Effect of inclusion rate of Fermenten on performance, carcass traits, and apparent total tract digestibility of growing Angus crossbred steers¹

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ABSTRACT: In Phase 1 (days 0 to 56) of a two-phase experiment, 81 steers (initial BW = 189 ± 22 kg) were arranged in a generalized randomized block design, allocated to nine pens (nine steers per pen) and assigned to one of three dietary treatments. Treatments consisted of different inclusion rates of Fermenten (FER) in a backgrounding diet fed ad libitum, and were as follows: 0% (CON), 2%, or 4% FER in the diet DM. Steer was considered the experimental unit, and individual DMI was measured using the GrowSafe system. In Phase 2 (days 57 to 112), treatments were discontinued and steers were relocated to a paddock with free access to a common basal diet, to assess potential residual effects of FER. Effect of treatment was measured on performance, concentration of serum urea nitrogen (SUN), NEFA and glucose, and apparent total tract digestibility of nutrients. On day 56, steers fed 4% FER had lesser ($P = 0.01$) BW than 2% FER steers. Steers fed CON also tended ($P = 0.08$) to have greater BW than 4% FER steers. ADG was not different ($P = 0.96$) between CON and 2% FER steers, whereas steers in the 4% FER treatment had lesser ($P \leq 0.01$) ADG than CON and 2% FER. Steers in

the 4% FER treatment had lesser ($P = 0.04$) DMI than CON, and were less feed efficient ($P \leq 0.04$) than 2% FER and CON steers. However, DMI as a percentage of the BW did not differ ($P = 0.07$) across treatments. A treatment effect was observed for final BW on day 112 ($P = 0.05$), where 4% FER tended ($P = 0.07$) to have lesser BW than CON. In Phase 2, ADG was not different ($P = 0.18$) among treatments. However, overall ADG (days 0 to 112) was lesser ($P = 0.02$) for steers fed 4% FER when compared with CON. There was no difference ($P \geq 0.12$) in longissimus muscle area gain or 12th rib fat depth gain. There was a treatment × day interaction for serum concentrations of glucose ($P < 0.001$), NEFA ($P < 0.001$), and SUN ($P < 0.001$). Steers fed 4% FER had greater ($P < 0.001$) DM, OM, NDF, ADF, and CP apparent total tract digestibility than CON. Similarly, 4% FER steers had greater ($P \leq 0.02$) DM, OM, NDF, and ADF digestibility than 2% FER. Results show that although inclusion of FER increased apparent total tract digestibility of nutrients, DMI and overall performance of growing beef cattle were negatively affected, mainly when FER was included at 4% of the diet DM.

Key words: carcass traits, digestibility, feed additive, Fermenten, performance, steers

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INTRODUCTION

Backgrounding programs are typically designed to provide low-cost feedstuff to young,

lightweight calves, which are efficient at converting the energy of the feed into BW gain (Crawford, 2009) allowing growing calves to deposit muscle and build frame before entering the feedlot. Meeting the protein requirements of growing calves during this period has an impact on subsequent growth performance in the finishing phase (Duff and Galyean, 2007; Koenig et al., 2013), with significant consideration given to fulfill metabolizable protein requirements of growing calves. Balancing the supply of RDP and rumen undegradable protein to maximize metabolizable protein flow to the small intestine while minimizing N excretion is one of the greatest challenges during the backgrounding phase. Ruminant microorganisms convert RDP and non-protein N into nutritionally valuable microbial protein (Dewhurst et al., 2000), as long as energy is not a limiting factor (Hristov et al., 2004). If N requirements of ruminal microorganisms are not met (e.g., diets deficient in RDP), fermentation of plant cell tissues will decrease, likely causing reduced DMI and volatile fatty acid (VFA) production (Dryden, 2008). Fermenten (FER; Church & Dwight Co. Inc., Princeton, NJ) is a byproduct of lysine production and a source of RDP. It contains a readily degradable fraction of non-protein N, in addition to AA and peptides (Cooke et al., 2009). The addition of FER to continuous culture fermenters resulted in increased DM, OM, and CP digestibility, as well as greater microbial N production (Lean et al., 2005). The addition of AA and peptides to growth media has been shown to enhance in vitro ruminal microbial growth (Cotta and Russell, 1982; Argyle and Baldwin, 1989). In addition, supply of AA and peptides possibly enhance the rate and extent of bacterial CP synthesis (NRC, 2000). Although provision of AA and peptides are not typically limited in common beef cattle diets, fiber-digesting bacteria may require an additional supply of branched-chain AA, which will be degraded to required branched-chain VFA, such as 2-methylbutyrate and isovalerate (NASEM, 2016). It is hypothesized that inclusion of FER in the backgrounding diet of growing cattle would result in enhanced nutrient digestibility and performance. The objective of this research was to evaluate increasing inclusion rates of FER on performance, carcass traits, and apparent total tract digestibility of nutrients in growing Angus beef steers.

