Effect of Feeding Yeast Culture on Performance, Health, and Immunocompetence of Dairy Calves

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ABSTRACT

Objectives were to determine effects of feeding a culture of *Saccharomyces cerevisiae* on performance, health, and immunocompetence of calves in the first 70 d of age. Holstein calves (n = 512) at 2 ± 1 d of age were randomly assigned to yeast culture (YC, 218 females and 37 males) or control (223 females and 34 males). Yeast culture was fed at 2% of the grain dry matter. All calves received colostrum during the first 24 h, pasteurized milk thereafter until 60 d of age, and grain was fed ad libitum for the first 70 d of age. Calves were housed in individual hutches, and grain intake was measured 5 d/wk. Body weight was measured at 5, 30, and 68 d of age, and attitude and fecal consistency were scored daily. Incidence and duration of health disorders and treatments were recorded. Neutrophil phagocytic and killing activities and antibody response to immunization with ovalbumin were measured. Concentrations of glucose and 3-hydroxybutyrate were measured in plasma. Grain intake did not differ between treatments and averaged 908 g/d throughout the study. Body weight change, concentrations of glucose, and 3-hydroxybutyrate did not differ between YC and control. Minor effects on neutrophil function were observed, and YC tended to increase the number of phagocytized bacteria and killing of phagocytized bacteria but did not influence humoral immune response. Attitude scores were similar between treatments throughout the study. Almost all calves experienced mild diarrhea during the study, but feeding YC improved fecal scores, reduced days with watery feces, incidence of fever and diarrhea, and risk of health disorders. Because of the high incidence of diarrhea, mortality preweaning was also high, but YC improved survival of calves by decreasing mortality rate past 13 d of age. Income at the end of the

study was improved by \$48/calf with YC. Feeding yeast culture in grain improved health, minimized frequency of health treatments, and reduced risk of morbidity and mortality in dairy calves.

Key words: calf, health, *Saccharomyces cerevisiae*, yeast culture

INTRODUCTION

Incorporation of microbial additives such as a culture of *Saccharomyces cerevisiae* to the diet has become a common practice in ruminant nutrition. Various *S. cerevisiae*-based products have been shown to affect DMI, rumen pH, and nutrient digestibility (Callaway and Martin, 1997; Kumar et al., 1997; Dann et al., 2000), but most studies have been conducted with lactating cows or in vitro. In vitro and in vivo studies have shown that yeasts and yeast cultures stimulate growth of rumen cellulolytic bacteria (Callaway and Martin, 1997), which is critical for carbohydrate digestion and rumen development in newborn calves. Some strains of *S. cerevisiae* have been shown to favor the establishment of fibrolytic bacteria in the digestive tract of gnotobiotically reared lambs, which accelerated microbial activities in the rumen, thereby potentially favoring the transition from a liquid to a solid diet in preruminant animals (Chaucheyras-Durand and Fonty, 2001). This improvement in rumen microbial activities might partially explain the improvements observed in calf growth when yeast or yeast culture was incorporated into the diet in some studies (Lesmeister et al., 2004; Galvão et al., 2005).

As the young calf matures and shifts from a liquid diet to a diet based on cereal grains and forages, the risk for diarrhea tends to decline (Davis and Drackley, 1998). Gastrointestinal infections and subsequent diarrhea and dehydration account for the majority of health problems affecting calves during the preweaning period and are the primary reason for death and poor development in the first 60 d of age (Davis and Drackley, 1998; NAHMS, 2007). In the most recent report of the

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NAHMS (2007), 7.8% of the unweaned heifers died in dairy farms in the United States.

Oligosaccharides present in the cell wall of *S. cerevisiae* such as glucan and mannan (Reed and Nagodawithana, 1991) have been shown to affect the immune system and to influence host-pathogen interactions in the digestive tract of humans and animals. In laboratory animals, consumption of glucan from oats improved neutrophil function as measured by killing activity (Murphy et al., 2007), which might have ramifications in the defense against pathogens. This may be particularly important in young calves, who are typically affected by a range of bacterial, viral, and protozoal pathogens that cause disease of the digestive tract, some potentially leading to systemic infections. In monogastric animals, use of yeast cultures and yeast cell wall extract products is a common practice in an attempt to minimize the risk of digestive diseases (White et al., 2002). In young calves, incorporating live yeast into the grain reduced the number of days with diarrhea (Galvão et al., 2005). Feeding yeast culture to calves reduced the incidence of elevated body temperature and antibiotic treatments from birth to 46 d of age (Seymour et al., 1995). In addition, soluble products present in yeast culture have been shown to inhibit microbial growth and activity (Jensen et al., 2008) and modulate the immune system (Jensen et al., 2007). Collectively, these results indicate potential benefits to animal health, which are not necessarily accompanied by improvements in growth performance.

Potential improvements on performance of young calves fed yeast culture might reflect increased feed intake and improved energy status, enhanced immune function, or reduced incidence of diseases. Thus, it was hypothesized that the inclusion of culture of *S. cerevisiae* into calf grain might accelerate consumption of dry feed, improve animal health, and reduce the risk of morbidity and mortality. Objectives were to determine the effects of feeding a yeast culture of *S. cerevisiae* incorporated into the grain during the first 70 d of age on growth, performance, health, and measures of humoral and innate immunocompetence of dairy calves.

MATERIALS AND METHODS

All procedures involving animals were approved by the University of California-Davis Institutional Animal Care and Use Committee.

Animals, Housing, and Feeding

The study was conducted in a commercial farm with approximately 5,300 milking cows located in central California. Holstein calves (441 females and 71 males)

Table 1. Nutrient composition (mean $\pm$ SD) of pasteurized milk fed to calves¹

Nutrient composition	As-is	DM basis
DM, %	10.89 $\pm$ 3.01	—
Fat, %	3.37 $\pm$ 0.98	32.35 $\pm$ 8.02
True protein, %	2.67 $\pm$ 0.57	25.67 $\pm$ 3.98
Lactose, %	3.77 $\pm$ 1.23	35.18 $\pm$ 5.98
Solids not fat, %	7.16 $\pm$ 1.86	67.65 $\pm$ 8.02
Ash, %	0.73 $\pm$ 0.22	6.80 $\pm$ 0.96
ME, ² Mcal/kg	0.60	5.51

¹Average of 11 samples collected weekly throughout the study.

²Metabolizable energy calculated according to NRC (2001) based on the composition of milk using average values for DM, fat, and true protein.

at 2 ± 1 d of age (d 1 = day of birth) were assigned to the study in 41 daily cohorts of 4 to 22 calves. Calves were housed in individual hutches located at approximately 60 cm apart and assigned in sequence of 3 per treatment.

