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Effects of Increasing the Dietary Energy Density by Replacing Grass Hay with Soybean Hulls and Dried Distillers Grains with Solubles on Nutrient Digestibility and Rumen Fermentation

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Effects of increasing the dietary energy density by replacing grass hay with soybean hulls and dried distillers grains with solubles on nutrient digestibility and rumen fermentation[1]

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Summary

We hypothesize that soybean hulls (SH) and dried distillers grains with solubles (DDGS) can be used in lamb diets to increase dietary energy density compared with a traditional grass hay (GH) and soybean meal (SBM) diet without causing adverse effects on nutrient digestibility and rumen function. To test this hypothesis, four ruminally-cannulated wethers were used in a 4x4 Latin square design to determine the effects of replacing GH with SH and replacing SBM with DDGS on nutrient digestibility and rumen fermentation. All diets were formulated to contain 60% roughage and 40% concentrate on DM basis. Dietary roughage source, however, varied from completely GH to completely SH, and SBM was replaced by DDGS. Diets were formulated to contain 13.9% CP and an increasing amount of dietary energy as SH and DDGS replaced GH and SBM. The control diet was composed of 60% GH and 11.6% SBM **(GH-SBM)**. Treatment diets were 60% GH and 25.4% DDGS **(GH-DDGS)**; 20% GH, 40% SH, 15.3% DDGS **(SH40-DDGS)**; or no GH, 60% SH, 10% DDGS **(SH60-DDGS)**. The SH, protein concentrate, and mineral portion of the diet was pelleted and mixed with the chopped GH, when GH was included in the diet. The SH60-DDGS diet was a completely pelleted diet. This trial was divided into four periods. Lambs were allowed 14 d to adapt to their respective treatment diet which was offered twice daily. Following adaptation, total feed, fecal, and urine samples were collected and weighed during the 4-d collection period and subsequently composited for nutrient analyses. On the day following collection of fecal and urine samples, rumen fluid was collected at -2, 0, 1, 4, 8, 12 h relative to feeding, for analysis of VFA and ammonia concentrations. Replacing GH with SH improved DM digestibility and the DE content of the diet. Although increasing SH in the diet decreased rumen pH, ADF and NDF digestibility was not affected adversely. Lower rumen pH did favor increased propionate concentrations in the rumen. These data are consistent with the hypothesis that DDGS and SH can be used to increase the energy density of lamb diets compared to a traditional GH and SBM diet without affecting nutrient digestibility and rumen pH adversely.

Introduction

Feed costs account for a majority of all costs associated with livestock production. These costs can vary dramatically based on the feed ingredients selected. In some cases, co-products have been utilized successfully in livestock diets at a more economically-favorable rate than traditional feedstuffs. Increased production of biofuels results in increased availability of co-products such as dried distillers grains with solubles (DDGS) and soybean hulls (SH) that can be competitively-priced feed ingredients for inclusion in ruminant livestock diets. Although their inexpensive price makes co-products enticing, there is concern that high inclusion could result in negative effects on rumen function or nutrient digestibility that would lessen their acceptability as feed ingredients. Previous research by Garces-Yepez et al. (1997) demonstrated less negative associative effects when the highly-digestible fiber source SH was used as a supplement to increase the nutritional value of a Bermudagrass hay diet as compared with a high-starch supplement. Soybean hulls, because they are composed of high-digestible fiber and not starch, result in a less rapid decline in rumen pH and fewer negative effects on fiber-digesting microbes (Klopfenstein and

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Owen, 1987; Hoover, 1986). The objective of this experiment was to determine the effects of replacing GH with SH and SBM with DDGS on nutrient digestibility and rumen pH.

Materials and Methods

Four ruminally-cannulated wethers were used in a 4x4 Latin square design. All diets were formulated to contain 60% roughage and 40% concentrate. Dietary roughage source, however varied from completely GH to completely SH, and SBM was replaced by DDGS. Diets were formulated to contain 13.9% CP based on laboratory analyses of ingredients and an increasing amount of dietary energy as SH and DDGS replaced GH and SBM (Table 1). The control for this experiment was composed of 60% GH and 11.6% SBM **(GH-SBM)**. Treatment diets were 60% GH and 25.4% DDGS **(GH-DDGS)**; 20% GH, 40% SH, 15.3% DDGS **(SH40-DDGS)**; and no GH, 60% SH, 10% DDGS **(SH60-DDGS)**. The SH, protein concentrate, and vitamin-mineral portion of each diet was pelleted and fed mixed with the chopped GH, when GH was included in the diet. The SH60-DDGS diet was a completely pelleted diet.

