Influence of feeding direct-fed microbial supplementation on growth performance and feeding behavior in naturally fed and conventionally fed finishing cattle with different dietary adaptation periods

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ABSTRACT: To determine the effects of finishing system (conventional vs. natural), dietary adaptation length (14 vs. 28 d), and direct-fed microbial (**DFM**) supplementation (no DFM vs. DFM) on growth performance and feeding behavior, 120 yearling steers (390 ± 2.8 kg) were used in a completely randomized design with a 2 × 2 × 2 factorial arrangement of treatments. Feed intake was monitored using the Insentec feeding system. Blood samples were collected every 28 d. After 140 d on feed, steers were slaughtered and carcass characteristics collected. Conventionally fed steers had greater ($P \leq 0.001$) final BW, carcass weight, and dressing %. Dry matter intake was not influenced ($P \geq 0.31$) by treatment. Length of dietary adaptation period did not influence ($P \geq 016$) final BW, ADG, and G:F. There was a feeding system × DFM interaction ($P \leq 0.02$) for ADG and G:F with conventionally fed steers fed DFM having the greatest ($P \leq 0.05$) and naturally fed steers supplemented with DFM having the least ($P \leq 0.05$) ADG and G:F. Number of visits to the feed bunk and number of meals per day did not differ ($P > 0.05$) among treatments. Time eating per visit and per meal was greater ($P = 0.05$) in steers supplemented with DFM than in steers not supplemented with DFM. On day 56 and 140, plasma glucose concentration was greater ($P \leq 0.03$) in steers adapted in 14 d than in steers adapted in 28 d. On day 84, plasma glucose concentration was greater ($P = 0.02$) in naturally fed compared to conventionally fed steers. On day 112, there was a dietary adaptation period × DFM interaction ($P = 0.004$) for plasma glucose concentration with glucose concentration greatest ($P \leq 0.05$) in steers adapted in 14 d supplemented with DFM and in steers adapted in 28 d not supplemented with DFM, least for steers adapted in 28 d supplemented with DFM, with steers adapted in 14 d not supplemented with DFM intermediate ($P \leq 0.05$). On day 112 and 140, plasma urea N concentration was greater ($P \leq 0.05$) in steers adapted in 28 d than in steers adapted in 14 d. These data indicate that conventionally fed steers generally had improved growth performance compared to naturally fed steers. Length of dietary adaptation and DFM supplementation had minimal effects on growth performance but did interact with feeding system to influence feeding behavior and blood metabolite concentrations.

Key words: dietary adaptation, direct-fed microbial, feed intake, finishing cattle, growth performance, natural feeding approaches

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INTRODUCTION

Dietary adaptation of cattle from a forage- to a concentrate-based diet results in a shift in the

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microbial population within the rumen from a predominately fibrolytic community to a predominately amylolytic community with a concomitant decrease in pH (Brown et al., 2006). If cattle are adapted too rapidly, the incidence of subclinical and clinical acidosis is more prevalent and results in decreased feed intake, G:F, and ADG (Owens et al., 1998). Direct-fed microbials (**DFM**) are live, naturally occurring microorganisms that can be added to diets to alter the microbial population in the digestive tract which can result in improved digestive health and animal performance (Krehbiel et al., 2003; Uyeno et al., 2015). Feeding DFM also may have the potential to decrease the length of the dietary adaptation period which would allow for increased consumption of a more energy-dense diet earlier in the finishing period, result in the need for less forage, and reduce the length of the feeding period. Additionally, there has been increased consumer demand for beef from natural feeding systems (no growth-promoting implants or antibiotics) and retailers are increasingly interested in offering their customers these alternatives in the market place (Fox et al., 2008). Feeding high-concentrate diets that do not contain ionophores may increase the risk of acidosis (Nagaraja et al., 1998). Supplementation with DFM could be an alternative to the use of ionophores and could potentially reduce the risk of acidosis, modify fermentation, and improve G:F in natural feeding systems. Therefore, our objectives were to determine the effects of and interactions between 1) conventional (growth-promoting implant and supplemental monensin and tylosin) vs. natural (no growth-promoting implant, no monensin, no tylosin) feeding systems, 2) dietary adaptation period (14 vs. 28 d), and 3) DFM supplementation (no DFM vs. DFM) on growth performance, feeding behavior, carcass characteristics, and liver abscess scores.

MATERIALS AND METHODS

All animal care and handling procedures were approved by the North Dakota State University Animal Care and Use Committee.

