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Influence of Feeding Enzymatically Hydrolyzed Yeast Cell Wall on Growth Performance and Digestive Function of Feedlot Cattle during Periods of Elevated Ambient Temperature

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ABSTRACT: In experiment 1, eighty crossbred steers (239±15 kg) were used in a 229-d experiment to evaluate the effects of increasing levels of enzymatically hydrolyzed yeast (EHY) cell wall in diets on growth performance feedlot cattle during periods of elevated ambient temperature. Treatments consisted of steam-flaked corn-based diets supplemented to provide 0, 1, 2, or 3 g EHY/hd/d. There were no effects on growth performance during the initial 139-d period. However, from d 139 to harvest, when 24-h temperature humidity index averaged 80, EHY increased dry matter intake (DMI) (linear effect, $p<0.01$) and average daily gain (ADG) (linear effect, $p = 0.01$). There were no treatment effects ($p>0.10$) on carcass characteristics. In experiment 2, four Holstein steers (292±5 kg) with cannulas in the rumen and proximal duodenum were used in a 4×4 Latin Square design experiment to evaluate treatments effects on characteristics of ruminal and total tract digestion in steers. There were no treatment effects ($p>0.10$) on ruminal pH, total volatile fatty acid, molar proportions of acetate, butyrate, or estimated methane production. Supplemental EHY decreased ruminal molar proportion of acetate ($p = 0.08$), increased molar proportion of propionate ($p = 0.09$), and decreased acetate:propionate molar ratio ($p = 0.07$) and estimated ruminal methane production ($p = 0.09$). It is concluded that supplemental EHY may enhance DMI and ADG of feedlot steers during periods of high ambient temperature. Supplemental EHY may also enhance ruminal fiber digestion and decrease ruminal acetate:propionate molar ratios in feedlot steers fed steam-flaked corn-based finishing diets. (**Key Words:** Yeast, Growth Performance, Digestion, Cattle)

INTRODUCTION

Temperature-Humidity index (THI; Mader et al., 2006) greater than 74 is considered stressful for cattle. This condition is prevalent during much of the summer months throughout the desert southwestern United States of America. This heat load causes a reduction in energy intake (Young and Hall, 1993; Hahn, 1994) and hence, average daily gain (ADG) and gain efficiency (Blackshaw and Blackshaw, 1994; Hubbard et al., 1999). Additionally, heat stress alters endocrine profiles and energy metabolism of cattle (Rhoads et al., 2009).

In dairy cattle, supplementation with yeast and/or yeast cell wall components has been associated with reduction of negative impact of heat stress on cattle that has improved milk yield, enhanced immune status, and reduced incidence of mastitis and somatic cell counts (Nocek et al., 2011; Liu et al., 2014). Likewise, supplementation improved health status and immune response, reducing physiological and acute phase responses of cattle exposed to endotoxin challenge (Lowry et al., 2005; Li et al., 2006; Chae et al.,

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2006; Sanchez et al., 2013; 2014). With respect to digestion, supplementation may also enhance ruminal pH and ruminal fiber digestion (Beauchemin et al., 2003). There is very limited information regarding the effects of enzymatically hydrolyzed yeast (EHY) cell wall components on growth performance of feedlot cattle, particularly during period of high ambient temperature to which a majority of feedlot cattle will be exposed during some portion of the growing-finishing period. The objective of present research was to evaluate influence of supplementing EHY on growth performance and digestive function of feedlot cattle during periods of elevated ambient temperature.

MATERIALS AND METHODS

All procedures involving animal care and management were in accordance with and approved by the University of California, Davis, Animal Use and Care Committee.

