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Intake and digestibility of tall fescue supplemented with co-product feeds

Omega J. Sanders[*], *Kenneth P. Coffey*[†], *Ashley N. Young*[§], *and Kristopher A. Bottoms*[‡]

ABSTRACT

Cows offered low quality hay require supplementation to meet their nutritional requirements. Our objective was to determine the impact of supplementation with soybean hulls (SH), distiller's dried grains with solubles (DDGS), or a 50:50 mixture of each (MIX) at 0.5% of body weight on ruminal fermentation characteristics and in situ forage disappearance in lactating (n = 3) and non-lactating (n = 3) ruminally cannulated cows (679 ± 18.7 kg body weight). Tall fescue was offered free-choice from large round bales for 6, 21-d periods. Dacron bags containing ground fescue hay were placed into the rumen of each cow at specified intervals over a 7-d period and removed on d 21. Rumen fluid samples were collected on d 21 of each period at 2 h intervals from 1600-2400 h for analyses of ruminal ammonia and volatile fatty acids (VFA). Ruminal forage disappearance was not affected ($P \geq 0.44$) by diets. Total VFA were greater ($P < 0.05$) from SH but the propionate percentage was greater ($P < 0.05$) from DDGS. Therefore, supplementation with DDGS should improve the energy status of cows fed poor-quality hay compared with SH or MIX.

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§ Ashley N. Young is a Masters student in the Department of Animal Science.
‡ Kristopher A. Bottoms is a May 2015 honors program graduate with a major in Animal Science and a concentration in Pre-Veterinary Medicine.

MEET THE STUDENT-AUTHORS

Omega Sanders

I was born and raised in Hot Springs, Arkansas, and I graduated from Lakeside High School in 2011. I graduated in May 2015 from the University of Arkansas with a Bachelor of Science in Animal Science. This fall, I will begin my new adventure in Baton Rouge, Louisiana, where I will be pursuing a Doctor of Veterinary Medicine at Louisiana State University.

During my undergraduate career, I was a member of the University of Arkansas Pre-Veterinary Club and Gamma Beta Phi. I served at the Vice-President for the Pre-Veterinary Club I also worked as a veterinary assistant at Wedington Animal Hospital. In the spring of 2012 and spring of 2013, I attended the APVMA symposium in Gainesville, Florida and Ames, Iowa. I was able to tour the host vet schools during this symposium and take various labs and lectures covering all aspects of veterinary medicine.

My inspiration for my honors research project was to gain large animal handling experience as well as learning more about large animals since I had no previous experience. I would like to thank Dr. Ken Coffey for all of his help with this project and for all of the encouragement and advice he gave throughout this project. I would also like to thank Ashley Young for providing assistance with both the animals and lab work, and Kristopher Bottoms for providing assistance with animal handling.

Kristopher Bottoms

I am from Oklahoma City, Oklahoma, and graduated from Southmoore High School in 2010. I graduated in 2015 from the University of Arkansas with a Bachelor of Science degree in Animal Science. This fall, I will begin pursuing a Doctor of Veterinary Medicine degree at Oklahoma State University.

During my undergraduate career at the U of A, I served as Treasurer and President for the Pre-Veterinary Club. I also worked as a Veterinary Assistant at Wedington Animal Hospital. During my time with the Pre-Veterinary Club, I was fortunate enough to attend the APVMA National Symposium at North Carolina State and the University of Florida. This symposium allowed me to learn about many areas of the veterinary industry that I had not known about previously. These conferences also allowed me to create friendships with people that share similar interests as mine, as well as strengthen my interest in small animal and exotic animal medicine.

During my time working on this research project, I learned many valuable skills about the 'research' side of animal science, as well as many animal care and animal handling techniques. I would like to thank Dr. Ken Coffey and Omega Sanders for allowing me to assist with the research project, and for teaching me the 'tricks of the trade' to working with cattle. My experiences will benefit me in vet school and throughout my life. I would also like to thank the Dale Bumpers College and the University of Arkansas for allowing me to strengthen my passion for animal science, and for getting me one step closer to my life-long dream of becoming a veterinarian.

