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Evaluation of *Saccharomyces cerevisiae* fermentation product as an alternative to monensin on growth performance, cost of gain, and carcass characteristics of heavy-weight yearling beef steers[1]

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ABSTRACT: Two hundred fifty-two cross-bred yearling steers (406 ± 24 kg BW) were used in a completely randomized block design with a 2 × 2 factorial arrangement of treatments (7 pens/treatment) to evaluate the effects of dietary *Saccharomyces cerevisiae* fermentation product (SFP) and monensin (MON) on growth performance and carcass characteristics. Dietary treatments arranged as a 2 × 2 factorial were 1) with or without SFP and 2) with or without MON. Finishing diets contained 19.7% of DM as dried distiller's grains with solubles. Both SFP and MON were added in the total mixed ration in place of an equal amount of cornmeal (DM basis; target intake = 2.8 g of SFP and 33 mg of MON/kg of dietary DM). Each treatment group was offered ad libitum access to a transition ration from d 1 to 8 and then to the finishing ration from d 9 to 125. Body weights were collected on d 0, 28, 56, 84, 110, and 125. Initial and final BW was an average of 2-d weights (d –1 and 0 and d 124 and 125, respectively). Steers were shipped for harvest on d 125. Overall ADG was decreased (P = 0.03) in steers supplemented with SFP, but final BW was similar among treatments. Feeding SFP was associated with lighter (P < 0.01) HCW and a greater (P = 0.01) number of carcasses grading USDA Choice. Twelfth rib fat thickness was not affected by SFP (P = 0.82) or MON (P = 0.35), but numerical decreases in 12th rib fat thickness among cattle receiving SFP or MON alone contributed to a tendency (P = 0.07) for greater 12 rib fat thickness when SFP and MON were provided. There was no effect of treatment on cost of gain ($P \geq 0.21$). The effects of SFP in the current study may have been limited in heavy yearling steers due to consumption of a finishing diet containing 19.7% dried distiller's grains with solubles.

Key words: beef, ionophore, yeast culture

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INTRODUCTION

It is current conventional practice to administer an antimicrobial, such as monensin (**MON**), as a growth-promoting feed additive in finishing beef feedlot diets in the United States. Monensin, which is an ionophore (Schelling, 1984), is used for improved feed efficiency and prevention of coccidiosis (Goodrich et al., 1984). There is growing consumer demand for "natural" and organically grown beef (Thompson et al., 2007). The USDA (2009) designates that naturally raised beef animals are to be grown without the use of growth hormones or antimicrobials. Therefore, establishing an economically competitive alternative to ionophores that allows access to markets that ban the use of ionophores and that does not compromise end-product quality is of interest to researchers and beef producers. Such an alternative could be a *Saccharomyces cerevisiae* fermentation product (**SFP**). Some SFP have been shown to stimulate rumen bacterial yield by providing soluble growth factors (Callaway and Martin, 1997) and to increase mineral retention (Cole et al., 1992) and nutrient digestibility (Wohlt et al., 1991). Comparative effects of SFP and ionophores on growth performance and carcass traits are lacking. The objective of this study was to evaluate SFP as an alternative to MON on growth performance, cost of gain, and carcass characteristics of finishing heavy-weight yearling beef steers. The hypotheses of the study were that steers fed SFP would perform similarly to cattle fed MON during the finishing period and that there would be no interactions between the 2 feed additives.

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MATERIALS AND METHODS

Animals

All sampling techniques, animal use, and handling were preapproved by the Colorado State University Animal Care and Use Committee.

