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Supplementing Corn or Soybean Hulls to Cattle Fed Bermudagrass Hay I: Intake, Apparent Digestion and Utilization

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Abstract: During balance trial, 12 steers received hay with: no supplement (HAY_B); corn 0.445% body weight (BW; $CORN_B$); or SBH 1.16% BW ($HULLS_B$). Hay Dry Matter Intake (DMI) was not different (p = .68; between 1.15 and 1.32%). Total DMI was greater (p<.01) for steers fed $HULLS_B$ (2.37%) than HAY_B (1.31%) or $CORN_B$ (1.66%). Apparent Dry Matter (DM) and Organic Matter (OM) digestibilities were greater (p = .01) when fed $CORN_B$ (69.91 and 71.23%) or $HULLS_B$ (70.47 and 72.12%) than HAY_B (57.54 and 59.12%). Apparent neutral (NDF) and acid (ADF) detergent fiber digestibilities were not different (p = .09; between 635.4 and 73.69%). Apparent CP and GE digestibilities were less (p = .02) when fed HAY_B (53.63 and 57.19%) than $CORN_B$ (703.7 and 69.68%) or $HULLS_B$ (63.85 and 70.06%), while apparent CP and GE utilization were greater (p<.01) when fed $HULLS_B$ (0.46 kg d^{-1} and 14.09 Mcal d^{-1}, respectively) than $CORN_B$ (0.13 kg d^{-1} and 9.83 Mcal d^{-1}, respectively) or HAY_B (-0.19 kg d^{-1} and 6.33 Mcal d^{-1}, respectively). During digestion trial, 6 cannulated steers receiving hay with: no supplement (HAY_D); corn 0.455% BW ($CORN_D$); or SBH 0.607% BW ($HULLS_D$). Hay DMI was not different (p = .18; ranging from 0.123-0.151%). Total DMI of steers fed $HULLS_D$ and $CORN_D$ was greater (p<.01; 1.98 and 2.08%, respectively) than those fed HAY_D (1.26%). Apparent DM, OM and CP digestion by steers fed HAY_D was less (p<.01; 52.85, 53.41 and 49.23%, respectively) than $CORN_D$ (61.98, 62.77, 64.72%, respectively) or $HULLS_D$ (65.68, 66.68 and 67.54%, respectively). Apparent NDF and ADF digestion were greater (p = .01) when fed $HULLS_D$, (63.95 and 64.45%, respectively) than $CORN_D$ (52.82 and 49.59%, respectively) or HAY_D (53.89 and 50.29%, respectively). Supplementing bermudagrass hay with corn or SBH enhanced total DMI and apparent DM, OM and CP digestion. Supplementation also increased CP and GE utilization while SBH supplementation tended to increased fiber digestion.

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

INTRODUCTION

Bermudagrass (*Cynodon dactylon* (L.) Pers.) is a predominant warm season forage in the southeastern United States. However, due to a combination of environmental constraints and forage management, the quality of hay is generally inadequate to meet the nutritional demands of growing cattle, thereby requiring supplementation (Smith *et al*., 1972). Grains fed to cattle consuming forage based diets have been shown to cause substitutive and associative effects, limiting the efficient utilization of lower quality forages (Campling and Murdoch, 1966; Klopfenstein and Owen, 1988; Galloway *et al*., 1993). Performance of cattle consuming SBH has been shown to be comparable to cattle consuming corn, implying similar availability of energy from both feed stuffs (Anderson *et al*., 1988). Despite similarities in performance, unlike corn, SBH are considered a roughage (>18.0% crude fiber) that can be readily digested within the rumen (Streeter and Horn, 1983; Hsu *et al*., 1987). Negative associative effects that impede forage utilization, have been minimized when feeding SBH, as opposed to corn (Highfill *et al*., 1987; Martin and Hibberd, 1990; Grigsby *et al*., 1992,1993). Previous published data indicates that substitutive effects of SBH are minimal (Martin and Hibberd, 1990; St. Louis *et al*., 2002), whereas feeding corn often exhibits greater degrees of forage substitution (Mertens and Loften, 1980; Chase and Hibberd, 1987). Therefore, SBH should be an ideal supplement that enhances utilization

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of low-quality forages (Klopfenstein and Owen, 1988; Chan *et al*., 1991). The objective of this experiment was to evaluate the effects of supplementing corn or SBH on intake, apparent digestion and utilization of energy and CP by cattle consuming bermudagrass hay.