One-hundred and twenty Angus-crossbred yearling steer calves (390 ± 2.8 kg) were used. Steers were purchased from an order buyer from a backgrounding lot and were managed on pasture for the summer months prior to entering the backgrounding lot. Eight treatments were implemented in a 2 × 2 × 2 factorial arrangement of treatments (8 treatments with 15 animals per treatment) with feeding system (natural vs. conventional), dietary adaptation length (14 vs. 28 d), and DFM supplementation (with or without DFM) as the 3 treatment main effects. Steers were assigned to treatment within 4 pens. Steers in pens 1 and 2 were fed conventional diets and steers in pens 3 and 4 were fed natural diets. Steers in pens 1 and 3 were adapted to final finishing diets over 28 d and steers in pens 2 and 4 were adapted to diets over 14 d. Half of the steers in each pen were fed diets containing DFM (see below for more detail) in 4 feeders and half of the steers were fed diets containing no DFM in 4 feeders.

Radio frequency ID tags were placed in the right ear of each steer prior to the beginning of the experiment. Each pen contained 8 Insentec electronic feeding stations (Hokofarm Group, Marknesse, The Netherlands) as described previously (Mader et al., 2009; Islas et al., 2014; Swanson et al., 2014) allowing for offering specific dietary treatments and monitoring of individual feed intake and feeding behavior characteristics. Steers were adapted to the Insentec feeding system over 2 wk and were fed a 50% concentrate receiving diet without monensin or tylosin. Then steers were subjected to conventional [dietary monensin (35 mg/kg of total diet DM basis; Elanco Animal Health, Greenfield, IN) and tylosin (8.8 mg/kg of total diet DM basis; Elanco Animal Health), and implanted with 80 mg trenbolone acetate and 16 mg estradiol (Merck Animal Health, Madison, NJ)] or natural (no monensin, tylosin, or implant) feeding programs and steers within each feeding program were supplemented with or without DFM. For DFM treatments (Priority IAC, Manitowoc, WI), 28 g per head per day of DFM containing 35 billion cfu/g of *Propionibacterium freudenreichii* and 661 million cfu/g *Saccharomyces cerevisiae* was added to the total mixed diet for the first 14 d. From day 15 until the end of the experiment, 14 g per head per day of a second DFM containing 176.6 million cfu/g of *Pediococcus pentosaceus*, *Lactococcus lactis*, *Enterococcus faecium*, *Lactobacillus plantarum*, *Lactobacillus casei*, and *Lactobacillus brevis*, and 1.3 billion cfu/g of *Saccharomyces cerevisiae* was added to the total mixed diet. Steers were adapted to a high-grain diet by transitioning from a 50% concentrate diet to a 90% concentrate diet over a 14- or 28-d period by increasing the percent concentrate by 10% units twice (14 d) or once (28 d) per week. The initial 50% concentrate diet was made up of dry-rolled corn, corn silage and dry hay with protein, mineral, and vitamin supplements. The final high-grain diet was made up of dry-rolled corn, corn silage, dry hay, dried distillers grains

Table 1. Diet composition[1]

Ingredient	Conventionally fed	Naturally fed
Dry-rolled corn	71.00	71.00
Corn dried distillers grains with solubles	10.00	10.00
Corn silage	9.00	9.00
Grass legume hay	5.00	5.00
Fine ground corn	2.02	2.05
Limestone	1.50	1.50
Urea	1.00	1.00
Salt	0.20	0.20
Concentrated separator byproduct	0.15	0.15
Trace mineral premix[2]	0.05	0.05
Vitamin premix[3]	0.05	0.05
Rumensin premix[4]	0.02	0
Tylan premix[5]	0.01	0

[1]DM basis (%). For direct-fed microbial treatment (DFM) treatments (Priority IAC, Manitowoc, WI), 28 g per head per day of DFM containing 35 billion cfu/g of *Propionibacterium freudenreichii* and 661 million cfu/g *Saccharomyces cerevisiae* was added to the total mixed diet for the first 14 d. From day 15 until the end of the experiment, 14 g per head per day of a second DFM containing 176.6 million cfu/g of *Pediococcus pentosaceus*, *Lactococcus lactis*, *Enterococcus faecium*, *Lactobacillus plantarum*, *Lactobacillus casei*, and *Lactobacillus brevis*, and 1.3 billion cfu/g of *Saccharomyces cerevisiae* was added to the total mixed diet.