All calves received 3 feedings of 1.9 L of frozen-thawed colostrum each in the first 24 h of life and were fed nonsaleable pasteurized whole milk (Table 1) thereafter, originated from recently calved cows or cows in the hospital pen. Milk was collected twice daily and pasteurized once using a continuous flow commercial calf milk pasteurizer (Terminator T1000, Goodnature Products Inc., Orchard Park, NY) by flash pasteurization, in which milk temperature was elevated and held at 72°C for 15 to 30 s and then quickly cooled to 35°C. Milk was fed twice daily at 0700 and 1400 h, and calves were offered 1.9 L in bottles at each feeding during the first 55 d of age and then once a day until 60 d of age, when calves were weaned from milk.

All calves were fed the same mixture of grains (Table 2) to meet or exceed nutrient requirements for a pre-weaned and early weaned Holstein calf to achieve adequate growth as suggested by the NRC (2001) and others (Davis and Drackley, 1998). Grain was fed once a day in the morning, immediately after milk feeding, for ad libitum intake during the first 70 d of age.

Treatments, Measurements of Grain DMI, and BW

Calves were randomly assigned to 1 of 2 treatments: yeast culture (YC, n = 255, 218 females, Diamond V XP Yeast Culture, Diamond V Mills Inc., Cedar Rapids, IA) or control (n = 257, 223 females). Yeast culture was incorporated daily into the grain at 2% of DM immediately before feeding. Grain was offered once daily to allow for 5% refusals, and amounts offered and refused were measured 5 d/wk for individual calves to calculate intake. Weekly averages of grain DMI were generated based on the 5 d of grain intake measurements.

Table 2. Ingredient composition of the calf grain and nutrient content (mean $\pm$ SD) of grain and yeast culture

Ingredient composition	Amount	
	DM basis	
Steam-rolled corn, %	30.0	
Steam-rolled barley, %	18.5	
Dried beet pulp, shreds %	20.0	
Pellet, ¹ %	25.0	
Cane molasses, %	6.5	
Nutrient composition	Calf grain ²	Yeast culture
	DM basis	
DM, %	84.84 $\pm$ 0.54	92.69
ME, ³ Mcal/kg	3.10	—
OM, %	92.65 $\pm$ 0.07	94.38
CP, %	20.90 $\pm$ 0.16	15.69
NDF, %	18.39 $\pm$ 1.05	23.99
ADF, %	10.03 $\pm$ 0.67	5.10
ADF insoluble CP, %	3.16 $\pm$ 1.48	—
Lignin, %	0.56 $\pm$ 0.13	—
NFC, ⁴ %	52.15 $\pm$ 3.05	47.61
Fat, %	4.38 $\pm$ 0.29	7.15
Ca, %	1.25 $\pm$ 0.01	0.25
P, %	0.74 $\pm$ 0.01	0.80
K, %	1.14 $\pm$ 0.01	0.29
Mg, %	0.41 $\pm$ 0.01	0.38
Na, %	0.16 $\pm$ 0.01	0.23
Cl, %	0.31 $\pm$ 0.01	0.20
S, %	0.37 $\pm$ 0.01	0.44
Zn, mg/kg	153.0 $\pm$ 9.9	68.0
Cu, mg/kg	18.5 $\pm$ 3.5	8.0
Mn, mg/kg	130.0 $\pm$ 4.2	35.0
Monensin, mg/kg	30	—

¹Pellet contained the following: 18.20% ProLak (blend of marine and animal by-products; H. J. Baker & Brothers Inc., Stamford, CT); 65.00% solvent extract soybean meal; 9.10% corn distillers grains; 1.80% calcium carbonate; 4.10% dicalcium phosphate; 0.55% sodium chloride; 0.55% magnesium oxide; 0.09% Zinpro 4-Plex (Zinpro Corporation, Eden Prairie, MN); 0.018% zinc sulfate; 0.01% manganese sulfate; 0.0003% sodium selenite; 0.40% of a mixture of iodine and vitamins A, D, and E; and 0.07% Rumensin 80 (176 mg/kg of monensin; Elanco Animal Health, Indianapolis, IN).

²Average of 3 composited samples collected weekly.

³Metabolizable energy according to NRC (2001) for a young calf consuming 1.0 kg of DM.

⁴Calculated according to the following formula: OM – (CP + NDF + Fat – NDF insoluble CP).

All calves were weighed the day after study enrollment and again at 30 and 68 d of age. To facilitate activities during the study, BW of calves was measured twice weekly for the respective cohort of animals according to age. Because of that, the median and mean ($\pm$ SD) ages of calves when BW was measured were, respectively, 5 and 5.5 $\pm$ 2.4 d for study enrollment, 30 and 29.9 $\pm$ 2.5 d for d 30, and 68 and 68.4 $\pm$ 1.2 d for d 68. Nevertheless, age of calves at each measurement of BW did not differ ($P > 0.70$) between treatments.

Grain and Milk Sampling and Nutrient Analyses

Grain was sampled once a week, dried at 55°C for 48 h, and moisture content was recorded. Dried samples

were ground to pass a 1-mm screen, and samples were then composited for 2-mo periods and analyzed for contents of DM, OM, ether extract (AOAC, 2000), ADF, and NDF (Van Soest et al., 1991). The N content of samples was analyzed using an N analyzer (FP-528 Nitrogen Determinator, Leco Corporation, St. Joseph, MI), and CP was calculated by multiplying the N content by 6.25. Mineral content was analyzed at the Dairyland Laboratory (Arcadia, WI) using an inductively coupled plasma mass spectrometer (Thermo Jarrell-Ash, Franklin, MA).

Samples of pasteurized milk were collected weekly throughout the study and analyzed for concentrations of TS, ash, lactose, fat, and true protein (Foss 303 Milk-O-Scan, Foss Foods Inc., Eden Prairie, MN) at the DHIA Laboratory in Tulare, California. Solids not fat were calculated by the difference between TS and fat. Composition of pasteurized milk (Table 1) was used to estimate the energy concentration in milk using NRC (2001) calculations. Although amount of milk consumed by each calf was fixed at 3.8 L/d, composition of milk varied throughout the study, which resulted in calves of different ages consuming different quantities of milk solids at different time points in the study. Therefore, weekly milk composition was used to determine total nutrient intake and ME intake of calves throughout the study.