Table 1. Ingredient composition of diets fed to metabolism wethers

	Dietary Treatment[1]			
	GH-SBM	GH-DDGS	SH40-DDGS	SH60-DDGS
	% Diet, DM basis			
Grass hay	60.00	60.00	20.00	0.00
Soy hulls	0.00	0.00	40.00	60.00
Corn	25.62	12.75	22.78	28.06
SBM	11.64	0.00	0.00	0.00
DDGS	0.00	25.39	15.34	10.00
Urea	1.00	0.45	0.40	0.40
Dical	0.39	0.05	0.40	0.60
Limestone	0.85	0.86	0.58	0.44
TMS[2]	0.50	0.50	0.50	0.50
	Nutrient composition, DM basis[3]			
CP, %	13.85	13.85	13.85	13.85
DIP, %[4]	45.60	45.76	45.70	45.93
ME, mcal/lb	5.28	5.52	6.20	6.53
Ca, %	0.68	0.68	0.68	0.68
P, %	0.34	0.34	0.34	0.34
NDF, %	45.56	51.99	46.10	43.10
ADF, %	27.60	29.49	29.54	29.53

[1] GH-grass hay, SBM-soybeam meal; DDGS- dried distillers grains with solubles; SH-soyhulls.
[2] Sodium chloride 92.6 ≤ 77.4%, zinc 8,999 ppm, manganese 7,199 ppm, iron 1125 ppm, iodine 90 ppm, cobalt 18 ppm, selenium 90 ppm, vitamin A 400,000 IU/lb, vitamin D3 40,000 IU/lb, vitamin E 2,000 IU/lb.
[3] Calculated from laboratory nutrient analyses of ingredients
[4] Degradable intake protein as a percent of dietary CP

This trial was divided into four, 19-d periods: 14-d adaptation, 4-d fecal and urine collection, and 1-d rumen fluid collection. For each period, lambs were allowed 14 d to adapt to their respective treatment diet that was offered twice daily at 800 and 2000 h. During the final 4 d of diet adaptation, lambs were acclimated to the metabolism crate, and *ad libitum* feed intake was established. During a 4-d collection period that followed adaptation, lambs were fed at 90% of *ad libitum* intake. All feed aliquots were weighed prior to the collection period, and a sub-sample was collected for nutrient analyses. During the 4-d collection period, feed refusals, fecal, and urine samples were collected and weighed before the daily 0800 h feeding. A 10% aliquot of from each of the 4 sample collection days was composited for fecal, and urine samples. The composite was analyzed for DM, CP, ash, ADF, and NDF. Gross energy (GE)

was determined using bomb calorimetery. By difference, digestibility of the nutrients was calculated. On the day following the final collection of urine and feces, rumen fluid samples were collected at -2, 0, 1, 4, 8, 12 h relative to feeding. Immediately following collection, rumen fluid pH was recorded and the sample was processed for analysis of volatile fatty acid (VFA) using gas chromatography and ammonia concentrations. After completion of a 19-d period, each diet was rotated to the next lamb and the adaptation and collection period was repeated. Upon completion of the 4 periods, each lamb had been sampled for each of the treatment diets.

Nutrient digestibility data were analyzed statistically as a Latin square with a model that accounted for variation that resulted from lamb, period, and treatment. Differences in least squares means for nutrient digestibilities that resulted from dietary treatment were separated using the PDIFF option of SAS. Ruminal pH, ammonia, and VFA data were analyzed statistically as repeated measures in time with a model that accounted for variation that resulted from lamb, period, treatment, time relative to feeding, and the interaction of time relative to feeding and treatment. Differences in least squares means for ruminal pH, ammonia, and VFA concentrations that resulted from dietary treatment, time, or their interaction were separated using the PDIFF option of SAS.

Results and Discussion

Nutrient digestibility. Including SH at 40 or 60 percent of the diet DM when using DDGS as the protein source improved DM digestibility ($P \leq 0.02$) and DE content of the diet ($P \leq 0.05$; Table 2). However, nitrogen (N) digestibility was decreased ($P \leq 0.02$) by replacing hay with SH and SBM with DDGS. Decreased N digestibility along with elevated rumen ammonia concentrations ($P \leq 0.01$) for SH-based diets, indicate a mis-match of dietary protein source and site of digestion. Digestibility of the ADF, NDF, FAT, and OM was not influenced by diet composition. Improvements in DMD and DE content could support improved lactation and growth performance.

Table 2. Nutrient digestibility for wethers fed increasing amounts of SH in combination with DDGS

	Dietary Treatments[1]					
Apparent total tract digestibility	GH-SBM	GH-DDGS	SH40-DDGS	SH60-DDGS	SE	$P <$
DM, %	66.92^{abc}	61.55^{c}	72.84^{ab}	74.84^{a}	2.39	0.03
OM, %	69.17	66.34	75.65	77.43	3.07	0.12
ADF, %	58.44	55.38	67.64	68.12	7.28	0.54
NDF, %	55.46	56.06	65.03	67.43	5.68	0.40
N, %	75.66^{a}	73.42^{a}	69.59^{b}	64.95^{b}	1.67	0.02
Ether extract, %	69.02	70.83	80.29	77.21	4.74	0.46
DE, mcal/lb	5.41^{c}	5.59^{bc}	6.45^{ab}	6.82^{a}	0.14	0.05
Ruminal metabolites						
Ammonia, mg/dL	9.76^{b}	8.03^{b}	11.04^{a}	10.97^{a}	0.77	0.02
Acetate : Propionate	3.74^{a}	2.78^{bc}	3.23^{b}	2.53^{c}	0.18	0.01
pH	6.55^{a}	6.60^{a}	6.20^{b}	5.80^{c}	0.04	0.01
	mmol / 100 mmol					
Acetate	65.62^{a}	62.22^{b}	63.17^{ab}	56.07^{c}	1.05	0.01
Propionate	17.93^{c}	23.45^{b}	20.87^{bc}	30.20^{a}	1.39	0.01
Butyrate	11.22^{ab}	9.92^{bc}	12.36^{a}	9.66^{c}	0.50	0.01
Isobutyrate	1.73^{a}	1.39^{b}	1.06^{c}	0.97^{c}	0.09	0.01
Valerate	1.15^{bc}	1.42^{ab}	1.10^{c}	1.70^{a}	0.10	0.01
Isovalerate	2.16^{a}	1.62^{b}	1.51^{b}	1.43^{b}	0.13	0.01

