Effects of Mannan Oligosaccharide or Antibiotics in Neonatal Diets on Health and Growth of Dairy Calves¹

A. J. Heinrichs, C. M. Jones, and B. S. Heinrichs

Department of Dairy and Animal Science
The Pennsylvania State University
University Park, 16802

ABSTRACT

Seventy-two Holstein calves were used to study the effect of feeding antibiotics or mannan oligosaccharides (MOS) in milk replacer. Calves were fed a 20% protein, 20% fat milk replacer containing antibiotics (400 g/ton neomycin + 200 g/ton oxytetracycline), MOS (4 g of Bio-Mos/d), or no additive (control) for 5 wk. Milk replacer was reconstituted to 12.5% dry matter and fed at 12% of birth weight during wk 1 and 14% of birth weight in wk 2 to 5. Fecal scores were monitored 3 times per week; body weight, heart girth, withers height, hip height, and hip width were measured at birth and weekly to 6 wk of age. Addition of MOS or antibiotics increased the probability of normal scores for fecal fluidity, scours severity, and fecal consistency as compared to control calves during the course of the study. Consumption of calf starter increased at a faster rate in calves fed MOS, and these calves consumed more calf starter after weaning (wk 6), than those fed antibiotic. No treatment differences in growth measures, total blood protein, or blood urea nitrogen were detected during the trial. Addition of MOS or antibiotics to milk replacer improved fecal scores in calves. Feed intake was improved in MOS-fed calves compared to antibiotic-fed calves, but this difference did not result in growth differences during the experimental period. The results suggest that antibiotics in milk replacers can be replaced with compounds such as mannan oligosaccharides to obtain similar calf performance.

(Key words: mannan oligosaccharide, milk replacer, antibiotic, calf)

Abbreviation key: MOS = mannan oligosaccharide.

INTRODUCTION

The discovery that antibiotics improved growth and feed efficiency led to widespread prophylactic antibiotic

use (Vissek, 1978), which continues in situations in which undiagnosed or subclinical systemic infections could limit growth and feed efficiency (Gustafson and Bowen, 1997). In dairy production, only young calves fed milk replacer still receive antibiotics on a routine and continual basis. A national study reported that 63% of dairy calves in the United States were fed milk replacer and that in 1990 to 1991, nearly 60% of milk replacers fed to dairy calves less than 3 wk of age were medicated (Heinrichs et al., 1995). Antibiotic use was even greater from 3 wk to weaning, as 71% of milk replacers contained medication (Heinrichs et al., 1995). Reported usage has been reduced in recent years; 55.7% of operations reported that they fed medicated milk replacer to dairy calves during 2001 (USDA, 2002). However, this figure does not account for antibiotics added to liquid milk replacer on the farm.

Use of antibiotics in animal production may contribute to antibiotic resistance of human pathogens (Fey et al., 2000). As a result interest in alternatives for antibiotics is strong. Some potential replacements include plasma proteins (Morrill et al., 1995; Quigley and Drew, 2000), probiotic bacterial (Jenny et al., 1991) or yeast cultures (Seymour et al., 1995), and oligosaccharides (Kaufhold et al., 2000; Donovan et al., 2002; Quigley et al., 2002).

Fructooligosaccharide inclusion in human diets appears to result in fecal bulking and selective stimulation of bifidobacteria growth in the colon (Van Loo et al., 1999). Mannan oligosaccharides (MOS) have improved performance in nursery pigs (Dvorak and Jacques, 1998) and weight gain and grain intake in dairy calves (Dvorak and Jacques, 1997). In addition, investigation continues into the potential relationship between oligosaccharides and human intestinal function (Jenkins et al., 1999) and their role in modulation of human gastrointestinal microflora (Gibson, 1999).

Mannan oligosaccharides contain cell wall fragments obtained from *Saccharomyces cerevisiae*. Yeast cells are lysed, and the resulting culture is centrifuged to isolate the cell wall components, which are subsequently washed and spray dried (Spring et al., 2000). Mannans on the cell surface are the primary antigenic compo-

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Corresponding author: A. J. Heinrichs; email: ajh@psu.edu.