Samples of colostrum and milk postpasteurization were sampled in the last 2 wk of enrollment, transported to the Milk Quality Laboratory at the Veterinary Medicine Teaching and Research Center, and cultured to determine number of colony-forming units per milliliter and presence of *Salmonella* spp.

Attitude and Fecal Consistency Scoring

Attitude and fecal consistency were scored daily by the research team during the morning milk feeding using a 1 to 4 scale. For attitude, calves were categorized as 1 when alert and responsive, 2 when nonactive, 3 when depressed, and 4 when moribund. Fecal consistency was scored as 1 when firm, 2 when soft or of moderate consistency, 3 when runny or mild diarrhea, and 4 when watery and profuse diarrhea. Weekly averages of attitude and fecal scores were generated for individual calves for statistical analyses. Calves with fecal score >2 were used for analysis of incidence of diarrhea.

Incidence of Health Disorders, Treatments, and Costs Associated with Treatments

Incidence of health disorders was recorded daily for individual calves. Rectal temperature was measured for calves displaying clinical signs of disease such as

diarrhea, bloat, coughing, increased respiratory frequency, depression, and lack of appetite. Calves with rectal temperature $>39.5^{\circ}\text{C}$ were considered to be febrile. Febrile calves were evaluated for diarrhea, which was characterized by presence of watery feces using fecal score >2 , and for pneumonia based on presence of respiratory distress, increased respiratory frequency, and nasal discharge. Day when disease was first diagnosed was recorded, and duration of each illness event was determined. Number of episodes of fever, diarrhea, and pneumonia was determined. To distinguish between different episodes, an interval of 4, 4, and 10 d between diagnoses of fever, diarrhea, and pneumonia, respectively, had to elapse to characterize a new event. Calves with digestive and respiratory problems were treated by farm personnel according to protocols established by the herd veterinarian. Medication used (antibiotics, anti-inflammatory, and antidiarrheic products), dosage, and duration of treatments were recorded for individual calves. Costs associated with health treatments were calculated based on current costs for each product, daily dosage for each medication for individual calves, which was administered based on BW of animals, estimated time spent by personnel with individual treatments, and respective personnel wages.

Calves that died after d 15 were subjected to a post-mortem examination, and specimens were collected for diagnostics performed by the California Animal Health and Food Safety System laboratory in Tulare, California. Risk of morbidity and mortality was evaluated. At 60 ± 3 d of age, calves received a dose of modified live vaccine for viral diseases including a bacterin against several serovars of *Lepstopira* spp. (Vista 5 L5, Intervet Inc., Millsboro, DE).

Economic Analysis of Calf Raising

An economic analysis of cost of raising calves was performed, and the analysis considered cost of grain consumed by each calf, cost of milk consumed by each calf, treatment costs for health problems, labor costs associated with feeding calves, vaccination costs, and the value of a calf that survived at the end of the study. The input values in the calculation were as follows: \$0.28/kg of grain DM; \$0.15/L of pasteurized milk considering \$0.11/L for nonsaleable milk and \$0.04/L for transportation and pasteurization costs; lost opportunity cost when a calf died considering a loss of \$500/heifer and \$100/bull calf, which corresponded to market values for a newborn of the respective sexes; and value of a live calf at 70 d of age and 80 kg of BW of \$750/heifer and \$300/bull calf. Labor cost was computed at actual local cost of \$9.00/h, with approximately 3 min/d spent per calf for daily activities such as feeding milk

and grain, replacing water, bedding the calf hutches, and other activities but excluded labor costs associated with health treatments and preparation of grain and pasteurization of milk, which were considered in costs of grain, milk, and health treatments. For YC, cost associated with treatment was considered based on market price for the product at \$0.9/kg. For calves that survived past 60 d, there was an additional cost for vaccination of \$1.5/calf to account for the vaccine and labor for application.

Blood Collection

Blood was sampled by puncture of the jugular vein using evacuated tubes (Vacutainer, Becton Dickinson, Franklin Lakes, NJ) containing either no anticoagulant for serum separation or K_2 EDTA for plasma separation. Blood tubes were placed on ice immediately after collection and later centrifuged at $2,000 \times g$ for 15 min in a refrigerated centrifuge at 6°C for separation of serum and plasma. Serum and plasma were frozen at -20°C for later analyses.

Analyses of Total Protein in Serum and Metabolites in Plasma

Concentration of total protein was measured in serum from all calves on enrollment day using a clinical refractometer. Plasma collected from a subset of 60 female calves (30 YC and 30 control) at 30 and 60 d of age was analyzed for concentrations of glucose by direct measurement using the YSI model 2700 SELECT Biochemistry Analyzer (Yellow Springs Instrument Co. Inc., Yellow Springs, OH) and BHBA using a commercial kit (RANBUT, D-3-Hydroxybutyrate, Randox Laboratories Ltd, Antrim, UK) based on the enzymatic oxidation of BHBA to acetoacetate and concomitant reduction of NAD^+ to NADH (Williamson et al., 1962).

Evaluation of Humoral and Innate Immune Responses

Ovalbumin (OVA) solution was prepared by dissolving 0.5 mg of OVA (Type VII, Sigma Chemical Co., St. Louis, MO) in 0.5 mL of PBS (0.1 M, pH = 7.4) and emulsified in 0.5 mg of adjuvant Quil-A (Accurate Chemical, Westbury, NY) diluted in 0.5 mL of PBS. The same subset of 60 female calves (30/treatment) from which blood was analyzed for concentrations of metabolites received an i.m. injection of 1 mL containing 0.5 mg of OVA at 3, 21, and 42 d of age. Blood was sampled immediately before each injection and again at 56 d of age for measurements of serum antibody concentration to OVA. Concentrations of IgG to OVA were measured by ELISA as described by Wagter et al. (2000).

Neutrophil phagocytosis and intracellular killing of *Escherichia coli* strains were evaluated. The assays were performed using the blood of the same subset of 60 female calves (30/treatment) on d 25 ± 3 of age, with *E. coli* ATCC 25922 and with a field strain of pathogenic *E. coli* collected from a case of clinical mastitis in a dairy cow.

Neutrophils were harvested from 50 mL of jugular blood, and bacteria were prepared as described by Hogan et al. (1992). Suspensions of neutrophils and opsonized bacteria were incubated in a 1:3 at 37°C and 100 rpm for 90 min in water bath. After incubation, 50 μ L of bacteria-neutrophil samples were mixed with 25 μ L of acridine orange solution and 25 μ L of crystal violet solution. Wet mount slides were prepared, and neutrophils were evaluated under an epifluorescent microscope. Bacteria present in the cytoplasm of neutrophils were stained in either red, when dead, or green, when live, and the number of neutrophils phagocytizing bacteria, and the number of dead and live bacteria was counted in the first 50 neutrophils visible under the microscope.