[2]Contained 3.62% Ca, 2.56% Cu, 16% Zn, 6.5% Fe, 4.0% Mn, 1,050 mg/kg I, and 250 mg/kg Co.

[3]Contained 48,510 kIU/kg vitamin A and 4,630.5 kIU/kg vitamin D.

[4]Contained 176 g monensin per kg premix.

[5]Contained 88 g tylosin per kg premix.

Table 2. Nutrient analysis of experimental diets

	Conventionally fed		Naturally fed	
Analysis	−DFM[1]	+DMF	−DMF	+DFM
DM, %	72.9	73.6	72.7	73.5
OM, % of DM	94.5	94.4	94.3	94.2
CP, % of DM	14.3	14.3	14.4	14.2
NDF, % of DM	31.7	31.4	31.1	32.0
ADF, % of DM	13.7	13.5	13.2	13.8
Ether extract, % of DM	3.62	3.59	3.60	3.52
Ca, % of DM	0.74	0.83	0.82	0.84
P, % of DM	0.35	0.35	0.36	0.35

[1]Direct-fed microbial.

plus solubles, and supplements (Tables 1 and 2). Feed was mixed and delivered daily beginning at approximately 0800 h. The feeding period was 140 d in length from the beginning of the dietary adaption period until slaughter. After 24 d on treatment, coccidiosis was observed in naturally fed steers. Therefore, decoquinate (Zoetis, Parippany, NJ) was fed at an average of 0.5 mg/kg of BW for 28 d to all steers so that all steers were treated similarly.

Dry matter intake per day and feeding behavior traits were summarized (Montanholi et al., 2010; Islas et al., 2014) as follows: events (number of bunk visits and meals daily), eating time (minutes; per visit, per meal, and per day), and feed intake (kg; per visit, per meal, and per minute) and these data were summarized as the average of each individual over the total feeding period. A visit was defined as each time the Insentec system detected a steer at a bunk. A meal was defined as eating periods that might include short breaks separated by intervals not longer than 7 min (Forbes, 1995; Montanholi et al., 2010). Dry matter intake variance was also calculated for each steer from daily DMI data over the entire feeding period.

Steers were weighed for 2 consecutive days at the beginning and the end of the experiment and every 28 d during the study. Average daily gain was calculated by linearly regressing BW on day of the experiment.

Blood samples were collected by jugular venipuncture into Vacutainer tubes containing sodium heparin (Becton Dickinson, Rutherford, NJ) before feeding on day 28, 56, 84, 112, and 140 when cattle were weighed. Plasma was isolated by centrifugation (Sorvall ST16R, Thermo Fisher Scientific, Waltham, MA) at 3,000 × *g* for 20 min at 4 °C and stored at −20 °C until analysis. Plasma urea N was determined (Jung et al., 1975) using a kit from BioAssay Systems (Hayward, CA). Plasma was analyzed for glucose concentrations using the hexokinase/glucose-6-phosphate dehydrogenase method (Farrance, 1987) using a kit from Thermo Scientific.

Steers were fed for 140 d and were marketed in 1 group. Steers were slaughtered at a commercial packing facility. Hot carcass weight was measured on the day of slaughter and carcass measurements were measured following a 24-h chill. Measurements collected were subcutaneous fat thickness at the 12th rib, LM area (LMA), marbling score, and KPH percentage. Liver abscesses were scored as described previously (Brink et al., 1990) using the following scoring system: no abscess (0), 1 or 2 small (less than ~2.5 cm in diameter) abscesses or abscess scars (1), 2 to 4 active abscesses under 2.5 cm in diameter or 1 larger (>2.5 cm in diameter) active abscess (2), and more than 5 active small abscesses or more than 1 large active abscess (3).

Seven animals did not train to the feeding system so were removed from the study before the beginning of the dietary adaptation period. Therefore, n = 14 for all treatments except for the naturally fed, 14 d dietary adaptation, with DFM treatment where n = 15. Data were analyzed as a completely randomized design with a 2 × 2 ×

2 factorial arrangement of treatments using the Mixed procedure of SAS. The model included effects of feeding system (conventional vs. natural), dietary adaptation period (14 vs. 28 d), DFM supplementation (no DFM vs. DFM), and all interactions. For plasma metabolites, data were analyzed as a completely randomized design with repeated measures and tested for the effects of feeding system, dietary adaptation period, feeding system, day, and all interactions using the Mixed procedure of SAS. Appropriate (minimize information criterion) covariance structures were utilized (Wang and Goonewardene, 2004). Data were considered different when $P \leq 0.05$.