MATERIALS AND METHODS

General: Two trials were conducted on the Leveck Animal Research Farm at Starkville, Mississippi to evaluate the impact of supplementation on utilization of low-quality (Table 1) 'Alicia' bermudagrass (Cynodon dactylon (L.) Pers.) hay by Angus, Hereford and/or Charolais steers. In both trials, free choice hay supplemented with corn, SBH, or no supplement. To predict supplement intake, DMI of hay was estimated to be 1.5% BW and entered into NRC (1996) Level 2 equations to calculate daily supplement intake. Soybean meal was included in the prediction equation to adjust metabolizable protein and bacterial nitrogen concentrations. For the first trial (balance trial) level 2 equations of NRC (1996) recommended feeding SBH at 161% of maintenance. However, based upon results of this trial, this recommendation appeared to overestimate DMI of steers supplemented with SBH, possibly by overestimating substitutive properties of SBH. Therefore, to further investigate SBH supplementation, a second trial(digestion trial) was conducted. In the digestion trial, the corn diets were again balanced for NE_m and metabolizable protein via NRC (1996) Level 2 equations. However, to better evaluate SBH supplements, NRC (1996) equations were not used. Rather, SBH supplements were calculated to be 120% of NRC (1996) recommendations for corn supplements, thereby reducing the amount of SBH offered during the digestion trial compared to the balance trial (Table 2). Similarly, metabolizable protein was only calculated for the corn rations and because the initial feedstuff analysis revealed similar CP content for corn and SBH, soybean meal was included equally with both corn and SBH supplements in attempt to remove confounding affects varying consumption of SBM might have.

Diets: Feedstuffs of similar quality were offered in both trials (Table 1). Samples were analyzed for CP, ADF, NDF and ash, while starch (6.0%), fat (2.0%), soluble nitrogen (22.0%) and true protein (25.8%) content of hay needed for NRC (1996) calculations were estimated from published table values. Digestibility rates for soybean hulls and corn were taken from NRC Appendix Table 1 and digestibility rates for bermudagrass hay were estimated from the same table based on CP, ADF and NDF content. Estimated nutrient composition and digestibilities were used in diet formulation by NRC (1996) Level 2 calculations.

Table 1: Nutrient composition of feedstuffs consumed by beef steers during a balance and digestion trial (DM basis)

Feedstuff [1]	DM (%)	OM (%)	NDF (%)	ADF (%)	HC [2] (%)	CP (%)	GE Mcal g^{-1}
Balance trial							
Hay	91.06	93.55	78.33	36.58	41.75	10.50	4.50
Corn	86.57	97.88	17.06	3.39	13.67	10.40	4.37
SBH	97.52	95.54	68.18	48.50	19.68	10.59	4.22
SBM	90.48	93.00	7.70	3.64	4.06	47.74	4.65
Digestion trial[2]							
Hay	89.65	94.25	76.08	36.40	39.68	7.31	ND
Corn	85.97	98.23	15.08	2.45	12.63	8.75	ND
SBH	88.57	94.74	62.43	44.59	17.83	12.42	ND
SBM	87.69	92.70	8.27	3.15	5.12	47.85	ND

[1]Hay = Bermudagrass hay; Corn = Cracked corn; SBH = Soybean Hulls; SBM = Soybean Meal, [2]HC = Hemicellulose, [3]ND = Not Determined

Table 2: Approximate energy availability and utilization from hay and supplements during a balance and digestion trial

