By-product feeds for meat goats: Effects on digestibility, ruminal environment, and carcass characteristics

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ABSTRACT: Crossbred wether goats (n = 24; 50% Boer, 6 per diet) initially averaging 27.4 ± 0.4 kg were fed either wheat middlings (wheat midds), soybean hulls (soyhulls), or corn gluten feed at 1% BW (as-fed) along with orchardgrass hay (10.7% CP) offered to ad-libitum consumption for 72 d followed by 5 d total fecal collection. The Control (hay) diet was supplemented with 5.7% soybean meal to bring total dietary protein to 12.5%, by-products were brought to a higher Ca:P ratio with limestone or dicalcium phosphate to make total dietary Ca:P 1.5:1, and soybean meal was added to soyhulls to bring them up to 17% CP (wheat midds = 17% and corn gluten feed = 21% CP). Total DMI (916 g/d ± 57 or 3.2% ± 0.2 BW) did not differ ($P > 0.92$) among treatments. Initial BW ($P = 0.25$), final BW ($P = 0.48$), and ADG ($P = 0.56$) did not differ for the four treatments. Carcass weight was greater ($P = 0.05$) for goats fed soyhulls (16.0 kg) or wheat midds (15.6 kg) as compared with goats fed the hay diet (14.5 kg), with carcass weight from goats fed corn gluten feed being intermediate (15.3 kg, SEM = 0.3 kg). Carcass grade did not differ ($P = 0.80$) and averaged 5.42 ± 0.4. Dressing percentage tended ($P = 0.12$) to be lower for goats fed the hay diet (46.4%) compared with soyhull (48.3%), corn gluten feed (48.3%), or wheat midd (48.8%) diets (SEM = 0.7). Ruminal pH was highest ($P < 0.01$) for goats fed the hay diet (6.52) and lowest for goats fed wheat midds (6.23) with soyhull (6.41) and corn gluten feed diets (6.35) being intermediate (SEM = 0.05). Digestibility of DM (70.1 ± 2.5%), OM (70.3 ± 2.6%,), CP (75.5 ± 2.0%), GE (68.5 ± 2.7%), NDF (68.1 ± 3.0%), ADF (65.4 ± 3.4%), cellulose (70.1 ± 2.9%), and lignin (31.1 ± 8.2%) did not differ ($P > 0.15$). Total ruminal VFA did not differ (86.0 ± 6.1 m*M*, $P = 0.59$), but acetate:propionate ratio was higher ($P < 0.01$) for hay (3.1) and soyhull diets (3.3) than for corn gluten feed (2.4) and wheat midd diets (2.4, SEM = 0.11). Ruminal ammonia (mg/100 mL) was lower ($P < 0.01$) for goats fed hay (15.4) and soyhull diets (11.6) than those fed corn gluten feed (25.2) and wheat midd diets (23.0, SEM = 1.35). Ruminal pH was lower for goats fed the by-products, but remained above 6. Serum urea nitrogen (mg/100 mL) averaged 21.0 ± 1.0 ($P = 0.11$) with soyhulls tending to be lowest (19.3) and corn gluten feed tending to be highest (22.8). Soyhulls, corn gluten feed, and wheat midds appear to be viable feed ingredients for meat goat diets.

Key Words: Carcass Quality, Corn Gluten Feed, Digestibiilty, Goats, Soybean Husks, Wheat Milling Residues

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Introduction

The meat-goat industry has grown recently (Oman et al., 1999; Cameron et al., 2001), providing many new opportunities for additional income on diversified farming operations. Meat-goat producers will need feeds that are economical and easily managed. Grain-based commercial supplements may not be economical for growing and finishing meat goats, and feeding these traditionally high-starch supplements may lead to reduced ruminal pH and fiber digestibility (Garces-Yepez et al., 1997). Some by-product feeds contain highly digestible fiber, which could potentially provide adequate gain without the management problems associated with high-starch (high-grain) diets. Several studies have evaluated by-products in diets for goats (Madrid et al., 1997; Maity et al., 1999), but these studies have primarily been in developing countries, and a minimal amount of work has been done with by-products widely available in the United States.