INTRODUCTION

Low-quality forages, such as tall fescue, often require supplementation in order to meet the nutritional requirements of ruminant animals. Previous studies have evaluated the effects of supplementation on low-quality forage intake and digestibility by supplementing with co-product feeds such as soybean hulls (SH) (Grigsby et al., 1992; Slater et al., 2000) and distiller's dried grains with solubles (DDGS) (Ham et al., 1994; Klopfenstein et al., 1978). Increased concentrations of volatile fatty acids (VFA) and increased digestibility of dry matter (DM) have been reported from feeding SH as a supplement (Grigsby et al., 1992; Slater et al, 2000). Distiller's dried grains with solubles fed as a supplement has been reported to act as an adequate protein and energy source when fed up to 40% of a finishing diet, and cattle require less fiber from forage in the diet to maintain rumen function (Ham et al., 1994; Klopfenstein et al., 1978). Feeding a combination of SH and DDGS resulted in improved digestibility compared with either co-product fed individually in a limit-feeding concentrate scenario (Smith, 2014). However, little information is available about the associative effects of feeding combinations of co-product feedstuffs on a basal diet of low-quality forage. Therefore, the objectives of this study were to determine the impact of supplementation with SH, DDGS, or a 50:50 mixture of the two (MIX) on ruminal fermentation characteristics and *in situ* forage disappearance kinetics in lactating and non-lactating ruminally cannulated beef cows fed tall fescue hay.

MATERIALS AND METHODS

This experiment was conducted in accordance with procedures approved by the University of Arkansas Institutional Animal Care and Use Committee (Protocol #12023). Three lactating and three non-lactating ruminally cannulated Angus × Gelbvieh crossbred beef cows (679 ± 18.6 kg body weight; BW) were offered tall fescue hay for *ad libitum* consumption from large round bales along with supplements fed at 0.5% of BW of each individual cow. Supplements fed included SH, DDGS, and MIX.

Cows within each production status (lactating or non-lactating) were allocated to separate 3 × 3 Latin Squares, and those squares were repeated for a total of six observations on each supplement within each production status. During the course of the experiment, the cows were housed together in a drylot pen and then sorted randomly into individual pens each day and offered their respective supplements at 1600 h. Calves of the lactating cows were not allowed in the pen with their dams while their dams were offered their supplements. The cows were allowed thirty min to consume the supplements and then were returned to their drylot pen. Each period lasted 21 d, having a 14-d adaptation period at the beginning of each period.

On d 8 of each period, 100 grams (± 0.01 g) of a supplement containing 10 g of an external marker of TiO_2 along with 90 g of a mixture of SH, DDGS, and liquid molasses (42.5:42.5:5) was added to each supplement prior to being given to each cow and was fed for the remainder of each period. During the last 7 d of each period, various samples were taken. Samples included fecal grab samples from each cow during the morning and afternoon along with samples of the tall fescue hay, SH, and DDGS each day during this 7-d period. Fecal and feed samples were dried to a constant weight at 50 °C in a forced-air drying oven and then ground to pass through a 1-mm screen using a Wiley mill (Arthur H. Thomas, Philadelphia, Pa., USA). Fecal samples were composited by cow and period, and feed samples were composited by type and period prior to grinding.

On d 15 of the study, an extra cow was used to gather a sample of consumed hay via the ruminal evacuation technique. Total ruminal contents were removed, and the cow was returned to the drylot pen and allowed to consume tall fescue for fifteen minutes. After the allotted time, the masticate sample was removed from the rumen, and the original contents were returned to the rumen. Masticate samples were lyophilized, ground, and composited by period for further analyses. This process was repeated on d 21 of each period. During the last 7 d of each period, Dacron bags (10 × 20 cm; 50 μm pore size) containing approximately 5 g of tall fescue that was ground to pass through a 2-mm screen using a Wiley mill were sealed with rubber bands and then placed inside of a mesh bag which was placed inside of the rumen of each cow. The bags were inserted at specified intervals to achieve ruminal incubation times of 0, 6, 12, 22, 34, 52, 76, 100, 124, and 148 h.

At 2000 h on d 21 of each period, the mesh bags containing the Dacron *in situ* bags were removed from the rumen of each cow and immediately submerged in cold water to suppress further microbial activity. The *in situ* bags were then removed from the mesh bag, rinsed again in cold water, and washed in a top loading washer 10 times with 1 min of agitation followed by 2 min of spinning for each cycle. The *in situ* bags were then placed into a drying oven and dried to a constant weight at 50 °C.