	Consumed (kg)		Retained (Mcal d^{-1})		Energy balance (Mcal kg^{-1})		
Diets	Hay	Supplement	Hay	Supplement	Hay	Supplement	SBH:Corn
Balance trial[1]							
HAY_B	2.32	0	6.33	0	2.73	0	
$CORN_B$	2.06	0.91	5.62	4.21	2.73	4.63	
$HULLS_B$	2.37	1.91	6.47	7.62	2.73	3.99	86.18%
Digestion trial[2]							
HAY_D	2.27	0	6.19	0	2.73	0	
$CORN_D$	2.60	1.00	7.09	4.63	2.73	4.63	
$HULLS_D$	2.19	1.31	5.97	4.85	2.73	3.70	79.91%

[1]Treatment Diets: HAY_B = bermudagrass hay with no supplement; $CORN_B$ = bermudagrass hay supplemented with corn (0.445% BW) and soybean meal(0.127% BW); $HULLS_B$ = bermudagrass hay supplemented with soybean hulls (1.16% BW) and soybean meal (0.073% BW). Associative effects were assumed to be nonexistent, [2]Treatment Diets: HAY_D = bermudagrass hay with no supplement; $CORN_D$ = bermudagrass hay supplemented with corn (0.445% BW) and soybean meal (0.127% BW); $HULLS_D$ = bermudagrass hay supplemented with soybean hulls (0.607% BW) and soybean meal (0.127% BW). Energy utilization was assumed to be equal to balance trial and associative effects were assumed to be nonexistent

Table 3: The effect of supplementing corn or soybean hulls on DM intake of steers consuming hay during a balance and digestion trial

		Dry matter intake[3]			
Item[1]	BW[2] kg	Hay kg d^{-1}	Total kg d^{-1}	Hay (%)	Total (%)
Balance trial					
HAY_B	178.1	2.32	2.32[b]	1.31	1.31[b]
$CORN_B$	178.7	2.06	2.97[b]	1.15	1.66[b]
$HULLS_B$	180.9	2.37	4.28[a]	1.32	2.37[a]
SE	7.832	0.274	0.280	0.156	0.156
p-values	0.96	0.69	<0.01	0.68	<0.01
Digestion trial					
HAY_D	175.0	2.27	2.27[b]	1.26	1.26[b]
$CORN_D$	174.0	2.60	3.60[a]	1.51	2.08[a]
$HULLS_D$	176.0	2.19	3.50[a]	1.23	1.98[a]
SE	4.300	0.165	0.174	0.105	0.100
p-values	0.42	0.23	<0.01	0.18	<0.01

[1]Treatment Diets: HAY_B = bermudagrass hay with no supplement; $CORN_B$=bermudagrass hay supplemented with corn (0.445% BW) and soybean meal (0.127% BW); $HULLS_B$ = bermudagrass hay supplemented with soybean hulls (1.16% BW) and soybean meal (0.073% BW). HAY_D=bermudagrass hay with no supplement; $CORN_D$ = bermudagrass hay supplemented with corn (0.445% BW) and soybean meal (0.127% BW); $HULLS_D$ = bermudagrass hay supplemented with soybean hulls (0.607% BW) and soybean meal (0.127% BW), [2] Body weight in kg, [3] Hay = bermudagrass hay; Total = total dry mater intake (hay and supplement), [a,b]Within trial and column, means without a common superscript differ ($p<0.05$)

Balance trial: Twelve steers (initial BW 184±14.3 kg) were used to evaluate apparent nutrient digestibility and apparent utilization of GE and CP in a completely randomized design consisting of 4 replicates per treatment. All steers received low-quality bermudagrass hay, free choice and were fed 1 of 3 supplements: no supplement (HAY_B); cracked corn at 0.445% BW d^{-1} ($CORN_B$); or pelleted SBH at 1.16% BW d^{-1} ($HULLS_B$), once daily. Both $CORN_B$ and $HULLS_B$ rations contained soybean meal (SBM; 0.127 and 0.073% BW d^{-1}, respectively) to satisfy metabolizable protein requirements. Body weights were obtained with no dietary restrictions for use in treatment allocation (Table 3) and steers were individually fed to facilitate diet adaptation (14 d). Mineral blocks were offered free choice only during diet adaptation (92.0-98.5% NaCl with added Zn, Fe, Mn, Cu, I and Co; Akzo Nobel Salt, Inc., Clarks Summit, PA). After adaptation, steers were placed in metabolism crates and allowed 4 d acclimation (d 15-18) immediately followed by 7-d data collection (d 19-25) period. Total fecal and urine excretion was measured and sampled daily, taking a 5% aliquot of each. Hay and supplements offered and hay orts were sampled daily and composited across trial. There were no supplement orts.