Experiment 1, influence of enzymatically hydrolyzed yeast on growth performance, dietary energetics and carcass characteristics

Eighty crossbred steers (approximately 25% Brahman with the remainder represented by Hereford, Angus, Shorthorn and Charolais breeds in various proportions) with an average weight of 239±15 kg were used in a 229-d experiment to evaluate the effects of EHY cell wall (TruMax, Vi-COR, Mason City, IA, USA) supplementation on growth performance, dietary net energy, and carcass characteristics of feedlot cattle. Upon arrival, steers were vaccinated for bovine rhinotracheitis-parainfluenza (Cattle Master Gold FP 5 L5, Zoetis, New York, NY, USA), clostridials (Ultrabac-7, Zoetis, USA), treated for parasites (Dectomax Injectable, Zoetis, USA), injected subcutaneously with 500,000 IU vitamin A (Vital E-A + D3, Stuart Products, Bedford, TX, USA), and 1,200 mg ceftiofur (Excede, Zoetis, USA), branded, ear-tagged, and implanted with Revalor-IS (Intervet, Millsboro, DE, USA). Bull calves were castrated and horns, if present, were tipped. Steers were blocked by weight and randomly assigned within weight groupings to 16 pens (4 pens per treatment; 5 steers per pen). Pens were 43 m^2 with 22 m^2 of overhead shade, automatic waterers, and 2.4 fence-line feed bunks. Treatments consisted of steam-flaked corn-based diets supplemented to provide 0, 1, 2, or 3 g EHY/hd/d. Ingredient and nutrient composition of diets are shown in Table 1. Diets were prepared at weekly intervals and stored in plywood boxes located in front of each pen. Steers were allowed *ad libitum* access to their experimental diets. Fresh feed was provided twice daily. Individual steers were weighed upon initiation and at periods of 28-d until completion of the 229-d trial. In the calculation of steer performance live weights were reduced 4% to adjust for digestive tract fill. Estimates of steer performance were based on pen means. Readings of daily ambient temperature and humidity during the course of the study were obtained from the California Department of Water Resources Information and Management System (CIMIS) weather station located roughly 100 meters distance from the feedlot.

Energy gain (EG) was calculated by the equation: EG = $ADG^{1.097}$ 0.0557 $W^{0.75}$, where EG is the daily-energy-deposited (Mcal/d), W is the mean shrunk body weight (BW) (kg; NRC, 1984). Maintenance energy (EM) was calculated by the equation: EM = $0.077W^{0.75}$ (NRC, 1996). Dietary net energy of gain (NEg) was derived from net energy of maintenance (NEm) by the equation: NEg = 0.877 NEm–0.41 (Zinn and Shen, 1998). Dry matter intake (DMI) is related to energy requirements and dietary NEm according to the equation: DMI = EM/NEm+EG/(0.877 NEm –0.41), and can be resolved for estimation of dietary NEm by means of the quadratic formula: $x = (-b\pm[b^2-4ac]^{0.5})/2a$, where x = NEm, a = –0.877DMI, b = 0.877 EM+0.41 DMI+EG, and c = –0.42 EM (Zinn and Shen, 1998).

Hot carcass weights (HCW) were obtained at time of slaughter. After carcasses chilled for 48 h, the following measurements were obtained: LM area (cm^2) by direct grid reading of the *Longissimus* muscle (LM) at the 12th rib; subcutaneous fat (cm) over the LM at the 12th rib taken at a location 3/4 the lateral length from the chine bone end (adjusted by eye for unusual fat distribution); kidney, pelvic and heart fat (KPH), as a percentage of HCW; marbling score (USDA 1997; using 3.0 as minimum slight, 4.0 as minimum small, 5.0 as minimum modest, 6.0 as minimum moderate, etc.), and estimated retail yield of boneless, closely trimmed retail cuts from the round, loin, rib and chuck (% of HCW; Murphey et al., 1960) = 52.56 – 1.95×subcutaneous fat – 1.06×KPH+0.106×LM area – 0.018×HCW.

For calculating steer performance, initial BW is the arrival off-truck shrunk weight. Interim and final LW was reduced 4% to account for digestive tract fill. Final shrunk LW was adjusted for HCW by dividing HCW by the decimal fraction of the average dressing percentage (0.64). Pens were used as experimental units. The experimental data were analyzed as a randomized complete block design experiment according to the following statistical model:

$$Y_{ij} = \mu + B_i + T_j + E_{ij}$$

Where μ is the common experimental effect, B_i represents initial weight group effect (df = 3), T_j represents dietary treatment effect (df = 3), and E_{ij} represents the residual error (df = 9). Treatments effects were tested using the following contrasts: 0 vs EHY, and linear and quadratic polynomials (Stastix 9, Analytical Software, Tallahassee,

FL, USA).