Also on d 21 of each period, rumen fluid samples were taken from each cow at 2-h intervals from 1600 h through 2400 h to correspond to times immediately prior to feeding and 2, 4, 6, and 8 h after feeding. Rumen contents were removed from various parts of the rumen and placed in a plastic bucket. The contents were then mixed and folded into eight layers of cheesecloth and the rumen fluid was strained into a specimen cup. The rumen contents were placed back into the rumen of each cow after straining.

The cows remained in their respective pens without access to hay during the period between 1600 and 2400 h.

Immediately after taking rumen fluid samples, the pH of each rumen fluid sample was recorded. Rumen fluid samples (1000 µL) from each cow at each time period were combined with 200 µL of a metaphosphoric acid solution containing 2-ethylbutryic acid as an internal standard in a centrifuge tube for later volatile fatty acid (VFA) analysis and placed into a cooler on ice. Also, 800 µL of rumen fluid was combined with 400 µL 0.1 *M* HCl in a centrifuge tube for ammonia-N analysis and placed in a cooler on ice. These samples were then placed into a freezer at 0 °C and frozen until analyses were completed. At the end of the sampling period, the cows were returned to their drylot pen. The following morning, the cows were gathered, weighed, and assigned to their new supplement for the beginning of the next period.

Dry matter (DM) was determined on all hay, feed, and fecal samples by being dried to a constant weight at 105 °C. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed non-sequentially using the ANKOM 200/220 Fiber Analyzer (ANKOM Technology Corporation, Fairport, N.Y., USA; Vogel et al., 1999). Organic matter was determined on all samples in a muffle furnace (Method 942.05; AOAC, 2000). Acid-detergent insoluble ash (ADIA) content of feed and fecal samples was determined using the methods outlined for the ADF procedure followed by combustion in a muffle furnace. Volatile fatty acids were analyzed by gas chromatography using the methods and equipment described by Akins et al. (2009). Ammonia-N concentrations in frozen rumen fluid samples were determined colorimetrically (Broderick and Kang, 1980). All samples were corrected to a DM basis.

Titanium dioxide concentrations of the supplement and fecal samples were determined using the procedures of Myers et al. (2004). Alkaline-peroxide lignin (APL) concentrations of masticate and fecal samples were determined using the procedures of Cochran et al. (1988). Fecal output was determined by dividing the daily dosage of TiO_2 by the TiO_2 concentration in the feces. Digestibility and forage intake were then determined by the following equations:

$$\text{DM digestibility} = 100 - 100 \times \frac{\text{APL concentration in the feed}}{\text{APL concentration in the feces}}$$

$$\text{DM intake} = \frac{\text{Fecal DM Output}}{1 - \left(\frac{\text{diet digest}}{100}\right)}$$

Statistical analysis was conducted using the mixed models procedure of SAS® (SAS Institute Inc., Cary, N.C., USA). The experimental design of this project was a replicated 3 × 3 Latin Square design within production status. There were two cows per supplement per period (one lactating and one non-lactating), and each cow was considered the experimental unit since each cow received her daily supplement allocation individually. Fixed effects in this model included the effects of supplement, production status, and the supplement × production status interaction. Random effects in this model include the period and the animal. The model for VFA and ammonia-N concentrations included sampling time as a repeated measurement and cow (supplement × period) as the subject.

The proportion of DM remaining in the *in situ* bags at each incubation time was fit to the non-linear model of Mertens and Loften (1980) using PROC NLIN of SAS. This model fractionated the forage into multiple fractions and assessed the disappearance characteristics of the forage from the Dacron bags. Fraction A is the immediately soluble fraction and fraction B is that fraction that disappeared at a measurable rate (fraction B). The disappearance lag time, and the rate of DM disappearance (k_d) were also derived directly from the model. The undegradable fraction (fraction U) was calculated as 100 – B – A. Effective ruminal disappearance was estimated as $A + B[k_d/(k_d + k_p)]$ (Ørskov and McDonald, 1979) where k_p is the rate of passage that was estimated at 0.035 h^{-1}. Data derived from the non-linear model were analyzed using mixed-models procedures of SAS as described previously. Statistical significance was designated as ($P < 0.05$) and ($0.05 < P < 0.10$) was considered a tendency in all instances.