[1] GH - grass hay, SBM - soybeam meal; DDGS - dried distillers grains with solubles; SH - soyhulls.
[a,b,c,d] Means within a row having different superscripts differ ($P \leq 0.05$) as a result of dietary treatment.

Rumen pH. Rumen pH decreased for all diets following feeding (Figure 1). Diets with higher inclusion rates of SH had a lower rumen pH ($P \leq 0.01$) subsequent to feeding than diets that included hay as the roughage source. However, only when SH were included at 60% of the diet DM and were the only source of dietary fiber, did rumen pH reach a point at which concern would be raised regarding acidosis (pH ≤ 5.5). Additionally, the length of time that rumen pH remained at the threshold of concern for acidosis was minimal. Rumen pH can negatively influence microbial populations when it falls below pH 6.0 for cellulolytic bacteria and below 5.5 to maintain a substantial protozoa concentration (Church, 1998). The low rumen pH in the SH60-DDGS diet did not depress fiber digestibility as ADF and NDF digestibilities remained similar across treatments. The dairy NRC (2001) states that the concentration of NDF is inversely related to ruminal pH and that NDF generally ferments slower and is less digestible than nonfiber carbohydrates. We observed a similar inverse relationship between dietary NDF and pH.

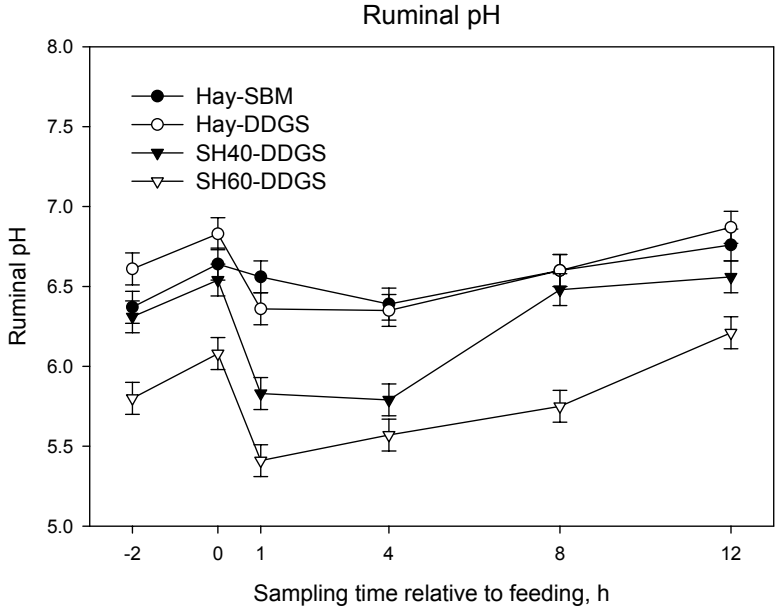

Figure 1. Summary of Rumen pH by Hour Post-Feeding

Our findings indicate a lower acetate:propionate ratio ($P \leq 0.01$) for the SH60-DDGS diet compared with the GH-SBM diet (Table 2). Bauman et al. (1971) and Esdale et al. (1968) also reported a shift in the molar concentration of acetate and propionate when feeding high-grain compared with high-fiber diets to lactating dairy cows. Davis (1967) measured acetate production in the rumen of cows fed high-forage compared with high-grain diets using an isotope dilution technique. The acetate concentration remained constant but propionate production increased. We speculate that replacing GH with SH resulted in increased propionate production that resulted in a shift in acetate:propionate. For lactating ewes and growing-finishing lambs, differences in the pH and acetate:propionate suggests that the SH-based diets would support greater milk production and more efficient gains, but could result in altered nutrient composition of milk.

Implications

These results imply that SH can be included in lamb diets as the sole fiber source without causing acidosis or deleterious effects on nutrient digestibility. Lower acetate:propionate ratios may result in improved growth efficiency in growing-finishing lambs and greater milk production in lactating ewes, however differences in rumen fermentation that resulted from ingredient composition may alter nutrient composition of milk. Additionally, intake was limited to 90% *ad libitum* and allowing *ad libitum* consumption may result lower rumen pH than that measured in this experiment.

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