Experimental Design and Statistical Analyses

The experimental design was a randomized complete block design. Daily, a cohort of 4 to 22 calves at 2 d of age were blocked according to sex and day of birth and, within each block, randomly assigned to treatments. A sample size calculation was performed assuming that risk for diarrhea would be reduced with addition of yeast culture. Baseline values were 40% of the calves affected with diarrhea based on farm data. To detect a decrease in risk for diarrhea from 40 to 32%, two hundred fifty calves per treatment were required ($\alpha = 0.05$ and $\beta = 0.20$; 2-tailed test).

Continuous variables were analyzed by ANOVA using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). Variables with a single measurement during the study were analyzed with the fixed effects of treatment and sex of calf. For neutrophil phagocytic and killing activities, the concentrations of serum total protein were used as covariates in statistical models. For BW changes, initial BW at study enrollment was used as covariate. Variables with repeated measurements within the same calf were analyzed with the fixed effects of treatment, time of measurement (day or week), interaction between treatment and time, sex of calf, and the random effect of calf nested within treatment. Other covariates were included in specific analyses when found appropriate. The repeated statement was included, and the covariance structure was chosen based on the smallest Schwartz's Bayesian criterion.

Daily fecal and attitude scores were analyzed in 2 ways. First, daily results were analyzed by the GENMOD procedure of SAS (SAS Inst. Inc.) fitting a Poisson distribution and log transformation function with repeated measures for count data. The model included the effects of treatment, day, interaction between treatment and day, and sex of calf. A second analysis was performed by averaging daily results into weekly means to normalize the data. Weekly means were then analyzed by the MIXED procedure of SAS (SAS Inst. Inc.) with a model that included the effects of treatment, week, interaction between treatment and week, and sex of calf, with calf nested within treatment as the random error. For the latter model, the covariance structure that best fitted the data was chosen based on the smallest Schwartz's Bayesian criterion. In addition, the proportion of days with either low or high scores was analyzed by the GLM procedure of SAS (SAS Inst. Inc.) with the effects of treatment and sex of calf.

Binomially distributed data were all analyzed by logistic regression using the LOGISTIC procedure of SAS (SAS Inst. Inc.). The models included the effects of treatment, sex of calf, serum total protein concentration, and interaction between treatment and serum total protein concentration. Adjusted odds ratio and the 95% confidence interval were calculated. Number of cases of health disorders per calf was analyzed by the Kruskal-Wallis nonparametric method to test equality of medians between treatments. Medians and mean rank were generated using MINITAB (Minitab Inc., State College, PA). Number of cases per 1,000 calf days at risk was calculated for each calf and analyzed for each treatment. Survival time was evaluated using the product limit method of the Kaplan-Meier model by the LIFETEST procedure of SAS (SAS Inst. Inc.). Calves that survived the entire study period were censored at 70 d of age.

Treatment differences with $P \leq 0.05$ were considered significant, and $0.05 < P \leq 0.10$ was designated as tendency.

RESULTS

Serum total protein concentrations on the day of study enrollment were similar between control and YC and were 6.18 ± 0.05 and 6.14 ± 0.05 g/dL, respectively. Using serum total protein ≤ 5.2 g/dL as the cut-off for failure of passive transfer, 8.6 and 9.4% of control and YC calves, respectively, did not receive adequate transfer of colostral antibodies, and proportions were similar ($P = 0.74$) between treatments.

Microbiological analyses of 12 colostrum and 12 post-pasteurized milk samples resulted in a mean ($\pm$ SD) of $15,727 \pm 16,416$ cfu/mL, with a median of 11,600 cfu/

Table 3. Least square means for the effect of feeding a yeast culture (YC) in grain on DM and nutrient intakes, BW changes, and plasma concentrations of metabolites in dairy calves

Item	Treatment ¹		SEM	P-value
	Control	YC		
Grain intake, g/d				
wk 1 to 4	153.5	139.1	6.6	0.05
wk 5 to 10	1,428.7	1,409.6	34.1	0.59
wk 1 to 10	916.5	900.1	23.8	0.54
Grain nutrient intake				
Protein, g/d	157.5	154.4	3.3	0.41
ME, Mcal/d	2.54	2.50	0.05	0.40
Milk nutrient intake				
TS, g/d	448.6	448.2	1.4	0.78
Protein, g/d	106.1	106.1	0.3	0.94
ME, Mcal/d	2.37	2.36	0.01	0.86
Total nutrient intake				
Protein, g/d	253.2	250.0	3.4	0.41
ME, Mcal/d	4.67	4.62	0.05	0.39
BW change, g/d				
d 5 to 30	229	212	11	0.15
d 30 to 68	780	772	16	0.67
Final BW at d 68, kg	76.4	76.7	0.5	0.39
Efficiency of grain utilization ²				
wk 1 to 4	1.50	1.22	0.21	0.22
wk 5 to 10	0.56	0.57	0.01	0.28
Glucose, mg/dL	75.9	76.1	1.5	0.92
BHBA, μ mol/L	344.7	342.5	15.7	0.92

¹Addition of 0 (control) or 2% YC to grain.²Body weight change (kg/d)/grain intake (kg/d).

mL and a range of 400 to 44,000 for colostrum, with 2 samples positive for *Salmonella* Newport and 1 sample positive for *Salmonella* Dublin. For postpasteurized milk, the mean ($\pm$ SD) was 467 ± 599 cfu/mL, with a median of 200 cfu/mL and a range of 0 to 1,600, and all samples were negative for *Salmonella* spp.

Grain intake was less than 40 g/d in the first 15 d of study. A marginal increase (14 g/d) in grain intake ($P = 0.05$) was observed between wk 1 and 4 for calves receiving the control compared with YC treatment, but no differences in intake were observed after 4 wk of age and averaged 1,420 g/d (Table 3). Likewise, grain intake throughout the study was similar between treatments and averaged 908 g/d. Nutrient intake from grain and milk was similar between treatments, and throughout the study, calves consumed an average of 252 g of protein/d and 4.65 Mcal of ME/d. Due to similar nutrient intake, BW gain was similar between treatments for wk 1 to 4 and wk 5 to 10 of age. Similarly, efficiency of grain utilization did not differ between treatments throughout the study.

Concentrations of glucose and BHBA in plasma did not differ between control and YC (Table 3). No interaction ($P > 0.10$) between treatment and age of calves was observed for concentration of glucose or BHBA. Concentrations of BHBA increased ($P < 0.01$) with age

of calves, but those of glucose remained similar throughout the study.