Table 1. Quality measurement of soybean hulls, distillers dried grains with solubles, tall fescue hay and masticate offered to lactating and non-lactating cows.

Item[†]	Soybean Hulls	Distillers dried grains + solubles	Hay	Masticate[§]
	----------% of DM----------			
Ash	5.3	4.6	7.5	8.9
NDF	64.2	45.4	73.9	73.7
ADF	49.7	18.3	nd[‡]	46.6
ADIA	0.36	0.05	nd	3.48
CP	12.2[¶]	30.4[¶]	nd	nd
Fat	2.1[¶]	10.7[¶]	nd	nd

[†] NDF = neutral detergent fiber; ADF = acid detergent fiber; ADIA = acid detergent insoluble ash; CP = crude protein.
[§] Masticate represents samples of hay selected by a ruminally cannulated cow following total ruminal evacuation.
[‡] nd = not determined.
[¶] represents values reported by NRC (2000).

RESULTS AND DISCUSSION

Fiber concentrations of DDGS and SH were similar to published values for these commodities (Table 1). Masticate samples gathered by the rumen evacuation procedure were high in NDF and indicative of a poor-quality tall fescue hay.

Although BW differed ($P < 0.05$) because of status, effects of supplement ($P = 0.47$) or status ($P = 0.19$) were not observed for BW change during the 21-d feeding periods (Table 2). Forage and total DM intake (g/kg BW) were greater ($P < 0.05$) from lactating cows compared with open cows, but were not different ($P \geq 0.19$) among supplements (Table 2). *In situ* forage disappearance measurements were not different ($P \geq 0.46$) among DDGS, SH, or MIX (Table 3). *In situ* effective ruminal disappearance was greater ($P < 0.05$) and rate of forage disappearance tended ($P = 0.05$) to be greater in non-lactating cows compared with lactating cows (Table 3). The supplement × production status interaction tended ($P = 0.06$) to affect effective ruminal disappearance, but other ruminal disappearance kinetic measurements were not different ($P \geq 0.19$) among supplements or production status.

Concentrations of ruminal NH_3-N and total VFA were affected ($P < 0.05$) by supplement and sampling time, but not by status ($P = 0.94$) or the supplement × sampling time interaction ($P = 0.19$; Table 4). Ruminal NH_3-N concentrations were greater ($P < 0.05$) from DDGS than

Table 2. Body weight and change, intake, and digestibility in lactating and non-lactating cows offered a basal diet of tall fescue hay and supplemented with soybean hulls, distillers dried grains, or a mix of the two at 0.5% of cow body weight.

	Supplement				Status			
Item[†]	Distillers	Mix	Soyhulls	SE	Lactating	Open	SE	Effect[§]
Body wt, kg	677	675	678	18.6	625	729	25.6	St
Body wt change, kg	-1	5	2	3.3	0	5	2.8	ns
Forage intake, kg/d	18	18	14	2.9	19	15	2.9	ns
Forage intake, g/kg bw	27	27	22	4.2	30	20	4.1	St
Total DM intake, kg/d	21	21	18	2.9	22	18	2.9	ns
Total DM intake, g/kg bw	31	32	26	4.2	35	25	4.0	St
Forage DM digest., %	72	72	67	4.3	72	69	4.17	ns
Diet DM digest., %	72	73	69	3.3	72	71	3.2	ns

[†] kg/d = kilograms per day; g/kg bw = grams per kilograms of body weight; DM = dry matter.
[§] ns = not significant; St = status effect ($P < 0.05$).

Table 3. *In situ* forage dry matter disappearance characteristics of tall fescue hay in lactating and non-lactating cows offered a basal diet of tall fescue hay and supplemented with soybean hulls, distillers dried grains, or a mix of the two at 0.5% of cow body weight.