RESULTS

Initial BW did not differ among treatments (Table 3). Final BW was greater ($P \leq 0.001$) in conventionally fed than naturally fed steers. There was a feeding system × DFM interaction ($P \leq 0.02$) for ADG and G:F with conventionally fed steers supplemented with DFM having the greatest ($P \leq 0.05$) and naturally fed steers supplemented with DFM having the least ($P \leq 0.05$) ADG and G:F with conventionally fed and naturally fed steers not supplemented with DFM intermediate ($P \leq 0.05$). Average DMI (kg/d and % of BW/d) for the entire feeding period was not influenced by dietary treatment (Table 3). There was a feeding system × dietary adaptation period interaction ($P = 0.05$) for DMI variance with naturally fed steers adapted in 28 d supplemented with DFM having the greatest ($P \leq 0.05$), conventionally fed steers adapted in 28 d having the least ($P \leq 0.05$), and conventionally fed steers adapted in 28 d and naturally fed steers adapted in 14 d intermediate ($P \leq 0.05$).

Number of bunk visits and number of meals per day did not differ among treatments (Table 4). Time eating per visit and per meal was greater ($P = 0.05$) in steers supplemented with DFM than in steers not supplemented with DFM. There was a feeding system × dietary adaptation interaction ($P = 0.02$) for time eating per visit with time eating per visit greatest ($P \leq 0.05$) in conventionally fed steers adapted in 14 d, least ($P \leq 0.05$) in naturally fed steers adapted in 14 d, with conventionally fed and naturally fed steers adapted in 28 d intermediate ($P \leq 0.05$). Time eating per day was greater ($P = 0.01$) in conventionally fed than in naturally fed steers (Table 4). There was a dietary adaptation period × DFM interaction ($P = 0.02$) for time eating per day with time eating per day the least ($P \leq 0.05$) for naturally fed steers not supplemented with DFM, greatest ($P \leq 0.05$) for conventionally fed steers with or without DFM supplementation, with naturally fed steers supplemented with DFM intermediate. Eating rate per visit and per meal did not differ among dietary treatments (Table 4). There was a dietary adaption period × DFM interaction ($P = 0.02$) for eating rate per min with naturally fed steers not supplemented with DFM having a greater ($P \leq 0.05$) eating rate than all other experimental treatments.

Hot carcass weight and dressing % was greater ($P \leq 0.001$) in conventionally fed than naturally fed steers (Table 5). There was a feeding system × dietary adaptation period × DFM interaction ($P = 0.04$) for liver abscess score with the greatest liver abscess score observed in naturally fed steers adapted in 14 d with no DFM supplementation. Marbling score was greater ($P = 0.02$) in naturally fed than in conventionally fed steers. There was a feeding system × dietary adaptation period × DFM interaction ($P = 0.04$) for back fat thickness as the effects of DFM and dietary adaptation period within feeding system were not consistent. There was a dietary adaptation period × DFM interaction ($P = 0.03$) for KPH with steers adapted for 28 d and supplemented with DFM having lesser ($P \leq 0.05$) KPH than other treatments.

There was a day × dietary adaptation period × DFM interaction ($P = 0.02$) for plasma glucose concentration so treatment effects were examined within day (Table 6). Plasma glucose concentration was not influenced by experimental treatment on day 28. On day 56 and 140, plasma glucose concentration was greater ($P \leq 0.03$) in steers adapted in 14 d than in steers adapted in 28 d. On day 84, plasma glucose concentration was greater ($P = 0.02$) in naturally fed compared to conventionally fed steers. On day 112, there was a dietary adaptation period × DFM interaction ($P = 0.004$) for plasma glucose concentration with glucose concentration greatest ($P \leq 0.05$) in steers adapted in 14 d supplemented with DFM and in steers adapted in 28 d not supplemented with DFM, least for steers adapted in 28 d supplemented with DFM, with steers adapted in 14 d not supplemented with DFM intermediate ($P \leq 0.05$).

