Journal of Animal and Veterinary Advances 6 (9): 1125-1134, 2007
ISSN: 1680-5593

Supplementing Corn or Soybean Hulls to Cattle Fed Bermudagrass Hay II: *In situ* Disappearance and Ruminal Dynamics

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Abstract: Objectives of this study were to compare supplementation of corn or soybean hulls against changes in apparent digestion and ruminal parameters. Six ruminally cannulated steers (initial BW 182 ± 24.8 kg) received bermudagrass Hay (HAY); hay, corn (0.445 % Body Weight (BW) and Soybean Meal (SBM, 0.127% BW; CORN); or hay, Soybean Hulls (SBH; 0.607 % BW) and SBM (0.127 % BW; HULLS) using 3×3 Latin Rectangle. At 0, 2, 4, 6 and 8 h post-feeding supplements, ruminal fluid was analyzed for pH, Volatile Fatty Acids (VFA) and NH_3-N. Feeds ruminally incubated for 0, 2, 4, 6, 8, 16 and 24 h were analyzed for Dry Matter (DM), Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and Crude Protein (CP) disappearance. Ruminal pH decreased ($p<0.01$) when steers consumed CORN (6.54-5.89) or HULLS (6.63-6.07). At 0 h, no differences ($p<0.52$) in total VFA occurred among HAY, CORN and HULLS (138.3, 143.9 and 149.2 mM L^{-1}, respectively). At 4, 6 and 8 h post-feeding, VFA concentrations were greater ($p<0.001$) when steers consumed HULLS than CORN and both were greater than those fed HAY. Disappearance ratios of hay DM, NDF and CP did not differ for HAY, CORN, or HULLS (ranging from 0.773-1.175) whereas hay ADF ratios were greater ($p<.04$) from 6-16 h when feeding HULLS. Data suggest that, compared to corn, SBH produce positive associative effects that may support more efficient ruminal digestion of low-quality bermudagrass hay. *In situ* incubation revealed limited effects upon hay digestion, under parameters of the current trial.

Key words: Beef cattle, bermudagrass hay, supplementation, digestibility, soybean hulls, corn

INTRODUCTION

Cattle fed medium or low-quality forages may respond differently to quality and quantity of energy supplementation. Reductions in fiber digestion and intake of low-quality forages upon corn supplementation is well documented (Sanson *et al*., 1990; Higgins *et al*., 1991; Garces-Yepez *et al*., 1997). Soybean Hulls (SBH), however, have been shown to neither decrease intake nor digestibility of forages (Martin and Hibberd, 1990; Wheeler *et al*., 1999). Galloway *et al*. (1993) reported that the Organic Matter Intake (OMI) of growing cattle consuming moderate-quality forage would increase equal to the amount of digestible energy consumed as corn or SBH. Martin and Hibberd (1990) found that OMI of low-quality native grass hay peaked with 1 kg SBH supplementation and declined as more SBH were fed. Data from the current trial found that supplementing SBH or corn enhanced total tract digestibility (Orr *et al*., 2007). However, the mechanisms by which SBH supplementation affects intake and digestion of low-quality forages remain unclear. The objectives of this trial were to obtain a more complete understanding of the impact of corn or SBH supplementation on utilization of low-quality forages by addressing the effects on ruminal pH, VFA, NH_3–N and *in situ* disappearance of feed nutrients.

MATERIALS AND METHODS

Animals and experimental design: This study was part of a larger *in vivo* digestibility study conducted at the Leveck Animal Research Farm of Mississippi State University, which is also reported in the companion paper by Orr *et al*. (2007). Angus, Hereford and (or) Charolais steers were allowed *ad libitum* access to 'Alicia' bermudagrass (*Cynodon dactylon* (L.) Pers.) hay *ad libitum* and were either not supplemented or supplemented with corn or SBH. Supplements were

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formulated to be isocaloric. Do to this added energy, soybean meal was used to balance protein intake and meet the increased metabolizable protein requirements per NRC (1996).

Six ruminally cannulated, crossbred growing steers (initial BW 182±24.8 kg) were used in a 3×3 Latin rectangle design consisting of 3 consecutive 28 day periods. Each steer received *ad libitum* access to bermudagrass hay and one of 3 treatments: No supplement (Shriver *et al*., 1986); cracked corn at 0.445 % BW (CORN); or pelleted soybean hulls at 0.607 % BW (HULLS). Because hay and supplements alone were inadequate source of Degradable Intake Protein (DIP) for supporting normal rumen function, (Sletmoen-Olson *et al*., 2000) soybean meal (0.127% BW) was included with the CORN and HULLS diets using NRC (1996) Level 2 equations.

Prior to each period, animals were weighed without dietary restriction. Each period began with diet adaptation (1-14 day), during which steers were collectively housed with *ad libitum* access to hay and a mineral block (92.0-98.5 % NaCl with added Zn, Fe, Mn, Cu, I and Co; Akzo Nobel Salt, Inc., Clarks Summit, PA). Daily, steers were individually fed their supplements. Immediately following diet adaptation, steers were randomly placed into individual digestion stalls (2.5×0.9 m), with individual feed troughs and automatic waters. Prior to apparent digestibility (18-24 day) data collection (Orr *et al*., 2007), 3 days were included for stall adaptation (15-17 day). Analysis of feedstuffs offered can be found in Table 1. In addition to apparent digestibility, parameters of ruminal dynamics were evaluated to better understand digestion and interaction between hay and supplements (18, 21 and 24 day).

