study. After 15 d, fecal scores, scours, and use of electrolytes and antibiotics were reduced dramatically (Table 5) as enteric challenge was no longer a problem. During the latter portion of the trial (d 29 to 56) no differences were apparent (data not shown).

Daily high and low ambient temperatures ranged from 4.9 to 37.0°C and -4.8 to 20.8°C, respectively. Mean high and low ambient temperatures over the study were 24.9 and 11.3°C, respectively. Ambient tem-

peratures were generally within the thermoneutral zone (NRC, 1981); however, minimum daily temperature was $<10^\circ\text{C}$ on 26 d, indicating that additional dietary energy was used to support thermoregulation outside the thermoneutral zone. Mean humidity and solar radiation during the trial were 69.5% and 375 kcal/cm², respectively.

DISCUSSION

Calves are often treated for diarrhea before weaning (Virtala et al., 1996), which is often associated with inadequate transfer of passive immunity. Many different treatments to provide immunological or nutritional support have been evaluated, including prophylactic use of antibiotics, probiotics, organic acids, oligosaccharides, and sources of IgG.

The provision of oral IgG from SDAP or bovine serum has the potential to improve performance, presumably by reducing enteric challenge in animals. In experiment 1, calves consumed 675 g of GAM or PLC during the first 15 d of the study. Differences among treatments were not due to differences in nutrient intake, as calves were fed similar amounts of DM and CP. Rather, reduced scours and use of electrolytes was due to differences in composition of oral supplements, presumably the bovine serum (as a source of IgG) and FOS. Oral IgG has been shown to improve animal performance under various conditions (Besser et al., 1988b; Mitra

Table 6. Least squares means of animal performance, experiment 2.

	Treatments ¹								Contrasts ²		
	P-A-	SE	P-A+	SE	P+A-	SE	P+A+	SE	P	A	I
N											
Begin	30	...	30	...	30	...	30	...	...	...	...
End	24	...	29	...	29	...	28	...	...	...	...
Mortality, %	20.0	5.0	3.3	5.0	3.3	5.0	6.7	5.0	NS	NS	0.05
IgG, g/L	8.6	1.1	9.3	1.1	7.5	1.1	10.1	1.1	NS	NS	NS
Hematocrit, %	33.4	1.2	32.9	1.2	34.1	1.2	32.4	1.2	NS	NS	NS
Plasma protein, g/L	55.4	1.3	55.6	1.3	54.5	1.3	58.6	1.3	NS	0.11	NS
BW, kg											
d 0	46.4	0.7	47.0	0.7	47.0	0.7	47.0	0.7	NS	NS	NS
d 28	52.2	1.4	52.0	1.2	52.3	1.2	52.4	1.2	NS	NS	NS
d 56	72.1	2.4	74.7	2.2	74.5	2.2	76.7	2.3	NS	NS	NS
BW gain, g/d											
d 0 to 28	216	43	177	38	191	39	194	39	NS	NS	NS
d 29 to 56	710	62	802	57	794	57	851	58	NS	NS	NS
d 0 to 56 ²	463	42	495	38	493	38	533	39	NS	NS	NS
DMI, g/d											
CMR ^{3,4}	460	1	461	1	462	1	462	1	0.03	0.09	NS
Starter ³	586	52	589	50	587	50	622	50	NS	NS	NS
Additive	0	0.01	12	0.01	0	0.01	12	0.01	NS	0.01	NS
Total ³	1044	52	1062	50	1049	50	1096	50	NS	NS	NS
Protein intake, g/d ³	248	10	258	10	225	10	241	10	0.06	NS	NS
Fat intake, g/d ³	109	2	110	2	126	2	127	2	0.01	NS	NS
Water intake, L/d ³	1.8	0.2	1.9	0.2	1.8	0.2	1.7	0.2	NS	NS	NS
ADG:DMI, g/kg ³	323	35	353	32	330	32	364	32	NS	NS	NS
Fecal scores ³	1.49	0.03	1.44	0.03	1.47	0.03	1.45	0.03	NS	0.06	0.08
Scours, d ³	5.0	0.6	3.5	0.6	4.7	0.6	4.0	0.6	NS	0.02	0.07
Electrolytes, d ³	2.2	0.4	1.4	0.4	1.6	0.4	1.4	0.4	NS	NS	NS
Antibiotics, d	4.2	0.6	1.8	0.6	2.5	0.6	2.0	0.6	NS	0.02	0.14

¹Treatments: Calf milk replacer (CMR) containing 0% (P-) or 4% (P+) spray-dried bovine plasma; A = addition of 0 (-) or 30 to 60 (+) g of additive/d for the first 15 d.

²Contrasts: P = main effect of P; A = main effect of A; I = interaction of P and A.

³Significant effect of week ($P < 0.01$).

⁴Significant week × treatment interaction ($P < 0.01$).

et al., 1995; Quigley and Drew, 2000; Yokoyama et al., 1997). Body weight gain and feed efficiency during d 29 to 56 may have been due to improved enteric health during the first 15 d of the study. Feed efficiency was improved after 28 d, when calves were offered CS. The IgG intake from GAM averaged approximately 7 g/d for the first 15 d of the study. Besser et al. (1988a) reported that movement of IgG into the intestine was responsible for clearance of IgG in young calves. Further research (Besser et al., 1988b) indicated that these sources of IgG reduced fecal shedding of rotavirus by calves orally challenged with rotavirus.