The purpose of this study was to evaluate by-product feeds that are readily available to meat-goat producers in the United States. The goal was to find feeds that could be economically included in growing and finishing meat-goat diets while minimizing negative changes in the ruminal environment attributed to feeding high-starch diets to ruminant animals. Additional characteristics sought were high digestibility, low cost, accept-

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Table 1. Chemical composition of ingredients used in diets for meat goats

	Ingredient				
Item	Hay	Soyhull mixture[a]	Corn gluten feed mixture[a]	Wheat midd mixture[a]	Soybean meal mixture[a]
	Performance phase (72 d)				
DM, %	92.5	90.3	91.9	90.7	92.7
OM, %[b]	93.5	94.1	85.5	89.3	79.7
CP, %[b]	10.7	15.7	21.2	16.9	47.0
NDF, %[b]	71.3	59.8	36.5	32.8	12.2
ADF, %[b]	36.8	41.2	10.1	9.2	4.6
Cellulose, %[b]	32.5	38.8	8.2	6.9	3.6
Lignin, %[b]	4.2	2.5	1.2	2.6	0.8
GE, mcal/kg[b]	4.5	4.2	4.1	4.2	4.0
IVTDMD[c], %[b]	67.2	94.5	91.9	82.7	99.0
IVTOMD[c], %[b]	67.8	94.8	92.4	82.6	99.4
Ca, %[b]	0.34	0.86	2.50	2.11	5.86
P, %[b]	0.28	0.33	1.37	1.21	0.79
Ca:P	1.21	2.61	1.84	1.74	7.42
	Digestibility phase (5 d)				
DM, %	92.8	91.2	92.3	91.3	92.7
OM, %[b]	93.7	94.5	85.7	89.9	82.9
CP, %[b]	10.6	18.0	21.6	16.9	48.3
NDF, %[b]	68.8	58.5	33.7	31.1	10.0
ADF, %[b]	36.1	39.3	9.2	8.6	3.9
Cellulose, %[b]	32.0	37.4	7.7	6.5	3.6
Lignin, %[b]	4.2	2.0	0.9	2.2	0.1
GE, mcal/kg[b]	4.4	4.2	4.1	4.2	4.1
IVTDMD[c], %[b]	66.4	94.6	91.7	83.7	99.2
IVTOMD[c], %[b]	66.4	95.0	92.2	83.8	99.6

[a]The by-products were mixtures as follows (DM basis): soybean meal = 91.8% soybean meal and 8.2% limestone; soyhulls = 87.5% soyhulls, 12.8% soybean meal, and 0.7% dicalcium phosphate; corn gluten feed = 94.3% corn gluten feed and 5.7% limestone; wheat midds = 94.6% wheat midds and 5.4% limestone.
[b]DM basis.
[c]IVTDMD = in vitro true DM disappearance and IVTOMD = in vitro true OM disappearance (48-h batch incubation with steer ruminal fluid and buffers; terminated with NDF).

able palatability, and a high-quality finished product (carcass).

Materials and Methods

Crossbred wether goats (n = 24; 50% Boer, 6 per diet) averaging 27.4 ± 0.4 kg at initiation of the study were individually fed one of four dietary treatments: either wheat middlings (wheat midds), soybean hulls (soyhulls), or corn gluten feed at 1% BW (as-fed) along with orchardgrass hay (10.7% CP) offered on an ad-libitum consumption basis, or the Control (hay) diet. The Control (hay) diet was supplemented with soybean meal to bring total dietary CP to 12.5% by feeding 5.7 g soybean meal for every 100 g hay offered. Diets were brought to a higher Ca:P ratio by adjusting supplement Ca and P levels with limestone (corn gluten feed, 5.7%; wheat midds, 5.4% limestone) or dicalcium phosphate (soyhulls, 0.7% dicalcium phosphate). Protein concentration of soyhulls was brought to a similar concentration as wheat midds by adding 12.8% soybean meal. Protein concentrations of the by-product feeds after minerals (and soybean meal for the soyhull diet) were added were: soyhulls, 17%; wheat midds, 17%; and corn gluten feed, 21% (Table 1). The design was a randomized complete block with two weight blocks (heavy and light; diets were assigned randomly within weight block).