Treatment did not affect serum titers for anti-OVA IgG of calves (Figure 1). Concentrations of anti-OVA IgG in serum differed ($P < 0.01$) with age and sequential immunizations of calves with OVA, but no interaction was observed between treatment and age. Similar to humoral responses, treatment with YC did not affect measures of neutrophil function of calves at 25 d of age when neutrophils were incubated with *E. coli* ATCC (Table 4). The proportion of neutrophils phagocytizing bacteria, number of phagocytized bacteria per neutrophil, proportion of phagocytized bacteria killed, and proportion of neutrophils killing bacteria were all similar between control and YC; however, when a pathogenic *E. coli* was incubated with neutrophils, the number of bacteria phagocytized and proportion of phagocytized bacteria killed tended ($P < 0.10$) to increase in neutrophils from calves fed YC compared with those fed the control.

Incidence of diseases, particularly diarrhea, was greater than initially anticipated. Almost all calves experienced at least 2 d of fecal score >2 . Attitude scores were similar between treatments throughout the study; however, calves fed YC tended ($P < 0.08$) to have smaller fecal score and experienced fewer ($P < 0.01$) days with mild or watery diarrhea (Table 5). Feeding YC tended ($P < 0.08$) to reduce the incidence of fever and diarrhea but had no effect on the proportion of calves affected by respiratory disease (Table 6). Median number of cases of fever per calf tended ($P = 0.10$) to be reduced by feeding YC, but cases per calf day at risk were similar between treatments (Table 7). Yeast culture also reduced ($P = 0.02$) the median number of cases of diarrhea and cases per calf day at risk ($P = 0.01$). Median number of cases of health disorders and cases per calf day at risk were both reduced ($P < 0.02$) by feeding YC. Because of the reduced incidence of health disorders, the proportion of calves treated with antiinflammatory and antidiarrheic products was reduced ($P < 0.04$) and that of calves treated with antibiotics tended ($P < 0.06$) to be reduced for YC compared with control (Table 8). Although differences in frequency of treatments were observed, costs associated with treatment of diseases were generally not influenced by dietary treatments and averaged US \$2.7/calf in the first 70 d of age. Calves fed YC experienced increased ($P = 0.01$) raising costs of approximately \$7/calf (Table 9), which were associated with increased ($P < 0.01$) costs associated with milk, labor, vaccination, and yeast culture. Nevertheless, net income at the end of the study was numerically greater, approximately \$48, for calves fed YC because of the numerical improvement in income with calf value.

Figure 1. Effect of feeding yeast culture (YC) in grain on IgG anti-ovalbumin (OVA) serum titers in response to ovalbumin immunization in calves. The LSM $\pm$ SEM for the entire study period were 0.50 ± 0.01 and 0.53 ± 0.01 for control and YC, respectively. Effect of treatment ($P = 0.13$), age ($P < 0.001$), and interaction between treatment and age ($P = 0.29$).

Table 4. Least square means and medians for the effect of feeding a yeast culture (YC) in grain on neutrophil function of dairy calves

Item	Treatment ¹		SEM	P-value
	Control	YC		
<i>Escherichia coli</i> ATCC				
Neutrophils phagocytizing, ² %	53.6	54.0	2.5	0.96
Intracellular bacteria/neutrophil, ³ n				
Mean	4.5	4.5	0.3	0.98
Median	4.6	4.7	—	0.78
Phagocytized bacteria killed, ⁴ %	92.9	93.8	1.4	0.67
Bacteria phagocytized, n				
Mean	124.2	134.3	8.6	0.68
Median	108	122	—	0.92
Neutrophils killing bacteria, ⁵ %				
Neutrophils phagocytizing	98.9	99.6	0.5	0.37
All neutrophils	52.9	53.7	2.4	0.94
<i>E. coli</i> (mastitis agent)				
Neutrophils phagocytizing, ² %	17.4	20.6	2.8	0.39
Intracellular bacteria/neutrophil, ³ n				
Mean	1.4	1.5	0.1	0.35
Median	1.0	1.3	—	0.26
Phagocytized bacteria killed, ⁴ %	96.4	99.8	1.4	0.10
Bacteria phagocytized, n				
Mean	11.8	17.2	2.2	0.08
Median	8.0	10.0	—	0.23
Neutrophils killing bacteria, ⁵ %				
Neutrophils phagocytizing	99.6	97.8	1.1	0.26
All neutrophils	17.3	20.2	2.6	0.21

¹Addition of 0 (control) or 2% YC to grain.

²Percentage of neutrophils containing at least 1 intracellular bacterium (live or dead).

³Number of bacteria phagocytized/number of neutrophils phagocytizing at least 1 bacterium.

⁴Number of dead, phagocytized bacteria/(number of live + dead phagocytized bacteria) $\times$ 100.

⁵Number of neutrophils containing at least 1 dead bacterium divided either by the number of neutrophils phagocytizing at least 1 bacterium or by the total number of neutrophils.

Table 5. Least square means and medians for the effect of feeding a yeast culture (YC) in grain on attitude and fecal scores of dairy calves

Item	Treatment ¹		SEM	P-value
	Control	YC		
Attitude score ² (1 to 4)				
Mean	1.06	1.05	0.01	0.76
Median	1.0	1.0	—	0.37
Proportion of days = 1	94.9	95.6	0.6	0.37
Fecal score ³ (1 to 4)				
Mean	1.47	1.44	0.01	0.06
Median	1.3	1.2	—	0.08
Proportion of days > 2	15.9	13.5	0.8	0.006
Proportion of days = 4	5.9	4.6	0.4	0.004

¹Addition of 0 (control) or 2% YC to grain.

²1 = alert and responsive; 2 = nonactive; 3 = depressed; 4 = moribund.

³1 = firm; 2 = soft or of moderate consistency; 3 = runny or mild diarrhea; 4 = watery and profuse diarrhea.

Feeding YC reduced ($P = 0.05$) the proportion of calves that died during the study (Table 6), and mortality rate was markedly decreased ($P = 0.05$) with YC after 13 d of age (Figure 2). In fact, risk of death before d 13 was similar ($P = 0.88$) between YC and control, and the proportions affected were 6.3 and 6.6%, respectively; however, past d 13, risk of mortality was 6-fold greater ($P = 0.008$) for control than YC (adjusted odds ratio = 6.0; 95% confidence interval = 1.6, 22.6), and the proportions affected were 1.3 and 5.8% for YC and control, respectively.