Digestion trial: Six steers with ruminal cannulae (initial BW 182±24.8 kg) were arranged using a 3×3 Latin Rectangle design consisting of 3 consecutive 28 day periods. All steers received free choice bermudagrass hay and were assigned one of 3 treatments, receiving a new supplement each period. To test dietary carryover affects, no 2 steers received treatments in the same sequence. Treatments included: no supplement (HAY_D); cracked corn at 0.445% BW ($CORN_D$); or pelleted SBH at 0.607% BW ($HULLS_D$). Both $CORN_D$ and $HULLS_D$ rations included SBM (0.127% BW) to satisfy metabolizable protein requirements. During each 28-d period, steers were individually fed for diet adaptation (1-14 day) and then placed into individual digestion stalls (2.44×0.876 m) allowing 3 d acclimation (15-17 day) before *in vivo* data collection (18-24 day).

At the beginning of each 14 day adaptation, BW were obtained with no dietary restrictions (Table 3). Steers received a different diet each period and mineral blocks were provided free choice only during diet adaptation (92.0-98.5% NaCl with added Zn, Fe, Mn, Cu, I and Co; Akzo Nobel Salt, Inc., Clarks Summit, PA). While in stalls, steers remained haltered and tied, able to stand or lie down at will. After 3 day stall acclimation, apparent nutrient digestibility was determined by measuring daily DMI and total fecal excretion from day 18 through 24. Fecal collections began on day 18, 17 day after introduced to treatment. Variation in ruminal digestion due to supplementation was evaluated (day 25-28) by measuring ruminal NH_3-N, VFA, pH and *in situ* disappearance. See the companion study (Nguyen *et al*., 2007) for methodology and results regarding ruminal dynamics.

Procedures and sample collection: In both trials, at 0700 total fecal output for each steer was weighed, mixed, sampled (5% aliquot) and dried in a forced air oven (65°C). Hay was provided free choice and hay remaining after 24 h was collected, weighed, sampled and discarded. Supplements were fed daily (0800) after hay orts were removed and before fresh hay was provided. Supplements were consumed within 30 min of feeding, with no refusal.

During balance trial, urine was collected in plastic buckets (0.2 mL Toluene) positioned under metabolism crates. At 0700 total urine volume was recorded, sampled (5% aliquot) and stored at −20°C. Hay orts as well as fecal and urine samples were compiled by steer, while samples of hay and supplements offered were compiled across trial.

During the digestion trail, hay orts and fecal samples were compiled by steer within period, while samples of hay and supplements offered were compiled by period.

Laboratory analysis: Hay, supplements and fecal samples from balance and digestion trials were ground in a Thomas Wiley Mill (model 4, Thomas Scientific, Swedesboro, NJ) to pass a 2-mm screen followed by laboratory analysis for DM, ash, CP, NDF and ADF

(Goering and Van Soest, 1970; AOAC, 2003). Fiber fractions were determined using the ANKOM fiber analyzer (ANKOM Technology, Macddon, NY). Analysis for NDF included sodium sulfite to aid in the removal of complex proteins and á-amylase was used to expedite the removal of starch. In addition to the above analysis, feed, fecal and urine samples from the balance trial were analyzed for GE using isoperibol bomb calorimetry (Parr Instrument Company, Moline, IL). Gross energy of urine was determined by adding 0.5 mL of urine to saturate 1 g of pelleted cellulose powder. Energy values of cellulose standards were subtracted to obtain GE of urine (Operating Instructions No. 205M, Parr Instrument Co.). Urine samples were also analyzed for CP content (AOAC, 2003).

