Effect of Supplemental Corn Dried Distillers Grains with Solubles Fed to Beef Steers Grazing Native Rangeland during the Forage Dormant Season

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ABSTRACT: Two experiments were conducted to evaluate the effects of the level of corn dry distillers grains with solubles (CDDGS) supplementation on growing performance, blood metabolites, digestion characteristics and ruminal fermentation patterns in steers grazing dormant forage. In Exp. 1, of growth performance, 120 steers (204±5 kg initial body weight [BW]) were distributed randomly into 3 groups (each of 40 steers), which were provided with the following levels of CDDGS supplement: 0%, 0.25%, or 0.50% BW. All groups of steers were grazed for 30 days in each of 3 grazing periods (March, April, and May). Approximately 1,000 ha of the land was divided with electric fencing into 3 equally sized pastures (333 ha in size). Blood samples were collected monthly from 20 steers in each grazing group for analysis of glucose (G), urea-nitrogen (UN) and non-esterified fatty acids. Final BW, average daily gain (ADG) and supplement conversion (CDDGS-C) increased with increasing levels of CDDGS supplementation (p<0.05).The CDDGS supplementation also increased the plasma G and UN concentrations (p<0.05). In Exp. 2, of digestive metabolism, 9 ruminally cannulated steers (BW = 350±3 kg) were distributed, following a completely randomized design, into groups of three in each pasture. The ruminally cannulated steers were provided the same levels of CDDGS supplementation as in the growing performance study (0%, 0.25%, and 0.50% BW), and they grazed along with the other 40 steers throughout the grazing periods. The dry matter intake, crude protein intake, neutral detergent fiber intake (NDFI), apparent digestibility of dry matter (ADDM), crude protein (ADCP) and neutral detergent fiber (ADNDF) increased with increasing levels of CDDGS supplementation (p<0.05). The ruminal degradation rates of CP (kdCP), NDF (kdNDF) and passage rate (kp) also increased with increasing levels of CDDGS supplementation (p<0.05). Ruminal ammonia nitrogen (NH_3-N) and propionate concentrations also increased with increasing levels of CDDGS supplementation (p<0.05). However, acetate concentrations decreased with increasing levels of CDDGS supplementation (p<0.05). Liquid dilution rate increased with increasing levels of CDDGS supplementation but ruminal liquid volume decreased (p<0.05). On the basis of these findings, we can conclude that CDDGS supplementation enhanced the productive performance of cattle grazing native rangeland without negatively affecting forage intake, glucose and urea-nitrogen blood concentrations, ruminal degradation and ruminal fermentation patterns. (**Key Words:** Corn Dry Distillers Grains with Solubles, Steers, Growing Performance, Blood Metabolites, Digestion Characteristics, Ruminal Fermentation)

INTRODUCTION

The Chihuahuan desert is the largest desert in North America and forage mainly grows during the summer in the

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regions. In these regions, large numbers of steers are maintained by grazing native or introduced grasslands and high levels of crude protein (CP) supplementation are often provided during the winter and spring months to increase rumen availability of nitrogen, fiber digestibility and subsequent energy availability before finishing in feedlots (McMurphy et al., 2014).

Because of the reduced nutritional value of this type of pasture during the fall and winter, average daily gain (ADG) from cattle is usually low. In fact, during the forage dormant season, beef steers grazing on Chihuahuan desert

grasslands do not consume sufficient protein for growth (Murillo et al., 2014). Growing steers are particularly susceptible to protein deficiencies because they require high levels of protein to support tissue growth. Cattle with high protein requirements, such as growing cattle, will require additional protein supplementation to meet the nutritional demands associated with growth when maintained under grazing conditions. Protein is often a limiting nutrient when cattle graze on dormant rangelands (Obeidat et al., 2002). However, protein supplementation may enhance intake of dormant range forage and improve beef cattle performance (Murillo et al., 2013). Moreover, supplying additional protein in the form of degradable ruminal protein and ruminal undegradable protein may influence nutrient partitioning via effects on glucose supply and metabolism (Waterman et al., 2006).