There were interactions ($P \leq 0.03$) between day and experimental treatments for plasma urea N concentration so experimental treatment effects were examined within day (Table 6). On day 28, there was a feeding system × DFM interaction ($P = 0.009$) for plasma urea N concentration with urea N concentration greatest ($P \leq 0.05$) in naturally fed steers not supplemented with DFM, least ($P \leq 0.05$) with conventionally fed steers not supplemented with DFM

Table 3. Influence of feeding system, dietary adaptation period, and direct-fed microbial supplementation on growth performance

	Feeding system													
	Conventionally fed				Naturally fed									
	14 d		28 d		14 d		28 d							
Item	−DFM[1]	+DFM	−DFM	+DFM	−DFM	+DFM	−DFM	+DFM	SEM[3]	*P*-values[2]				
										Syst	Adapt	DFM	Syst × adapt	Syst × DFM	Adapt × DFM	Syst × Adapt × DFM
Initial BW, kg	390	395	397	397	387	379	390	388	7.9	0.12	0.32	0.79	0.88	0.50	0.95	0.67
Final BW, kg	619	624	607	632	600	591	593	593	11.4	0.001	0.77	0.51	0.98	0.21	0.39	0.68
ADG, kg/d	1.64	1.63	1.53	1.70	1.48	1.42	1.50	1.39	0.048	<0.001	0.67	0.87	0.85	0.02	0.29	0.08
DMI, kg/d	11.2	11.3	11.4	11.6	11.0	11.3	11.2	11.4	0.28	0.48	0.31	0.41	0.87	0.78	0.98	0.86
DMI, % of BW/d	2.22	2.22	2.23	2.22	2.22	2.23	2.23	2.23	0.043	0.10	0.23	0.38	0.87	0.13	0.42	0.89
DMI variance, kg[2]	6.75	7.45	6.87	6.30	6.28	7.18	7.59	7.49	0.481	0.39	0.67	0.50	0.05	0.62	0.10	0.83
G:F	0.147	0.144	0.134	0.147	0.136	0.126	0.134	0.122	0.0039	<0.001	0.16	0.33	0.65	0.006	0.20	0.09

[1]Direct-fed microbial; − = without, + = with.

[2]Syst = conventionally fed vs. naturally fed; Adapt = 14 vs. 28 d; DFM = −DFM vs. +DFM.

[3]Standard error of the mean for the Syst × Adapt × DFM interaction.

and naturally fed steers supplemented with DFM, with conventionally fed steers supplemented with DFM intermediate ($P \leq 0.05$). On day 28, there also was a dietary adaptation × DFM interaction ($P < 0.001$) for plasma urea N concentration with urea N greater ($P \leq 0.05$) in steers adapted in 14 d not supplemented with DFM and steers adapted in 28 d supplemented with DFM than in steers adapted in 14 d supplemented with DFM and steers adapted in 28 d not supplemented with DFM. On day 56, there was a dietary adaptation period × DFM interaction ($P = 0.02$) with urea N greater ($P \leq 0.05$) in steers adapted in 14 d not supplemented with DFM than steers from other treatments. On day 84, there was feeding system × DFM interaction ($P = 0.04$) for urea N concentration with the greatest ($P \leq 0.05$) concentration in conventionally fed and naturally fed steers not supplemented with DFM, least concentration in conventionally fed steers supplemented with DFM, with naturally fed steers supplemented with DFM intermediate ($P \leq 0.05$). On day 112 and 140, plasma urea N concentration were greater ($P \leq 0.05$) in steers adapted in 28 d than in steers adapted in 14 d. On day 140, there was a feeding system × DFM interaction ($P < 0.001$) for plasma urea N concentration with urea N greater ($P \leq 0.05$) in naturally fed steers not supplemented with DFM than in steers from other treatments ($P \leq 0.05$).

DISCUSSION

This experiment allowed us to examine the interactions between DFM supplementation and feeding management factors (use of growth-promoting technology and dietary adaptation management) on growth performance, feeding behavior, metabolism, and carcass traits in finishing cattle. The 2 × 2 × 2 arrangement of treatments resulted in the observation of many statistical interactions. The majority of interactions occurred between feeding system and DFM supplementation followed by interactions between dietary adaptation period and DFM supplementation. Only 2 interactions were observed between feeding system and dietary adaptation period (DMI variance time eating per visit). This suggests that the effects of DFM supplementation could largely depend on other management factors such as length of dietary adaptation, feeding system, or potentially other factors not evaluated in this experiment.