Ruminal environment: On 18, 21 and 24 day ruminal fluid was sampled at 0, 2, 4, 6 and 8 h post-feeding of supplements beginning at 0800 by sampling ruminal contents from 4-5 locations within the rumen, which was pressed through 4 layers of cheesecloth. Collected ruminal fluid was immediately placed on ice. After chilling, the pH was determined using Thermo-Orion combination electrode meter (model 290A meter, Beverly, MA). Ruminal fluid was sub-sampled and centrifuged (900×g, 20 min). Supernatant was transferred to plastic vials (sorted by date, steer and h of collection) containing m-phosphoric acid (25% wt vol^{-1}) at a 5 sample 1^{-1} acid ratio. After mixing, vials were placed on ice until subsequent ruminal fluid collections were completed; samples were then frozen (-20°C) until VFA and NH_3-N analysis.

Upon VFA analysis, frozen ruminal fluid was thawed and shaken, 5 mL sub-samples were centrifuged (30,000×g, 4°C, 20 min). To the resulting supernatant, 2-ethyl butyric acid was added (2 g L^{-1}) followed by VFA analysis using gas chromatography equipped with mass spectrophotometer. Analysis was based on procedures described by (Grigsby *et al*., 1992) and temperature gradient program described by (Bateman *et al*., 2002). Helium was used as the carrier gas with an injection flow rate of 60 mL min^{-1}.

Ammonia-N was analyzed using original ruminal fluid samples (i.e., without 2-ethyl butyric acid). Samples were thawed, vortexed and centrifuged (3.500×g, 4°C, 15 min) followed by analysis using a direct colorimetric method described by McCullough (1967). Samples were incubated at 91% humidity, 5% CO_2 and 37°C for at least 35 min prior to colorimetric analysis. Results from preliminary data necessitated revising McCullough's (1967) such that the samples were not deproteinated prior to NH_3-N determination.

***In situ* study:** On 26, 27 and 28 day *in situ* ruminal digestion was evaluated. For each period, pooled samples of daily feed offered during the *in vivo* collection was ground to pass a 2-mm screen. Three g of ground hay and 5 g of ground corn or soybean hulls were directly weighed into separate nylon *in situ* bags (# 510; 5 cm×10 cm; 50±20 μm, Ankom, Fairport, NY). Each steer received 14 *in situ* samples of hay and 14 *in situ* samples of respective supplement. *In situ* samples for hay and supplements were held in separate mesh bags allowed to move freely within the rumen. At 0800, respective mesh bags containing *in situ* samples were immersed in a bucket of warm water prior to placement in the rumen to dampen samples and facilitate immediate microbial inoculation. At 0, 2, 4, 6, 8, 16 and 24 h after initiation, 2 *in situ* samples of hay and 2 *in situ* samples of supplement were randomly withdrawn from each steer and immediately placed in ice water to cease microbial digestion. All harvested *in situ* samples were washed by hand according to a procedure described by Vanzant *et al*. (1996). Dried bags were weighed and the remaining sample was analyzed for DM, NDF, ADF and CP (Goering and Van Soest, 1970; AOAC, 2003). Analysis for NDF included sodium sulfite and α-amylase to aid in the removal of complex proteins and starch, respectively (ANKOM Technology, Fairport, NY).

Calculations and statistical analysis: *In situ* disappearance was determined by performing nutrient analysis on samples after ruminal incubation. Nutrient composition after incubation was used to create a ratio with respective nutrient composition of initial samples. Response variables were analyzed as a 3×3 Latin Rectangle, using repeated measures and the Mixed procedure of SAS (SAS Institute Inc., Cary, NC). Least square means were calculated and when significant (p<0.05), means were separated using pair wise t-test (Tukey's Honestly Significant Difference).

RESULTS AND DISCUSSION

Ruminal characteristics: Ruminal ammonia. Feeding HULLS did not change ruminal ammonia concentrations of steers fed bermudagrass hay (Fig. 1). By contrast, CORN increased (p<0.008) ruminal ammonia concentration 2 h after feeding. A numerical increase in rate of CP disappearance from the rumen by steers consuming corn cannot explain this tendency because ruminal ammonia concentration does not solely depend on degradability of CP but also involves total digestible intake protein. Further, hay CP disappearance does not follow a trend similar to DM, NDF, or ADF. This could be due to contamination of samples with microbial protein. Even at 24 h *in situ* samples contained sufficient fiber (i.e., approximately 0.73 %) components (Table 1) to facilitate microbial attachment. Further, diets included adequate SBM to prevent protein deficiency. Had diets been protein deficient, greater protein disappearance from feedstuffs may have been observed.