	Supplement				Status			
Item[†]	Distillers	Mix	Soyhulls	SE	Lactating	Open	SE	Effect[§]
A, %	15.8	15.6	15.6	0.84	15.7	15.7	0.81	ns
B, %	59.0	59.5	60.1	1.46	59.6	59.5	1.44	ns
U, %	25.3	24.9	24.3	1.20	24.8	24.9	1.23	ns
k, h^{-1}	0.029	0.030	0.027	0.0019	0.026	0.031	0.0020	ns
lag, h	2.6	2.4	2.7	0.54	2.7	2.5	0.49	ns
Extent of disappearance, %	74.8	75.1	75.7	1.20	75.2	75.2	1.22	ns
Effective disappearance, %	42.3	42.6	41.4	1.24	40.6	43.6	1.25	St

[†] A= immediately soluble fraction; B = fraction that disappeared at a measurable rate; U = undegradable fraction and was calculated as 100 – B – A, k = rate of disappearance from the Dacron bags; lag = time from bag insertion until measurable disappearance of the B fraction occurred; Extent of disappearance = A + B; Effective disappearance = A + B[$k_d/(k_d+k_p)$].
[§] ns = not significant ($P \geq 0.10$).

from SH or MIX; whereas, total VFA were greater ($P < 0.05$) from SH compared with MIX and from MIX compared with DDGS.

The supplement × sampling time interaction affected ($P < 0.05$) molar concentrations of acetate (Fig. 1). Immediately prior to feeding, molar concentrations of acetate did not differ ($P > 0.10$) among supplements (Fig. 1). At 2 h post-feeding, molar concentrations of acetate were greater ($P < 0.05$) from SH compared with MIX, and did not differ ($P > 0.10$) between MIX and DDGS. From 4 h to 8 h post-feeding, molar concentrations of acetate were greatest ($P < 0.05$) from SH compared with MIX and from MIX compared with DDGS.

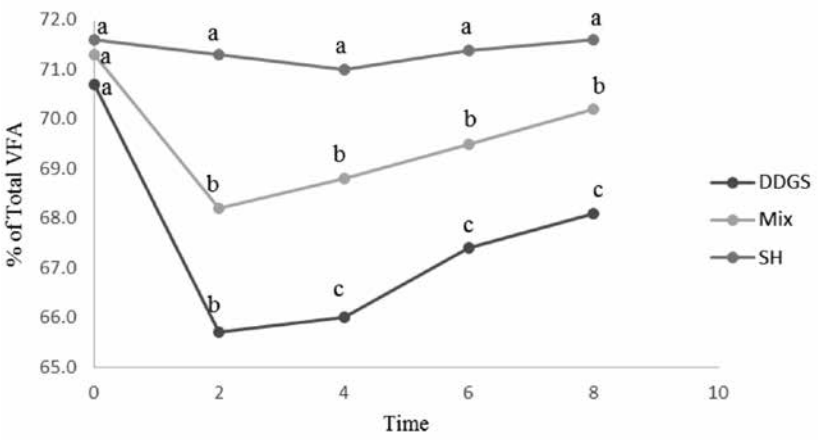

Fig. 1. Molar percent of acetate over time after feeding co-product feedstuffs. DDGS = distillers dried grains with solubles; MIX = 50:50 mixture of DDGS and soybean hulls; SH = soybean hulls; VFA = volatile fatty acids. a,b,c = means within a sampling time without a common superscript differ ($P < 0.05$).

The supplement × sampling time interaction also affected ($P < 0.05$) molar concentrations of propionate (Fig. 2). Immediately prior to feeding, molar concentrations of propionate did not differ ($P > 0.10$) between SH and MIX, or between MIX and DDGS, but were greater ($P < 0.05$) from DDGS compared with SH. At 2 h to 8 h post-feeding, molar concentrations of propionate were greater ($P < 0.05$) from DDGS compared with MIX and from MIX compared with SH.

Isobutyrate concentrations were greater ($P < 0.05$) from DDGS and MIX than from SH (Table 4). There was no supplement × sampling time interaction for isobutyrate ($P = 0.32$). The supplement × sampling time interaction affected ($P < 0.05$) the molar concentrations of butyrate (Fig. 3). Immediately prior to feeding, molar concentrations of butyrate did not differ ($P > 0.10$) among supplements. From 2 h to 8 h post-feeding, molar concentrations

Table 4. Ruminal fermentation measurements from cows offered a basal diet of tall fescue hay and supplemented with soybean hulls, distillers dried grains, or a mix of the two at 0.5% of cow body weight.