Experiment 2, influence of enzymatically hydrolyzed yeast on digestive function of steers

Four Holstein steers (264±5 kg) with cannulas in the rumen (3.8 cm internal diameter) and proximal duodenum (Zinn and Plascencia, 1993) were used in a 4×4 Latin square experiment to evaluate the influence of EHY (TruMax, Vi-COR, USA) supplementation-level in finishing diets for steers based on steam-flaked corn and distillers dried gains plus solubles on characteristics of rumen and total tract digestion. Dietary treatments were the same as indicated for the finishing diet used in Trial 1 (Table 1) plus the inclusion of chromic oxide (2.5 g/kg) as a digesta marker. Steers were maintained in individual pens (5.6 m^2) with automatic waterers. Diets were fed at 08:00 and 20:00 h daily. In order to avoid the complications of feed refusals, DMI was restricted to 6.02 kg/d (2.3% of BW). Experimental periods were 14 d, with 10 d for dietary treatment adjustment, 4 d for collection. During collection, duodenal and fecal samples were taken twice daily as follows: day 1, 0750 and 1350 h; day 2, 0900 and 1500 h; day 3, 1050 and 1650 h, and day 4, 1200 and 1800 h. Individual samples consisted of approximately 700 mL of duodenal chyme and 200 g (wet basis) of fecal material. Samples from each steer within each collection period were composited for analysis. During the final day of each collection period, ruminal samples were obtained from each steer via ruminal cannula 4 h after feeding. Ruminal fluid pH was determined on fresh samples. Samples were strained through 4 layers of cheesecloth. Two milliliters of freshly prepared (25 g/100 mL) meta-phosphoric acid was added to 8 mL of strained ruminal fluid. Samples were then centrifuged (17,000×g for 10 min), and supernatant fluid was stored at –20°C for volatile fatty acid (VFA) analysis (gas chromatography; Zinn, 1988). Upon completion of the experiment, ruminal fluid was obtained via the ruminal cannula from all steers and composited for isolation of

Table 1. Composition of experimental diets fed to steers[1]

Item	Diets (%, DM basis)			
	Receiving[2]	Transition 1[3]	Transition 2[4]	Finishing[5,6]
Alfalfa, hay	20.0	10	5.0	0.0
Sudangrass hay	12.0	12.0	12.0	12.0
Steam-flaked corn	36.31	45.63	52.24	57.73
Distillers dried gains+solubles	20.0	20.0	20.0	20.0
Tallow	2.0	2.0	2.0	2.3
Cane molasses	8.0	8.0	6.0	5.0
Limestone	0.73	1.2	1.49	1.6
Urea	0.45	0.65	0.75	0.85
Magnesium oxide	0.10	0.10	0.10	0.10
Trace mineral salt[7]	0.40	0.40	0.40	0.40
Rumensin	0.014	0.017	0.017	0.017
Nutrient composition (DM basis)[8]				
NE (Mcal/kg)				
Maintenance	1.97	2.06	2.11	2.17
Gain	1.33	1.40	1.15	1.51
Crude protein (g/kg)	16.02	15.48	15.28	15.03
Ether extract (g/kg)	6.4	6.51	6.65	7.04
Calcium (g/kg)	0.80	0.80	0.80	0.75
Magnesium (%)	0.30	0.30	0.29	0.29
Phosphorus (g/kg)	0.37	0.38	0.38	0.39
NDF	28.79	25.43	23.92	22.32

DM, dry matter; NE, net energy; NDF, neutral detergent fiber; EHY, enzymatically hydrolyzed yeast.

[1] Diets were supplemented to provide for an average estimated intake of 0, 1, 2, or 3 g/hd/d of EHY (TruMax, Vi-COR, Mason City, IA, USA) during respective feeding periods.

[2] Receiving diet (fed from d 1 to d 28) supplemented with 0, 171.8, 343.5, or 515.3 mg/kg EHY (DM basis).

[3] Transition 1 diet (fed from d 28 to d 35) supplemented with 0, 147.5, 295.0, or 201.1 mg/kg EHY (DM basis).

[4] Transition 2 diet (fed from d 35 to d 42) supplemented with 0, 138.5, 277.0, or 415.5 mg/kg EHY (DM basis).