Ruminal ammonia will also be affected by microbial metabolism of available N and not all ruminal bacteria share the same N-requirement (Chalupa *et al*., 1970; Allison, 1980). Ruminal ammonia also depends on recycled ammonia and more importantly, on the extent of carbohydrate fermentation. Thus, it is suspected that reduction in ammonia-N concentration coinciding with an increase in fiber digestion (Table 2) when steers consumed HULLS (Fig. 1) may be a result of a more efficient utilization of N derived from the diet by ruminal microbes, allowing rapid microbial growth. This also reasonably explains increased concentrations of total VFA, (Fig. 2) which suggests a more complete fermentation of soybean hulls than corn. In this study, ammonia values were found within the optimal range (2-5 mg dL^{-1}) as proposed by (Satter and Styler, 1974).

Table 1: Chemical composition of feedstuffs offered on DM basis

Item	Cracked corn	Soybean hulls	Soybean meal	Hay [1]
	Feedstuffs offered (%)			
DM	85.9	88.5	87.6	89.6
OM	98.2	94.7	92.7	94.3
Ash	1.8	5.3	7.3	5.8
NDF	15.0	62.4	8.2	76.0
ADF	2.4	44.5	3.1	36.4
CP	8.7	12.4	47.8	7.3

[1]Hay = Bermudagrass hay

Ruminal pH and VFA: Prior to feeding, ruminal pH was similar among treatments, but after consuming supplements declined over time for each of the 3 diets

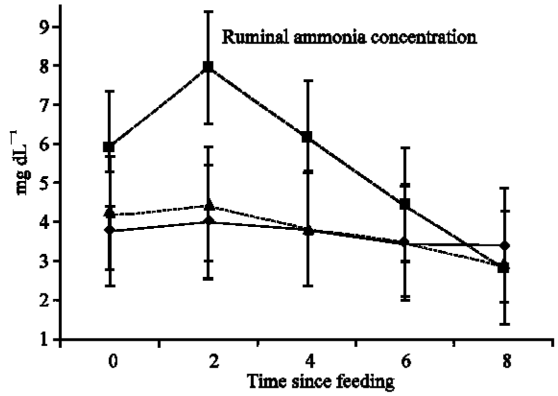

Fig. 1: Change in ruminal ammonia from 0 to 8 h after feeding corn (■) or soybean hulls (▲) supplements to steers consuming bermudagrass hay (◆). HAY = bermudagrass hay diet with no supplement; CORN = hay diet supplemented with corn (0.445 % BW) and soybean meal (0.127 % BW); HULLS = hay diet supplemented with soybean hulls (0.607 % BW) and soybean meal (0.127 % BW). Trt×Time interaction. Means within time differ: 0 (p = 0.07), 2 (p = 0.008), 4 (p = 0.11), 6 (p = 0.50) and 8 (p = 0.70)

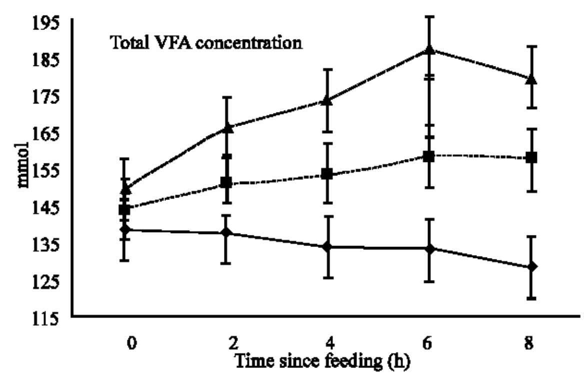

Fig. 2: Total volatile fatty acid concentration (m*M*) of steers fed bermudagrass hay (◆) and supplemented with corn (■) or soybean hulls (▲) from 0-8 h after receiving supplement. HAY = bermudagrass hay diet with no supplement; CORN = hay diet supplemented with corn (0.445 % BW) and soybean meal (0.127 % BW); HULLS = hay diet supplemented with soybean hulls (0.607 % BW) and soybean meal (0.127 % BW). Trt x Time interaction. Means within time differ: 0 (p = 0.19), 2 (p<0.001), 4 (p<0.001), 6 (p<0.001) and 8 (p<0.001)

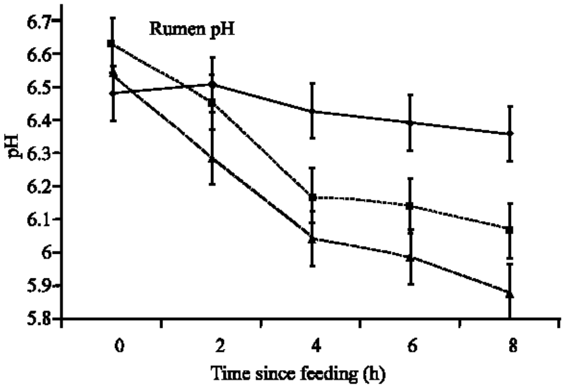

Fig. 3: Change in ruminal pH from 0-8 h after feeding corn (■) or soybean hulls (▲) supplements to steers consuming bermudagrass hay (◆). HAY = bermudagrass hay diet with no supplement; CORN = hay diet supplemented with corn (0.445 % BW) and soybean meal (0.127 % BW); HULLS = hay diet supplemented with soybean hulls (0.607 % BW) and soybean meal (0.127 % BW). Trt x Time interaction. Means within time differ: 0 (p = 0.07), 2 (p = 0.008), 4 (p<0.001), 6 (p<0.001) and 8 (p<0.001)