Calculations and statistical analysis: In both trials, DM and Organic Matter (OM) intake were calculated, as were DM, OM, CP, NDF and ADF apparent digestibilities. During the balance trial, apparent energy utilization was determined by accounting for fecal and urinary energy excretion. Gaseous and heat energy losses were not accounted for in the calculation. The balance trial was analyzed as a completely randomized design, while the digestion trial was analyzed as a 3×3 Latin rectangle, accounting for dietary carryover effects. Both experiments were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). When significant, means were separated using Fisher's protected LSD. No significant interactions were found ($p<0.05$).

RESULTS

Balance trial: Nutrient composition of feedstuffs offered during the balance trial is listed in Table 1. The DMI of hay was not affected by treatment (Table 3). Total DMI was greater ($p<0.01$) for steers consuming $HULLS_B$ than $CORN_B$ or HAY_B and supplemented steers had greater ($p<0.02$; Table 4) apparent DM, OM, CP and GE digestibility than those fed HAY_B. However, the apparent digestibility of NDF, ADF and hemicellulose were not different ($p = 0.09$). Steers consuming HAY_B had the least ($p<0.003$; Table 5) apparent utilization of GE and CP compared to steers receiving either $CORN_B$ or $HULLS_B$. Steers fed $HULLS_B$ had greater ($p<0.003$) apparent utilization of GE and CP than those fed $CORN_B$.

Digestion trial: Nutrient composition of feedstuffs offered during digestion trial is listed in Table 1. The DMI of hay was not affected ($p<0.23$) by treatment (Table 3).

Table 4: The effect of supplementing corn or soybean hulls to low-quality hay on apparent nutrient digestibility during a balance and digestion trial

	Apparent nutrient digestibility						
Items[1]	DM (%)	OM (%)	NDF (%)	ADF (%)	HC[2] (%)	CP (%)	GE (%)
Balance trial							
HAY_B	57.54 [b]	59.12 [b]	65.07	63.54	66.41	53.63 [b]	57.19 [b]
$CORN_B$	69.91 [a]	71.23 [a]	71.07	70.71	71.36	70.37 [a]	69.68 [a]
$HULLS_B$	70.47 [a]	72.12 [a]	73.69	74.47	72.66	63.85 [a]	70.06 [a]
SE	2.888	2.867	2.705	3.120	2.376	3.258	3.024
p-values	0.01	0.01	0.12	0.09	0.20	0.01	0.02
Digestion trial							
HAY_D	52.85 [b]	53.41 [b]	53.89 [b]	50.29 [b]	56.99 [b]	49.23 [b]	ND
$CORN_D$	61.98 [a]	62.77 [a]	52.82 [b]	49.59 [b]	55.54 [b]	64.72 [a]	ND
$HULLS_D$	65.68 [a]	66.68 [a]	63.95 [a]	64.45 [a]	61.08 [a]	67.54 [a]	ND
SE	1.309	1.341	1.633	2.117	1.437	1.474	ND
p-values	<0.01	<0.01	<0.01	0.01	0.06	<0.01	ND

[1]Treatment Diets: HAY_B = bermudagrass hay with no supplement; $CORN_B$ = bermudagrass hay supplemented with corn (0.445% BW) and soybean meal (0.127% BW); $HULLS_B$ = bermudagrass hay supplemented with soybean hulls (1.16% BW) and soybean meal (0.073% BW). HAY_D = bermudagrass hay with no supplement; $CORN_D$ = bermudagrass hay supplemented with corn (0.445% BW) and soybean meal (0.127% BW); $HULLS_D$ = bermudagrass hay supplemented with soybean hulls (0.607% BW) and soybean meal (0.127% BW), [2]HC = Hemicellulose, [3]ND = Not determined, [a,b]Within trial and column, means without a common superscript differ ($p<0.05$)

Table 5: The effect of supplementing corn or soybean hulls to steers consuming bermudagrass hay on CP and GE utilization during balance trial

	Nutrient utilization	
Item[1]	CP, kg d^{-1}	GE, Mcal d^{-1}
HAY_B	-0.19 [c]	6.33 [c]
$CORN_B$	0.13 [b]	9.83 [b]
$HULLS_B$	0.46 [a]	14.09 [a]
SE	0.060	1.007
p-values	<0.01	<0.01