[5] Finishing diet (fed from d 42 to d 229) supplemented with 0, 116.0, 232.0, or 348.0 mg/kg EHY (DM basis).

[6] Chromic oxide (0.40%) was added as digesta marker in experiment 2.

[7] Trace mineral salt contained: $CoSO_4$, 0.068%; $CuSO_4$, 1.04%; $FeSO_4$, 3.57%; ZnO, 0.75%; $MnSO_4$, 1.07%; KI, 0.052%; NaCl, 93.4%.

[8] Based on tabular values for individual feed ingredients (NRC, 1984) with exception of supplemental fat which was assigned NE_m and NE_g values of 6.03 and 4.79 Mcal/kg, respectively (Zinn, 1988).

ruminal bacteria by differential centrifugation (Bergen et al., 1968).

Feed and fecal samples were subjected to the following analysis: DM (oven drying at 105°C until no further weight loss); ash (method 942.05, AOAC, 1986), Kjeldahl N (method 984.13, AOAC, 2000); aNDFom (Van Soest et al., 1991), corrected for neutral detergent fiber (NDF)-ash, incorporating heat stable α-amylase (Ankom FAA, Ankom Technology, Macedon, NY, USA) at 1 mL per 100 mL of NDF solution); chromic oxide (Hill and Anderson, 1958); and starch (Zinn, 1990). Duodenal samples were subjected the following analysis: DM (oven drying at 105°C until no further weight loss); ash (method 942.05, AOAC, 1986), Kjeldahl N (method 984.13, AOAC, 2000), ammonia N (method 941.04, AOAC, 2000); aNDFom (Van Soest et al., 1991), corrected for NDF-ash, incorporating heat stable α-amylase (Ankom FAA, Ankom Technology, USA) at 1 mL per 100 mL of NDF solution); purines (Zinn and Owens, 1986); chromic oxide (Hill and Anderson, 1958); and starch (Zinn, 1990). Duodenal flow and fecal excretion of DM were calculated based on marker ratio, using chromic oxide. Microbial organic matter (MOM) and N (MN) leaving the abomasum was calculated using purines as a microbial marker (Zinn and Owens, 1986). Organic matter (OM) fermented in the rumen was considered equal to OM intake minus the difference between the amount of total OM reaching the duodenum and MOM reaching the duodenum. Feed N escape to the small intestine was considered equal to total N leaving the abomasum minus ammonia-N, MN, and endogenous N ($0.195 \times BW^{0.75}$, Ørskov et al., 1986). Methane production (mol/mol glucose equivalent fermented) was estimated based on the theoretical fermentation balance for observed molar distribution of VFA (Wolin, 1960).

The effects of EHY cell wall level (0, 1, 2, or 3 g EHY/hd/d) on characteristics of digestion in cattle were analyzed as a balanced 4×4 Latin square design experiment:

$$Y_{ijk} = \mu + S_i + P_j + T_k + E_{ijk},$$

Where, Y_{ijk} is the response variable, μ is the common experimental effect, S_i is the steer effect, P_j is the period effect, T_k is the treatment effect and E_{ijk} is the residual error. Treatment effects were tested using the following contrasts: 0 vs EHY, and linear and quadratic polynomials (Stastix 9, Analytical Software, USA).

RESULTS AND DISCUSION

Experiment 1, influence of enzymatically hydrolyzed yeast on growth performance, dietary energetics and carcass characteristics

Treatment effects on growth performance are shown in Table 2. There were no effects on growth performance during the initial 139-d period. However, from d-139 to harvest, when 24-h temperature humidity index averaged 80, EHY increased DMI (linear effect, $p<0.01$) and ADG (linear effect, $p = 0.01$). This improvement in ADG was largely due to increased DMI, as gain efficiency and estimated dietary NE were not affected by EHY supplementation (Table 2). Comparable studies evaluating effects of EHY on feedlot cattle growth-performance are limited. In a 56-d feeding trial, Finck et al. (2010) observed increased ADG associated with increased DMI in feedlot steers fed a receiving diet supplemented to provide 5 g/d yeast cell wall. In a 50-d feeding trial, Lei et al. (2013) observed increased ADG and gain efficiency in feedlot steers fed 2 g d of a yeast cell wall product.