One day before the start of this experiment (June 11, 2008), 312 commercial cross-bred yearling beef steers were received at the Southeast Colorado Research Center (**SECRC**; Lamar, CO). Before entry at SECRC and before being sorted as candidates for the study, the cattle were backgrounded for approximately 30 d and received individual identification ear tags, were implanted with 120 mg trenbolone acetate and 24 mg estradiol (Revalor-S; Merck Animal Health, Summit, NJ) in the middle third of the ear, and were treated with Pyramid 2 + Type II BVD (Fort Dodge Animal Health, Fort Dodge, IA), ProMectin (ivermectin; IVX Animal Health, Inc., St. Joseph, MO), Presponse SQ (Fort Dodge Animal Health), and Safe-Guard Suspension 10% (fenbendazole; Merck Animal Health, Summit, NJ). Once selected for the study, steers were ranked and stratified by coat color score, unshrunk BW, and rectal temperature at processing at SECRC. Cattle did not receive any growth implants on or after arrival at SECRC. Details of previous implant status are not known because the steers used in this study were from a commercial source. Steers with a coat color score representative of either Brahman or Holstein influence and those that were beyond ± 2 SD from mean unshrunk BW (406 ± 24 kg) or mean rectal temperature (39.6 ± 0.33°C) were excluded from the study. Coat colors included within the study were black (84.1%), black with a white face and markings similar to an Angus × Hereford cross (9.1%), red (3.6%), or white (3.1%) and at least 2 representatives of each color grouping were included equally across treatments.

The remaining 252 steers were blocked by unshrunk BW (7 blocks) and randomly assigned a number from 1 to 1,000 using the random number function in Microsoft Excel (Microsoft, Redmond, WA). Steers were then ranked according to weight. For each successive set of 7 steers, the individual with the lowest random number was assigned to replicate 1, the second lowest random number assigned to replicate 2, and so forth until the individual with the greatest random number within the set was assigned to replicate 7. This process was repeated for each successive group of steers until all steers had been assigned to 1 of 7 replicates. By following this randomization schedule, 7 replicates of 9 steers of similar weight distribution were assembled for each of the 4 treatments in the study. Following their initial weighing on d 0, steers had access to long-stem grass hay and water overnight. The following morning, steers were reweighed and received visual tags identifying trial, treatment, replicate, and individual steer within trial. Steers were sorted and housed in dirt surfaced pens (6.1 by 18.3 m) with 3.5 m of linear bunk space located on a concrete feeding apron. Every 2 pens shared a common water fountain that was located along the fence line. No wind breaks or shade structures were provided.

Diets and DMI

Dietary treatments were initiated on d 1. Each pen replicate was randomly assigned to 1 of 4 dietary treatments. Main effect factors were 1) with or without SFP (Diamond V XP; Diamond V Mills, Cedar Rapids, IA) and 2) with or without MON (Rumensin; Elanco, Division of Eli Lilly and Company, Greenfield, IN) in finishing diets containing 19.7% dried distiller's grains with solubles (**DDGS**; DM basis). Each treatment group was offered a transition ration from d 1 through 8 and then fed a finishing ration fed from d 9 through the duration of the trial. Ingredient and nutritional composition of each diet is presented in Table 1. All rations during both phases were formulated to be isonitrogenous and isoenergetic. The SFP was offered at the manufacturer's recommended inclusion level of 56 g/d (as-fed basis) during the transition phase and then decreased to 28 g/d (as-fed basis) during the finishing phase (2.8 g/kg of DMI). Monensin was offered at the inclusion level of 11 mg/kg of DMI during the transition phase and then increased to 33 mg/kg of DMI for the finishing phase (Berthiaume et al., 2006). Both SFP and MON were offered in the total mixed ration in place of an equal amount of cornmeal on a DM basis. Both water and diets were offered for ad libitum intake throughout the study.

Steers were fed twice daily (at approximately 0700 and 1700 h) at an estimated 105% of the previous week's daily ad libitum intake. Orts were quantified and removed weekly. Diets were mixed in a truck-mounted feed processor immediately before feeding. To avoid carryover of SFP and MON from the feed processor to treatment groups not intended to receive SFP or MON, interim diets for nonstudy cattle were mixed and fed between batches. Daily deliveries of as-fed diets were recorded for each treatment pen and used for determination of DMI. Every 7 d, random diet samples (approximately 200 g) from the 0700 h feeding were obtained in triplicate. Two of the 3 samples were weighed, dried at 55°C for 48 h, and then reweighed for determination of DM (Table 1). Samples were then ground in a Wiley Mill (Thomas Model 4; Thomas Scientific, Swedesboro, NJ), passed through a 1-mm screen, and stored in a sealed, plastic bag at 4°C pending analysis. The third sample was stored (as-fed basis) at 4°C to serve as a backup. At the end of each 28-d period, the 2 DM samples from each week were mixed with other weekly samples from that 28-d period to make a composite 28-d diet sample, which was then submitted