MATERIALS AND METHODS

A two-phase experiment was conducted at the University of Florida, IFAS, North Florida

Research and Education Center (NFREC), located in Marianna, Florida. All research procedures were reviewed and approved by the University of Florida, Institutional Animal Care and Use Committee (protocol # 201408406).

Animals, Housing, and Diets

Eighty-one Angus crossbred steers were housed at the NFREC Feed Efficiency Facility in nine pens (nine steers per pen), starting on day -14 to favor acclimation to feeding management practices. During this 14-d adaptation period prior to the beginning of Phase 1, steers received a common basal diet consisting of (DM basis): 41% peanut hulls, 35% soy hull pellets, 19% corn gluten feed pellets, and 5% of liquid supplement containing a mineral and vitamin mix. For Phase 1 (days 0 to 56), 81 recently weaned Angus crossbred steers (initial BW = 189 ± 22 kg) were arranged in a generalized randomized block design, using initial BW as blocking factor (27 light, 27 medium, and 27 heavy steers). Pens were assigned randomly to one of three treatments: 0% (CON), 2% (2% FER), and 4% (4% FER) inclusion rate of FER (Church & Dwight Co., Inc.) in the diet DM. The experimental diet was a total mixed ration comprised of peanut hulls, corn gluten feed, soybean hulls, and soybean meal (Table 1). Diets of Phase 1 were formulated to be similar in RDP concentrations (6.5%, DM basis), using book-referenced RDP concentrations for each ingredient, and isocaloric (70.6% of total digestible nutrients, DM basis). Steers had ad libitum access to feed and water. During Phase 1, individual feed intake was recorded using an electronic radio-frequency monitoring system (GrowSafe System Ltd., Airdrie, Alberta, Canada). Feed was delivered every morning to the pens to allow for ad libitum intake. Weekly feed samples taken for DM determination and nutrient analysis were taken from every feed bunk in three locations of the GrowSafe bunk, and at three points of the day. On the day of feed sampling, samples were taken at feed delivery, when approximately half of the feed was consumed and at the bottom of the feed bunk, prior to the new feed delivery. Thus, a total of nine subsamples from each bunk were composited within each weekly feed sampling, to account for potential sorting and change in diet composition. Phase 2 (days 57 to 112) began immediately after finishing Phase 1. Phase 2 was designed to assess any potential residual effects of feeding FER on subsequent performance of steers. During Phase 2, steers were relocated to a dormant bahiagrass

Table 1. Ingredients and nutritional composition (DM basis) of experimental diets

	CON ¹	2% FER ²	4% FER ³
Ingredients, % DM			
Fiber pellets ⁴	28.0	28.0	28.0
Soybean hulls pellets	35.0	36.0	38.0
Corn gluten feed pellets	17.0	15.0	12.0
Peanut hulls pellets	13.0	13.0	13.0
Soybean meal	2.0	1.0	—
Liquid supplement ⁵	5.0	5.0	5.0
Fermenten ⁶	—	2.0	4.0
Nutritional composition ⁷ , % DM			
DM, % as fed	91.6	91.5	91.6
CP	13.7	15.7	16.0
RDP ⁸	6.8	6.5	6.2
α NDF	54.7	51.4	51.5
ADF	43.0	37.9	39.2
NE _g , Mcal/kg DM	1.10	1.14	1.14
Calcium	1.03	1.39	1.33
Phosphorus	0.30	0.34	0.31
Magnesium	0.24	0.27	0.26
Potassium	1.32	1.52	1.45
Sodium	0.28	0.45	0.46

¹CON: no inclusion of Fermenten in the diet.

²2% FER: 2% inclusion of Fermenten in the diet DM.

³4% FER: 4% inclusion of Fermenten in the diet DM.