Considering supplemental yeast, per se, Hinman et al. (1998) in a 115-d trial observed greater ADG and gain efficiency in feedlot steers supplemented with yeast. In contrast, Swyers et al. (2014) did not observed an effect of supplemental yeast on in a 125-d feedlot growth performance of yearling steers. Likewise, Baumann et al. (2004) observed no advantage of yeast supplementation on 126-d ADG and gain efficiency of growing-finishing feedlot steers.

Observed variation in growth-performance response to EHY supplementation as affected by periods of unfavorable ambient conditions, may be more particularly a function of immune status (Swyers et al., 2014). Heat stress alters endocrine profiles and energy metabolism in cattle (Rhoads et al., 2009). Supplemental EHY can modulate immune status (Nocek et al., 2011; Lei, et al., 2013; Sanchez et al., 2013; 2014). Sanchez et al. (2014) observed that in beef heifers newly-received into the feedlot, supplementation with yeast cell wall enhanced energy metabolism during an immune challenge. Ganner et al. (2010) observed that yeast derivatives (cell walls) had a selective effect against some pathogenic bacteria. Reisinger et al. (2012) observed that yeast cell wall supplementation increased jejunal goblet cell density, reducing the number of apoptotic enterocytes. Lei et al. (2013) observed that yeast cell wall can effectively bind lipopolysaccharides within the intestine, preventing translocation into the circulation.

Liu et al. (2014) observed that yeast supplementation improved milk yield and immune response of dairy cows under conditions of heat stress. Temperature–humidity index (THI = [0.8×ambient temperature]+[{% of relative humidity/100}×{ambient temperature–14.4}]+46.4), a measure of heat load, is coded as follows: normal, THI <74; alert, 75<THI<78; danger, 79 <THI<83; and emergency, THI >84 (Mader et al., 2006). In the present study, enhancements in DMI and ADG during the period of high THI may indicate a potential role of EHY in association with heat stress.

Consistent with overall treatment effects on ADG and

Table 2. Influence of enzymatically hydrolyzed yeast (EHY) supplementation on growth-performance of crossbred feedlot steers

Item	EHY (g/steer/d)				SEM	p-value		
	0	1	2	3		0 vs EHY	Linear	Quadratic
Pen replications	5	5	5	5				
Body weight (kg)[1]								
Initial	235.0	233.9	235.0	234.5	0.3			
139 d	467.2	457.4	460.1	470.7	10.5	0.73	0.77	0.88
229 d (Final)	550.2	545.2	548.4	566.3	12.0	0.82	0.36	0.91
ADG (kg/d)								
1 to 139 d	1.67	1.61	1.63	1.70	0.07	0.76	0.77	0.94
139 to 229 d	0.92	0.98	0.97	1.06	0.03	0.04	0.01	0.29
1 to 229 d	1.38	1.36	1.37	1.45	0.05	0.80	0.35	0.86
DMI (kg/d)								
1 to 139 d	7.75	7.69	7.49	7.72	0.17	0.58	0.73	0.49
139 to 229 d	8.00	7.98	8.38	8.40	0.10	0.07	<0.01	0.12
1 to 229 d	7.85	7.80	7.84	7.99	0.14	0.88	0.49	0.96
ADG/DMI								
1 to 139 d	0.215	0.209	0.217	0.220	0.006	0.99	0.42	0.48
139 to 229 d	0.115	0.123	0.116	0.126	0.004	0.20	0.17	0.12
1 to 229 d	0.175	0.174	0.175	0.181	0.004	0.80	0.38	0.81
Dietary NE (Mcal/kg)								
1 to 139 d maintenance	2.17	2.12	2.19	2.20	0.04	0.96	0.36	0.31
1 to 139 d gain	1.49	1.45	1.51	1.52	0.03	0.96	0.36	0.31
139 to 229 d maintenance	2.06	2.10	2.02	2.12	0.04	0.75	0.66	0.15
130 to 229 d gain	1.40	1.43	1.36	1.45	0.04	0.75	0.66	0.15
1 to 229 d maintenance	2.10	2.09	2.10	2.15	0.04	0.82	0.40	0.86
1 to 229 d gain	1.43	1.43	1.43	1.47	0.03	0.82	0.40	0.86