Table 1. Ingredient and nutritional composition of diets[1]

	Transition[2]				Finishing[3]			
Item	Control	SFP	MON	S+M	Control	SFP	MON	S+M
Ingredient, % of DM								
Alfalfa hay	9.3	9.3	9.3	9.3	5.5	5.5	5.5	5.5
Corn silage	12.6	13.2	12.6	13.2	9.0	9.0	9.0	9.0
Flaked corn	57.8	56.9	57.7	56.9	63.5	63.5	63.5	63.5
Dried distiller's grains with solubles	18.1	18.3	18.1	18.3	19.7	19.7	19.7	19.7
Limestone	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6
Corn meal	0.49	0.01	0.48	–	0.31	0.01	0.31	–
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Mineral oil	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Trace mineral premix[4]	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Vitamin E[5]	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016
Vitamin A[5]	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Yeast culture[6]	–	0.526	–	0.526	–	0.311	–	0.311
Monesin[7]	–	–	0.015	0.015	–	–	0.016	0.016
Nutritional composition[8]								
DM, %	71.3	71.5	73.4	73.4	74.8	74.8	75.5	74.9
CP, % of DM	12.8	13.2	13.3	12.8	14.1	13.9	14.0	13.8
NPN, % of DM	0.40	0.31	0.26	0.29	0.61	0.40	0.33	0.35
NDF, % of DM	18.0	18.1	17.5	18.2	16.8	16.6	17.2	17.4
Ether extract, % of DM	5.28	5.35	5.16	5.05	5.70	5.41	5.66	5.71
NEg, Mcal/kg DM[9]	1.42	1.42	1.42	1.42	1.47	1.47	1.47	1.47
Calcium, % of DM	0.72	0.66	0.59	0.65	0.82	0.80	0.83	0.73
Phosphorus, % of DM	0.39	0.40	0.40	0.38	0.39	0.39	0.39	0.38
Potassium, % of DM	0.76	0.75	0.73	0.75	0.74	0.74	0.79	0.72
Magnesium, % of DM	0.21	0.21	0.19	0.20	0.19	0.18	0.18	0.17
Sulfur, % of DM	0.26	0.30	0.27	0.28	0.24	0.26	0.26	0.27

[1]Treatments included a basal control diet, a diet supplemented with *Saccharomyces cerevisiae* fermentation product (SFP; Diamond V "XP"; Diamond V Mills, Inc., Cedar Rapids, IA), a diet supplemented with monensin (MON; Rumensin; Elanco, Division of Eli Lilly and Company, Greenfield, IN), and a diet supplemented with both SFP and MON (S+M).

[2]Transition ration fed for d 0 to 8 of trial.

[3]Finishing ration fed for d 9 to 125 of trial.

[4]Formulated to provide the following on a DM basis: 75 mg/kg Zn, 85 mg/kg Fe, 10 mg/kg Cu, 25 mg/kg Mn, 0.20 mg/kg Co, 0.25 mg/kg I, and 0.12 mg/kg Se.

[5]Vitamin supplements provided 2,205 IU of vitamin A and 33 IU of vitamin E per kg diet DM.

[6]*Saccharomyces cerevisiae* fermentation product was added at manufacturer's recommended inclusion rate of 56 g/d during transition phase and 28 g/d during finishing phase (2.8 g/kg of DMI).

[7]The ionophore was added at the inclusion rate of 11 mg/kg of DMI during transition phase and increased to 33 mg/kg of DMI during finishing phase, as described by Berthiaume et al. (2006).

[8]With the exception of NEg, values reported for nutritional composition of diets are based on nutrient analysis from samples of total mixed ration collected every 7 d throughout the study.