⁴Commercial pellets made of cotton and peanut byproducts (AFG Feed LLC, Donalsonville, GA).

⁵Molasses-based liquid supplement custom formulated to provide vitamins (A, D, and E) and minerals and to supply 35 mg of monensin/kg of diet DM (Westway Feed Products Inc., New Orleans, LA).

⁶Church & Dwight, Princeton, NJ.

⁷Analyzed by a commercial laboratory using a wet chemistry package (Dairy One, Ithaca, NY).

⁸Calculated using book values for rumen degradable protein (RDP).

paddock with free access to a basal diet without inclusion of FER. The diet was common to all steers and the composition was similar to that of the diet used during the 14-d adaptation prior to Phase 1. Samples of the diets offered in both phases were collected weekly and dried in a forced air oven for 72 h at 55 °C to determine DM concentration. Dry samples were ground in a Wiley mill (Arthur H. Thomas Co., Philadelphia, PA) to pass a 2-mm sieve and composited within treatment. Samples of the diets and FER were analyzed for nutritional composition by a commercial laboratory (Dairy One Forage Laboratory, Ithaca, NY). Composition and nutritional profile of the diets are described in Table 1.

Performance and Carcass Traits

Initial BW was calculated as the average unshrunk BW of steers on days –1 and 0 for Phase

1, and days 55 and 56 for Phase 2, while final BW was the average unshrunk BW measured on days 55 and 56 for Phase 1, and days 111 and 112 for Phase 2. The observed NE for each diet was calculated from the performance data using the equation proposed by Zinn and Shen (1998) based on individual animal intake and ADG. Energy gain (EG) was calculated as $EG = (0.0557 \times BW^{0.75}) \times ADG^{1.097}$ (NRC, 1984), in which EG is daily energy deposited (Mcal/d) and BW is mean shrunk BW. The equation used to calculate maintenance energy expended (EM; Mcal/d) was $EM = 0.077 \times BW^{0.75}$ (Lofgreen and Garrett, 1968). From the calculated amounts of energy required for maintenance and gain, the NE_m of each diet was obtained by the quadratic equation $NE_m = [-b \pm (b^2 - 4ac)^{1/2}] / 2a$, in which $a = -0.41 \times EM$, $b = 0.877 \times EM + 0.41 \times DMI + EG$, and $c = -0.877 \times DMI$ (Zinn and Shen, 1998). The NE_g of each diet was obtained by the equation $NE_g = 0.877 \times NE_m - 0.41$ (Zinn and Shen, 1998). Real-time ultrasound measurements were taken at 28-d intervals on the right flank 12th rib to determine Longissimus muscle area (LMA), and rib fat thickness (RFT). The real-time ultrasound equipment used was an Aloka 500v (Aloka USA, Inc., Wallingford, CT) and a superflab guide to ensure fit of the transducer to the natural curvature of the animal body shape. Vegetable oil was applied to the skin and used as coupling medium. For each real-time ultrasound image, measurements were obtained with the ImageJ 1.48v software (Wayne Rasband, National Institutes of Health). Carcass measurements were used to determine LMA and RFT gain, calculated as the increment in LMA and RFT from the start (day 0 for Phase 1 and day 56 for Phase 2) to the end (day 56 for Phase 1 and day 112 for Phase 2) of each phase.

Blood Metabolites

Blood samples were collected at 0700 hours every 14 d to determine serum concentrations of glucose, serum urea nitrogen (SUN), and NEFA. Blood samples were collected via jugular venipuncture into 10 mL serum (red top) BD Vacutainer tubes with conventional stopper (Vacutainer, Becton Dickinson, Franklin Lakes, NJ). Following collection, blood was allowed to clot for 1 h at room temperature, and then refrigerated for 24 h at 4 °C. Blood samples were centrifuged at $2,360 \times g$ for 15 min at 4 °C in a Beckman Coulter Centrifuge (Avanti J-E, Beckman Coulter Inc., Palo Alto, CA). Serum was frozen at –20 °C until subsequent analyses. Glucose and SUN concentrations were

determined using quantitative colorimetric kits G7521 and B7551, respectively (Pointe Scientific Inc., Canton, MI). Serum NEFA was determined using the acyl-CoA synthetase, acyl-CoA oxidase method (NEFA-HR, Wako Pure Chemical Industries, Richmond, VA). Intra- and inter-assay CV were 1.9% and 1.8%, respectively, for serum concentrations of glucose, 2.4% and 3.7%, respectively, for SUN, and 2.4% and 2.3%, respectively, for NEFA.