[1]Treatment diets: HAY_B = bermudagrass hay with no supplement; $CORN_B$ = bermudagrass hay supplemented with corn (0.445% BW) and soybean meal (0.127% BW); $HULLS_B$ = bermudagrass hay supplemented with soybean hulls (1.16% BW) and soybean meal (0.073% BW), [a,b,c]Within a column, means without a common superscript differ ($p<0.05$)

However, steers offered $CORN_D$ or $HULLS_D$ had greater ($p<0.004$) total DMI compared to steers not supplemented. Steers consuming HAY_D had reduced ($p<0.003$) apparent digestion of DM, OM and CP than those receiving either supplement (Table 4). Apparent NDF and ADF digestibilities were greater ($p<0.02$) when steers consumed $HULLS_D$ compared to $CORN_D$ or HAY_D. Following the same trend, $HULLS_D$ consumption tended to correspond with an increase ($p<0.063$) in apparent hemicellulose digestibility.

DISCUSSION

Diets fed in the balance trial were formulated using the NRC (1996) Level 2 equations, which recommended feeding SBH at 161% maintenance. However, this value was an apparent overestimation of the steer's requirement, given the energy utilization and digestibilities calculated during the balance trial. Further, the balance trail did not indicate any substitution of hay when $CORN_B$ or $HULLS_B$ were consumed. Therefore, to better understand the similarities and differences between corn and SBH supplementation, a digestion trail was conducted and the energy balance of SBH was assumed to be 80% of that of corn, as indicated from the balance trial. Therefore, SBH were fed at approximately 120% of the energy within the corn diet to maintain approximate isocaloric conditions across supplements. This value was further intended to remove confounding affects that may have occurred during the balance trial by feeding SBH more than twice than corn (1.16 and 0.455% BW d^{-1}, respectively), per NRC (1996) level 2 recommendations. Greater supplementation by $HULLS_B$ than $CORN_B$ at least partially contributes to variation of recorded DMI. In contrast, during the digestibility trial, after deviating from NRC (1996) level 2 recommendations for SBH, steers consuming both $CORN_D$ and $HULLS_D$ demonstrated greater total DMI than steers receiving HAY_D, with no differences in DMI between $CORN_D$ and $HULLS_D$.

During the balance trial, CP content among hay, corn and SBH were similar (between 10.4 and 10.6%); however, during the digestibility trial the CP content among feedstuffs was more variable (between 7.3 and 12.4%), due in part to the reduced-quality hay provided during the digestibility trial (Table 1). For these 2 trials, hay intake was not affected by supplementation, indicating that corn and SBH were supplemental to and not substitutive of the bermudagrass hay. In fact, supplementation increased ($p<0.02$) apparent DM and OM digestibilities in both trials, exemplifying the benefits of adding readily digestible protein and energy sources such as corn or SBH to low-quality hay. This increase in digestibility is due, at least in part, to the addition of readily digestible DM to the diet. Therefore, to better understand an individual supplement's impact on apparent digestibility, ruminal *in situ* disappearance was evaluated and is reported in the companion paper (Nguyen *et al*., 2007).

While apparent NDF and ADF digestibilities were unaffected ($p<0.12$) by supplementation during the balance trial, feeding $HULLS_D$ during the digestion trial increased apparent digestibility of NDF and ADF of the diet. The nutrient composition of the hay offered during the balance and digestion trial were similar, with lower-quality hay offered during the digestion trial; therefore the reason there was no effect on fiber digestibility during the balance trial is elusive.

