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Josie Booth
Iowa State University

Howard Tyler
Iowa State University

Peggy Miller-Auwerda
Iowa State University

Jeanette Moore
North Carolina State University

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Josie Booth, Graduate Research Assistant
Howard Tyler, Associate Professor
Peggy Miller-Auwerda, Associate Professor, Iowa State University and
Jeanette Moore, North Carolina State University, Raleigh

Summary and Implications

Soybean hulls (SH) have been successfully fed to ruminant animals as an economical substitute for hay. This feedstuff is a source of highly digestible fiber and does not contain starch. The purpose of this trial was to evaluate SH as a replacement fiber in horse diets. Four cecally cannulated Quarter Horse geldings, aged 6 to 10 years and averaging 502 kg, were used in a 4x4 Latin Square design with 21-day periods. Diets consisted of alfalfa-bromegrass hay (14.4% CP, 58.1% NDF, 39.1% ADF) with the addition of either 0, 25, 50, or 75% unpelleted SH (13.1% CP, 60.6% NDF, 43.7% ADF). Diets were offered at 2% of bodyweight (as fed) daily and body weights were measured weekly. Cecal samples (90-min post-feeding) and total fecal collections (3 d) were taken at the end of each treatment period. Fecal collection bags were emptied every 6 hours and 10% of the total amount was frozen for later analysis. Total cecal VFA production increased linearly from 70 mM to 109 mM as proportions of SH in diets increased ($P = 0.02$). Proportions of propionate increased linearly ($P < 0.01$) and cubically ($P = 0.03$) with means of 15.7, 18.0, 16.6, and 21.9 moles per 100 moles total VFA for the 0, 25, 50, and 75% SH diets respectively. Proportions of butyrate decreased linearly ($P < 0.01$) from 5.3 to 3.9 moles per 100 moles total VFA. The acetate to propionate ratio decreased linearly ($P = 0.02$) and cubically ($P = 0.03$) with means of 4.9, 4.2, 4.9, and 3.3. Apparent digestibility of DM, OM, NDF, ADF, cellulose, and hemicellulose did not differ ($P > 0.24$) with treatment. Apparent digestibility of N decreased linearly ($P < 0.01$) as concentrations of SH increased in the diet, most likely due to increased cecal fermentation and microbial biomass production. Cecal pH decreased linearly ($P = 0.01$) from 7.00 to 6.45 as the level of SH increased, but there was no change (P linear = 0.68) for cecal ammonia (mean concentration of 3.85 mM). Soybean hulls appear to stimulate cecal fermentation and to be a suitable replacement for hay in equine diets. This may be an especially important finding for owners of geriatric horses that often have difficulty consuming roughages.

Introduction

Soybean hulls (soyhulls) may be added to equine rations as a source of fiber. This by-product feed is a source of highly digestible fiber. Due to thick cell walls, most of the polysaccharides are found in the NDF fraction of the plant. The NDF fraction of soyhulls contains large amounts of cellulose and hemicellulose; however, it contains relatively little lignin, allowing extensive bacterial fermentation. Soyhulls are high in pectins and other soluble fibers, but they contain relatively little starch. Therefore soyhulls provide adequate energy without some of the common management problems associated with high grain diets in both ruminant animals and horses. Due to the fibrous nature of the feedstuff, digestion of soyhulls occurs primarily in the cecum. Fiber in equine diets is important to maintain a stable hindgut environment that is less susceptible to acidosis.

Soyhulls have been successfully fed to ruminant animals as an economical substitute for grain and hay. Studies in beef cattle, meat goats, and dairy cows report favorable responses in the rumen environment when soyhulls are substituted for hay in their diets. The use of soyhulls in these diets also increased total rumen VFA and increased digestibility of DM, OM, and cell walls.

The purpose of this trial was to evaluate the use of soyhulls as a replacement fiber source for the horse, specifically evaluating effects of this feedstuff on digestibility and cecal environment.

Procedures

The Iowa State University Animal Care and Use Committee approved all procedures used in this experiment.

Horses and Treatments.