Of the calves subjected to postmortem diagnosis, 1 was diagnosed with *Cryptosporidium parvum*, and death was caused by dehydration and transmural necrosis of the small intestine; 4 calves died because of

septicemia caused by *Salmonella* Dublin; 2 calves died because of septicemia by *E. coli*; and 2 died because of bronchopneumonia caused by mixed bacteria and enteritis associated with *Salmonella* Newport. No clear differences in cause of death were observed between treatments.

DISCUSSION

Alternatives to nonantimicrobial feed additives that enhance health and performance of young calves are continuously being evaluated as methods to minimize the need for antimicrobial additives (Heinrichs et al., 2003). Yeast culture contains yeast cells and compounds produced during fermentation activity such as B vitamins, polyphenols, and organic acids, and all of them might be responsible for the positive effects on performance and health when incorporated into the diet of animals. Components of the yeast cell wall such as the oligosaccharides glucan and mannan might benefit the local and systemic immune responses (Newman, 1994; Murphy et al., 2007). Furthermore, metabolites produced by *S. cerevisiae* in culture might have antimicrobial activities against pathogens (Jensen et al., 2008) and modulatory effects on the immune system (Jensen et al., 2007). Nevertheless, data on benefits to feeding yeast and yeast culture on calf health are scarce and not conclusive (Cole et al., 1992; Seymour et al., 1995; Galvão et al., 2005).

Response to feeding yeast products on performance of young calves has been variable. Lesmeister et al. (2004) reported that addition of 1% of yeast culture to the grain of young calves did not affect performance, but when included at 2%, yeast culture improved DM

Table 6. Effect of feeding a yeast culture (YC) in grain on incidence of health disorders and mortality in dairy calves

Item	Treatment ¹		AOR ²	95% CI ³	P-value
	Control	YC			
	— % (n/n) —				
Fever ⁴	41.6 (107/257)	34.1 (87/255)	1.38	0.96 to 1.97	0.08
Diarrhea ⁵	99.6 (256/257)	97.3 (248/255)	7.22	0.88 to 59.58	0.07
Respiratory disease ⁶	14.0 (36/257)	13.7 (35/255)	1.03	0.62 to 1.69	0.92
Mortality	12.1 (31/257)	7.5 (19/255)	1.79	0.98 to 3.32	0.05

¹Addition of 0 (control) or 2% YC to grain.

²AOR = adjusted odds ratio (YC served as referent for comparison).

³CI = confidence interval.

⁴Rectal temperature >39.5°C.

⁵Presence of watery feces for at least 2 d during the study.

⁶Calves with signs of respiratory distress and fever.

Table 7. Effect of feeding a yeast culture (YC) in grain on risk of health disorders

Item	Treatment ¹		<i>P</i> -value
	Control	YC	
Fever ²			
Median number of cases (mean rank) ³	0 (265.5)	0 (247.4)	0.10
Cases/1,000 calf days at risk ⁴ (LSM ± SEM)	13.0 ± 1.8	11.2 ± 1.8	0.40
Diarrhea ⁵			
Median number of cases (mean rank)	1.0 (268.4)	1.0 (244.5)	0.02
Cases/1,000 calf days at risk (LSM ± SEM)	34.5 ± 2.4	27.6 ± 2.4	0.01
Respiratory disease ⁶			
Median number of cases (mean rank)	0 (256.6)	0 (256.4)	0.98
Cases/1,000 calf days at risk (LSM ± SEM)	2.5 ± 0.5	2.8 ± 0.5	0.57
Any health disorder ⁷			
Median number of cases (mean rank)	2.0 (270.7)	1.0 (242.2)	0.02
Cases/1,000 calf days at risk (LSM ± SEM)	48.6 ± 3.6	39.9 ± 3.6	0.03

¹Addition of 0 (control) or 2% YC to grain.

²Rectal temperature >39.5°C. A new case was characterized when 4 d had elapsed between episodes.

³Mean rank generated by the Kruskal-Wallis nonparametric test to evaluate differences between median values.

⁴Calculated as (number of cases per calf/number of calf days at risk) × 1,000 d.

⁵Presence of watery feces at least 2 d during the study. A new case was characterized when at least 4 d had elapsed between episodes.

⁶Calves with fever and increased respiratory frequency. A new case was characterized when at least 10 d had elapsed between episodes.

⁷Includes fever, diarrhea, pneumonia, bloat, and keratoconjunctivitis.

intake, BW gain, and feed efficiency compared with a diet without yeast culture. In agreement, Galvão et al. (2005) observed improvements in grain intake, BW gain, and blood parameters of calves when fed live yeast incorporated into the grain during the preweaning but not the postweaning period. Quigley et al. (1992) ob-

served no differences in intake, BW gain, or efficiency of gain in calves fed yeast culture for 12 wk and suggested that the high incidence of health problems and low grain intake might have masked response to treatments (Quigley et al., 1992). On the other hand, addition of yeast culture to the grain increased rumen pH

Table 8. Effect of feeding a yeast culture (YC) in grain on frequency and costs associated with health treatments

Item	Treatment ¹		<i>P</i> -value
	Control	YC	
Antiinflammatory			
Calves treated, % (n/n)	26.1 (67/257)	16.5 (42/255)	0.008
Treatment days/calf in study			
Mean (±SEM)	0.39 ± 0.05	0.28 ± 0.05	0.07
Median (mean rank) ²	0 (268.4)	0 (244.5)	0.01
Cost, \$/calf (mean ± SEM)	0.13 ± 0.02	0.10 ± 0.02	0.09
Antidiarrheic			
Calves treated, % (n/n)	96.9 (249/257)	92.9 (237/255)	0.04
Treatment days/calf in study			
Mean (±SEM)	3.05 ± 0.13	2.99 ± 0.13	0.66
Median (mean rank)	3 (260.7)	3 (252.3)	0.51
Cost, \$/calf (mean ± SEM)	0.93 ± 0.04	0.91 ± 0.04	0.67
Injectable antibiotics			
Calves treated, % (n/n)	61.1 (157/257)	52.9 (135/255)	0.06
Treatment days/calf in study			
Mean (±SEM)	1.64 ± 0.13	1.51 ± 0.13	0.40
Median (mean rank)	1 (269.6)	1 (243.3)	0.03
Cost, US \$/calf (mean ± SEM)	1.70 ± 0.15	1.63 ± 0.15	0.69
Total treatment cost/calf, US \$	2.77 ± 0.17	2.64 ± 0.17	0.51

¹Addition of 0 (control) or 2% YC to grain.