Although there were interactions between feeding system, dietary adaptation period, and DFM supplementation, the greatest effects observed in

Table 4. Influence of feeding system, dietary adaptation period, and direct-fed microbial supplementation on feeding behavior

	Feeding system															
	Conventionally fed				Naturally fed											
	14 d		28 d		14 d		28 d			*P*-values[2]						
Item	−DFM[1]	+DFM	−DFM	+DFM	−DFM	+DFM	−DFM	+DFM	SEM[3]	Syst	Adapt	DFM	Syst × adapt	Syst × DFM	Adapt × DFM	Syst × Adapt × DFM
Events, d^{-1}																
Visits[4]	22.5	23.2	47.7	23.1	26.0	26.3	24.1	22.9	2.02	0.60	0.97	0.41	0.07	0.59	0.24	0.49
Meals[5]	8.20	7.87	8.07	8.05	7.94	7.65	7.88	7.97	0.333	0.42	0.75	0.56	0.83	0.88	0.47	0.95
Time eating, min																
Per visit	4.52	4.76	3.65	4.66	6.52	6.61	3.93	4.40	0.329	0.02	0.79	0.05	0.02	0.46	0.22	0.66
Per meal	11.9	12.8	11.1	12.7	11.4	11.7	11.6	12.0	0.57	0.23	0.89	0.05	0.40	0.29	0.61	0.72
Per day	96.5	97.3	88.7	101.6	90.1	86.5	88.3	95.1	3.45	0.01	0.74	0.08	0.29	0.28	0.02	0.87
Eating rate, g																
Per visit	526	558	472	531	431	472	494	526	39.5	0.16	0.75	0.15	0.08	0.85	0.84	0.72
Per meal	1393	1483	1447	1447	1397	1538	1461	1447	68.5	0.70	0.96	0.26	0.81	0.85	0.23	0.73
Per min	118	117	131	115	123	134	129	121	5.1	0.07	0.80	0.31	0.23	0.17	0.02	0.78

[1]Direct-fed microbial.

[2]Syst = conventionally fed vs. naturally fed; Adapt = 14 vs. 28 d; DFM = −DFM vs. +DFM.

[3]Standard error of the mean for the Syst × Adapt × DFM interaction.

[4]A visit was defined as each time the Insentec system detected a steer at a bunk.

[5]A meal was defined as eating periods that might include short breaks separated by intervals not longer than 7 min (Forbes, 1995; Montanholi et al., 2010).

Table 5. Influence of feeding system, dietary adaptation period, and direct-fed microbial supplementation on carcass characteristics

	Feeding system															
	Conventionally fed				Naturally fed											
	14 d		28 d		14 d		28 d			*P*-values[2]						
Item	−DFM[1]	+DFM	−DFM	+DFM	−DFM	+DFM	−DFM	+DFM	SEM[3]	Syst	Adapt	DFM	Syst × adapt	Syst × DFM	Adapt × DFM	Syst × Adapt × DFM
Hot carcass weight, kg	374	375	367	382	355	349	352	356	7.0	<0.001	0.80	0.50	0.83	0.35	0.22	0.84
Dressing%	60.5	60.1	60.6	60.5	59.2	59.1	59.5	60.2	0.38	0.001	0.08	0.89	0.47	0.33	0.28	0.62
Liver abscess score[4]	0.500^{ab}	0.140^{a}	0.000^{a}	0.429^{ac}	1.214^{b}	1.000^{bc}	1.200^{b}	0.143^{a}	0.2749	0.002	0.16	0.12	0.40	0.09	0.94	0.04
LMA, in^2	75.9	77.8	75.9	76.5	75.9	73.9	73.9	72.6	2.0	0.08	0.36	0.92	0.83	0.33	0.97	0.67
Marbling score[5]	486	465	471	458	535	467	492	537	25.1	0.02	0.94	0.42	0.47	0.87	0.08	0.13
Back fat, cm	12.7^{a}	12.2^{a}	12.0^{ab}	11.6^{ab}	13.4^{a}	11.1^{ac}	9.8^{bc}	12.7^{a}	0.87	0.55	0.17	0.89	0.80	0.50	0.03	0.04
KPH[6], %	1.80	1.86	1.75	1.86	2.02	1.91	1.81	2.01	0.057	0.002	0.26	0.10	0.70	0.58	0.03	0.10

[1]Direct-fed microbial.

[2]Sys = conventionally fed vs. naturally fed; Adapt = 14 vs. 28 d; DFM = −DFM vs. +DFM.

[3]Standard error of the mean for the feeding system × Adapt × DFM interaction.