Cecally fistulated Quarter Horse geldings (n = 4) from the Iowa State University Horse Farm were utilized in a 4x4 Latin Square design with 21-day treatment periods. Horses ranged in age from 6 to 10 yr and body weight averaged 502 kg. Treatments consisted of 4 diets containing alfalfa-bromegrass hay with the inclusion of either 0, 25, 50, or 75% unpelleted soyhulls. Diets were offered at 2% of bodyweight (as-fed) daily. Body weight was measured weekly and diets were adjusted accordingly throughout the treatment period. Horses were fed twice daily and housed in individual stalls, receiving approximately 4 h of free exercise daily. Water and mineral sources were provided on an ad libitum basis. Vaccinations and deworming practices were consistent with farm protocol.

Sample Collection

Cecal samples were collected on the first day and on d 17 of each period. Samples were obtained approximately 90 min after the morning feeding. The cannula was opened and cecal contents (solid and liquid) were collected in an insulated container. Cecal samples were immediately analyzed for pH using a Corning 314 hand-held pH meter. Cecal fluid samples were then frozen until thawed for further analysis at North Carolina State University.

Total fecal collections were obtained for the last 3 d of each treatment period; collections began on days 18, 39, 60, and 81 of the trial. During the 3-d collection period horses were fitted with fecal collection bags and housed individually in tie stalls. Fecal samples were removed from th bags every 6 h. For each 24 h, a 10% subsample of feces (by weight) was collected, placed in individual bags, and frozen for later analysis. Samples of soyhulls, hay, and diet refusals were also obtained throughout the total collection period and stored for further analysis.

Chemical Analysis

Hay, soyhull, diet refusal, and fecal samples were analyzed for DM, OM, and Kjeldahl-N according to AOAC (1995) protocols. Crude protein was calculated as a percentage of Kjeldahl-N x 6.25. All samples were analyzed for NDF, ADF, cellulose, lignin, and hemicellulose according to procedures described for use in an Ankom fiber apparatus.

Cecal VFA concentrations were determined by a Varion 3800 gas chromatograph. The gas chromatograph was fitted with a Nikol fused silica capillary column (15 m; 0.53 mm i.d.; 0.5 µm film thickness; Supleco, Bellefonte, PA). Cecal ammonia concentrations were determined via colorimetric procedures used for Kjeldahl N.

Statistical Analysis

Data were analyzed using the PROC GLM procedure of SAS. Data from all animals were included in the analysis. Linear, quadratic, and cubic effects were tested in the form of contrasts. In all cases, probabilities less than 0.05 were considered to be statistically significant. Probability values between 0.05 and 0.15 were considered to be trends towards significance.

Results and Discussion

Diet Composition

Composition of hay, soyhulls, and diets used throughout the experiment are listed in Table 1. Soyhulls utilized in this trial had a similar chemical composition to published values (12.2% CP, 66.3% NDF, and 49.0% ADF; NRC, 1989) indicating there was little contamination with soybean meal. Soyhulls are often variable in composition, making comparisons between trials difficult. The composition of hay used in this trial was consistent with values typical for a medium-quality grass-legume mix, and chemical composition of the hay was comparable to the soyhull product with the exception that soyhulls had 70% less lignin.

No health problems were encountered during the trial. Unpelleted soyhulls are quite dusty, suggesting possible risks to respiratory health. However, no apparent respiratory difficulties were encountered during this trial. There were also no apparent difficulties with respect to gastrointestinal health.

Intake and Body Weight

Horses readily consumed the soyhulls with no significant refusals of dietary treatments (Table 2). Measured intake of soyhulls as a percentage of diet DM was 97% of what was offered for the 25% soyhull diet and 99% for the 50% soyhull diet; however, it was only 93% for the 75% diet, indicating this level is at the upper end of what is acceptable to horses.

Digestibility

Digestibilities of DM, OM, NDF, ADF, cellulose, and hemicellulose did not differ ($P > 0.25$) with increasing inclusion rates of soyhulls in the diet (Table 3). Moore-Colyer et al. (2002) observed greater total tract DM, OM, CP, ADF, and NDF digestibility of SH when compared to hay cubes fed as the sole forage source. In that trial, total tract digestibility was calculated using the mobile bag technique rather than total fecal collection, and the hay cubes fed were of lower quality (8.2% CP, 62.3% NDF, 35.4% ADF) than the grass-legume hay fed in our trial.