Apparent Total Tract Digestibility of Nutrients

Determination of apparent total tract digestibility of DM, OM, CP, NDF and ADF was performed during Phase 1 of the experiment on a subsample of 27 steers (nine medium steers per treatment), using indigestible NDF (iNDF) as an internal marker. Concentrations of iNDF in feed and fecal samples were determined as described by [Cole et al. \(2011\)](#) with modifications proposed by [Krizsan and Huhtanen \(2013\)](#). Diet and fecal grab rectal samples were collected beginning on days 33 and 34, respectively, for four consecutive days. Both feed and fecal samples were collected twice per day, at 0800 and 1700 hours. After collection, samples were frozen at -20°C until further processing and analysis. At the end of the experiment, feed and fecal samples were dried at 55°C for 48 h in a forced-air oven. Then, samples were ground in a Willey mill (Arthur H. Thomas Co., Philadelphia, PA) to pass a 2-mm sieve and pooled within steer, on an equal weight basis per sample, for determination of nutrient and marker concentration.

For determination of feed and fecal sample DM and OM, ~ 0.5 g of sample was weighed in duplicate, dried in a forced-air oven at 100°C for 24 h, and ashed at 550°C for 6 h. For determination of the fibrous components, 0.5 g of dry feed and fecal samples were weighed in duplicate into F57 bags (Ankom Technology Corp., Macedon, NY) and analyzed for NDF, using heat-stable α -amylase and sodium sulfite, and subsequently for ADF as described by [Van Soest et al. \(1991\)](#) in an Ankom 200 Fiber Analyzer (Ankom Technology Corp.). Concentration of CP in the samples was determined by rapid combustion using a micro elemental N analyzer (Vario Max CN, Elementar Americas Inc., Mt. Laurel, NJ) according to the official method 992.15 ([AOAC, 1995](#)).

For the determination of iNDF, 0.5 g of feed and fecal samples were weighed in duplicate into F57 bags (Ankom Technology Corp.), incubated in the rumen of a cannulated steer for 288 h, and the

residue analyzed for NDF, as previously described. Apparent total tract digestibility of DM, OM, CP, NDF, and ADF was calculated using the following formula:

$$100 - 100 \times \left[\left(\frac{\text{marker concentration in feed}}{\text{marker concentration in feces}} \right) \times \left(\frac{\text{nutrient concentration in feces}}{\text{nutrient concentration in feed}} \right) \right]$$

Statistical Analysis

Data were analyzed as a generalized randomized block design, with steer as experimental unit, using the MIXED Procedure of SAS (SAS Institute Inc., Cary, NC). For performance parameters and carcass traits, the model included the fixed effect of treatment and the random effect of block. Steers used for the determination of apparent total tract digestibility of nutrients belonged to the same block (medium initial BW), and therefore the model only included the fixed effect of treatment. Blood metabolites were analyzed as repeated measures and the model included the fixed effect of treatment, day, and treatment $\times$ day interaction, and the random effect of steer within treatment. Repeated measures were fitted using the unstructured covariance as determined by the Akaike information criterion. Significance of fixed effects was declared when $P \leq 0.05$. Fisher's protected LSD procedure was used to separate treatment means. Statistical differences between treatment means were declared at $P \leq 0.05$, while tendencies were declared when $0.05 < P \leq 0.10$. During Phase 1 of the experiment, one steer assigned to the heavy block and 2% FER treatment died from causes not related to the application of treatments, therefore data previously recorded from this experimental unit was removed from the analysis. For performance and carcass traits, the Tukey–Kramer adjustment was used to account for the lost experimental unit and for multiple comparisons, while for apparent total tract digestibility of nutrients, a Tukey adjustment was used.