SEM, standard error of the mean; ADG, average daily gain; DMI, dry matter intake; NE, net energy.
[1] Initial weight is off-truck arrival weight. Interim and final weights reduced 4% to account for fill.

final harvest weight, there were no treatment effects (p>0.10) on carcass characteristics (Table 3). Comparable studies involving yeast cell wall are limited. With regard to yeast supplementation, per se, Hinman et al. (1998) and Baumann et al. (2004) did not observe an effect of supplemental yeast on carcass characteristics of feedlot steers. Gomes et al. (2009) observed that supplemental yeast increased carcass dressing percentage, but did was without effect on other carcass measures. Swyers et al. (2014) observed that supplemental yeast increased the proportion of carcass that graded USDA Choice or better.

Experiment 2, influence of enzymatically hydrolyzed yeast on digestive function of steers

Treatment effects on characteristics of digestion are shown in Table 4. There were no treatment effects (p>0.10) on ruminal digestion of OM, starch, feed-N, microbial efficiency (g microbial N/kg OM fermented) and N efficiency (non-ammonia N entering the small intestine/N intake). Ruminal digestion of NDF tended to increase (linear effect; p = 0.08) with the increasing level of EHY, reflecting a stimulatory effect of EHY on cellulase activity (Kmet et al., 1992). There were no treatment effects (p>0.10) on total tract digestion of DM, OM, NDF, starch, and N.

Table 3. Influence of enzymatically hydrolyzed yeast (EHY) supplementation on carcass characteristics of feedlot steers

Item	EHY (g/steer/d)				SEM	p-value		
	0	1	2	3		0 vs EHY	Linear	Quadratic
Pen replications	5	5	5	5				
HCW	357.9	356.4	353.3	364.3	6.6	0.99	0.60	0.60
Dressing percentage	65.0	65.4	64.4	64.4	0.6	0.65	0.29	0.43
Fat thickness (cm)	1.46	1.37	1.33	1.24	0.13	0.35	0.25	0.85
KPH (%)	2.56	2.71	2.86	2.58	0.07	0.11	0.55	0.24
LM area (cm^2)	85.4	84.3	81.4	80.9	2.9	0.64	0.23	0.93
Yield grade (%)	49.3	49.3	49.1	49.2	0.4	0.82	0.70	0.76

SEM, standard error of the mean; HCW, hot carcass weights; KPH, kidney, pelvic and heart fat, as a percentage of HCW; LM, *Longissimus* muscle.

Table 4. Influence of enzymatically hydrolyzed yeast (EHY) supplementation on characteristics of ruminal and total tract digestion

Item	EHY (g/steer/d)				SEM	p value		
	0	1	2	3		0 vs EHY	Linear	Quadratic
Intake (g/d)[1]								
Dry matter	6,015	6,016	6,017	6,018				
Organic matter	5,637	5,638	5,639	5,640				
NDF	1,227	1,227	1,228	1,228				
Starch	2,937	2,938	2,938	2,939				
Nitrogen	136	136	136	136				
Flow to duodenum (g/d)								
Organic matter	2,874	2,894	2,981	2,901	75	0.58	0.63	0.53
NDF	724	718	661	665	25	0.18	0.08	0.86
Starch	343	323	387	376	41	0.70	0.41	0.92
Nitrogen	147	145	157	144	4.9	0.80	0.89	0.32
Microbial N	89.2	84.8	91.9	86.8	2.6	0.67	0.99	0.90
Ammonia N	6.47	5.61	6.09	6.07	0.4	0.24	0.67	0.29
Non ammonia N	140	139	150	138	4.9	0.72	0.87	0.29
Feed N	51.2	54.3	58.7	50.9	3.8	0.47	0.84	0.20
Ruminal digestion (%)								
Organic matter	64.83	63.71	63.43	63.96	1.34	0.49	0.65	0.56
NDF	41.00	41.48	46.13	45.87	2.01	0.18	0.08	0.86
Starch	88.32	89.00	86.82	87.22	1.39	0.70	0.41	0.92
Feed N	62.29	60.04	56.79	62.52	2.80	0.49	0.84	0.20
Microbial efficiency[2]	24.43	23.65	25.81	24.14	0.76	0.91	0.71	0.58
N efficiency[3]	1.03	1.02	1.11	1.01	0.04	0.73	0.88	0.29
Fecal excretion (g/d)								
Dry matter	1,285	1,205	1,308	1,200	36	0.30	0.38	0.71
Organic matter	1,117	1,043	1,143	1,033	66	0.29	0.34	0.61
NDF	630	615	654	549	28	0.49	0.16	0.16
Starch	20.2	16.9	23.1	16.2	2.8	0.66	0.66	0.56
Nitrogen	33.2	30.7	34.2	31.9	1.1	0.50	0.97	0.93
Total tract digestion (%)								
Dry matter	78.64	79.98	78.26	80.06	0.60	0.30	0.38	0.71
Organic matter	80.18	81.50	79.73	81.68	0.58	0.28	0.33	0.61
NDF	48.66	49.91	46.75	55.26	2.30	0.49	0.16	0.16
Starch	99.31	99.43	99.21	99.45	0.10	0.99	0.68	0.59
Nitrogen	75.58	77.41	74.81	76.51	0.79	0.76	0.96	0.93