The goats were fed once daily throughout the entire trial. Goats readily consumed the by-product feeds, which were offered 30 min before hay. Goats were fed individually in indoor, raised, slotted floor pens and had access to trace-mineralized salt blocks and automatic waterers. The project received IACUC approval before initiation and was conducted at North Carolina State University's Metabolism Educational Unit in Raleigh.

At the initiation of the trial, goats were moved into the metabolism barn and allowed 12 d to adapt to their pens. Following the adaptation period, goats were weighed in the morning on two consecutive days before feeding. After 72 d on trial, goats were again weighed before feeding on two consecutive days to determine BW gain. Goats were also weighed every 2 wk during this performance phase to adjust the amount of by-product to be fed.

Following the performance phase, goats were fitted with canvas fecal-collection bags (Figure 1) and allowed 8 d to adapt to them before initiation of a 5-d fecal collection. Fecal-collection bags were emptied twice daily. Daily feces were weighed, mixed, and a constant percentage for each animal was taken to be dried at

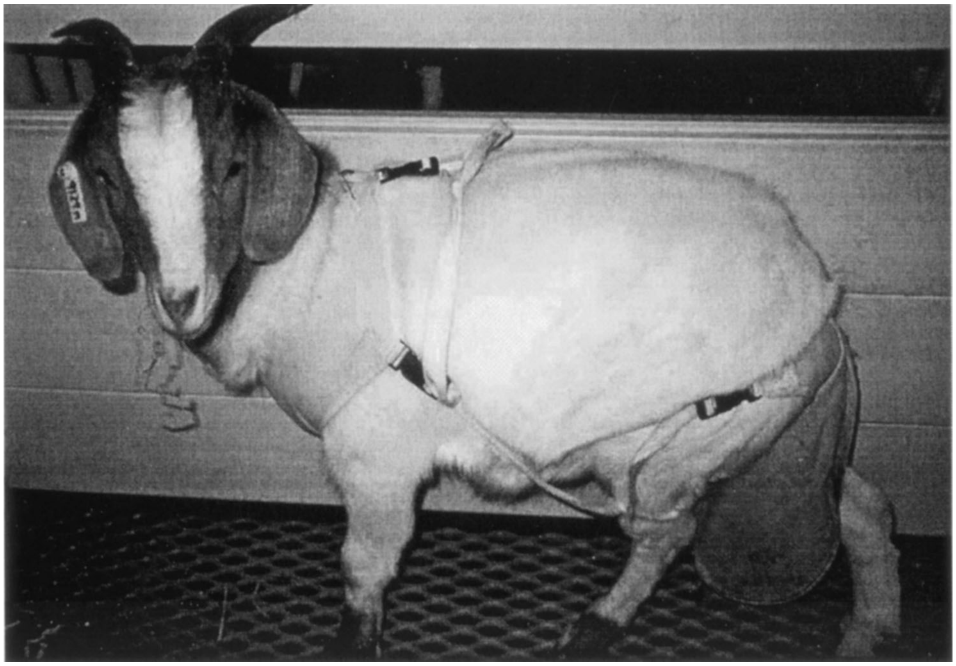

Figure 1. The canvas fecal-collection apparatus consisted of a collar portion and a detachable fecal-collection bag with a zipper to facilitate emptying.

55°C; this was followed by a 48-h air equilibration to determine air-dried fecal output. Daily fecal samples were pooled relative to 24-h air-dried fecal output (the same percentage from each day's output) to provide a representative sample of the 5-d fecal output. Throughout both the performance and digestion phases, feed and orts were weighed daily.