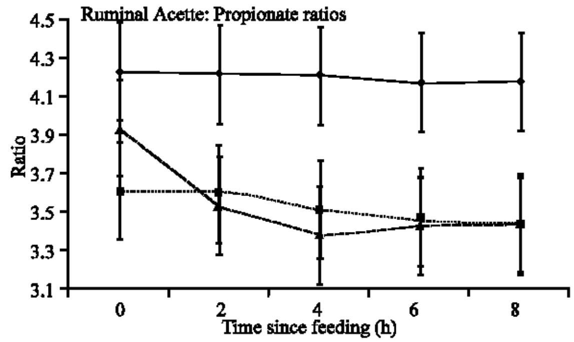

Fig. 4: Acetate: Propionate ratio 0-8 h after steers fed bermudagrass hay (◆) were supplemented with corn (■) or soybean hulls (▲). HAY = bermudagrass hay diet with no supplement; CORN = hay diet supplemented with corn (0.445 % BW) and soybean meal (0.127 % BW); HULLS = hay diet supplemented with soybean hulls (0.607 % BW) and soybean meal (0.127 % BW). Trt x Time interaction. Means within time differ: 0 (p = 0.02), 2 (p<0.01), 4 (p = 0.001), 6 (p<0.01) and 8 (p<0.01)

(Fig. 3) with HULLS resulting in a faster rate of decline followed by CORN and HAY. At 4 and 6 h post feeding, steers consuming CORN and HULLS had similar ruminal pH that was more acidic (p<0.001) than those fed HAY. By 8 h post-feeding, steers fed HULLS had the least while those fed HAY had the greatest ruminal pH, which coincided with the increase in total ruminal VFA concentrations (Fig. 2). Fermentation by-products, such as VFA and lactic acid, readily reduce ruminal pH (Burrin and Britton, 1986; Olson *et al*., 1999) and research has shown that feeding SBH minimized reductions in ruminal pH, providing a ruminal environment more conducive to fiber digestion, compared to corn (Klopfenstein and Owen, 1988). However, in the present study, feeding SBH reduced ruminal pH, but neither corn nor soybean hull consumption resulted in pH below the normal physiological range. Shriver *et al*. (1986) reported ruminal pH of 5.8 to be characterized by a 43% reduction in proportion of microbes associated with fiber particles. If bacteria are unable to adhere to feed particles, ruminal digestion cannot take place. Ruminal pH of the current study approached but was not less than 5.8, between 2 and 8 hours post-feeding. Despite the fact ruminal pH was on the lower functional end, apparent forage digestibility was greater for steers consuming HULLS, than those receiving C ORN or HAY. The reduction in ruminal pH also corresponds to increases in total ruminal VFA, an indication of greater fermentation and diet utilization within the rumen.

Total VFA concentration of steers consuming HAY remained relatively stable at an average of 132 mM L^{-1}, which was less than those supplemented with corn or SBH (p<0.001; Fig. 2). At 0 and 2 h post feeding, steers consuming HULLS had a numerically greater VFA concentration than those fed CORN and from 4-8 h post-feeding, total VFA production was greater (p<0.001) when HULLS were consumed. These results agree with Grigsby *et al*. (1992) who found a linear increase in total VFA when substituting bromegrass hay with incremental amounts of soybean hulls. However, when Galloway *et al*. (1993) supplemented bermudagrass or orchardgrass hay with small amounts of corn or soybean hulls (0.5 and 0.7% BW, respectively) no differences in total VFA concentrations were found. In the current study, supplemented steers had greater total VFA concentrations, indicating enhanced digestion, as was seen by improvements in apparent digestibilities of DM, OM and CP, reported in the companion paper (Orr *et al*., 2007). The diurnal fluctuations at total VFA concentrations for steers consuming HULLS indicate SBH were readily digestible in the rumen even though highly fibrous (62.4 % NDF and 44.5 % ADF; Table 1). Other researchers have also reported SBH to be digested relatively well *in vivo*, as much as 75.0 % (Streeter and Horn, 1983; Hsu *et al*., 1987).