The greater consumption of ground pelleted SBH by steers in the balance trial may have increased rate of passage, thereby decreasing ruminal retention and overall fiber digestion by ruminal microbes compared to the digestion trial. Weidner and Grant (1994) reported that non-forage fiber sources, such as SBH, may increase ruminal rate of passage and reduce NDF digestibility due to small particle size and greater specific gravity. However, when Hintz *et al*. (1964) fed equal amounts of hay and SBH, crude fiber digestibility increased 80.5%. This improvement in fiber digestibility has been attributed to a change in consistency of the ruminal hay mat (Welch, 1982,1986) for which, the addition of course fiber to the diet tends to trap SBH particles in the rumen resulting in a reduced rate of passage while increasing ruminal fermentation. The reduced-quality hay provided in the digestion trial may have allowed for greater SBH retention within ruminal mat, thereby increasing digestion. This explanation is partially supported by the companion *in situ* data (Nguyen *et al*., 2007), which indicated enhanced disappearance of hay ADF from nylon bags when supplements were offered.

Garleb *et al*. (1988) reported non-forage fiber sources have potential to replace dietary forage, due to their low concentration of lignin and because they contain a large portion of digestible fiber. Presumably, NRC (1996) prediction equations are based on an assumption similar to Garleb *et al*. (1988). Resulting in an under estimation of SBH feeding value. St. Louis *et al*. (2002) supplemented 24 mature non-lactating cows on a bermudagrass hay diet with either corn or SBH at 161% of recommended NE_m, as in the balance trial of the current project. St. Louis *et al*. (2002) reported that NRC level 2 equations tended to overestimate SBH intake by 0.5 kg d^{-1}. Further, it was reported that by feeding corn (4.08 kg d^{-1}) or SBH (8.016 kg d^{-1}), hay DMI was underestimated by 2.4 and 6.58 kg d^{-1}, respectively, thereby overestimating substitution effects of the supplements. During the current digestibility trial, substitution affects were not evident, however, associative affects appeared to be, as shown by greater ($p = 0.01$) apparent digestibilities of fiber fractions (Table 4) when steers consumed $HULLS_D$ compared to $CORN_D$. This may have been a direct result of formulating the $HULLS_D$ ration with the assumption that SBH contained approximately 80% energy of corn. This assumption was based on the energy utilization data collected during the balance trial (Table 2). However, the feeding value of SBH may still be under-estimated in the digestion trial of the current study. In the companion paper, Nguyen *et al.* (2007) reported a greater total ruminal VFA production by steers consuming $HULLS_D$, while molar proportions of propionate were similar to steers fed $CORN_D$. In addition, the *in situ* data showed enhanced disappearance of hay ADF from nylon bags when steers consumed $HULLS_D$. Further, SBH should be contributing to the overall protein balance of the animal by increasing microbial protein production, as implied by the increased total VFA concentrations.

El Shazly *et al.* (1961) reported a reduction in fiber digestibility when feeding starch with minimal NH_3-N availability. This is supported by Grant and Mertens (1992) who evaluated the effects of pure corn starch on *in vitro* fiber digestion. Compared to corn, the release of energy from SBH is likely slower and more uniform, which coincides with protein availability to enhance microbial fermentation. Soybean hulls contain approximately 45.0% ADF and 20.0% hemicellulose (Table 1) for the current 2 trials and although SBH are fibrous, the fiber is easily digested by ruminal microbes. Previous reports indicate that SBH contain very little lignin, cutin, waxes or other plant structures that can inhibit microbial activity (Hoover, 1986; Garleb *et al.*, 1988). Further, ground pelleted SBH have a relatively small particle size, thereby increasing the surface area and allowing for more efficient digestion of feed particles by fiber digesting microbial populations (Hoover, 1986; Klopfenstein and Owen, 1988). These factors likely lead to the increase in apparent digestibility of DM, OM, NDF and ADF during the current digestion trial.