SEM, standard error of mean; NDF, neutral detergent fiber.
[1] Dry matter intake was restricted to 2.2% of body weight.
[2] Microbial nitrogen, g/kg organic matter fermented.
[3] Non-ammonia nitrogen flow to the small intestine as a fraction of nitrogen intake.

Comparable studies evaluating effects of supplemental EHY on characteristics of digestion are limited. Lei et al. (2013) observed increased fiber digestion in steers supplemented with yeast cell walls. Indeed, enhanced fiber digestion has been a consistent response to yeast supplementation, per se, across a variety of diets and feeding practices (Dawson et al., 1990; Williams et al., 1991; Zinn and Borquez, 1993; Plata et al., 1994; López-Soto et al., 2013). Nevertheless, as fiber comprises a comparatively small component of the conventional finishing diets, effects of supplementation on total tract digestion were small and non-appreciable.

Treatment effects on characteristics of ruminal fermentation are shown in Table 5. There were no treatment effects ($p>0.10$) on ruminal pH, total VFA, or molar proportion of butyrate. Consistent with the present study, Baumann et al. (2004) and Lopez-Soto et al. (2013) did not observe an effect of supplemental yeast on ruminal pH. In contrast, Vyas et al. (2014) observed an increase in ruminal pH with yeast supplementation of feedlot diet. Although, as in the present study, yeast supplementation did not affect ruminal VFA concentration.

Supplemental EHY decreased ruminal molar proportion of acetate ($p = 0.08$), increased molar proportion of

Table 5. Influence of enzymatically hydrolyzed yeast (EHY) supplementation on characteristics of ruminal fermentation

Item	EHY (g/steer/d)				SEM	p value		
	0	1	2	3		0 vs EHY	Linear	Quadratic
Ruminal pH	5.93	5.95	6.11	5.80	0.10	0.87	0.61	0.16
Total VFA	101.6	99.5	88.9	94.3	7.2	0.42	0.36	0.63
Ruminal VFA (mol/100 mol)								
Acetate	61.6	56.3	54.8	58.1	2.1	0.08	0.25	0.09
Propionate	26.9	34.4	35.9	33.4	3.2	0.09	0.20	0.17
Butyrate	11.5	9.3	9.3	8.5	1.3	0.16	0.19	0.62
Acetate/propionate	2.46	1.68	1.54	1.81	0.31	0.07	0.18	0.14
Methane[1]	0.53	0.44	0.42	0.46	0.04	0.09	0.22	0.15

SEM, standard error of mean; VFA, volatile fatty acids.
[1] Methane, mol/mol glucose equivalent fermented.

propionate (p = 0.09), and decreased acetate:propionate molar ratio (p = 0.07) and estimated ruminal methane production (p = 0.09). A similar effect on ruminal acetate:propionate supplementation has been observed with yeast supplementation, per se (Williams et al., 1991; Plata et al., 1994; Hinman et al., 1998).

CONCLUSION

Supplemental EHY may enhance DMI and ADG of feedlot steers during periods of high ambient temperature. Supplemental EHY may also enhance ruminal fiber digestion and decrease ruminal acetate:propionate molar ratios in feedlot steers fed steam-flaked corn-based finishing diets.

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