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nents of whole yeast cells and cell walls (Ballou, 1970). Because many gram-negative bacteria attach to the intestinal epithelium using mannose-specific fimbriae (Ofek et al., 1977), MOS provides competitive binding sites for these intestinal pathogens. Multiple strains of *Escherichia coli* and *Salmonella* agglutinated MOS in vitro (Spring et al., 2000). The MOS is not enzymatically digested in the small intestine; therefore, bacteria bound to MOS likely exit the intestine without attaching to the epithelium (Spring et al., 2000). Mannan oligosaccharides may also enhance health by stimulating antibody production (Savage et al., 1996) or by affecting intestinal morphology and function (Iji et al., 2001).

The objective of the current experiment was to study the effects of feeding milk replacer containing antibiotics or MOS on growth and health of dairy calves fed milk replacer at high rates.

MATERIALS AND METHODS

Seventy-two male and female Holstein calves from the Penn State Dairy Production Research and Teaching Center were randomly assigned to treatments at birth in a balanced complete block design. Calves were removed from their dams and fed colostrum within 2 h of birth and housed in individual pens in a naturally ventilated barn. Calves were fed colostrum for 2 d then abruptly switched to milk replacer containing 20% all-milk protein and 20% fat (Land O' Lakes Animal Milk Products Co., Arden Hills, MN). Milk replacers were supplemented with antibiotic (400 g/440 kg of neomycin + 200 g/440 kg of oxytetracycline), MOS (4 g Bio-Mos per animal daily), or no additive (control). Replacer was mixed at 134 g of powder to 1 L of water (12.5% DM). Calves were fed at 12% of birth BW per day from d 3 through 7, then abruptly increased to 14% of birth BW and fed at this rate until weaning at wk 5. Calves remained in individual pens until the conclusion of the study at 6 wk of age.

Calves received milk replacer twice daily at 0500 and 1500 h; calf starter (Agway, Inc., Syracuse, NY) and water were available ad libitum from d 3. Intakes of milk replacer and calf starter were monitored daily. Concentrate samples were collected weekly and composited monthly for analysis of nutrient composition (Table 1). The BW and skeletal growth (heart girth, withers height, hip height, and hip width) were measured at birth and weekly to 6 wk of age (4 h after a.m. feeding). Blood samples were collected via jugular venipuncture at the time of weighing and analyzed for hematocrit, plasma urea N, and total protein. Fecal scores (fluidity, scours severity, and consistency) were monitored three times per week and evaluated using a

Table 1. Nutrient composition of experimental milk replacer and calf starter on a dry matter basis.

Item	Milk Replacer	Grain
CP, %	20	20.9
Fat, %	20	3.03
ME ¹ , Mcal/kg		3.04
Ca, %	0.75	1.65
P, %	0.70	0.88
Vitamin A, IU/kg	44,000	17,200
Vitamin D ₃ , IU/kg	11,000	4,000
Vitamin E, IU/kg	220	55

¹Estimated: Metabolizable energy (ME) = TDN × 0.04409 × 0.82.

referenced standard (modified from Larson et al., 1977). Daily health was also recorded.

In all analysis calves were considered random, and correlations within calves were considered in the calculations. Ordinal fecal scores were analyzed using MIXOR (Hedeker and Gibbons, 1996). This program uses Gauss-Hermite quadrature to numerically integrate over the distribution of the random effects, thus avoiding the biases that can occur when penalized quasi-likelihood is used. Data analysis was done on continuous data using PROC MIXED (SAS, 2001). Slopes were compared on the logit scale and converted to probabilities for clarity of interpretation. There were no significant differences for any variable at baseline; therefore significance was determined as differences in slopes compared with control on the logit scale.

Mixed models with repeated measures were utilized for growth, feed intake, and blood data using the MIXED procedure of SAS (2001). In each case calves nested within blocks were considered random. Several covariance structures were considered for repeated measurements, and the primary criteria for selecting covariance structure were Akaike's information criteria and log-likelihood. Blood measurements included the hematocrit value as a covariant to account for variation due to hydration status.