[9]Rations were formulated for NEg values listed, which was calculated from NRC (2000) values.

to a commercial lab (SDK Laboratories, Hutchinson, KS) for analysis of nutrient composition. Briefly, feed was analyzed for DM at 105°C and NDF (Van Soest et al., 1991). Nitrogen (method 990.03), calcium (method 968.08), and phosphorus (method 965.17) were analyzed following methods of AOAC International (2005). The fraction of DM was used to calculate delivery of DM to each pen, which was then divided by the number of steers in that pen to arrive at DMI/animal. Feed bunks were cleaned and orts were collected on a weekly basis (before the 0700 h feeding), weighed, analyzed for proximate analysis, and subtracted from the original feed offered to determine actual feed intakes.

Performance and Carcass Characteristics

Steer performance was monitored by collection of individual BW on d 0, 28, 56, 84, 110, and 125. Body weights recorded during each weigh day were transformed to shrunk BW (**SBW** = BW × 0.96) for analysis. Initial and final SBW was an average of 2-d weights (d –1 and 0 and d 124 and 125, respectively). Following each processing and weighing procedure, steers were returned to their designated treatment pens to continue treatment assignments through d 125. Average daily gain and G:F were calculated on a live basis for each 28-d period. Incidence and description of morbid-

Table 2. Finishing performance of steers fed diets supplemented with or without *Saccharomyces cerevisiae* fermentation product and with or without monensin (n = 7)

	Treatment[1]					*P*-value		
Item	Control	SFP	MON	S+M	SEM	SFP	MON	SFP × MON
Number of steers[2]	63	63	62	63	–	–	–	–
Number of pens	7	7	7	7	–	–	–	–
Initial BW,[3] kg	391	392	393	391	8.1	0.96	0.94	0.89
Final BW,[3] kg	603	590	603	592	7.9	0.11	0.88	0.88
DMI, kg/d	10.38	10.17	10.43	9.72	0.30	0.12	0.49	0.39
ADG, kg	1.679	1.544	1.616	1.574	0.04	0.03	0.68	0.24
G:F	0.165	0.154	0.157	0.165	0.01	0.82	0.77	0.14
Cost of gain, $/kg[4]	1.77	2.00	1.89	1.85	0.11	0.41	0.92	0.21
Morbidity,[5] %	0	0	2	0	–	1.00	0.32	1.00
Mortality,[5] %	0	0	2	0	–	1.00	0.32	1.00

[1]Treatments included a basal control diet, a diet supplemented with *Saccharomyces cerevisiae* fermentation product (SFP; Diamond V "XP"; Diamond V Mills, Inc., Cedar Rapids, IA), a diet supplemented with monensin (MON; Rumensin; Elanco, Division of Eli Lilly and Company, Greenfield, IN), and a diet supplemented with both SFP and MON (S+M).

[2]On d 110 of the trial, 1 steer was removed from the study for respiratory problems that led to mortality.

[3]Body weights are reported as shrunk BW (BW × 0.96). Initial BW was an average of d –1 and 0, and final BW was an average of d 124 and 125. Steers were shipped for harvest on d 125.

[4]Cost of feed on DM basis/G:F.

[5]Categorical data with no SEM available.

ity and mortality were recorded. Production costs were calculated for each treatment group for each 28-d period using this formula: cost of gain (US$/kg) = cost of feed on DM basis/G:F. Steers were shipped for harvest on d 125. Carcass measurements were obtained for all steers by a data collection service (Cattlemen's Carcass Data Service, Canyon, TX) at a commercial slaughter facility. Hot carcass weight and liver abscesses were recorded at slaughter, whereas other carcass measurements were obtained after a 24-h chill. Marbling scores and USDA quality and yield grades were determined by a USDA grader.