RESULTS AND DISCUSSION

Performance and Carcass Traits

At the beginning of the experiment (Phase 1, day 0) steer BW did not differ ($P = 0.90$; [Table 2](#)) among treatments, however at the end of Phase 1 (day 56), 2% FER steers were heavier ($P = 0.01$)

Table 2. Performance and carcass traits of Angus crossbred steers fed backgrounding diets containing Fermenten at various inclusion rates

Item	Treatment ¹			SED ²	P-value
	CON	2% FER	4% FER		
N	27	26	27		
BW, kg					
Day 0	188	189	188	3.9	0.90
Day 56	238 ^{abx}	242 ^{ax}	226 ^{by}	5.4	0.01
Day 112	290 ^x	288 ^{xy}	274 ^y	7.5	0.05
ADG, kg					
Days 0 to 56	0.88 ^a	0.90 ^a	0.68 ^b	0.07	0.002
Days 56 to 112	0.94	0.83	0.85	0.06	0.18
Days 0 to 112	0.91 ^a	0.87 ^{ab}	0.77 ^b	0.05	0.02
DMI					
Days 0 to 56, kg/d	6.33 ^a	6.30 ^a	5.62 ^b	0.29	0.02
% of BW	2.96	2.92	2.73	0.11	0.07
G:F	0.14 ^a	0.14 ^a	0.12 ^b	0.008	0.007
Calculated ³ dietary NE _g , Mcal/kg of DM	1.12	1.14	1.05	0.032	0.06
Longissimus muscle area gain, cm ²					
Days 0 to 56	0.05	0.02	0.01	0.022	0.12
Days 56 to 112	0.09	0.11	0.09	0.022	0.49
Rib fat thickness gain, cm					
Days 0 to 56	0.15	0.14	0.10	0.029	0.17
Days 56 to 112	0.21	0.22	0.19	0.046	0.80

^{a,b,x,y}Within a row, means with uncommon superscripts differ at $P \leq 0.05$ or $0.05 < P \leq 0.10$, respectively.

¹Fermenten included at 0 (CON), 2 (2% FER), or 4% (4% FER) of dietary DM.

²SE of treatments differences of means.

³Calculated from performance and individual feed intake from days 0 to 56, based on [Zinn and Shen \(1998\)](#).

than 4% FER steers. In addition, CON steers also tended ($P = 0.08$) to be heavier than 4% FER. BW was not different ($P = 0.77$) between steers in CON and 2% FER. By the end of Phase 2 (day 112), a treatment effect ($P = 0.05$) was observed for BW, where steers fed 4% FER tended ($P = 0.07$) to have lesser BW than CON, while steers fed 2% FER did not differ from the other treatments ($P \geq 0.13$). This indicates a residual effect of FER on animal performance, negating any potential for compensatory growth.

During Phase 1, steers in the 4% FER treatment had lesser ($P = 0.002$) ADG than CON and 2% FER steers. However, by the end of Phase 2, steers ADG across treatments did not differ ($P = 0.18$). Overall ADG from days 0 to 112 (Phases 1 and 2 combined) was different ($P = 0.02$), as 4% FER steers had lesser ADG ($P = 0.02$) than CON, while ADG of 2% FER was intermediate, not differing from treatments ($P \geq 0.14$). No differences among treatments were observed in calculated NE_g ($P = 0.06$; [Table 2](#)), despite the differences in ADG and DMI.

The observed performance responses could partly be explained by different DMI ($P = 0.02$) measured across treatments during Phase 1 of the experiment. Data showed that both CON and 2%

FER steers had greater DMI ($P \leq 0.05$) than 4% FER steers. However, when DMI was expressed as a percentage of BW, no differences were observed ($P = 0.07$) among treatments. During Phase 1, there was a treatment effect ($P = 0.007$) for feed efficiency. G:F was not different ($P = 0.87$) between CON and 2% FER steers. Steers in the 4% FER group had lower ($P \leq 0.03$) feed efficiency than CON and 2% FER steers.

[Penner et al. \(2009\)](#) fed different levels of FER in low- and high-sugar diets to Holstein cows and reported no interaction or effect of FER on DMI or BW change, although high-sugar diets resulted in greater BW gain. A sugar $\times$ FER interaction for BCS was observed by [Penner et al. \(2009\)](#), where cows receiving FER in the high-sugar diet gained more BCS than cows in the low-sugar diet. [Cooke et al. \(2009\)](#) showed that beef heifers grazing Bahiagrass and receiving grain-based supplements (isonitrogenous and similar in RDP) containing either FER or urea, had no difference in ADG, although pregnancy rate was lower for heifers receiving FER.