On the other hand, dietary supplementation with corn dry distillers grains with solubles (CDDGS), which contain high levels of protein, energy, easily digestible fiber, fat and phosphorus but low levels of starch, improves the performance of cattle grazing on pasture and introduced grasses (Klopfenstein et al., 2008). Because of the increasing production of DDGS, studies to evaluate DDGS as a protein source have been widely conducted (Kim et al., 2015). In addition, DDGS may be a less expensive source of energy and protein than corn or other protein sources and there is no risk of starch decreasing forage digestibility.

Until now, no studies have evaluated the effects of CDDGS supplementation on productive performance, intake, digestibility, *in situ* degradability, fermentation patterns and concentrations of blood metabolites in beef cattle grazing on arid rangelands. We hypothesized that supply of CDDGS to steers grazing native rangeland during the forage dormant season will increase productive performance and nutrient intake without affecting digestibility, *in situ* degradability, fermentation patterns or concentrations of blood metabolites. The objective of the study was to determine the effects of the level of CDDGS supplementation provided to steers grazing native rangeland during the forage dormant season on growing performance, blood metabolites, intake, apparent digestibility, ruminal degradation, ruminal fermentation patterns and liquid and solid kinetics.

MATERIAL AND METHODS

Surgical and animal handling procedures were conducted using protocols approved by Animal Protection Committee of Durango State (Mexico).

Exp. 1. Growth performance
Study site, animals, vegetation, and CDDGS supplementation: This study was carried out during a two-year period (2011 and 2012) in a Chihuahuan desert rangeland in northern Mexico (24°N 106°W). Precipitation averages in the 3 months of study (average two years) was 8.8 mm, with maximum of 12.4 mm during May and minimum of 4.2 mm during March. Pasture was classified as short grassland with shrub dominated by *Melinisrepens Willd* (rose natal grass), *Boutelouagracilis* (bluegrama), *Prosopisjuliflora* (mesquite), *Opuntiaspp* (prickly pears chollas) and *Viguieralinearis* (romerillo). In this experiment 120 Brahman×Angus steers (204±5 kg initial body weight [BW]) were distributed randomly in 3 groups of 40 steers, which were provided with the following levels of CDDGS supplement: 0%, 0.25%, and 0.50% BW. The CDDGS samples was dried at 55°C for 48 h and ground through a Willey mill with a 2-mm screen and were analyzed for dry matter (DM), crude protein, ether extract (EE) and starch (AOAC, 2000), neutral detergent fiber (NDF) and acid detergent fiber (ADF) (ANKOM, 2008). The nutritional characteristics of CDDGS used in this study were the following: 93.4% DM; 28.2% CP; 13.1% EE; 5.2% starch; 26.8% NDF; and 11.3% ADF.

Approximately 1,000 ha of the land was divided with electric fencing into 3 equally sized pastures (333 ha in size). To avoid the effect of grazing on forage quality, each pasture (333 ha) was divided into three 111 ha paddocks. Forty steers for each supplementation level, grazed for 3 grazing periods of 30 days (March, April, and May). The steers were moved to a new paddock at the beginning of each grazing period, so that each group grazed each paddock once. The CDDGS supplement was placed in feeders three times a week at 7:00 AM. The steers had free access to water in all pastures. The total amount of supplement provided was consumed. Steers were weighed at the beginning and end of each month to measure BW gain and for calculation of supplement conversion (CDDGS-C). Supplement conversion values were calculated as daily supplement intake (kg) (CDDGS-I) divided by the difference in ADG (kg/d) between the group provided a specific supplement and the group receiving no supplement (0% of BW).

Blood metabolites: Once a month (March, April, and May), blood samples were drawn from the jugular vein of 20 steers in each grazing group, always in the morning (7:00 AM). The blood (10 mL) was collected into a vacutainer containing heparin (to separate the plasma) and centrifuged at 2,500 rpm for 20 min at 10°C. The harvested plasma was stored in polypropylene vials and frozen for later analysis of glucose (G), urea nitrogen (UN) and non-esterified fatty acids (NEFA). The plasma metabolites were measured using the following laboratory kits according to the manufacturer's specifications: 2,614 from Randox, for glucose; Urease/Berthelot 640, for urea; and 115 from Randox, for NEFA. Coefficients of variation (intra-assay; n

= 4) for G, UN, and NEFA measurements, were 1.8%, 2.4%, and 4.3%, respectively.