Statistical Analysis

The trial was conducted as a 2 × 2 factorial, completely randomized block design with repeated measures. Pens of steers (or replicates) were treated as the experimental unit and individual steer as the sampling unit in the analysis. Analysis of variance for each continuous response variable was performed using mixed model procedures in SAS (version 9.1.3; SAS Inst. Inc., Cary, NC). The model included a repeated measures statement for performance data collected over the course of the trial, the random effect of block, and the fixed effects of SFP, MON, SFP × MON, data collection day, and interactions between day and treatments. The continuous response variables analyzed by this model included SBW, DMI, ADG, G:F, cost of gain, HCW, dressing percentage, LM area, KPH, 12th rib fat thickness, and marbling score. Discrete response variables were analyzed using PROC GLIMMIX of SAS using the same model as listed above. A binomial distribution was assumed for categorical data. The Link = Logit option of the model statement and the ILINK option of the LSMEANS statement were used to calculate the likelihood ± SEM that an individual within each pen qualified for a specific category. Where applicable, Tukey's comparison procedure was used to test differences between least square means if significant (or tendencies of) main effects or interactions were found. Significance was declared at $P \leq 0.05$ and a tendency at $0.05 < P \leq 0.10$.

RESULTS

One steer from the MON treatment was treated and then removed on d 110 for respiratory reasons that resulted in death (data is presented with deads removed). This was the only incidence of morbidity or mortality in the study. There were no SFP × MON interactions detected for any growth performance traits (Table 2). When BW was analyzed as a repeated measure, there was a main effect of day on BW ($P < 0.01$), where all cattle gained weight as the study progressed. Additionally, ADG was reduced ($P = 0.03$) in steers by the main effect of SFP. Twelfth rib fat thickness was not affected by SFP ($P = 0.82$) or MON ($P = 0.35$), but numerical decreases in 12th rib fat thickness among cattle receiving SFP or MON alone contributed to a tendency ($P = 0.07$) for greater 12th rib fat thickness when SFP and MON were provided (Table 3). Feeding SFP reduced ($P < 0.01$) HCW, increased ($P = 0.01$) number of carcasses grading Choice, and reduced ($P < 0.04$) number of carcasses grading Select.

Table 3. Carcass characteristics of pens of steers fed diets supplemented with or without *Saccharomyces cerevisiae* fermentation product and with or without monensin (n = 7)

	Treatment[1]					*P*-value		
Item	Control	SFP	MON	S+M	SEM	SFP	MON	SFP × MON
Number of steers[2]	63	63	62	61	–	–	–	–
Number of pens	7	7	7	7	–	–	–	–
HCW, kg	373.5	363.3	375.3	368.3	5.11	0.01	0.28	0.61
Dressing percentage, %	61.97	62.27	61.60	62.14	0.35	0.49	0.25	0.74
LM area, cm^2	92.2	89.1	92.2	91.5	1.54	0.22	0.45	0.44
KPH, %	1.855	1.896	1.857	1.890	0.05	0.42	0.95	0.92
12th rib fat, cm	1.176	1.102	1.047	1.142	0.05	0.82	0.35	0.07
USDA yield grade, calculated	2.59	2.58	2.46	2.55	0.10	0.65	0.34	0.59
USDA yield grade 1,[3] %	18	15	5	5	–	0.85	0.76	0.84
USDA yield grade 2,[3] %	58	66	62	56	–	0.91	0.97	0.55
USDA yield grade 3,[3] %	23	19	18	19	–	0.82	0.53	0.67
USDA yield grade 4 and 5,[3] %	2	0	0	5	–	0.43	0.41	0.11
Marbling score[4]	411	422	408	407	10.5	0.64	0.36	0.52
Quality score[5]	388	398	387	391	6.0	0.23	0.42	0.62
USDA Premium Choice,[3] %	10	12	15	3	–	0.24	0.29	0.21
USDA Choice,[3] %	45	55	30	58	–	0.01	0.36	0.18
USDA Select,[3] %	45	33	53	38	–	0.04	0.39	0.79
USDA Standard,[3] %	0	0	2	0	–	–[6]	0.63	0.35
Liver abscesses,[3] %	18	23	31	20	–	0.83	0.43	0.15

[1]Treatments included a basal control diet, a diet supplemented with *Saccharomyces cerevisiae* fermentation product (SFP; Diamond V "XP"; Diamond V Mills, Inc., Cedar Rapids, IA), a diet supplemented with monensin (MON; Rumensin; Elanco, Division of Eli Lilly and Company, Greenfield, IN), and a diet supplemented with both SFP and MON (S+M).

[2]On d 110 of the trial, 1 steer from SFP was removed from the study for respiratory problems that lead to mortality. Also, 2 carcasses from S+M were not accounted for from carcass data collection service.