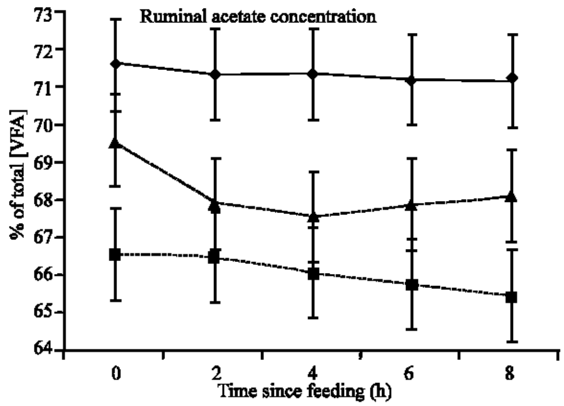

Fig. 5: Molar proportions of acetate 0-8 h after steers fed bermudagrass hay (◆) were supplemented with corn (■) or soybean hulls (▲). HAY = bermudagrass hay diet with no supplement; CORN = hay diet supplemented with corn (0.445 % BW) and soybean meal (0.127 % BW); HULLS = hay diet supplemented with soybean hulls (0.607 % BW) and soybean meal (0.127 % BW). Trt x Time interaction. Means within time differ: 0 ($p<0.001$), 2 ($p<0.001$), 4 ($p<0.001$), 6 ($p<0.001$) and 8 ($p<0.001$)

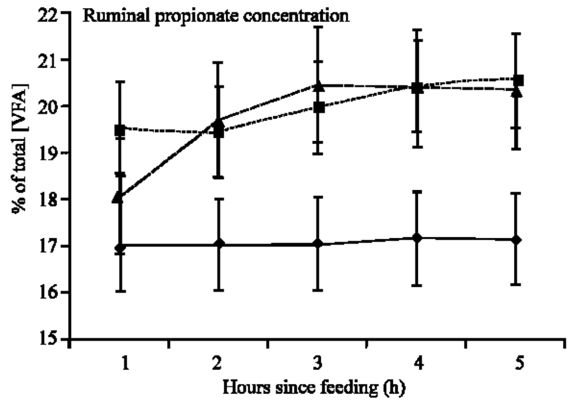

Fig. 6: Molar proportions of propionate 0-8 h after steers fed bermudagrass hay (◆) were supplemented with corn (■) or soybean hulls (▲). HAY = bermudagrass hay diet with no supplement; CORN = hay diet supplemented with corn (0.445 % BW) and soybean meal (0.127 % BW); HULLS = hay diet supplemented with soybean hulls (0.607 % BW) and soybean meal (0.127 % BW). Trt x Time interaction. Means within time differ: 0 ($p = 0.047$), 2 ($p = 0.03$), 4 ($p = 0.01$), 6 ($p = 0.01$) and 8 ($p = 0.01$)

Upon supplementation, molar proportions of acetate and propionate shifted, with proportionally more propionate by steers fed CORN or HULLS (Fig. 4). These results contradict those of Galloway *et al.* (1993) who reported a decrease ($p<0.06$) in molar proportions of propionate by corn or soybean hulls supplementation. In addition, Grigsby *et al.* (1992) reported that when low-quality bromegrass was substituted with 15, 30, 45 and 60% soybean hulls, the acetate: propionate ratio increased linearly. The present study agrees with Chase and Hibberd (1987) who reported that native grass hay supplemented with 0, 1, 2 or 3 kg ground corn linearly decreased the acetate: propionate ratio. These results are also in agreement with those of Martin and Hibberd (1990) in which the acetate: propionate ratio decreased when increasing amounts of soybean hulls were supplemented.

In the present study, molar proportions of acetate (Fig. 5) were greatest ($p<0.001$) for HAY and least for CORN and HULLS from 2-8 h. In contrast to acetate, both corn and soybean hulls generated greater ($p = 0.03$) proportions of propionate (Fig. 6). At 6 h the proportion of propionate for steers consuming HAY stabilized at about 17.0% which was less ($p = 0.01$) than those consuming CORN or HULLS, stabilizing at approximately 20.0%. Unlike propionate or acetate, the molar proportion of butyrate (Fig. 7) for CORN was greater ($p = 0.02$) compared to HAY or HULLS, which were similar from 0 through at least 8 hours post-feeding. Butyrate, though a predominant VFA, changes relatively little upon diet variation. Although steers consuming CORN had greater molar proportions of butyrate, it is considered to be of little consequence.

Acetate and propionate are 2 primary VFA produced in the rumen, with acetate residing in greater quantities. Consumption of grains usually results in a relative increase in molar proportions of propionate while fiber typically elevates molar proportions of acetate. Even though SBH contain mostly fiber and little starch, the present study and data reported by Martin and Hibberd (1990) showed SBH supplementation to decrease molar proportions of acetate and increase propionate. Acetate concentrations were still greater than propionate, but the proportional difference was reduced. Similarly, Grigsby *et al.* (1992) feeding a diet of approximately 90.0 % SBH reported increased ruminal acetate concentrations and reduced ruminal propionate concentrations. Because the present study showed improvements in apparent fiber digestibility (Orr *et al.*, 2007) by steers supplemented with SBH, the increased proportions of propionate and reductions in the molar proportions of acetate are possibly indications of increased microbial efficiency in acquiring and harnessing nutrients into microbial DM as seen by greater energy and CP retention (Orr *et al.*, 2007).