	Supplement				Status			
Item	Distillers	Mix	Soyhulls	SE	Lactating	Open	SE	Effect[†]
Rumen NH_3-N, mM	6.1[a]	4.4[b]	3.8[b]	0.63	4.8	4.7	0.71	S, T, St*T
total vfa, mM	90.5[c]	94.2[b]	100.9[a]	3.59	96.2	94.2	3.82	S, T
	---------- mole/100 mole ----------							
acetate	67.6	69.6	71.4	0.28	69.9	69.2	0.26	S, T, St, S*T, St*T
propionate	19.3	18.5	17.5	0.22	18.4	18.5	0.20	S, T, S*T, St*T
isobutyrate	0.9	0.8	0.8	0.04	0.8	0.8	0.04	S, T, St, St*T
butyrate	10.3	9.2	8.6	0.17	9.2	9.6	0.17	S, T, St, S*T, St*T
isovalerate	1	1	0.9	0.06	0.9	0.9	0.07	S, T, S*T, St*T
valerate	1	0.9	0.8	0.04	0.8	0.9	0.04	S, T, S*St, S*T, St*T
total branched chain vfa	1.8	1.8	1.7	0.10	1.7	1.8	0.10	S, S*T, St*T

[†] S = supplement effect ($P < 0.05$); T = time effect ($P < 0.05$); St = status effect ($P < 0.05$); S*T = supplement × time effect ($P < 0.05$); St*T = status × time effect ($P < 0.05$); S*St = supplement × status effect ($P < 0.05$).

[a,b,c] Main effect means within a row and either supplement or production status category without a common superscript letter are different ($P < 0.05$).

of butyrate were greater ($P < 0.05$) from DDGS compared with MIX and from MIX compared with SH.

The supplement × sampling time interaction affected ($P < 0.05$) the molar concentrations of isovalerate and valerate, but these concentrations were very low and are therefore not displayed in a figure. Immediately prior to feeding, molar concentrations of isovalerate were greater in SH compared with MIX or DDGS. At 8 h post feeding, molar concentrations of isovalerate were greater (P < 0.05) from DDGS compared with those from SH and MIX (data not shown). However, molar concentrations of isovalerate did not differ ($P > 0.10$) among supplements from 2 h to 6 h post-feeding. Valerate concentrations on the other hand were not different ($P > 0.10$) among supplements at the time of feeding, but were greater ($P < 0.05$) from DDGS compared with MIX and from MIX compared with SH at all sampling times after feeding.

The supplement × sampling time interaction affected ($P < 0.05$) the molar concentrations of total branched-chain VFA, but the data are not shown in a figure because of the low concentrations (<2% of total VFA). Immediately prior to feeding and 2 h post-feeding, total branched chain VFA did not differ ($P > 0.10$) between DDGS and MIX, but these concentrations were greater ($P < 0.05$) than those from SH. Molar concentrations of total branched-chain VFA did not differ ($P > 0.10$) among supplements at 4 h and 6 h post-feeding. At 8 h post-feeding, total branched-chain VFA were greater ($P < 0.05$) from DDGS compared with those from MIX and SH which did not differ ($P > 0.10$) from each other.

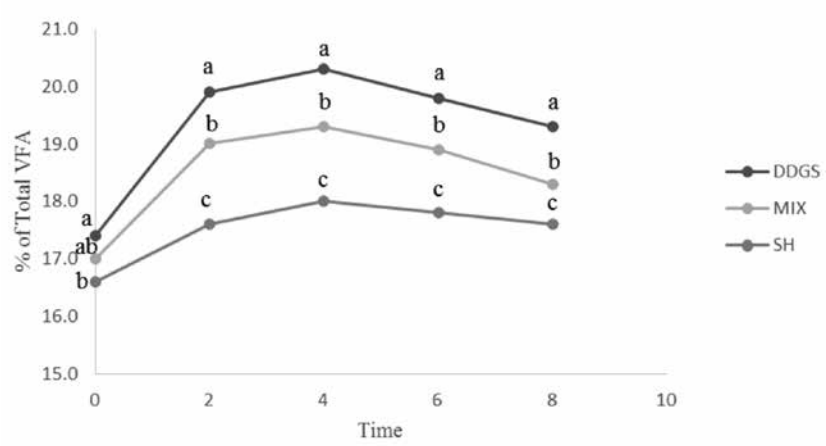

Fig. 2. Molar percent of propionate over time after feeding co-product feedstuffs. DDGS = distillers dried grains with solubles; MIX = 50:50 mixture of DDGS and soybean hulls; SH = soybean hulls; VFA = volatile fatty acids. a,b,c = means within a sampling time without a common superscript differ ($P < 0.05$).