Digestibility lignin ($P = 0.04$) decreased as inclusion rates of soyhulls increased (Table 3). Lignin is not a source of nutrients and is present in the feed in low amounts. Digestibility of N ($P < 0.01$) also decreased as dietary SH level increased (Table 3). The decreased N digestibility is most likely due to increased production of microbial biomass in the cecum; microbial N is lost in the feces because the cecum is beyond the site of protein digestion. The increase in VFA production (Table 4) suggests an increase in microbial biomass occurred.

This experiment demonstrated that inclusion of soyhulls in forage-based diets for horses at limited intake does not influence the digestibility of DM, OM, NDF, and ADF. This is different than what has been found with ruminant animals. For example, increases in the digestibility of NDF, ADF, N, OM, and DM is observed in the diets of goats as proportions of soyhulls in diets increased.

Cecal Fluid

Total cecal VFA ($P < 0.02$) production increased as proportions of soyhulls in diets increased (Table 4). This suggests that soyhulls are indeed highly fermentable in the cecum and this increased production of VFA would contribute to the energy needs of the horse. The increase in total VFA concentrations observed in our trial is similar to that seen in previous studies with similar diets fed to ruminants and rabbits.

This increase in total VFA production suggests that additions of soyhulls to horse diets increased microbial biomass in the cecum, contributing to increased fecal N output and reducing the apparent digestibility of N. Fecal N concentrations (1.4, 1.7, 1.8, and 2.5% N for diets containing 0, 25, 50, and 75% SH respectively) increased as dietary inclusion rates of SH increased ($P < 0.02$). Increased fecal N was observed in rabbits receiving SH as the sole forage source compared to those fed alfalfa hay.

Proportions of cecal propionate increased linearly ($P < 0.01$) and cubically ($P = 0.03$). Cecal propionate concentrations from horses fed the 0% SH diet in our trial were similar to values observed in other trials when horses were fed grass-legume hay mixture. Addition of soyhulls to diets causes an increase in propionate similar to that observed when concentrate is added to rations. Acetate to propionate ratios also decreased both linearly ($P = 0.02$) and cubically ($P = 0.03$) as the inclusion rates of soyhulls increased.

Butyrate concentrations decreased linearly ($P < 0.01$) as proportions of soyhulls in diets increased. Cecal butyrate concentrations observed in our trial are in agreement with values reported in ponies fed clover either with or without oats. In our trial, there were no significant differences ($P > 0.16$) between treatments for proportion of acetate, isobutyrate, isovalerate, and valerate.

Increases in proportions of propionate and decreases in butyrate suggest changes in microbial populations based on changes in available substrate and pH of the cecum. Cecal pH decreased linearly ($P = 0.01$) as inclusion rates of soyhulls in diets increased. Cecal ammonia concentrations ($P = 0.68$) were not linearly different with treatment (Table 4), but the cubic response was significant ($P = 0.01$). Ammonia concentrations in our trial are higher than those observed for ponies fed timothy hay.
Cecal pH decreased as inclusion rates of soyhulls in diets increased. However, this decrease in pH was not large and did not approach levels indicative of subclinical acidosis (less than 6).

Soyhulls appear to be an acceptable replacement for up to 70% of the total forage in diets for horses. This feedstuff is economically feasible, readily available, palatable, and digestible. Horses in our study readily consumed all experimental diets with no adverse reactions, but longer-term feeding experiments should be conducted to confirm the safety of these feeding recommendations. Soybean hulls appear to stimulate cecal fermentation and are a suitable replacement for hay in equine diets.