One day after ending the fecal collection and 2.4 h after feeding, ruminal fluid samples were taken by rumenocentesis, and blood samples were obtained for serum urea nitrogen determination Rumenocentesis was a modification of the procedure described by Nordlund and Garret (1994), which involved extracting a minimum of 5 mL ruminal fluid from the ventral sac using a 5-cm, 14-gauge needle and a 20-mL syringe without local anesthetic. Blood samples were taken from the jugular vein using 10-mL vacutainer tubes (Becton Dickinson Vacutainer Systems, Franklin Lakes, NJ) with 20-gauge, 2.54-cm needles and no additives. Serum was obtained by allowing blood to clot under refrigeration for a minimum of 6 h, by centrifuging tubes at 3,600 × *g* for 10 min, by decanting into clean tubes, and then by storing frozen until analyzed. Ruminal pH was determined immediately after obtaining samples using a Cardy Twin pH meter (Spectrum Technologies, Inc., Plainfield, IL). Ruminal fluid samples were then placed in a crushed ice/water solution to stop fermentation and then frozen until they were thawed in preparation for analysis.

On the day after ruminal fluid and blood sampling were taken (d 99), goats were graded live as described by Luginbuhl et al. (2000), weighed for determination of dressing percentage, and then moved to a local abattoir to be harvested. Goat carcass quality grades were determined based on leanness and conformation using a system similar to that currently used to grade lamb carcasses (Romans et al., 1994). The numeric system was: 1 = prime+, 2 = prime, 3 = prime-minus, 4 = choice+, 5 = choice, 6 = choice-minus, 7 = good+, 8 = good, 9 = good-minus, 10 = utility+, 11 = utility, and 12 = utility-minus.

Preparation of Samples for Chemical Analysis. Hay and supplements were collected weekly during the entire trial, ground through a 5-mm screen in a Wiley Mill (Thomas Scientific, Swedesboro, NJ), and pooled by month for chemical analysis. During the 5-d fecal collection period, samples of hay, supplements, and orts were taken daily, composited, and subsampled. All feed, ort, and fecal samples were ground through a 1-mm screen in a Wiley Mill prior to laboratory analyses.

Ruminal fluid samples were thawed and centrifuged at 3,600 × *g* for 10 min. Supernate (8 mL) was mixed with 25% metaphosphoric acid (2 mL). The mixture was covered, held at room temperature for 30 min, centrifuged again at 3,600 × *g* for 10 min, and analyzed for ammonia and VFA.

Laboratory Analyses. Hay and supplement samples from the performance phase, and hay, supplement, ort and fecal samples from the fecal-collection phase were analyzed for DM, OM, Kjeldahl-N, and GE according to AOAC (1995), and CP was calculated as percentage Kjeldahl-N × 6.25. All samples were analyzed for NDF, ADF, and acid detergent lignin as described by Van Soest et al. (1991) modified (Komarek et al., 1994) for use in an Ankom fiber apparatus (Ankom Technology, Fairport, NY). In vitro true DM and OM disappearance (IVTDMD and IVTOMD) was determined using a 48-

h incubation with steer ruminal inoculum and buffer (Tilley and Terry, 1963) in a batch fermenter (Ankom Technology, Fairport, NY) with NDF termination.

Ruminal VFA concentrations were determined on a Varion 3800 gas chromatograph (Varian Chromatography Systems, Walnut Creek, CA) using a Nikol fused silica capillary column (15 m; 0.53 mm i.d.; 0.5 μm film thickness; Supelco, Bellefonte, PA). Ruminal ammonia was determined by the colorimetric procedure used for Kjeldahl N (AOAC, 1995). Serum urea N was determined colorimetrically by an automated, diacetyl-monoxime method (Marsh et al., 1965).