[3]Categorical data with no SEM available.

[4]Small00 = 400.

[5]Select = 300–399.

[6]Insufficient carcasses qualifying as Standard prevented the successful completion of the analysis for this category using PROC GLIMMIX (SAS; SAS Inst. Inc., Cary, NC).

DISCUSSION

Effect of Saccharomyces cerevisiae *Fermentation Product*

It has been demonstrated that SFP promotes a less acidic ruminal pH environment by reducing the concentration of L-lactate (Williams et al., 1991; Erasmus et al., 1992). This elevated pH may reduce the incidence of acidosis by reducing lactate production and may be more favorable for the growth of cellulolytic bacterial species, such as *Fibrobacter succinogenes*, *Ruminococcus albus*, and *Ruminococcus flavefaciens* in the rumen (Callaway and Martin, 1997; Miller-Webster et al., 2002). In our review of the literature, as indicated below, the most consistent response to SFP is stimulation of ruminal cellulolytic bacteria. Reports range from 5 to 40 times greater number of cellulolytic bacteria present, particularly in ruminants fed high-roughage diets (Hillman et al., 1985; Newbold et al., 1993). In addition to increasing rumen pH, SFP stimulates rumen bacterial yield by providing soluble growth factors, such as organic acids, B vitamins, and AA (Callaway and Martin, 1997). Enhancing the fermentative capacity of rumen cellulolytic species has been shown to increase fiber digestion, mineral retention, and flow of microbial protein from the rumen (Cole et al., 1992; Martin and Nisbet, 1992; Newbold et al., 1996). Yeast culture supplementation to lactating Holstein cows (fitted with ruminal and duodenal cannulas) increased digestibilities of CP and ADF (Erasmus et al., 1992). Erasmus et al. (1992) reported no difference in total tract DM digestibility and commented on nonsignificant proportionate increases in DM disappearance of wheat straw from in situ incubations at 12 and 24 h after feeding. Others have demonstrated increased digestibility, specifically the fiber and protein portion of the diet, when SFP was offered (Wohlt et al., 1991; Miller-Webster et al., 2002).

The increased prevalence of the fuel ethanol industry has decreased the availability of corn as an energy source for beef finishing rations, but corn has been replaced by byproducts such as wet and dried distiller's grains (Vasconcelos and Galyean, 2007a). In the current study, DDGS were included in the ration not only due to price competitiveness but also because DDGS are greater

in NDF and CP concentrations and lower in starch concentration than corn (DM basis; NRC, 2000). Flaked corn was in our finishing diet at 63.5% of DM, and the inclusion of DDGS elevated the concentration of CP and NDF and decreased concentrations of starch. In a survey conducted by Vasconcelos and Galyean (2007b), the majority of beef finishing rations are formulated to include 70 to 85% grain on a DM basis. The inclusion level of flaked corn in the current study was slightly below those values. Additionally, in an effort to target current industry feeding practices, the inclusion level of DDGS in the current study were based on figures provided by the Vasconcelos and Galyean (2007b) survey. The survey indicated that 83% of nutritionists formulate rations to include 5 to 50% ethanol byproducts (DM basis) in finishing rations (average = 16.5%, mode = 20%). In our study, the transition ration contained 18% of DM as DDGS and the finishing ration 19.7% of DM as DDGS.