Statistical analysis: The BW changes, ADG, CDDGS-C, CDDGS-I, G, UN, and NEFA were analyzed using the MIXED procedure of SAS (2003). The model included supplementation level (0%, 0.25%, and 0.50% BW), grazing period (30, 60, and 90 d) and their interactions. Supplementation level was considered as a fixed effect and year as a random effect using the pasture as the experimental unit. Grazing period was considered the repeated measure. Compound symmetry was used as the covariance structure for the presentation of the results. Because the interaction supplementation level×grazing period was not significant (p>0.05), only overall values were showed. Significant differences were accepted at p<0.05.

Exp. 2. Digestive metabolism

Animals, experimental periods, and forage chemical composition: This study was carried out during a two-year period (2011 and 2012) in a Chihuahuan desert rangeland in northern Mexico. For this experiment, 9 ruminally cannulated steers (Brahman×Angus, BW = 350±3 kg) were distributed in groups of three in each native rangeland pasture (3 steers/pasture/CDDGS level). The nine ruminally cannulated steers grazed along with the other 120 steers throughout the grazing periods (March, April, and May) in both years. Two experimental periods per month each 13 day long were conducted during the three grazing periods. Before beginning the experimental periods and during two days, 9 steers with ruminal cannula were used to collect forage samples (extrusa) available in pastures. Collection of rumen digesta involved penning the steers 24 h before sample collection to prevent grazing. The next morning the rumen was evacuated and the digesta was placed in plastic bags lining 100-L plastic containers. The steers were then transported to the identified grazing area and allowed to graze for 1 h before being returned to the working facility for collection of ruminal digesta. Composite samples were made for each steer by combining 300 g subsamples of each steer diet. The extrusa were dried at 55°C for 48 h and ground through a Wiley mill with a 2-mm screen and were analyzed for CP (AOAC, 2000), NDF and *in vitro* dry matter digestibility (IVDMD) (ANKOM, 2008). The levels of CDDGS supplementation were the same as in the growing performance experiment (0%, 0.25%, and 0.50% BW) and were provided once daily in the morning (7:00 AM). Steers were given access to the supplements for 1 h, after which uneaten supplement was fed into the rumen through the ruminal cannula.

Forage intake and apparent digestibility: Forage intake was determined by dividing DM total fecal output by *in vitro* DM indigestibility (100 IVDMD %). Fecal output was estimated by the chromic oxide technique. The steers were ruminally dosed with cellulose paper capsules containing chromic oxide (8 g) twice daily (at 7:00 AM and 7:00 PM) during the 13 day experimental period. Fecal samples were collected daily on days 1 to 5 of each experimental period. Fecal samples (300 g) were taken directly from the rectum of all steers as follows: on day 1 at 1:00 PM; on day 2, at 1:00 AM and 7:00 PM; on day 3, at 4:00 PM and 10:00 PM h; on day 4, at 7:00 AM; and on day 5, at 4:00 and 10:00 PM. Apparent digestibility was estimated using chromic oxide as an internal marker.

In situ degradability: On days 6 to 9 and during grazed of ruminally cannulated steers the *in situ* degradability of extrusa sample was determined. Polyester bags (10×20; pore size 50±10 μm; Ankom, Spencerport, NY, USA) containing 10 g of forage samples ground to 2 mm were suspended in the rumen for intervals of 0, 3, 6, 9, 15, 24, 36, 48, 72, 96 hours. Bags were inserted into the rumen in reverse order of incubation times and all bags were removed simultaneously, at 0 h. The bags were rinsed in cold tap water until the effluent was clear, to remove large particulate matter, and the contents were dried at 60°C for 48 hours in a forced-air oven. The residues obtained from each incubation time were analyzed for DM, CP, and NDF. Degradability of CP and NDF was determined at time "0" by immersing the bags containing 10 g of sample in the rumen for 1 minute and then washing them as described above (Klopfenstein et al., 2001). Crude protein degradability was corrected by subtraction of residues the CP linked to acid detergent fibre (N-ADF×6.25) (Klopfenstein et al., 2001). The ruminal degradation parameters and effective degradability (ED) for DM, CP, and NDF were calculated using the model of Ørskov and McDonald (1979): $Deg_{(t)} = a+b×(1 – exp^{–kdt})$; where $Deg_{(t)}$ = disappearance of DM, CP, and NDF at time t; a = soluble fraction of DM, CP, and NDF at the initiation of incubation (time 0); b = fraction of DM, CP, and NDF potentially degradable in the rumen; kd = rate constant of degradation of fraction b; and t = is time of incubation. ED = $a+(b×kd)/(kd+kp)$ where a, b, and kd are parameters them as described above and kp is the ruminal passage rate calculated in this study.