²Mean rank of the data generated by the Kruskal-Wallis nonparametric test to evaluate differences between medians.

Table 9. Least square means for the effect of feeding a yeast culture (YC) in grain on raising costs and income

Item	Treatment ¹		SEM	P-value
	Control	YC		
Raising costs, ² \$/calf				
Pasteurized milk	28.5	31.1	0.7	0.01
Grain	14.4	15.6	0.6	0.19
YC	0	1.0	0.02	<0.001
Labor for feeding	26.2	28.5	0.7	0.01
Vaccination	1.18	1.32	0.04	0.01
Health treatment	2.77	2.64	0.17	0.51
Total raising costs, \$/calf	71.8	78.9	1.9	0.01
Income with calf value, ³ \$/calf	402.9	458.2	26.9	0.14
Net income, \$/calf	331.1	379.4	25.0	0.17

¹Addition of 0 (control) or 2% YC to grain.

²Costs associated with each of the items listed.

³A dead calf represented a lost opportunity of \$500/heifer and \$100/bull, which corresponded to the market price of newborns. A live calf at 70 d of age represented a net gain of \$750/heifer and \$300/bull.

and rumen VFA concentration (Quigley et al., 1992; Kumar et al., 1997), which could benefit rumen health and development.

Results from the current study indicate that YC did not increase grain intake, and, as a result, the BW change did not differ between treatments. The smaller grain intake in the first month of age for YC calves is unlikely to be of any importance, because the difference was negligible, approximately 14 g/d (10% of YC intake), and it did not influence the overall energy and

protein consumption by the calves. Another report (Seymour et al., 1995) also observed a decrease in DM intake in the first weeks for calves fed brewer's yeast, with no influence on the overall DM intake, growth rate, and feed efficiency. Differences in response to feeding yeast products on grain intake may be related to type of yeast product (live yeast vs. yeast culture), strain of yeast, and amount fed. Only when calves were abruptly weaned at 35 d of age, yeast culture was beneficial to grain intake in the week after weaning (Lesmeister et al., 2004). In fact, the work by Lesmeister et al. (2004) only observed differences in grain intake with feeding 2% yeast culture in grain in the final week of a 6-wk experiment. In the current study, calves were not weaning abruptly, and grain intake remained similar ($P = 0.23$) between control and YC (control = 2,574 vs. YC = 2,463 g/d) in the week after weaning. Collectively, these studies suggest that, with few exceptions (Lesmeister et al., 2004), addition of yeast products to the grain generally does not influence intake and BW gain of calves in the first 70 d of age.

In the first weeks after birth, in systems in which milk is fed at restricted amounts, calves usually maintain or gain little BW (Davis and Drackley, 1998; Galvão et al., 2005). Because most of the nutrient intake in the first 30 d of the current study was supported by consumption of milk, and less by grain intake, calculated efficiency of grain conversion into BW was high. After 30 d, the increased DM intake of grain, and the

Figure 2. Effect of feeding yeast culture (YC) in grain on survival of calves during the first 70 d of age. Calves that survived were censored at 70 d of age. For control and YC, the mean $\pm$ SEM days to death were 63.6 ± 1.1 and 66.0 ± 1.0 , respectively. Effect of treatment ($P = 0.05$).

relatively smaller contribution of nutrients from milk, resulted in efficiency of grain conversion into BW similar to that observed by others (Lesmeister et al., 2004; Galvão et al., 2005). The lack of effects of YC on feed efficiency is similar to results observed by others (Quigley et al., 1992; Lesmeister et al., 2004; Galvão et al., 2005).

Concentration of glucose in plasma was not affected by treatment, possibly because of a lack of effect on overall nutrient intake. Concentrations of glucose in plasma are influenced by energy consumption resulting in greater glucose absorption but also by utilization by tissues. In young calves, increased glucose availability is expected to result in improved BW gain. Because YC and control calves experienced similar intake of milk and grain ME and protein, and also experienced similar BW changes, it is unlikely that glucose availability was altered by treatment, which was reflected by the similar plasma concentrations. When intake of grain increased with feeding yeast, so did concentrations of glucose in plasma (Galvão et al., 2005). On the other hand, feeding yeast culture to Jersey calves in the first 12 wk of age did not influence intake, BW gain, and concentrations of glucose (Quigley et al., 1992).

Glucose is the main source of energy for calves before ruminal development, but as intake of dry feeds increases and the rumen starts development, the contribution of VFA to the energy needs of calves also increases, and it results in elevated concentrations of BHBA in plasma (Quigley et al., 1991; Galvão et al., 2005). Quigley et al. (1991) suggested that the increased concentrations in plasma of BHBA resulted from the increased ketogenesis in the rumen, which is influenced by the rapid increase in intake of solid feeds after weaning. In young calves, concentrations of BHBA in plasma shifted abruptly by 4 h after feeding (Quigley et al., 1992), supporting the concept that ruminal production of BHBA is the main source of ketones in calves with adequate energy intake. Similar to the findings of others (Quigley et al., 1991; Lesmeister et al., 2004; Galvão et al., 2005), plasma BHBA increased with age of calves, which paralleled the increased grain intake; however, because no difference in grain intake was observed between treatments, feeding YC did not affect concentrations of BHBA. Furthermore, because feeding different concentrations of yeast culture resulted in marginal nonsignificant effects on measures of structural rumen development of calves (Lesmeister et al., 2004), it is unlikely that addition of yeast culture to the grain promotes changes in functional rumen development.

Yeast culture contains yeast cells and soluble products with potential antimicrobial effects. Incubation of *E. coli*, *Staphylococcus aureus*, *Candida tropicalis*, or healthy oral microbial flora with soluble metabolites

of yeast culture extract suppressed the growth of *C. tropicalis* and *E. coli* but not of *S. aureus* or oral flora obtained from healthy human saliva (Jensen et al., 2008). The same authors observed that these soluble products not only inhibited the growth of *E. coli* but also suppressed the activity of the bacteria. Furthermore, metabolites present in the yeast culture have been shown to modulate immune response in vitro, with reduction in inflammatory response and oxidative stress (Jensen et al., 2007). This can be important in diseases in which inflammatory response exacerbates the deleterious effects of the illness such as in chronic processes or in infections associated with gut pathogens like enterotoxigenic *E. coli*. These effects are expected to improve gut health and might explain the benefits to fecal scores and diarrhea observed in the current study when calves were fed YC.