Considering the NDF provided by DDGS in our diets, a synergistic effect between DDGS and SFP was expected to increase feed efficiency and growth in the finishing steers. In disagreement with our hypothesis, SFP-fed cattle did not significantly outperform the cattle fed neither feed additive (**CON**) or MON cattle. The reason for this is unknown. Previously, Cole et al. (1992) reported no effect on growth performance of calves fed increasing levels of SFP in receiving diets. However, when calves were challenged intranasally with infectious bovine rhinotracheitis virus, those calves receiving SFP had greater DMI and improved weight gain (Cole et al., 1992). Similarly, Phillips and VonTungeln (1985) reported that the addition of SFP to the receiving ration of feeder calves tended to increase DMI but had no consistent effect on ADG. The authors from both studies (Cole et al., 1992; Phillips and VonTungeln, 1985) concluded that SFP supplementation seemed to provide a greater benefit in stressed calves. Additionally, Phillips and VonTungeln (1985) noted that when SFP was added to receiving rations containing MON, ADG was depressed compared to those that did not receive the combination of SFP and MON (0.87 and 1.04 kg/d, respectively). Although cattle in this trial were fed a different SFP product at a lower dosage, a similar response was observed in our study when SFP was added to the MON diet. Average daily gain was less for SFP and MON fed together than when only MON was fed. Conversely, Hinman et al. (1998) reported that the addition of SFP in the finishing diet of cross-bred steers increased both ADG and G:F. Schingoethe et al. (2004) reported increased feed efficiency in mid-lactation Holstein cows when 60 g/d SFP was offered. In the Schingoethe study, the percentages of dietary CP and NDF were greater than in our study (17.5 and 30.8% vs. 13 and 18%). This disparity between study results could be attributed to differences in NDF and starch concentration in the diet and differences in the level of stress experienced by the animals. The reader should be cautioned that many other factors beyond what we have listed could explain the decrease in ADG by SFP and lack of response in G:F. In the current study, only 1 steer was treated and removed from the study due to health reasons, which indicates that cattle were minimally stressed and generally in good health; we speculate that this could have contributed to a lack of growth performance response to the dietary supplements. It could be suggested that the apparent age and BW of cattle in our study may have minimized response to SFP. It also seems likely that because cattle were heavy-weight (406 kg BW) yearling steers, the age and weight of cattle likely contributed to the minimal stress experienced by the cattle when introduced to the finishing study conditions. We are unsure what mechanism specifically (i.e., stimulation of immune response, alteration of digestive tract flora, etc.) may contribute to this response.

It is worth noting that although the carcasses of SFP-fed steers were superior in carcass USDA Quality Grades, they were also the lightest in HCW. These results could be interpreted to suggest that SFP steers were more optimally finished at a reduced end weight than either the CON or MON-fed steers and may not require as many days on feed. The positive effect of SFP on USDA Quality Grade has been previously observed (Diamond V Mills, Inc., Cedar Rapids, IA, personal communication). However, the difference in USDA Quality Grade is not supported by a corresponding difference in either quality or marbling score. It is likely that this discrepancy could be attributed to how similar the carcasses were within the Choice/Select USDA grading assignment. The National Beef Quality Audit (Garcia et al., 2008) reported that 79.96% of carcasses (≥USDA Yield Grade 1) from United States–fed steers and heifers fall within the Choice/Select USDA quality grading assignment and that the vast majority of the marbling scores are in the lower grade levels (e.g., low Choice = 64.21%).

An increase in total VFA production and a decrease in ruminal acetate:propionate ratio has been previously reported when SFP was offered to ruminants (Williams et al., 1991; Carro et al., 1992; Erasmus et al., 1992). Although not measured, we hypothesize that SFP supplementation may have caused an increase in total ruminal VFA production along with a decreased acetate:propionate ratio as compared to CON cattle. Increased VFA production, particularly concentration of propionate, could potentially increase intramuscular fat deposition and be the explanation for the increased number of carcasses that graded USDA Choice or better for SFP-fed steers. Smith and Crouse (1984) reported that acetate will provide 70 to 80% of the acetyl units to in vitro lipogenesis in subcutaneous adipose tissue and only 10 to 25% in intramuscular adipose tissue. Conversely, glucose (made from propionate in the

liver) will provide 1 to 10% of the acetyl units in subcutaneous adipose tissue and 50 to 75% in the intramuscular depot. Therefore, feeding SFP could alter VFA concentrations in such a way that would positively affect marbling and carcass quality.

Effect of Monensin

Feeding MON had no effect on growth or carcass characteristics. Although our carcass results are consistent with previous studies, growth performance results are conflicting. Multiple studies on feeding MON to ruminants have been consolidated (Goodrich et al., 1984; Nagaraja et al., 1997) and indicate that across various diets, types of cattle, and conditions, MON has consistently improved feed efficiency by reductions in feed intake. Additionally, MON reduces lactic acid production, incidence of bloat, and acidosis. The lack of response to MON in our study is not clear.