Table 1. Composition of ingredients used in diets for horses

Item	Hay	SH[a]	Diet[b]			
			0% SH	25% SH	50% SH	75% SH
DM, %	92.22	91.71	92.22	92.09	91.97	91.84
	---------- DM basis ----------					
OM, %	91.88	94.78	91.88	92.61	93.33	94.06
NDF, %	58.12	60.57	58.12	58.73	59.34	59.95
ADF, %	39.12	43.71	39.12	40.26	41.41	42.56
Cellulose, %	30.94	40.98	30.94	33.45	36.96	38.47
Lignin, %	7.40	2.19	7.40	6.10	4.79	3.49
Acid Insol. Ash, %	0.66	0.42	0.66	0.60	0.54	0.48
CP, %	14.43	13.11	14.43	14.10	13.77	13.44

[a]Soybean hulls.
[b]Diets were 0% SH = 0% soybean hulls + 100% hay; 25% SH = 25% soybean hulls + 75% hay; 50% SH = 50% soybean hulls + 50% hay; 75% SH = 75% soybean hulls + 25% hay. Nutrient values are calculated based on analyses of hay and soybean hulls.

Table 2. Intake and body weight of horses receiving diets containing soybean hulls

Item	Diet[a]				SEM	Linear *P* value
	0% SH	25% SH	50% SH	75% SH		
Total intake, %BW	1.8	1.8	1.8	1.6	0.1	0.08
Soyhulls, % total intake	0.0	24.3	49.4	70.0	1.2	< 0.01
BW, kg	505.8	501.7	505.8	493.3	4.0	0.11

[a]Diets were 0% SH = 0% soybean hulls + 100% hay; 25% SH = 25% soybean hulls + 75% hay; 50% SH = 50% soybean hulls + 50% hay; 75% SH = 75% soybean hulls + 25% hay.

[b]Horses were offered 1.8% of body weight as feed DM.

Table 3. Apparent digestibility (%) of diets containing soybean hulls offered to horses

Item	Diet[a]				SEM	Linear *P* value[b]
	0% SH	25% SH	50% SH	75% SH		
DM	64.58	65.85	65.10	64.55	2.97	0.95
OM	66.71	67.83	67.02	65.43	2.60	0.70
NDF	55.30	58.56	58.40	60.49	3.30	0.34
ADF	48.90	53.51	53.25	55.77	4.13	0.31
Cellulose	60.86	64.22	61.65	62.02	2.31	0.93
Lignin	28.91	30.36	23.47	8.27	5.80	0.04
Hemicellulose	69.88	71.79	67.43	67.72	1.90	0.25
N	78.85	75.37	70.79	58.70	2.85	<0.01

[a]Diets were 0% SH = 0% soybean hulls + 100% hay; 25% SH = 25% soybean hulls + 75% hay; 50% SH = 50% soybean hulls + 50% hay; 75% SH = 75% soybean hulls + 25% hay.
[b]Quadratic and cubic *P*-values were all greater than 0.18.

Table 4. Cecal fluid measurements from horses fed diets containing soybean hulls

Item	Diet[a]				SEM	Linear *P* value
	0% SH	25% SH	50% SH	75% SH		
Total VFA, mM	70.32	86.25	79.09	108.50	7.15	0.02
Acetate, mol/100 mol	76.88	75.37	78.73	72.73	1.29	0.17
Propionate mol/100 mol	15.74	18.04	16.55	21.89	0.87	<0.01
Acetate:Propionate ratio	4.90	4.20	4.89	3.34	0.29	0.02
Isobutyrate, mol/100 mol	0.87	0.63	0.33	0.54	0.25	0.30
Butyrate mol/100 mol	5.30	4.98	4.12	3.89	0.18	<0.01
Isovalerate mol/100 mol	0.80	0.51	0.09	0.38	0.25	0.19
Valerate, mol/100 mol	0.42	0.48	0.18	0.58	0.14	0.78
pH	7.00	6.70	6.74	6.45	0.10	0.01
NH_3, mg/100 mL	4.32	3.41	4.37	4.10	0.15	0.68

[a]Diets were 0% SH = 0% soybean hulls + 100% hay; 25% SH = 25% soybean hulls + 75% hay; 50% SH = 50% soybean hulls + 50% hay; 75% SH = 75% soybean hulls + 25% hay.