Ruminal fermentation and liquids ruminal kinetics: On days 10 to 12 of the experimental period, Co-tetra acetic ethylene diamine acid was dosed intra-ruminally (200 mL) at 7:00 AM as a marker of liquids kinetics. Ruminal liquid samples were collected from all steers at time 0 (immediately before dosing) and 3, 6, 9, 12, 18, 24, 36, and 48 h after dosing. Ruminal liquid pH was determined immediately after collection and samples were then strained through four layers of cheesecloth and divided into three subsamples. The first subsample (10 mL) was acidified with 0.3 mL of 50% H_2SO_4 and frozen immediately at –40°C and

later analyzed for ammonia nitrogen (NH_3-N); the second subsample (10 mL) was acidified with 2.5 mL of 25% metaphosporic acid and frozen at –40°C for posterior analysis of volatile fatty acids (VFA); the third subsample was used to determine the Co concentration by atomic absorption spectroscopy with an air acetylene flame (Uden et al., 1980).

Passage rate: On day 13 of the sample collection period and before the steers began grazing, all ruminal contents were collected from each steer into black polyethylene bags. A sample (0.5 kg) of ruminal content was weighed and immediately replaced in the rumen of the steer from which it was obtained. Acid insoluble ash (AIA) was measured in forage sample as well as in samples of ruminal content. Once concluded the first experimental period, two days later was continued the second experimental period.

Calculations and statistical analyses: Liquids dilution rate was determined by regression of the natural log of rumen liquid concentrations against time of sampling. Ruminal liquids volume was calculated by dividing dose by ruminal concentration extrapolated to 0 h and turnover time was calculated as the inverse of fractional dilution rate. Ruminal passage rate (kp) was determined by dividing the AIA content in the forage by total AIA in the ruminal content (Ogden et al., 2005).

Intake, ruminal degradability parameters and passage rate were analyzed using the MIXED procedure of SAS (2003), with supplement level, grazing period and their interactions in the model. Year was considered a random variable and grazing period was considered the repeated measure. Compound symmetry was used as the covariance structure for the presentation of the results. Because the interaction supplementation level×grazing period was not significant (p>0.05), only overall values were showed. The MIXED procedure of SAS (2003) was also used to analyze the ruminal fermentation variables (pH, NH_3-N, VFA) and

liquids ruminal kinetics with a split-plot design. The model included supplementation level, collection time through the day and supplementation level×time interaction. The repeated measure was collection time and steer within supplementation level was used as the error term for the split plot. Because the interaction supplementation level× time was not significant (p>0.05), only overall values were showed. The model proposed by Colucci et al. (1990), was used for estimate the kinetics liquid parameters.

RESULTS AND DISCUSSION

Exp. 1. Growth performance

The effects of CDDGS supplementation on the growing performance and blood metabolites in steers grazing native rangeland during forage dormant season are summarized in Table 1. The final BW, ADG, supplement intake (CDDGS-I) and CDDGS-C were affected by CDDGS supplementation levels between 0 and 90 days of grazing (p<0.05). Although there were no differences in ADG between 0.25% and 0.50% CGGDS supplementation levels; the ADG was respectively 0.166 kg/d and 0.155 kg/d higher than in the unsupplemented steers (p<0.05). The ADG values recorded in this study were similar to those reported by Martinez et al. (2013), who fed steers grazing native rangeland with DDGS at 0%, 0.2%, 0.4%, and 0.6% of BW. A similar increase in ADG was reported for growing calves fed with medium quality hay supplemented with DDGS (Islas et al., 2014). However, the ADG obtained in this study is not consistent with the value reported by Griffin et al. (2012), who fed steers grazing cool season meadow DDGS at 0%, 0.6%, and 1.2% BW. The supplemental CP as well as energy from fat supplied by DDGS probably contributed to improve ADG (MacDonald et al., 2007). The highest CDDGS-C was yielded by the 0.25% supplementation level (3.07). The results observed for all grazing periods in CDDGS-C were