Ionophores modify the movement of ions across biological membranes, specifically causing Na entry into cells (Haney and Hoehn, 1967; Pressman, 1976; Smith and Rosengurt, 1978). The biological response of this action has been previously outlined (Schelling, 1984; Nagaraja et al., 1997); MON increases the molar proportion of propionate at the expense of lactate and concurrently decreases molar proportions of acetate and butyrate produced in the rumen. An increase in propionate improves energy utilization of MON-fed animals. Consequently, these changes in ruminal fermentation, caused by feeding MON, have been shown to prevent acidosis and bloat. Typically, MON is fed in diets high in rapidly fermentable carbohydrates as a preventative measure against such digestive disturbances. In the current study, the proportion of rapidly fermentable, high-concentrate feedstuffs was diluted with DDGS. As already mentioned, DDGS have more NDF and less starch than corn (NRC, 2000). Nagaraja et al. (1997) reported moderate to marked inhibition of fiber digestibility when cattle were fed MON. Perhaps the discrepancy between the lack of effect on growth performance in MON-fed steers compared to previous studies could be explained by the inability of MON to be effective when fed in diets containing distiller's grains. Although the inclusion of corn was relatively high in our diets, it was still below industry averages (Vasconcelos and Galyean, 2007b). It seems possible that an effect on growth performance due to MON was not detected because some of the starch was replaced with DDGS; hence, the mode of action of MON may have been limited. Depenbusch et al. (2008) reported that feeding MON to finishing heifers offered no growth performance or carcass advantage when distiller's grains replaced 25% of the steam-flaked corn in the diets. Meyer et al. (2013) reported no significant advantage in ADG or carcass traits of steers fed finishing diets containing distiller's grains and supplemented with MON. However, contrary to the current study where MON had no effect on G:F, Meyer et al. (2013) reported a significant improvement in G:F when MON was fed to cattle consuming 25% wet distiller's grains and 29.75% each of high-moisture corn and dry-rolled corn.

Feeding MON had no significant effect on carcass characteristics. Carcass results are in agreement with 228 previous trials, summarized by Goodrich et al. (1984), which involved 11,274 head of cattle fed MON-containing diets. The summary indicated that dressing percentage, marbling score, fat depth, quality grade, and yield grade were either not affected or negatively affected by MON. Additionally, the inclusion of MON has shown no effect on liver abscess incidence in several studies summarized by Nagaraja and Chengappa (1998).

Production Costs

The average price for all diets was $0.28/kg of DM (data not shown). Therefore, with ration costs being equal, differences in cost of gain are determined solely by G:F. Although the cost of gain was greatest for the SFP-fed cattle, the difference was not significant. This value is greatest due to the greatest numerical value for G:F in the SFP-fed steers. Cattle fed SFP cost approximately 5.82% more to feed than MON-fed cattle. Previous work shows that naturally fed cattle tend to cost 39% more (Fernandez and Woodward, 1999) and that consumers are willing to pay more for the product (Boland et al., 2002). Based on this study, the producer would need to be compensated by a market premium of at least 6% to maintain their profit margin per kilogram of gain if SFP was used as an alternative to MON for the production of "natural beef." The conclusion could also be drawn that the CON diet could replace the MON diet without the cost of the ionophore or a decrease in performance. It should also be noted that feed cost analysis should be interpreted with caution, as markets may shift; however, due to the relative lack of change in diet costs within the current study, the relationships between cost of gain and performance would likely remain regardless of changes in feed costs.

Summary and Implications

The results of this study indicate that the response of feedlot cattle to MON was limited in steers consuming a diet with 19.7% DDGS (DM basis). Therefore, because few differences were detected due to either SFP or MON treatment, the results of the current study indicate that the conditions were favorable for cattle to perform well without any feed additive. Factors that may have been novel in this study were good bunk management, ration design, weather, and a subset of cattle that would allow for abandonment of feed additives and thus access to

markets that may ban such feed additives. Further research is needed for determination of effective dosage level of SFP in finishing beef rations dependent on varying levels of roughage and starch.

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