Similarly, Bernard and McNeill (1991) fed a corn, soybean meal and corn silage diet to lactating dairy cows and substituted a portion of the basal diet with either corn gluten feed, soybean hulls, or wheat middlings (high fiber energy supplements) to provide 22% of DMI. They reported that substituting with SBH resulted in the greatest NDF and ADF digestibilities. Previous research indicates that SBH may increase intake by providing a source of energy and protein, which collectively facilitate optimum microbial fermentation (Martin and Hibberd, 1990; Grigsby *et al.*, 1992). Although, corn contains both energy and protein, it did not facilitate increased fiber digestibility in either of the present trials. Likely, the rapidly fermentable starch of corn caused alterations in microbial populations (Klopfenstein and Owen, 1988) resulting in negative associative effects. Further, the availability of protein and energy in corn may not have coincided, thus reducing fiber utilization. According to NRC (1996), optimum utilization of protein in the rumen should occur when protein and energy are digested simultaneously, circumstances that are often negated by the physical and chemical characteristics of many feedstuffs. It is likely that because of their different physical and chemical makeup, nutrients within corn and SBH are not available at the same rate, which further complicates an explanation for previous similarities in animal growth.

As a result of such differences between corn and SBH, NRC (1996) prediction equations can tend to over predict DMI (Garleb *et al.*, 1988; Moore *et al.*, 1997; St. Louis *et al.*, 2002). Corn may be degraded too rapidly to be effectively fed with SBM and/or hay, whereas energy from SBH is likely released at a time when more amino acids or NH_3 are available for rumen microbial populations. Efficient utilization of protein by microorganisms is reduced for low-quality forage diets when more available energy is used for microbial maintenance, rather than growth and proliferation. This is important to note because, bacterial protein can provide 50-100% of metabolizable protein required by beef cattle, depending on ruminal degradability of protein in the diet (NRC, 1996). For starch based diets, there tends to be reduced ruminal NH_3 and increased branched chain fatty acid concentrations, both of which are essential for cellulolytic bacteria to thrive (El Shazly *et al.*, 1961; Russell and Sniffen, 1984; Bach *et al.*, 1999). In the presence of SBH, fiber digestion was impeded when concentrations of branched chain fatty acids were artificially deprived (Bach *et al.*, 1999).

During the balance trial, steers consuming $HULLS_B$, had greater apparent CP and energy utilization than steers consuming HAY_B, or $CORN_B$, implying that the synthesis of microbial protein was more efficient when SBH were consumed. In like manner, Garces-Yepez *et al.* (1997) reported utilization and availability of TDN from soybean hulls to be 15-30% greater than availability of TDN from corn for improving performance of growing cattle. Because low-quality hay used in the present trial did not contain sufficient energy or CP for rapid weight gain, additional energy and protein supplied by supplements may have allowed for improved protein utilization as indicated by increased apparent CP digestibility.

Cumulatively, current and previous data implies that NRC prediction equations do not adequately estimate feed value of SBH, potentially due in part to assuming more substitution effects than actually occur. This is supported by Moore *et al.* (1997) and (St. Louis *et al.*, 2002) when intake predictions were over estimated for low energy and low protein diets. Similarly, Mertens (1987) fill-limiting intake model based upon dietary NDF predicted DMI to be 8.07 kg (4.43% BW) for hay alone, more than the observed 1.25% BW, DMI of the current trial (2.27 kg; Table 3). Several factors are known to control DMI, which are not related to chemical or physical attributes of the feed, such as specific animal physiological factors. Complex models to date have not been successful in predicting DMI more accurately than simple models (Mertens, 1994; Minson and Wilson, 1994). Until researchers develop more accurate methods to predict DMI, direct and indirect methods for predicting intake must be used. Further investigation is needed to verify accuracy of the current NRC (1996) level 2 estimates regarding DMI and apparent digestibility of SBH.

CONCLUSION

Soybean hulls, when incorporated the diets of cattle consuming low to moderate quality forages, can provide a readily degradable source of energy that is comparable to corn. However, unlike corn, the energy from soybean hulls is fiber based rather than starch based and the energy available from the digestion of soybean hulls may coincide with nitrogen availability, thereby facilitating a ruminal environment favorable to microbial populations responsible for fiber digestion. As a result, negative associative effects may be minimized and forages would be more completely and efficiently utilized, reducing supplementation requirements. Therefore, caution should be taken when using NRC (1996) level 2 equations to formulate diets containing soybean hulls. Until further investigation can be made regarding the accuracy of the NRC (1996) calculations, soybean hulls should be considered to contain between 80-90% NEm of corn.

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