Differences in BW and ADG were not reflected in ultrasound measured carcass traits ([Table 2](#)); LMA gain and RFT gain were not different for all

treatments during both phases of the experiment ($P > 0.12$). Yambayamba et al. (1996) reported no differences in muscle weight of full left-side weight (obtained after sagittal split of the carcass, quarter partition between the 12th and 13th rib, and separation of components in muscle, bone, and fat) between beef heifers feed-restricted for 92 d and beef heifers fed ad libitum. However, restricted heifers had greater bone proportion, and less side fat than heifers fed ad libitum. When restricted heifers were also fed ad libitum, both groups had similar carcass characteristics, even though the proportion of liver and spleen relative to empty BW was lower for restricted heifers throughout the experiment (Yambayamba et al., 1996).

Blood Metabolic Parameters

There was a treatment $\times$ day interaction ($P < 0.001$) for SUN, serum concentrations of NEFA, and serum concentrations of glucose (Table 3). On day 28 of Phase 1, SUN was lower ($P \leq 0.02$) for CON steers compared to 2% and 4% FER steers, and 2% FER steers had lower ($P < 0.01$) SUN compared to 4% FER steers.

During Phase 2, there was more variability in concentrations of SUN among treatments within sampling day; in general, CON steers had greater SUN concentrations ($P \leq 0.01$) than 2% FER steers (days 70, 84, and 98) and greater SUN concentration ($P \leq 0.04$) than 4% FER steers (days 70, 98, and 112). Steers in the 2% FER treatment had lower ($P = 0.002$) SUN concentration than 4% FER steers on day 84; conversely, on day 98, 2% FER steers had greater ($P = 0.03$) SUN concentration than 4% FER steers (Figure 1).

Within sampling day, serum concentrations of NEFA (Figure 2) were not different ($P > 0.10$) among treatments for most part of the experiment. On day 0, during Phase 1, CON steers had lesser ($P \leq 0.05$) serum concentrations of NEFA than 2% FER and 4% FER steers. A treatment effect was also observed on day 56, where 4% FER steers had greater ($P \leq 0.002$) serum NEFA concentration than CON and 2% FER steers. During Phase 2, serum NEFA concentrations were not different ($P > 0.10$) across treatments except on day 70, when CON steers had greater ($P = 0.02$) serum concentrations of NEFA than 4% FER steers.

Table 3. Concentrations of SUN, serum NEFA, and serum glucose of Angus crossbred steers fed backgrounding diets containing Fermenten at various inclusion rates

Item	Treatment ¹			SED ²	P-value		
	CON	2% FER	4% FER		TRT ³	Day ³	TRT $\times$ day ³
N	27	26	27				
SUN, mg/dL	10.91	10.58	10.76	0.265	0.45	<0.001	<0.001
NEFA, mEq/L	0.28	0.29	0.29	0.017	0.80	<0.001	<0.001
Glucose, mg/dL	58.15	56.76	55.29	0.389	0.12	<0.001	<0.001

¹Fermenten included at 0% (CON), 2% (2% FER), or 4% (4% FER) of dietary DM.

²SE of treatment differences of means.

³P-value: observed significance levels for the effects of treatment (TRT), day, and their interaction (TRT $\times$ day).

Figure 1. Effects of inclusion rate of Fermenten on serum urea nitrogen (SUN) concentrations of Angus crossbred steers fed a backgrounding diet ad libitum ($n = 27$ /treatment for CON and 4% FER, $n = 26$ /treatment for 2% FER). Treatments were applied on Phase 1 (days 0 to 56) and suspended on Phase 2 (days 56 to 112), to assess carryover effects of Fermenten. A treatment $\times$ time interaction was observed ($P < 0.001$). CON: 0% inclusion of Fermenten in the diet DM, 2% FER: 2% inclusion of Fermenten in the diet DM, 4% FER: 4% inclusion of Fermenten in the diet DM. *Means within day of sampling differ ($P < 0.05$). Within day of sampling, error bars represent the SE of treatment differences for treatment $\times$ time interaction.

Serum concentrations of glucose were variable throughout the experiment (Figure 3). On Phase 1 at day 0, CON steers had greater serum concentrations of glucose ($P \leq 0.04$) than 4% FER and 2% FER steers. On day 28, 4% FER steers had the greatest ($P < 0.001$) serum concentrations of glucose. Conversely, on day 42, 4% FER steers had the least ($P < 0.001$) serum concentrations of glucose. Other differences were also observed on day 56, when 2% FER steers had greater ($P \leq 0.002$) serum concentrations of glucose than CON and 4% FER groups, and on day 70, when CON steers had greater ($P = 0.02$) serum concentrations of glucose than 4% FER steers.