Yeast cell wall also contains approximately 35% mannan and 30% glucan (Reed and Nagodawithana, 1991), which are normally not digested or absorbed in the small intestine (Newman, 1994), and their presence in the gut might enhance immune response and prevent colonization by pathogens. Mannan and glucan may bind to receptors on a variety of defense cells of the gut, which activates immune defenses such as phagocytosis (Murphy et al., 2007). Moreover, mannan present in the cell wall of yeasts might block bacterial attachment to the intestinal epithelium (Newman, 1994), which might explain the similar efficacy of mannan to improve fecal scores in calves compared with antibiotics (Heinrichs et al., 2003).

Although immune response of the gut was not evaluated in the current study, measures of innate and humoral immune responses were generally not influenced by feeding YC. Serum titers for OVA were similar between treatments. Likewise, measures of phagocytosis and intracellular killing activity of neutrophils were unaffected when cells were incubated with a nonpathogenic strain of *E. coli*. On the other hand, when neutrophils were incubated with a pathogenic strain of *E. coli*, the mean number of phagocytized bacteria and the proportion of phagocytized bacteria killed tended to increase for YC compared with control. Feeding oligosaccharides such as glucan improved neutrophil chemotaxis and respiratory burst activity (Murphy et al., 2007). Therefore, it is possible that consumption of oligosaccharides present in YC might have enhanced phagocytic activity of neutrophils against pathogenic *E. coli*. Nevertheless, these data suggest that feeding YC had minor effects on the measures of immune response evaluated, and only when neutrophils were incubated with pathogenic bacteria, differences were observed.

In spite of the small differences in immunocompetence of calves, fecal score and susceptibility to digestive disease were markedly reduced by feeding YC. It is important to indicate that in the current study the population of calves suffered from more diarrhea than initially expected, with 98% of the calves experiencing fecal score >2 for at least 2 consecutive days. Because colostrum contained high colony-forming unit counts and *Salmonella* spp. was present in some samples, it is possible that the excessive bacterial load present in colostrum favored the high incidence of gastrointestinal diseases observed in the current study. Although incidence of diarrhea was high, less than 15% of all the fecal scores were >2, and diarrhea affected 3.1% of the calf days at risk in the preweaning period. Under those circumstances, feeding YC reduced the risk of fever and diarrhea, suggesting protective effects of YC in calves subjected to high risk of morbidity. Differences in risk of enteric diseases are important, because diarrhea associated with dehydration is the major cause of death of young calves in the first weeks of life (Davis and Drackley, 1998; NAHMS, 2007). In fact, calves fed YC not only experienced reduced risk for gastrointestinal diseases, but they also experienced reduced risk of morbidity and lesser mortality. The reduced mortality rate was observed after 13 d of age (Figure 2), which might be related to increased grain intake with age and, therefore, intake of yeast culture.

Diarrhea in calves can be caused by pathogenic bacteria that attach and may or may not invade the intestinal cells of the host. Of the calves subjected to postmortem diagnosis, *Salmonella* spp. and *E. coli* were the predominant pathogens. It is possible that feeding YC might have decreased the risk of diarrhea by reducing the attachment and invasion of intestinal cells by these pathogens, because they might bind to oligosaccharides present in the yeast cell wall (Newman, 1994; White et al., 2002; Pérez-Sotelo et al., 2005), minimizing the growth of enteric pathogens by the metabolites present in yeast culture (Jensen et al., 2008) or reducing inflammatory response in the gut because of the metabolites of yeast culture (Jensen et al., 2007). In vitro, the majority of *Salmonella* spp. isolates adhered to the cell wall of *S. cerevisiae* (Pérez-Sotelo et al., 2005), which might prevent attachment and invasion of intestinal cells. In fact, Rodrigues et al. (1996) observed a protective effect of *S. cerevisiae* against *Salmonella* Typhimurium and *Shigella flexneri* in mice.

Although data on the effects of yeast culture and yeast cell wall components on risk of enteric diseases is more common in monogastrics (Newman, 1994; White et al., 2002), others have also observed a decrease in days with diarrhea in calves fed yeast (Galvão et al., 2005) and improved fecal scores with feeding mannan

oligosaccharides (Heinrichs et al., 2003). Similarly, feeding brewer's yeast reduced the incidence of fever and frequency of antibiotic treatments during the preweaning period in calves (Seymour et al., 1995). In a series of studies with stressed beef calves, Cole et al. (1992) demonstrated that feeding yeast culture reduced duration of disease and improved intake in morbid calves. Adding mannan oligosaccharides to milk replacer fed to calves improved fecal sores in a similar manner to feeding antibiotics in milk (Heinrichs et al., 2003). Because of the positive effects of yeast culture on enteric health, morbidity and mortality were reduced with feeding YC, in spite of the similar risk of respiratory diseases. Frequency of health treatments was also reduced with YC. These data suggest that feeding YC might improve overall gut health of calves in spite of similar measures of systemic immunity.

Costs associated with treatments were generally lesser for calves fed YC, although raising costs increased for YC compared with control. The increased raising costs of approximately \$7/calf for those fed YC was caused by increased feeding and labor costs as a result of improved survival of calves. As more calves fed YC survived, total consumption of milk, number of doses of vaccine, and labor needed to feed and care for calves also increased. In spite of the increased raising costs, feeding YC resulted in a numerical improvement in net income at the end of the study of approximately \$48/calf, or 14.6% over the net income of calves fed control. Results of the present study indicate that incorporation of yeast culture at 2% of the grain DM has the potential to improve health of calves by reducing risk of morbidity and, ultimately, mortality and also to minimize the frequency of health treatments in the first 70 d of life.

CONCLUSIONS

Incorporation of yeast culture at 2% of the grain fed to dairy calves from 2 to 70 d of age did not alter DM, protein and ME intake, feed efficiency, and BW gain. Humoral immune response was not influenced by dietary treatment, but some improvements in neutrophil function were observed with supplemental yeast culture when cells were incubated with pathogenic *E. coli*. Although reduction of costs for health treatments were not significant, calves fed yeast culture had decreased frequency of medical treatments because of reduced incidence of fever and diarrhea and reduced overall morbidity. The improvement in health of calves was consequent to reduction in enteric diseases and culminated with reduced mortality, particularly after 13 d of age, which probably reflected the increased intake of grain and yeast culture after 2 wk of age. Improve-

ments in survival of calves resulted in numerical improvement in net income of \$48/calf fed yeast culture at the end of the study. Under the conditions of the current study, in which incidence of diarrhea was high, these data support the concept that yeast culture improves health of the digestive tract of young calves and reduces morbidity and mortality. Further studies are needed to determine the exact components of yeast culture and respective mechanisms that elicit these positive effects on animal health.

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