Table 1. Effect of corn dried distillers grain with solubles supplementation on productive performance and blood metabolites of beef steers grazing native rangeland

	Level of CDDGS supplementation			SEM	p value
	0% BW	0.25% BW	0.50% BW		
Initial body weight (kg)	206[a]	205[a]	208[a]	2.6	0.63
FBW (kg)	224[b]	238[a]	240[a]	1.8	0.04
CDDGS-I (kg)	-	0.510[b]	0.970[a]	1.2	0.05
ADG (kg/d)	0.200[b]	0.366[a]	0.355[a]	0.22	0.04
CDDGS-C	-	3.07[b]	6.25[a]	1.18	0.02
Blood metabolites					
G (mg/dL)	46.5[b]	53.8[a]	54.4[a]	1.52	0.05
UN (mg/dL)	6.7[b]	12.8[a]	13.9[a]	0.96	0.05
NEFA (mM/L)	0.128[a]	0.124[a]	0.117[a]	0.038	0.34

CDDGS, corn dry distillers grains with solubles; BW, body weight; SEM, standard error of mean; FBW, final body weight; CDDGS-I, corn dry distillers grains with solubles intake; ADG, average daily gain; CDDGS-C, corn dry distillers grains with solubles conversion; G, glucose; UN, urea nitrogen; NEFA, non-esterified fatty acids.

[a,b] Means followed by different letters within the same row were significantly different (p<0.05).

similar to those obtained in previous studies in which the feed of grazing heifers and steers was supplemented with different levels of DDGS (Martinez et al., 2013).

Plasma G and UN concentrations increased with increasing supplemental CDDGS provided during all grazing periods (p<0.05). The CDDGS supplementation did not affect NEFA blood concentrations (p>0.05). No data on the effects of CDDGS supplementation on plasma metabolite concentrations in grazing cattle on native rangelands are available for comparison. Nevertheless, plasma glucose concentrations observed in supplemented and unsupplemented steers in this study, were within normal concentrations for beef cattle (45 to 75 mg/dL; Kaneko et al., 1997), which indicates that steers were able to maintain glucose homeostasis during the dormant forage season. Likewise, increased plasma glucose concentrations can probably be attributed to the CDDGS supplementation, which may have provided suitable amounts of gluconeogenics precursors such as propionic acid and rumen degradable protein (Leng, 1990). This is also supported by the propionic acid concentrations and ED of protein obtained in present study (discussed later), which were higher in steers supplemented with 0.25% and 0.50% CDDGS levels. The unsupplemented steer group (0% CGGDS) showed plasma urea-nitrogen concentrations below usual concentrations for beef cattle (10 to 14.8 mg/dL; Arias and Nesti, 1999). Plasma urea nitrogen concentrations above 12 mg/dL are associated with adequate dietary CP, which indicates the potential improvements in performance yielded by energy supplementation (Hammon et al., 1997). Therefore, steers fed with CDDGS may have exhibited improved performance with additional CDDGS energy. It has been suggested that cattle with plasma urea-nitrogen concentrations below 9 mg/dL are most likely to respond to protein supplementation when maintained on forage-based diet (Hammond et al., 1997). The effects of CDDGS supplementation on plasma urea-nitrogen concentrations observed in this study can be attributed to increase in CP intake as well as ruminal ammonia nitrogen concentrations. Although there were no differences in plasma NEFA concentrations between CGGDS supplemented steers and unsupplemented steers, it can be assumed that the CGGDS improved the energy balance of supplemented steers.