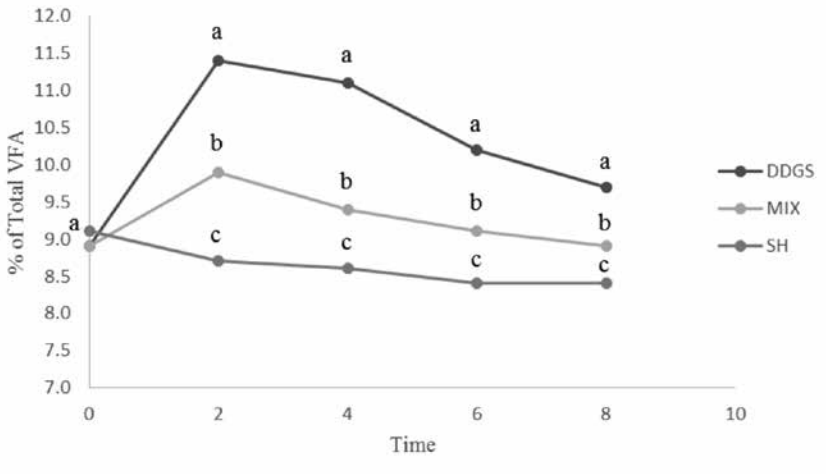

Fig. 3. Molar percent of butyrate over time after feeding co-product feedstuffs. DDGS = distillers dried grains with solubles; MIX = 50:50 mixture of DDGS and soybean hulls; SH = soybean hulls; VFA = volatile fatty acids. a,b,c = means within a sampling time without a common superscript differ ($P < 0.05$).

In the present study, it is feasible that differences in *in situ* forage disappearance were not detectable due to the low amounts of supplements fed or that all supplements were offered at the same proportion of BW. In a previous study (Smith, 2014), initial *in situ* forage disappearance was reduced ($P < 0.05$) when cows were offered limit-fed SH and limit-fed distillers dried grains with solubles but not from cows offered a mix of SH and DDGS. In that study, the different co-product feedstuffs were offered to meet the metabolizable energy requirement of the cows which meant that they were offered at considerably greater levels than those offered in the present study. Each cow in the present study was only offered supplements at 0.5% of total BW. This was done in order to meet the NRC (2000) requirements for the lactating cows while attempting to still meet the majority of their energy requirements with the poor-quality hay. Lactating cows had a higher level of forage intake and total DM intake in this study. This could be due to the fact that lactating cows have higher energy requirements than non-

lactating cows and require more forage to meet these energy requirements.

Ruminal ammonia-N concentrations and molar concentrations of propionate were greatest when cows were fed DDGS. Therefore, DDGS may better meet both the energy and protein requirements of cows offered poor-quality hay than SH or MIX. Although supplementation with SH resulted in greater total VFA and acetate concentrations, propionate is utilized more efficiently in the body once absorbed resulting in greater energy return compared with the other VFA. A study by Aschenbach et al. (2011) makes a point that measurements taken from ruminal fluid can vary. They state that ruminal fluid is not homogeneous throughout the rumen and that different sampling techniques will produce varied results (Aschenbach et al., 2011). It is possible that the technique used in this study for rumen fluid collection caused VFA results to vary. However, samples were pulled from four different sections of the rumen, mixed together, and strained through cheesecloth in the present study to minimize these effects.

Supplement × sampling time interactions were observed in the molar concentrations of acetate, propionate, butyrate, and total branched-chain amino acids. It appears that the differences in molar concentration occurred during later hours of the afternoon and into the evening (after 1800 h). No differences were detectable in most cases immediately prior to feeding, which implies that the impacts of the different supplements had subsided by that time.

CONCLUSION

Overall, minimal differences were observed for *in situ* forage disappearance measurements among lactating and non-lactating cows and none were observed because of the supplements offered. Forage intake and total DM intake were greater in lactating cows as compared to non-lactating cows. Supplementation with DDGS improved molar concentrations of propionate and butyrate for at least 8 h after feeding. Since these VFA result in greater energy production once absorbed by the cow, combined with the greater ruminal ammonia-N concentrations, DDGS should improve the energy and protein status of cows offered poor-quality tall fescue hay compared with those offered supplementation with SH or MIX.

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