Statistical Analyses. Data were analyzed by the PROC GLM procedure of SAS (SAS Inst. Inc., Cary, NC) with class variables including diet and weight block (heavy or light weight block). The model was diet | block (diet, block, and diet × block interaction) when all 24 animals were used (performance and ruminal measurements), which means the degrees of freedom were distributed as diet = 3, block = 1, diet × block = 3, and residual (error term) = 16. No diet × block interactions were significant ($P > 0.26$). For the digestibility measurements, only 20 animals could be used due to loss of fecal-collection bags during some of the 24-h periods. If the animal did not have three or more days of collection, it was eliminated from the analyses. Three of the four goats that could not be used were on the corn gluten feed diet, leaving only one animal in the heavier weight block for the corn gluten feed digestibility measurements. Due to this problem, BW was run as a covariate for digestibility measurements (rather than using weight block), and the model included diet and BW (BW was not a class variable), which means df were distributed as diet = 3, BW covariate = 1, and residual (error) = 15. For all measurements, the least-squares means were separated by least significant difference (pdiff) only when the overall F value was <0.05.

Results

Diet Composition. Composition of hay and modified supplements during the performance and digestibility phases of the experiment are presented in Table 1. Initial composition of the by-products before they were adjusted for CP, Ca, and P content was: soyhulls = 11.8% CP, 63.5% NDF, 45.1% ADF, 0.65% Ca, and 0.16% P; wheat midds = 17.5% CP, 37.1% NDF, 12.8% ADF, 0.16% Ca, and 1.11% P; corn gluten feed = 23.2% CP, 33.2% NDF, 10.9% ADF, 0.19% Ca, and 1.19% P (DM basis). Adjustments in CP and Ca:P ratio resulted in supplements of similar CP for both soyhulls and wheat midds, whereas the corn gluten feed supplement was higher in CP. The ratio of Ca to P was similar among the modified supplements (Table 1).

Weight Gain and Carcass Measurements. There were no differences in final live weights ($P = 0.45$) or ADG ($P = 0.56$) for the goats fed the four different diets (Table 2). There were differences in carcass weight ($P = 0.05$) with carcasses from goats fed the soyhulls or wheat midds weighing more than those fed the hay diet. There was a tendency ($P = 0.12$) for dressing percentage to be higher for goats fed any of the by-products as compared with the hay diet, but there were no differences ($P = 0.80$) in carcass grade.

Intake and Digestibility. Dry matter intake during the 72-d performance phase of the experiment averaged 916 ± 57 g/d (Table 3, $P = 0.92$), which was 3.2 ± 0.2% BW ($P = 0.99$). Hay intake was lower ($P = 0.05$) for the supplemented diets. Dry matter intake during the digestibility phase was slightly higher because it was the last 5 d of the experiment (1,153 ± 99 g/d, $P = 0.73$).

The number of days (out of 5 d possible) that were used in the digestibility calculations did not differ ($P = 0.44$) for the four diets and averaged 4.3 ± 0.3 d (Table 3).

Digestibility of DM, OM, GE, NDF, ADF, cellulose, and lignin did not differ ($P > 0.28$) for the four diets (Table 3). Digestibility of CP ($P = 0.15$) tended to be higher for the hay diet.

Ruminal Fluid and Blood Measurements. Serum urea nitrogen values tended ($P = 0.11$) to be highest for goats fed the corn gluten feed diet, and goats fed this diet also had higher ruminal ammonia concentration ($P < 0.01$) as compared with those fed the hay and soyhull diets (Table 4).

There were no differences in total VFA in the rumen ($P = 0.59$), but there were differences in proportions of acetate relative to propionate ($P < 0.01$) with the soyhull and hay diets producing higher acetate:propionate ratios than the corn gluten feed or wheat midd diets. There was a tendency for a higher proportion of butyrate in the ruminal fluid of goats fed the corn gluten feed diet and a lower proportion of butyrate in goats fed the hay diet ($P = 0.06$). Proportions of isobutyrate and isovalerate were higher ($P < 0.01$) in the ruminal fluid of goats fed the hay or corn gluten feed diets as compared with those fed the soyhull or wheat midd diets. The proportion of valerate was highest ($P < 0.01$) in the ruminal fluid of goats fed corn gluten feed, intermediate for those fed wheat midds, and lowest for goats on the hay and soyhull diets.