RESULTS AND DISCUSSION

Increasing milk replacer amounts from 12 to 14% BW at the end of the first week did increase occurrence of mild scours lasting several days in nearly all calves. However, only 10 of 72 calves were treated for clinical scours (scours score = 5) during the study; 5 on control replacer, 3 on antibiotic-treated replacer, and 2 on MOS replacer. Fecal samples from scouring calves were submitted to the Penn State Animal Diagnostic Laboratory. Of the samples, 6 tested positive for rotavirus, 1 for cryptosporidia, and the remaining 3 were nonconclusive. All of these calves recovered within 5 d, and none died during the study.

Figure 1. Probability of fecal fluidity scores by week of age for calves fed milk replacer containing antibiotic (O), mannan oligosaccharide (MOS, Δ), or no additive (□).

Fecal scores included fluidity (ranked 1 to 4), scours severity (ranked 1 to 5), and consistency (ranked 1 to 5, but collapsed to 3 categories). Data for fluidity observations were summarized by the probability of having normal, soft, runny, or watery feces. Because milk feeding was abruptly changed at d 3 and 7 of age, nearly all calves showed some increase in scour scores that was likely due in part to the nutritional stress placed on them.

Fecal Scores

Figure 1 shows the probability of each fecal fluidity score by treatment and week of age. The antibiotic and MOS treatments had a higher overall probability ($P < 0.01$) of normal feces throughout the study than the control calves. A large majority of calves showed some degree of increased fecal fluidity during the first 2 wk of age. Both antibiotics and MOS decreased the probability of soft and runny feces compared to the control (Figure 1). There were no differences in the probability of extremely high fecal scores on any treatment. This is likely a result of scours being primarily of nutritional

origin rather than infectious origin, as demonstrated by the results from laboratory culture of fecal samples. Figure 2 shows the probability of normal feces, or low scours severity score. There was an increase ($P < 0.01$), in normal fecal scores for antibiotic and MOS treatments compared to control. Figure 2 also demonstrates the corresponding decrease ($P < 0.01$), in scours severity scores 2 and 3 that occurred for antibiotic and MOS treatments. Very few calves on any treatment had scours severity scores of 4 or 5. The probability of the fecal consistency scores by week of age for calves fed the three different diets is shown in Figure 3. Both the antibiotic and MOS treatments had higher probabilities of normal fecal scores ($P < 0.01$) from wk 3 through the end of the experiment. This difference is primarily due to lower incidence of foamy/mucus feces, since few consistency scores of 'sticky' were observed during the experiment.

Fecal data clearly show an overall decrease in scours resulting from addition of either antibiotic or MOS to the diet. On antibiotic and MOS treatments, scouring calves recovered at a faster rate than control calves, as supported by the increased slope ($P < 0.01$) of lines

Figure 2. Probability of fecal scours severity scores by week of age for calves fed milk replacer containing antibiotic (○), mannan oligosaccharide (MOS, △), or no additive (□).

representing probability of normal fecal scores (Figures 1, 2, and 3). Donovan et al. (2002) also showed similar scours score results with milk replacers containing similar levels of antibiotics or a combination product containing fructooligosaccharides, allicin, and gut-active microbes. Calves fed milk replacer containing galactosyl-lactose (a trisaccharide derived from *Aspergillus oryzae*) had lower fecal scores and fewer days of scouring than calves fed control replacer (Quigley et al., 1997). When an additive containing fructooligosaccharide and bovine serum was fed to purchased bull calves for 15 d, fecal score, days scouring, and days of antibiotic treatment were decreased compared with control calves (Quigley et al., 2002). In addition, calves fed the additive tended to have fewer days of electrolyte treatment than control calves (Quigley et al., 2002). A consensus report on nondigestible carbohydrates in human diets concluded that consumption of oligosaccharides results in a fecal bulking effect of 1.5 to 2 g/g oligosaccharide ingested due to increased bacterial biomass (Van Loo et al., 1999). In addition, provision of fructooligosaccharide in oral electrolyte solution increased recovery rate for beneficial bacteria in the intestine of young pigs with induced diarrhea (Oli et al., 1998).

Feed Intake

The experimental design dictated milk replacer intake for all calves, and, with few exceptions, calves consumed all milk replacer offered. In a small number of cases (<10), when individual calves were scouring, a limited amount of replacer was refused for one or two feedings.