[4]Presence of liver abscesses were scored using a 3-point scale [no abscess (0), 1 or 2 small (less than ~2.5 cm in diameter) abscesses or abscess scars (1), 2 to 4 active abscesses under 2.5 cm in diameter or 1 larger (<2.5 cm in diameter) active abscess (2), more than 5 active small abscesses or more than 1 large active abscess (3)].

[5]400 = small^0 marbling; 500 = modest^0 marbling.

[6]Kidney, pelvic, and heart fat.

[a–c]Means with uncommon superscripts differ ($P < 0.05$).

Table 6. Influence of feeding system, dietary adaptation period, and direct-fed microbial supplementation on plasma glucose and urea N concentrations (mM) by day

	Feeding system															
	Conventionally fed				Naturally fed											
	14 d		28 d		14 d		28 d			*P*-values[2]						
Item	−DFM[1]	+DFM	−DFM	+DFM	−DFM	+DFM	−DFM	+DFM	SEM[3]	Syst	Adapt	DFM	Syst × Adapt	Syst × DFM	Adapt × DFM	Syst × Adapt × DFM
Glucose																
Day 28	5.59	5.77	5.71	5.04	5.69	5.67	5.54	5.85	0.266	0.39	0.42	0.79	0.38	0.28	0.47	0.11
Day 56	6.34	5.81	6.00	5.56	6.56	6.51	5.80	5.70	0.245	0.20	0.002	0.10	0.15	0.22	0.95	0.83
Day 84	6.04	6.25	5.72	5.79	6.91	6.27	6.04	6.41	0.285	0.02	0.07	0.99	0.96	0.49	0.28	0.15
Day 112	6.57	6.51	7.83	6.04	7.11	7.43	7.19	6.35	0.359	0.26	0.84	0.02	0.07	0.18	0.004	0.56
Day 140	6.84	6.24	6.10	6.16	6.54	6.58	5.67	6.20	0.328	0.70	0.03	0.98	0.64	0.24	0.22	0.86
Urea N																
Day 28	7.85	7.18	7.15	8.87	9.09	7.09	7.59	7.60	0.416	0.78	0.99	0.40	0.09	0.009	<0.001	0.73
Day 56	9.78	9.34	9.10	9.32	12.30	10.27	10.32	10.56	0.462	<0.001	0.06	0.12	0.43	0.22	0.02	0.20
Day 84	14.0	12.4	13.8	12.3	13.3	13.7	13.2	12.4	0.48	0.93	0.20	0.01	0.44	0.04	0.37	0.30
Day 112	12.2	13.4	14.8	13.7	12.4	13.2	13.2	13.7	0.72	0.38	0.04	0.39	0.48	0.52	0.18	0.34
Day 140	12.4	12.8	11.6	11.5	14.1	11.8	13.9	11.5	0.48	0.02	0.05	0.002	0.25	<0.001	0.65	0.76

[1]Direct-fed microbial.
[2]Sys = conventionally fed vs. naturally fed; Adapt = 14 vs. 28 d; DFM = −DFM vs. +DFM.
[3]Standard error of the mean for the feeding system × Adapt × DFM interaction.

growth performance were in response to feeding system with conventionally fed steers having greater ADG and generally improved G:F than naturally fed steers. These results are similar to results as reported previously (Wileman et al., 2009; Maxwell et al., 2015) when conventional and natural feeding systems were compared. Together these reports indicate that a significant premium is necessary if implementing natural feeding programs. Length of dietary adaptation generally did not influence overall growth performance. However, visual observation suggests that there was minimal incidence of subacute or acute acidosis during the dietary adaptation period for steers adapted over 14 or 28 d. The observance of coccidiosis early in the feed period in naturally fed steers was likely because of the lack of monensin in the diet as monensin is a coccicidiostat. It is not known how decoquinate supplementation may have influenced the effects of DFM, dietary adaptation, and feeding system on the observed results. However, all steers from all treatments were treated similarly.

Supplementation with DFM also did not influence overall growth performance although it did appear to interact with feeding system to influence ADG and G:F as ADG and G:F were negatively influenced by DFM in naturally fed steers but not in conventionally fed steers. However, it is unclear as to the biological significance of this finding. It is also not clear why DFM may have interacted with feeding system. Additional research is warranted if interest in natural feeding programs continues to grow and if DFM are being considered as an alternative to the use of ionophores in finishing programs.