Discussion

The by-products were readily consumed by the goats within 30 min in most cases even though the dustiness of the by-products might suggest they would be unpalatable. No health problems were noted with the goats despite quite high phosphorus content of both the wheat midds and corn gluten feed. The by-products were supplemented with limestone to correct Ca:P ratio, and that may have helped prevent clinical urinary calculi. For longer feeding periods, however, urinary calculi might still be a concern as it has been noted that goats generally do not develop symptoms until after being fed 100 d on diets that tend to favor calculi development (Unanian et al., 1985). Another concern of feeding high P feeds is the effect on the environment, because excess P in manure may be undesirable when soil P is high.

Table 2. Weight and carcass measurements of meat goats fed hay plus soybean meal or hay plus soybean hulls, corn gluten feed, or wheat middlings

	Diet					
Item	Hay with soybean meal	Soyhull mixture[d]	Corn gluten feed mixture[d]	Wheat midd mixture[d]	SEM	P value
Final weight, kg	31.3	33.0	31.7	31.9	0.75	0.45
ADG (72 d), g/d	33	49	51	38	10	0.56
Carcass weight, kg	14.5[a]	16.0[b]	15.3[a,b]	15.6[b]	0.34	0.05
Dressing percentage	46.4	48.3	48.3	48.8	0.70	0.12
Carcass grade[c]	5.7	5.3	5.5	5.2	0.37	0.80

[a,b]Superscripted means within a row that do not have a common superscript differ ($P < 0.05$).
[c]Numeric system for carcass grades: 1 = prime+, 2 = prime, 3 = prime-minus, 4 = choice+, 5 = choice, 6 = choice-minus, 7 = good+, 8 = good, 9 = good-minus, 10 = utility+, 11 = utility, 12 = utility-minus.
[d]By-product mixtures were fed at 1% BW as-fed.

Corn gluten feed may also be high in sulfur, so total dietary sulfur content should be considered in areas where the water or other diet ingredients are high in sulfur (Kunkle et al., 2000). Sulfur concentrations in our ingredients (prior to Ca, P, and CP adjustment) as determined by the Northeast Dairy Herd Improvement Forage Testing Laboratory (Ithaca, New York) were: hay, 0.15%; soyhulls, 0.11%; corn gluten feed, 0.45%; wheat midds, 0.19%; and soybean meal, 0.44% (DM basis).

Hay, wheat midd, and soyhull diets were all similar in CP concentration and exceeded the goats' requirements (NRC, 1981). The corn gluten feed diet was higher in CP, but the decision was made to not increase the CP concentration of the wheat midd, soyhull, and hay diets further to make all diets isonitrogenous due to the excessive cost of oversupplementing with CP.

Others have shown that supplementation of forages with by-product concentrates (wheat bran or citrus pulp) increased growth rates, intake, and digestibility (Madrid et al., 1997; Maity et al., 1999) in goats, but in those studies diets were based on straws and were deficient in CP (<5%), such that supplementation helped correct a protein deficiency. Adeloye (1994, 1995) demonstrated that supplementing goats on low-quality forage with cow pea husks improved performance and digestibility more than grain-based supplements. In the present study, the forage quality was higher in CP (10.7%) and in vitro digestibility, which may explain the lack of a response in digestibility and rate of gain.

In a study with cattle, Garces-Yepez et al. (1997) reported that supplementing low-quality bermudagrass hay with either soyhulls or wheat midds improved animal performance when fed at 25 or 50% of projected TDN intake. In that same study, sheep were used to determine diet digestibility, and both by-products improved OM digestibility at both feeding levels. Sudweeks (1977) also showed that in sheep fed bermudagrass hay, a level of soybean mill feed similar to the level of soyhulls in the current study resulted in improved digestion coefficients.