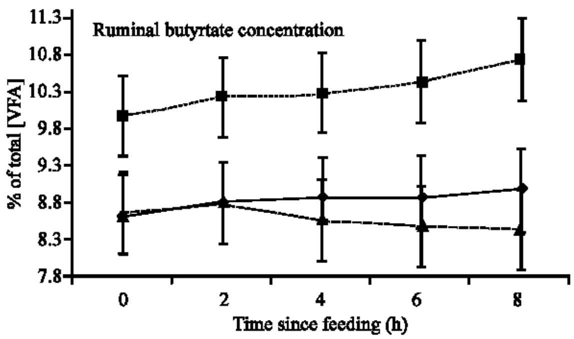

Fig. 7: Molar proportions of butyrate 0 -8 h after steers fed bermudagrass hay (◆) were supplemented with corn (■) or soybean hulls (▲). HAY = bermudagrass hay diet with no supplement; CORN = hay diet supplemented with corn (0.445 % BW) and soybean meal (0.127 % BW); HULLS = hay diet supplemented with soybean hulls (0.607 % BW) and soybean meal (0.127 % BW). Trt x Time interaction. Means within time differ: 0 ($p = 0.02$), 2 ($p = 0.01$), 4 ($p<0.01$), 6 ($p<0.001$) and 8 ($p<0.001$)

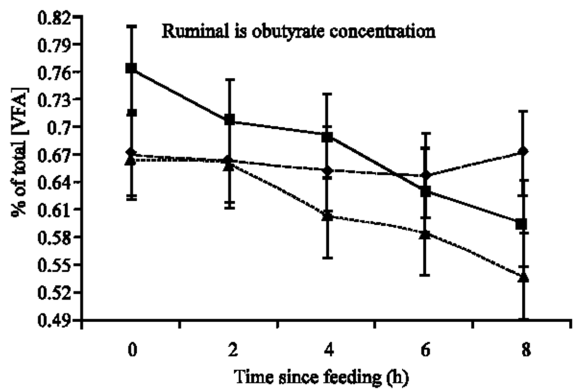

Fig. 8: Molar proportions of isobutyrate 0-8 h after steers fed bermudagrass hay (◆) were supplemented with corn (■) or soybean hulls (▲). HAY = bermudagrass hay diet with no supplement; CORN = hay diet supplemented with corn (0.445 % BW) and soybean meal (0.127 % BW); HULLS = hay diet supplemented with soybean hulls (0.607 % BW) and soybean meal (0.127 % BW). Trt x Time interaction. Means within time differ: 0 ($p = 0.04$), 2 ($p = 0.31$), 4 ($p = 0.06$), 6 ($p = 0.17$), 8 ($p<0.01$)

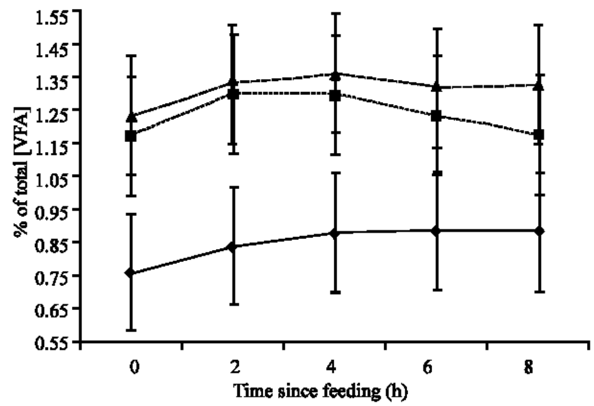

Fig. 9: Molar proportions of valerate 0-8 h after steers fed bermudagrass hay (◆) were supplemented with corn (■) or soybean hulls (▲). HAY = bermudagrass hay diet with no supplement; CORN = hay diet supplemented with corn (0.445 % BW) and soybean meal (0.127 % BW); HULLS = hay diet supplemented with soybean hulls (0.607 % BW) and soybean meal (0.127 % BW). Trt x Time interaction. Means within time differ: 0 ($p = 0.01$), 2 ($p = 0.01$), 4 ($p = 0.01$), 6 ($p = 0.02$), 8 ($p = 0.01$)

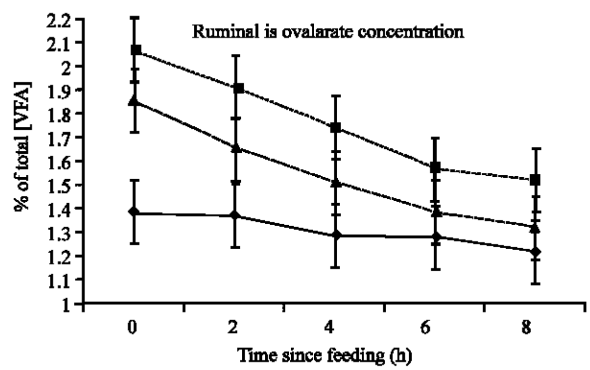

Fig. 10: Molar proportions of isovalerate 0-8 h after steers fed bermudagrass hay (◆) were supplemented with corn (■) or soybean hulls (▲). HAY = bermudagrass hay diet with no supplement; CORN = hay diet supplemented with corn (0.445 % BW) and soybean meal (0.127 % BW); HULLS = hay diet supplemented with soybean hulls (0.607 % BW) and soybean meal (0.127 % BW). Trt x Time interaction. Means within time differ: 0 ($p<0.001$), 2 ($p<0.001$), 4 ($p = 0.001$), 6 ($p = 0.03$), 8 ($p = 0.03$)