There were no differences in grain intake at the beginning of the experiment (Table 2). During wk 6, calves fed milk replacer containing MOS consumed more grain than calves on the antibiotic treatment ($P < 0.05$). Grain intakes during wk 6 were 0.85 , 0.79 , and 0.94 ± 0.05 kg/d for control, antibiotic, and MOS treatments. Rate of feed intake increase, as determined by the slope of feed intake by week of age, was also greater ($P < 0.05$) for MOS treatment compared with antibiotic treatment. The numerically lower feed intake of antibiotic-fed calves compared with control calves could result from improved feed efficiency, which is often observed when antibiotics are added to milk replacer (Morrill et al., 1977; Quigley et al., 1997). Differences observed in feed intake were not significant enough or measured for a long enough period to show growth differences during this experiment.

Figure 3. Probability of the observed fecal consistency scores by week of age for calves fed milk replacer containing antibiotic (○), mannan oligosaccharide (MOS, △), or no additive (□).

Table 2. Least squares means of intake and performance of calves fed milk replacer containing antibiotic, mannan oligosaccharide (MOS), or no additive.

	Control	Antibiotic	MOS	SE
BW				
Initial, kg	51.4	51.5	51.4	1.1
Final, kg	66.5	67.2	65.7	1.3
ADG, kg/d	0.36	0.38	0.34	0.03
Withers height				
Initial, cm	76.85	76.67	76.51	0.49
Final, cm	84.51	83.84	83.98	0.49
ADG, cm/d	0.18	0.17	0.18	0.01
Hip height				
Initial, cm	81.01	80.69	80.36	0.51
Final, cm	88.57	87.89	87.97	0.51
ADG, cm/d	0.18	0.17	0.18	0.01
Hip width				
Initial, cm	18.46	18.20	18.36	0.18
Final, cm	21.12	20.91	21.10	0.18
ADG, cm/d	0.06	0.07	0.07	0.00
Heart girth				
Initial, cm	77.39	77.05	77.10	0.60
Final, cm	87.57	87.31	87.53	0.60
ADG, cm/d	0.24	0.24	0.25	0.01
Grain intake				
Wk 1 to 5, kg/d	0.130	0.117	0.137	0.012
Wk 6, kg/d	0.850 ^{ab}	0.793 ^b	0.944 ^a	0.047

^{a,b}Means within a row with different superscripts differ; $P < 0.05$.

Growth and Blood Parameters

No differences in growth parameters (BW, heart girth, withers height, hip width, and hip height) were found in this experiment (Table 2), and ADG was similar for all groups of calves. Donovan et al. (2002) also showed no differences in feed intake or growth in a short (5 wk) study. Quigley et al. (1997) reported increased ADG and a tendency for improved feed efficiency in calves fed galactosyl-lactose in milk replacer. Addition of fructooligosaccharide to milk replacer improved ADG in veal calves 10 wk of age (Kaufhold et al., 2000), and feeding a product containing bovine serum and fructooligosaccharide in milk replacer for 15 d improved ADG from d 29 to 56 in purchased bull calves (Quigley et al., 2002).

Total blood protein was not different for any treatments. Overall values were 5.3 , 5.3 , and 5.4 ± 0.4 mg/dl for control, antibiotic, and MOS treatments, respectively. Blood urea N levels were 10.0 , 10.4 , and 10.0 ± 2.7 mg/dl for control, antibiotic, and MOS treatments, respectively. These data suggest there were no major metabolic problems in any treatment group, and that scours were not severe enough to cause blood imbal-

ances, which was also indicated by the low number of calves with severe scouring.

CONCLUSIONS

The addition of MOS improved fecal scores in a similar manner as antibiotics when compared to control milk replacer in this experiment. Observed fecal scores were indicative of slight to moderate scours for all calves in the early weeks of this study due to abrupt changes in intake of milk replacer. Ad libitum grain intake was improved in calves fed MOS compared to those fed an antibiotic treatment; however, this increase did not result in BW differences during the 6-wk study. Under the circumstances of this study, addition of MOS to milk replacer appeared to benefit calf health and reduce scours, indicating that MOS could effectively replace antibiotics in milk replacer.

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