In experiment 2, similar responses in enteric health were observed, except that the reduced use of antibiotics was statistically significant. In addition, mortality in this group was greater, presumably because the calves were purchased from sale barns (and exposed to a greater number of pathogens), were exposed to additional comingling, transportation stress, and had lower plasma IgG concentrations on arrival. Fecal scores were

numerically lower in experiment 2 (1.46) compared with experiment 1 (overall mean fecal score = 1.60); however, differences in feeds offered, method of feeding CMR, time of the year, and other factors make interpretation of this difference difficult.

Causes of death were not determined on calves that died during experiment 2. Therefore, it is not possible to conclude that calves died from disease caused by enteric pathogens, nor that treatment reduced mortality caused by enteric pathogens. Mean number of days that calves were on the study at death were 15, 2, 27, and 29 d for calves fed no SDAP and no GAM, calves fed GAM and not SDAP, calves fed SDAP and no GAM and SDAP and GAM, respectively. During the 7 d before death, the mean number of days that calves had a rectal temperature greater than 38.9°C were 2.5, 0, 6, and 3, respectively. During the 7 d before death, the mean number of days that calves were treated with electrolytes and antibiotics were 3.5, 0, 7, and 3, respectively, and mean number of days with fecal score >2 were 1.7,

0, 1, and 0, respectively. These data suggest that at least the signs of enteric infection (elevated rectal temperature and treatment with electrolytes and antibiotics) were consistent with infectious agents during the study.

The inclusion of FOS in diets of veal calves tended to increase BW gain in veal calves (Kaufhold et al., 2000). Feeding these compounds in combination contributed to improved health and reduced incidence and severity of enteric disease in the current study. Intake of DM, CP, and fat were unaffected by treatment; therefore, responses observed with the addition of GAM to CMR for the first 15 d was not due to differences in nutrient intake.

Weekly mean feed efficiencies were typical for young calves purchased and transported during the first weeks of life; i.e., low or negative feed efficiency during the first week as calves adjusted to transportation and a new environment, followed by increase in efficiency with increasing age. A depression in efficiency during wk 5 and 6 in experiment 1 was probably due to reduced CMR feeding coupled with low (albeit increasing) intake of CS. By 8 wk, mean feed efficiencies had reached 600 g of BW/kg of DMI.

The inclusion of SDAP in CMR formulation did not dramatically affect animal performance in this study. While Morrill et al. (1995) reported improved animal performance (growth and efficiency of BW gain) in calves fed CMR containing bovine but not porcine plasma to 42 d, Quigley and Bernard (1996) reported similar intake and growth in calves fed CMR containing proteins from spray-dried animal plasma (combination of bovine and porcine) or whey protein concentrate.

In addition to IgG, SDAP may also provide other immunological components that may reduce the incidence and severity of enteric disease. Nollet et al. (1999b) fed calves 2 L of milk 3×/d with SDAP at 0, 10, or 25 g/L. Calves were orally challenged with 10^{10} cfu of *E. coli* at 12 to 24 h of age. The SDAP was pasteurized (50°C for 15 min) to eliminate IgG activity. Calves fed 25 g/L of bovine plasma were protected from enteric challenge. Calves fed 10 g/L showed moderate signs of enteric disease (anorexia, scours, depression) and one calf died. All calves fed 0 g of bovine plasma died within 7 d of challenge due to colibacillosis.

Antibiotics in CMR reduced the incidence of scours and improved BW gains in calves (Kiser, 1976; Morrill et al., 1977; Quigley et al., 1997), and supplementation of CMR with antibiotics remains a common practice. The National Dairy Heifer Evaluation Project reported that 63.1% of US producers reported feeding CMR to calves before weaning; 52.7% reported using CMR containing antibiotics (Heinrichs et al., 1995). More producers in the northeast, Midwest, and southeast United

States reported using CMR containing antibiotics (>70%) than did those in the western United States (50.1%). Use of antibiotics in CMR has been accepted widely and may be used in dairy calf production to compensate for poor colostrum feeding practices, hygiene, and management (Kiser, 1976). Management of antibiotics on dairy farms to maximize response while limiting the risk of transmission of antimicrobial resistance may be inadequate (Goodger et al., 1993), and subtherapeutic use of antimicrobials in animal feeds causes significant risk (Glynn et al., 1998). Removing antibiotics from CMR may reduce the spread of microbial resistance to antibiotics and the possible transfer of antibiotic resistance to pathogens of medical importance. Therefore, alternatives to antimicrobial compounds will become important to producers rearing young calves.

Oral IgG used in GAM and SDAP in this study were derived from bovine blood. The biological safety of animal-derived proteins is a consideration in the use of such products. As of late 2000, the US FDA had determined that blood proteins were low risk material and were exempted from the ban on feeding of ruminant-derived proteins to ruminants.

CONCLUSIONS

Feeding GAM improved survival and health of calves by reducing the proportion of calves with scours (fecal score of 3 or 4), reducing use of electrolytes and antibiotics, and improving BW gain and feed efficiency. It is likely that calves with lower incidence of scours were better prepared to begin aggressive CS intake, which would explain the increased in BW gain from 29 to 56 d in experiment 1.

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