Isobutyrate, isovalerate and valerate are 3 minor VFA found in relatively small quantities within the rumen. According to Church (1988), cellulolytic bacteria require these VFA, which must be produced by non-cellulolytic microorganisms, in order to form amino acids and long-chain fatty acids. In the current trial, molar proportions of valerate, isovalerate and isobutyrate remained relatively stable when steers consumed HAY from 0-8 h post-feeding, while molar proportions of isovalerate and isobutyrate declined from 0-8 h when steers were fed

Table 2: Comparison of hay degradation ratio of incubated to initial hay nutrient content between supplemented and non-supplemented steers

	Degradation ratios						
	Ruminal Incubation Time, h						
Trt [1]	0	2	4	6	8	16	24
Hay DM							
HAY	0.9192	0.912	0.8997	0.8828	0.8628	0.786	0.7077
CORN	0.9232	0.919	0.907	0.8877	0.8645	0.7757	0.7187
HULLS	0.9258	0.91	0.8945	0.8767	0.8467	0.7792	0.7168
SE	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132
p =	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Hay NDF							
HAY	1.168	1.1692	1.1727	1.1705	1.1678	1.1735	1.165
CORN	1.1737	1.1685	1.1617	1.1682	1.1655	1.1633	1.1698
HULLS	1.1648	1.1685	1.1658	1.172	1.1642	1.175	1.1613
SE	0.0063	0.0063	0.0063	0.0063	0.0063	0.0063	0.0063
p =	0.66	0.66	0.66	0.66	0.66	0.66	0.66
Hay ADF							
HAY	1.0803	1.0863	1.0783	1.0887 [ab]	1.0935 [ab]	1.091 [ab]	1.1017
CORN	1.0873	1.0592	1.0977	1.1105 [b]	1.1187 [b]	1.1443 [b]	1.1033
HULLS	1.079	1.0748	1.0858	1.0683 [a]	1.0755 [a]	1.0672 [a]	1.086
SE	0.0208	0.0208	0.0208	0.0208	0.0208	0.0208	0.0208
p =	0.69	0.19	0.35	0.045	0.041	0.0004	0.41
Hay CP							
HAY	0.7733	0.7743	0.794	0.81	0.8622	0.9237	0.9372
CORN	0.742	0.7737	0.7877	0.8403	0.8665	0.8875	0.9352
HULLS	0.7692	0.8263	0.83	0.8423	0.8547	0.8842	0.9203
SE	0.0265	0.0265	0.0265	0.0265	0.0265	0.0265	0.0278
p =	0.55	0.55	0.55	0.55	0.55	0.55	0.55

[1] HAY = Bermudagrass hay diet with no supplement; CORN = Hay diet supplemented with corn (0.445% BW) and soybean meal (0.127% BW); HULLS = Hay diet supplemented with soybean hulls (0.607% BW) and soybean meal (0.127% BW)

microorganisms are utilizing some aspect of the fibrous soybean hulls since they contain very little starch.

Furthermore, it is widely accepted that cellulose catabolism yields acetate by an extracellular cellulose complex first releasing glucose and other heterodimeric sugars (Church, 1988) and even though bacteria attach to feed to minimize lost of subsequent nutrients, some loss still occurs (Van Soest, 1994). Furthermore, Van Soest (1994) reported that numerous amylolytic bacteria utilize cellobiose where propionate is still the product of fermentation. Therefore, if the fiber of SBH were readily degraded in the rumen such that glucose and (or) cellobiose were released and made available to amylolytic bacteria, this would explain why characteristics of steers receiving SBH mimicked the responses of steers fed corn, with respect to ruminal VFA, pH and NH_3-N. This may indicate that during the current study SBH were effectively providing nutrients to both amylolytic and cellulolytic bacterial populations. To better understand the interaction of feeds within the rumen and better interpret digestibility as well as rumen parameters, *in situ* ruminal digestion was also evaluated.

Ruminal disappearance: Ruminal disappearance of hay DM (Table 2) was not affected ($p = 0.58$) when consuming HAY, CORN, or HULLS. Even though *in vivo* apparent fiber digestibility increased while soybean hull supplementation, reasons why *in situ* hay DM was not affected is unclear. Had ruminal incubation been carried beyond 24 h, stratification of *in situ* disappearance may have occurred as with previous reports (Mertens and Loften, 1980). Hay CP disappearance showed no differences among treatments. Increased ratio between CP of sample and initial feed could be explained by disappearance of other nutrients from ruminal samples (i.e., DM, NDF, etc) as well as at least partially explained by residual microbial protein contaminating ruminal samples.