Similar to past research (Maxwell et al., 2015), the results in the current experiment suggest that, over the entire feeding period, average DMI was not influenced by feeding system. However, there is limited information available directly comparing DMI between conventional and natural cattle feeding programs although the use of growth-promoting implants has been shown to increase DMI in finishing cattle (Reinhardt, 2007; Wileman et al., 2009), whereas supplementation with monensin or monensin and tylosin has resulted in decreased DMI (Stock et al., 1995). Less information is available when examining differences in DMI over the course of the feeding period. Interestingly, treatment differences were not consistent throughout the feeding period suggesting that changes in DMI are dynamic over time (data not shown).

Conventionally fed steers generally spent less time eating per visit and more time eating per day than naturally fed steers. This potentially could be because of changes in the ruminal environment with the inclusion of monensin in the conventionally fed steers, therefore moderating feeding behavior throughout the day. There is limited information on the effects of feeding system (conventionally fed vs. naturally fed) on feeding behavior, although past research has suggested that feeding monensin or a combination of monensin and tylosin results in decreased feed intake variance among individual steers (Stock et al., 1995) especially during dietary adaptation (Burrin et al., 1988). Although there were no effects of feeding behavior measurements with differing dietary adaptation period length, steers supplemented with DFM had greater eating time per visit and per meal. The interaction between feeding system and DFM supplementation for time eating per day suggests that naturally fed steers without DFM supplementation spent less time eating than other steers. This may suggest that DFM supplementation may reduce eating rate in naturally fed steers and therefore could help moderate the ruminal environment. More research as to the specific effects of DFM supplementation on ruminal fermentation and microbial populations and function seems warranted. However, in this experiment, the observed changes in feeding behavior were not associated with changes in growth performance.

The results generally indicating that conventionally fed steers had heavier carcasses, greater dressing percentage, larger LMA, decreased marbling score, and decreased KPH percentage than naturally fed steers would be expected as growth-promoting implants typically increase carcass weight, LMA and decrease marbling (Reinhardt, 2007). Dietary adaptation period length and DFM supplementation generally did not influence carcass characteristics. The lack of an effect of DFM on marbling is in agreement with past research (Krehbiel et al., 2003), although increased carcass weight and carcass-adjusted ADG was reported with DFM supplementation. Although the number of experimental observations relative to the incidence of liver abscesses was low, liver abscess scores were greater in naturally fed than in conventionally fed steers. This is in agreement with research (Nagaraja and Lechtenberg, 2007) showing that cattle receiving monensin and tylosin typically have reduced incidence of liver abscesses. Interestingly, DFM supplementation reduced liver abscess score in naturally fed steers adapted for 28 d but did not influence liver abscess scores for naturally fed steers adapted for 14 d or for conventional steers. More research is needed on the interactions of DFM with

other dietary management factors on ruminal fermentation and pathology associated with the incidence of liver abscesses.

Although feeding system did not impact plasma glucose concentration, steers adapted over 14 d as compared to 28 d had greater plasma glucose concentrations on day 56 and 140 and steers adapted in 28 d supplemented with DFM had the lowest plasma glucose concentration on day 56 and 140 compared to no DFM supplementation. Increased plasma glucose concentration during finishing could be an indicator of decreased insulin sensitivity or increased glucose supply (De Koster and Opsomer, 2013) that potentially could be mediated through increased propionate production in the rumen (Aschenbach et al., 2010). Glucose is an important precursor for intramuscular fat deposition (Smith and Crouse, 1984). However, the observed differences in plasma glucose concentrations between treatments were not associated with changes in marbling score. Further research on dietary adaptation length, glucose supply, insulin sensitivity, and marbling seems warranted.

The multiple interactions between finishing system and DFM for plasma urea N concentration indicate that DFM may influence N metabolism differently depending on whether monensin, tylosin, and growth-promoting implants are used as part of the feeding management program. However, in general urea N concentrations were greater in naturally fed than in conventionally fed steers and were decreased in steers supplemented with DFM vs. no DFM. With similar levels of dietary N intake, decreased plasma urea N could indicate improved utilization of dietary N (Kohn et al., 2005). This was likely the case for conventional vs. natural steers as conventional steers had increased growth resulting in increased carcass weight and LMA. Direct-fed microbials could influence N use efficiency by altering ruminal fermentation (Krehbiel et al., 2003) resulting in improved N capture in the rumen by microbes.

In conclusion, these data indicate that conventionally fed steers have improved growth performance. Length of dietary adaptation and DFM supplementation had minimal effects on growth performance but did influence and interact with feeding system to influence feeding behavior and blood metabolites.

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