Greater serum concentration of NEFA and lower concentrations of glucose in steers receiving an inclusion rate of 4% FER at day 56 of Phase 1 indicate that animals in this group were closer to a catabolic state compared to steers in the 2% FER and CON steers. Removing FER from the

diet improved the metabolic state of steers in the 4% FER group and promoted cattle recovery in this group, as evidenced by lack of treatment effect for serum concentration of NEFA and glucose for the final portion of the experiment (days 84, 98, and 112). Variable concentrations of glucose across sampling days in 4% FER could have been associated to different factors; for instance, serum concentrations of glucose on day 28 could have resulted from a stress response mechanism, while lower concentrations on day 42 are more likely to have been triggered by the decreased DMI and subsequent energy deficit state. In addition, greater concentrations of SUN on day 28 would further support the idea of catabolic processes being developed in response to stress factors.

According to Doornenbal et al. (1988), reference mean concentrations of SUN and glucose for Shorthorn calves (mean BW ranging from 166 to 290 kg) are 12.07 ± 2.32 and 82.15 ± 7.38 mg/dL,

Figure 2. Effects of inclusion rate of Fermenten on serum concentrations of nonesterified fatty acids (NEFA) of Angus crossbred steers fed a backgrounding diet ad libitum ($n = 27$ /treatment for CON and 4% FER, $n = 26$ /treatment for 2% FER). Treatments were applied on Phase 1 (days 0 to 56) and suspended on Phase 2 (days 56 to 112), to assess carryover effects of Fermenten. A treatment $\times$ time interaction was observed ($P < 0.001$). CON: 0% inclusion of Fermenten in the diet DM, 2% FER: 2% inclusion of Fermenten in the diet DM, 4% FER: 4% inclusion of Fermenten in the diet DM. *Means within day of sampling differ ($P < 0.05$). Within day of sampling, error bars represent the SE of treatment differences for treatment $\times$ time interaction.

Figure 3. Effects of inclusion rate of Fermenten on serum concentrations of glucose of Angus crossbred steers fed a backgrounding diet ad libitum ($n = 27$ /treatment for CON and 4% FER, $n = 26$ /treatment for 2% FER). Treatments were applied on Phase 1 (days 0 to 56) and suspended on Phase 2 (days 56 to 112), to assess carryover effects of Fermenten. A treatment $\times$ time interaction was observed ($P < 0.001$). CON: 0% inclusion of Fermenten in the diet DM, 2% FER: 2% inclusion of Fermenten in the diet DM, 4% FER: 4% inclusion of Fermenten in the diet DM. *Means within day of sampling differ ($P < 0.05$). Within day of sampling, error bars represent the SE of treatment differences for treatment $\times$ time interaction.

respectively. In contrast to serum concentrations of NEFA and glucose, SUN was more variable during Phase 2, with CON steers generally having greater concentrations of SUN.

Sources of RDP, like Fermenten, contribute to microbial protein synthesis by providing AA, peptides, or $\text{NH}_3\text{-N}$. However, when N concentration is greater relative to energy in the rumen, excess ruminal ammonia enters the portal blood, is transported to the liver, and is converted to urea (Hammond, 1997). Cooke et al. (2009) supplemented heifers grazing a Bahiagrass pasture with a grain-based supplement containing different sources of RDP, either urea or FER, and reported greater mean BUN (average BUN $\pm$ SEM; 11.9 mg/dL $\pm$ 0.39) and glucose (average glucose $\pm$ SEM; 80.15 mg/dL $\pm$ 11.7) concentrations than those observed in this experiment, although no differences between treatments were observed. Concentrations of blood metabolites are correlated to body growth and development. According to Cooke et al. (2009), similar concentrations of blood urea nitrogen and glucose in their study reflected the similar body growth and development of heifers, indicating that FER failed to increase the availability of nutrients to the animal. Similarly, other studies indicated no differences in plasma concentrations of glucose (65.48 mg/dL), urea N (13.13 mg/dL), and β -hydroxybutyric acid (8.25 mg/dL) of Holstein cows fed low- and high-sugar diets supplemented with FER (Penner et al., 2009).