Exp. 2. Digestive metabolism

The effects of CDDGS supplementation levels on intake, apparent digestibility, ruminal degradability and passage rate of forage consumed by beef steers grazing native rangeland during forage dormant season are shown in Table 2. In general, the forage consumed by steers during the three grazing period was low nutritive quality (44.2 CP g/kg DM; 801 NDF g/kg DM; 533 IVDMD g/kg DM). Intake of

Table 2. Effect of corn dried distiller grains with solubles supplementation on intake, apparent digestibility, ruminal degradability and passage rate of forage consumed by beef steers grazing native rangeland

	Level of CDDGS supplementation			SEM	p value
	0% BW	0.25% BW	0.50% BW		
Intake					
DMI (kg/d)	6.9[b]	7.8[b]	8.3[a]	1.4	0.05
CPI (kg/d)	0.310[c]	0.325[b]	0.362[a]	0.92	0.02
NDFI (kg/d)	6.3[c]	7.1[b]	7.5[a]	1.1	0.04
Apparent digestibility					
ADDM (%)	55.6[b]	56.4[a]	56.8[a]	0.13	0.05
ADCP (%)	46.8[b]	47.4[a]	47.8[a]	0.62	0.04
ADNDF (%)	35.3[c]	36.5[b]	37.2[a]	0.15	0.01
Ruminal degradability					
kdCP (%/h)	3.1[c]	3.8[b]	4.4[a]	0.13	0.03
kdNDF (%/h)	1.9[c]	2.4[b]	3.1[b]	0.28	0.05
EDCP (%)	63.6[c]	64.5[b]	65.8[a]	1.4	0.02
EDNDF (%)	28.1[c]	29.5[b]	35.0[a]	2.2	0.05
Passage rate					
kp (%/h)	1.3[c]	2.2[a]	2.9[a]	0.42	0.05

CDDGS, corn dry distillers grains with solubles; BW, body weight; SEM, standard error of mean; DMI, dry matter intake; CPI, crude protein intake; NDFI, neutral detergent fiber intake; ADDM, apparent digestibility of dry matter; ADCP, apparent digestibility of crude protein; ADNDF, apparent digestibility of neutral detergent fiber; kdCP, digestion rate of crude protein; kdNDF, digestion rate of neutral fiber detergent; EDCP, effective degradability of crude protein; EDNDF, effective degradability of neutral detergent fiber; kp, passage rate; SEM, standard error of mean.
[abc] Means followed by different letters within the same row were significantly different (p<0.05).

dry matter (DMI), crude protein (CPI), and neutral detergent fiber (NDFI), apparent digestibility of dry matter (ADMD), crude protein (ADCP) and neutral detergent fiber (ADNDF), digestion rate of CP (kdCP) and NDF (kdNDF), effective degradability of crude protein (EDCP) and neutral detergent fiber (EDNDF) and passage rate (kp) increased with increasing level of CDDGS supplementation (p<0.05). The increases in DMI, CPI, and NDFI, observed in this study are not consistent with data obtained in previous studies (Martinez et al., 2013), in which less forage was consumed by cattle when the levels of DDGS supplementation were increased. Reductions in forage intake and digestibility associated with corn (energy) supplementation have been attributed to the high starch content of corn. The reductions have also been attributed to either depressions in ruminal pH or a carbohydrate effect (Mould et al., 1983). The decreased ruminal pH associated with increasing levels of dietary starch may cause a shift the ruminal bacterial population toward larger numbers of amylolytic bacteria and lower numbers of cellulolytic bacteria. During the process of obtaining ethanol, the starch

is removed from corn generating CGGDS as a by-product. In this study, ruminal pH was not affected by CDDGS supplementation levels. Therefore, the observed increases in forage intake may be attributed to the protein supplied by the CDDGS. The energy from fat supplied by DDGS probably also contributed to improve forage digestibility (Zinn and Plascencia, 1993). Winterholler et al. (2012) reported increases in ADCP and ADNDF digestibility with increasing DDGS supplementation level in steers and beef cows consuming moderate-quality forage and low quality forage, respectively. The observed increases in kdCP, kdNDF, EDCP, and EDNDF, with increasing CDDGS supplementation level may be due to improved microbial efficiency as a result of increased nitrogen availability within the rumen in the supplemented steers groups (Ortiz-Rubio et al., 2007). This would improve the rate of forage degradation in the supplemented steers relative to the unsupplemented group. This would also indicate that rumen microbes may have utilized supplemental nutrients to meet their requirements (Waterman et al., 2006). This is also indicated by ammonia concentrations obtained in present study (discussed later), which were lower in unsupplemented steers than steers fed CDDGS at 0.25% and 0.50% BW. In general, the kdCP and kdNDF values observed for unsupplemented steers are similar to those reported by Obeidat et al. (2002). Faster passage rates were expected due to the observed improvements in DMI, ADMD, and ADNDF in response to increasing levels of supplemental CDDGS (Martinez et al., 2013).