There was no difference in ruminal hay NDF disappearance, but hay ADF disappeared at a greater ($p<.04$) rate at 6, 8 and 24 h incubation when steers consumed HULLS compared to HAY (Table 2). Apparent fiber digestion was greater when steers consumed HULLS (Orr *et al*., 2007), which involved total tract digestion and therefore fiber from both hay and SBH. The addition of digestible SBH no doubt was contributing to *in vivo* fiber digestibility. It is assumed that supplying a fibrous feedstuff to the rumen would promote fiber-digesting bacteria while suppressing starch bacteria. In such a case, fiber digestion of both SBH and hay should be enhanced.

Disappearance of NDF from supplements were greater ($p<0.03$) for SBH than corn. No differences were observed in disappearance of ADF from supplements

Table 3: Comparison of corn and soybean hull degradation ratios of incubated to initial supplement nutrient content

	Degradation ratios						
	Ruminal Incubation Time, h						
Supplement[1]	0	2	4	6	8	16	24
DM							
Corn	0.8212	0.777	0.7432	0.687	0.6438	0.5448	0.4185
SBH	0.9108	0.8717	0.8265	0.7928	0.752	0.603	0.4955
SE	0.0231	0.0231	0.0231	0.0231	0.0231	0.0231	0.0231
p =	0.0003	0.001	0.0006	<.0001	<.0001	0.0145	0.0015
NDF							
Corn	1.2225	1.2392	1.2435	1.3132	1.2905	1.4475	1.7078
SBH	1.0755	1.1298	1.1365	1.1443	1.1712	1.252	1.2602
SE	0.0903	0.0903	0.0903	0.0903	0.0903	0.0903	0.0903
p =	0.11	0.23	0.24	0.07	0.19	0.035	<.0001
ADF							
Corn	0.95	1.0423	1.1232	1.1987	1.2842	1.1465	1.3833
SBH	0.9863	1.0532	1.0705	1.098	1.126	1.2982	1.2697
SE	0.0669	0.0669	0.0669	0.0669	0.0669	0.0669	0.0669
p =	0.34	0.34	0.34	0.34	0.34	0.34	0.34
CP							
Corn	0.8738	0.8643	0.871	0.8965	0.9152	0.9208	1.0883
SBH	0.8853	0.8815	0.8668	0.871	0.8758	0.8408	0.8912
SE	0.0367	0.0367	0.0367	0.0367	0.0367	0.0367	0.0367
p =	0.07	0.07	0.07	0.07	0.07	0.07	0.07

[a,b]Within column, means without a common superscript differ ($p<0.05$). [1] SBH = soybean hulls, CORN or HULLS (Fig. 8-10). This would imply that non-cellulolytic and(or) generalist

(Table 3). Ruminal disappearance of supplement DM was greater ($p<0.01$) for corn than SBH (Table 3). Ruminal disappearance of CP from corn and SBH was not affected by treatment ($p<0.05$). However, ruminal CP disappearance approached significance ($p<0.06$) and pair-wise comparisons indicated greater CP disappearance from corn than SBH at 16 ($p<0.03$) and 24 h ($p<0.0001$) incubation. Although SBH were digested slower than corn they still proved to be highly digestible, which is supported by previous studies evaluating the digestion of soybean hulls by cattle (Quicke *et al*., 1959; Hintz *et al*., 1964; Ludden *et al*., 1995).

In situ samples were individually hand washed to minimize any impact that processing might have upon analysis. It is possible that both bacterial as well as particles from the ruminal media infiltrated the nylon bags effecting weights and percent disappearance. This would help explain why there was inconsistency in nutrient disappearance from hay and supplements. Corn contains very little fiber therefore small magnitudes of digestion may result in significant fiber digestibility estimates. However, because SBH are fibrous, it is more difficult to observe alterations in NDF and ADF digestibility. In order for hay to be more efficiently digested when combined with supplement both in total tract digestion and *in situ* ruminal digestion, protein would have to be available and be metabolized. The reason differences in hay CP and supplement CP was not detected could be due to either contamination by microbial protein or because adequate protein was provided via SBM in the diet. Had diets been protein deficient, greater CP disappearance from hay and supplements may have been observed.

In situ results tended to agree with *in vivo* digestibility (Orr *et al*., 2007) when CORN and HULLS enhanced apparent DM and OM digestibility. Furthermore, soybean hull supplementation appeared to not only be additive but also positively associative to hay digestion, while corn supplementation produced only an additive effect (Orr *et al*., 2007).

CONCLUSION

In this study, growing steers with *ad libitum* access to bermudagrass hay were supplemented with corn or soybean hulls to provide approximately 4.19 MJ NE_m per kg of diet. In spite of its high fiber content, soybean hulls showed a tendency to allow greater disappearance of hay ADF *in situ,* while producing a greater volume of VFA in the rumen. This data suggest that a feeding system using low-quality forage, with a moderate amount (at least 0.5% of BW) of soybean hulls can enhance moderate quality forage digestion through additive and associative effects resulting in a more efficient supplement compared to corn.

ACKNOWLEDGMENT

The authors acknowledge H. G. Bateman, II and C. C. Williams from Louisiana State University, Department of Dairy Science and A. M. Chapa from Mississippi State University, Department of Animal and Dairy Sciences, for their invaluable contributions to this experiment.

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