Apparent Total Tract Digestibility

During the days of collection of samples for determination of apparent total tract digestibility, steers had similar ($P \geq 0.06$) DM, OM, and CP intake among treatments. However, there was a treatment effect ($P \leq 0.02$) on intake of NDF and ADF. Steers in the 4% FER treatment had lower ($P = 0.03$) NDF and lower ($P = 0.01$) ADF intake than CON steers. Steers in the 2% FER had NDF and ADF intake intermediate to both groups ($P > 0.10$).

There was a treatment effect ($P < 0.01$, Table 4) on apparent total tract digestibility of DM, OM, NDF, ADF, and CP. Steers in the 4% treatment had greater ($P \leq 0.02$) DM, OM, NDF, and ADF digestibility than 2% FER and CON steers, whereas 2% FER steers had greater ($P \leq 0.03$) DM, OM, NDF, and ADF digestibility than CON steers. Steers fed 2% FER and 4% FER did not differ ($P = 0.10$) in apparent total tract digestibility of CP, and both had

Table 4. Intake and apparent total tract digestibility of nutrients in Angus crossbred steers fed backgrounding diets containing Fermenten at various inclusion rates

Item	Treatment ¹			SED ²	P-value
	CON	2% FER	4% FER		
N	9	9	9		
Intake, kg/d					
DM	6.56	6.75	5.51	0.554	0.07
OM	6.08	6.13	5.03	0.510	0.07
NDF	3.87 ^a	3.62 ^{ab}	2.98 ^b	0.317	0.02
ADF	2.93 ^a	2.64 ^{ab}	2.18 ^b	0.237	0.01
CP	0.81	0.96	0.79	0.073	0.06
Digestibility, %					
DM	44.07 ^a	55.52 ^b	61.90 ^c	1.908	<0.01
OM	44.70 ^a	55.88 ^b	61.84 ^c	1.934	<0.01
NDF	30.36 ^a	39.72 ^b	47.64 ^c	2.539	<0.01
ADF	25.56 ^a	32.66 ^b	40.52 ^c	2.590	<0.01
CP	37.82 ^a	58.49 ^b	65.19 ^b	3.118	<0.01

^{a,b}Within a row, means with uncommon superscripts differ at $P \leq 0.05$.

¹Fermenten included at 0 (CON), 2 (2% FER), or 4% (4% FER) of dietary DM.

²SE of treatment differences of means, $n = 9$ steers per treatment.

greater CP digestibility than CON ($P < 0.001$). The DM and OM intake of 4% FER steers tended to be less ($P = 0.07$), which might have affected nutrient digestibility due to a longer retention time of feed in the rumen. Augmented dietary intake may result in increased ruminal escape of feed nutrients, and therefore, decreased ruminal digestion of diet components and increased escape of microbial nitrogen (Robinson et al., 1985). No differences in apparent total tract digestibility of the DM, OM, CP, starch, and NDF were observed for cows on a low- and high-sugar diet supplemented with FER (Penner et al., 2009). Conversely, a meta-analysis from a data set of continuous culture fermenter trials on studies using FER or BioChlor (Church & Dwight Co.), which is a similar product, with different mineral concentration, indicated that either FER or BioChlor increased CP digestibility by 11% (Lean et al., 2005). In addition, an interaction with sugar or starch content of the diet was reported, both of which increased CP digestibility when FER was included. Furthermore, FER increased DM and OM digestibility by 3.6% and 7.9%, respectively, compared with the control treatment (Lean et al., 2005). Increased fiber breakdown when preformed AA are provided in the diet may be an effect from the stimulation of the noncellulolytic microorganisms associated with the fiber, instead of a direct stimulation of the cellulolytic organisms (Newbold,

1999). Noncellulolytic microorganisms are the main contributors to the removal of fiber degradation products, therefore preventing feedback inhibition of cellulose lysis (Cheng and McAllister, 1997). The Cornell Net Carbohydrate Protein System states that nonstructural carbohydrate fermenting bacteria use either ammonia or peptides and AA as N source, while structural carbohydrate fermenting bacteria is only able to use and assimilate ammonia, as a source of nitrogen (Russell et al., 1992).

The results observed in this study do not indicate a better response of steers when supplemented with different levels of Fermenten as a portion of the RDP in a typical backgrounding diet. Overall, a low inclusion rate of Fermenten resulted in similar performance to that of control treatment, while a greater inclusion rate resulted in decreased DMI and subsequent poorer performance.

Conflict of interest statement. None declared

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