The effect of amount CDDGS supplemental on ruminal fermentation patterns and liquids kinetics of forage consumed by beef steers grazing a native range during forage dormant season are shown in Table 3. Ruminal pH values in this study ranged from 6.65 to 6.68 and were not affected by CDDGS supplementation level (p>0.05). These values were higher than values known to decrease ruminal digestion fiber; according Orskov (1982) pH values below 6.2 reduce ruminal digestion fiber. Because most of the starch is removed from CDDGS, supplementation did not lead to decreased pH, which may have resulted in a more favourable ruminal microbial population for fermentation of fibrous forages (NRC, 2000). Therefore, the ruminal pH associated with CDDGS supplementation levels in this study can be regarded as optimal for fibre digestion and cellulolytic bacterial growth. Ruminal ammonia concentrations recorded in unsupplemented steers were lower than suggested for optimal microbial growth. However, the ruminal ammonia concentrations associated with 0.25% and 0.50% CDDGS supplementation levels were higher than the 5 mg/100 mL suggested by Satter and Slyter (1974) as the minimal concentration required for optimum microbial protein synthesis. In this study, differences in NH_3-N ruminal concentrations between DDGS supplementation levels are probably explained by total protein intake as well as ruminal degradation rates of forage protein, which increased with the level of CDDGS supplementation. Observed increases in ruminal propionate concentrations with increasing levels of CDDGS supplementation may also be due to DMI and crude protein, which increased with the amount of supplemental CDDGS. We assume that the lower concentrations of ruminal acetate are explained by increases in NDFI, kdNDF, and EDNDF from forage in response to CDDGS supplementation. The values of ruminal NH_3-N, total VFA (TVFA), acetate, propionate, butyrate concentrations are consistent with those reported by Gunter et al. (1995) for unsupplemented cattle grazing on desert rangeland. In this study, differences in ruminal volume are probably explained by increased

Table 3. Effect of corn dried distiller grains with solubles supplementation on ruminal fermentation patterns and liquid kinetics by beef steers grazing native rangeland

	Level of CDDGS supplementation			SEM	p value
	0% BW	0.25% BW	0.50% BW		
Ruminal fermentation					
pH	6.68[a]	6.65[a]	6.66[a]	0.18	0.82
NH_3-N (mg/dL)	4.5[c]	5.6[b]	8.1[a]	0.12	0.05
Total VFA (mM/L)	82.6[a]	81.8[a]	80.8[a]	1.1	0.53
VFA (mol/100 mol)					
Acetate	67.8[a]	64.6[b]	61.1[c]	1.3	0.05
Propionate	11.7[c]	12.1[b]	13.4[a]	1.7	0.02
Butyrate	3.6[a]	3.2[a]	3.1[a]	1.4	0.16
Liquid kinetics					
Ruminal liquids volume	63.7[a]	60.8[b]	58.0[c]	3.3	0.05
Liquids dilution rate (%/h)	4.3[c]	5.5[b]	6.4[a]	0.66	0.03
Turnover time (h)	21.1[a]	18.0[b]	17.2[c]	1.14	0.05

CDDGS, corn dry distillers grains with solubles; BW, body weight; SEM, standard error of mean; NH_3-N, ammonia nitrogen; TVFA, total volatile fatty acids.
[abc] Means followed by different letters within the same row were significantly different (p<0.05).

DMI in response to CDDGS supplementation.

CONCLUSION

The results indicate that supplementing cattle grazing native rangelands with CDDGS at up to 0.50% BW yields increases in ADG, supplement conversion, intake, apparent digestibility, ruminal degradation, ruminal fermentation patters, as well as in plasma glucose and urea-nitrogen concentrations. The highest CDDGS conversion rate was obtained with the supplement fed at 0.25% BW. Therefore, CDDGS appears to be a suitable supplement for grazing cattle during forage dormant seasons. Additional studies are required to determine the effect of CDDGS on metabolic hormones and on the productive performance of grazing cattle under drought conditions.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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