Using cattle, Grigsby et al. (1993) showed that increasing the level of soyhulls in a bromegrass hay diet increased diet DM and NDF digestibility in a linear fashion, and although ruminal pH was decreased to nearly 6.2 on the highest level of soyhulls (60% of the diet), it apparently was not low enough to negatively impact fiber digestion. In the current study, ruminal pH determined 2-h post-feeding was lower when wheat midds or corn gluten feed were fed, but it was not lower than the hay diet when soyhulls were the supplement. The pH of ruminal samples from intact animals has been questioned because of salivary contamination, but the technique we used (rumenocentesis) involves taking a sample directly from the ventral sac that gives a more accurate assessment of ruminal acidity (Nordlund and Garret, 1994).

Grigsby et al. (1992) also reported VFA levels and noted that increasing soyhulls in the diet resulted in an acetate:propionate ratio slightly higher than the all-hay diet, which is in agreement with the present study. In contrast, wheat midds and corn gluten feed, which have less fiber and more starch than soyhulls, resulted in a decrease in acetate:propionate ratio in the current study, which is in agreement with studies conducted with cattle (Sunvold et al., 1991; Poore and Mueller, 1996).

Lack of a significant response for growth rate or digestibility and only a slight improvement in carcass weight and dressing percentage may be due to a species difference, as most published studies with the three by-products fed in the current study were done with either cattle or sheep. Goats have a faster passage rate of particulates than either cattle or sheep (Uden et al., 1982), and the fibrous by-products may not be retained in the rumen long enough to achieve their high-potential digestibility.

Garces-Yepez et al. (1997) reported substitution rates (percentage change = g change in hay intake per 100 g of supplement intake; a substitution rate of −100% means hay intake was reduced by the same amount that supplement intake was increased) that were quite low for

Table 3. Intake and digestibility of by-product diets fed to meat goats

Item	Diet				SEM	P value
	Hay with soybean meal	Soyhull mixture	Corn gluten feed mixture	Wheat midd mixture		
	Performance phase (72 d)					
DMI, g/d	905	950	896	914	57	0.92
Supplement DMI, g/d	58[a]	267[b]	263[b]	267[b]	3.5	<0.01
Hay DMI, g/d	847[b]	683[a]	633[a]	647[a]	56	0.05
DMI, % BW	3.2	3.2	3.2	3.2	0.19	0.99
	Digestibility phase (5 d)					
Days in calculation[c,d]	4.0	4.7	4.0	4.3	0.34	0.44
No. goats in calculation[c]	5	6	3	6	—	—
DMI, g/d	1,159	1,186	1,228	1,076	99	0.73
Supplement DMI, g/d	76[a]	279[b]	282[b]	282[b]	6.0	<0.01
Hay DMI, g/d	1,083	907	946	793	96	0.20
DMI, % BW[d]	3.6	3.7	3.8	3.3	0.29	0.68
Digestible OM intake, g/d	763	794	800	704	92	0.85
CP intake, g/d	153	149	165	133	11	0.26
Apparent digestibility, %						
DM	70.8	70.8	68.5	69.6	2.5	0.92
OM	70.6	70.8	69.0	70.1	2.6	0.97
CP	78.7	72.5	74.0	76.7	2.0	0.15
GE	68.7	68.6	67.4	68.7	2.7	0.99
NDF	70.0	70.8	66.0	64.8	3.0	0.37
ADF	67.0	69.2	62.9	61.5	3.4	0.31
Cellulose	71.3	73.4	68.8	66.5	2.9	0.28
Lignin	35.2	32.6	24.3	29.4	8.2	0.85

[a,b]Superscripted means within a row that do not have a common superscript differ ($P < 0.05$).
[c]Only goats with three or more complete days of fecal collection were used in the calculation of intake and digestibility. Of the 24 goats, four were not used in the calculations.
[d]Body weight was not used as a covariate for determination of "Days in Calculation" or "DMI as a percentage of BW."

either wheat midds or soyhulls fed to both cattle and sheep. At the low rate of feeding, substitution rate was –2% for wheat midds and –25% for soyhulls fed to cattle, and –32% for wheat midds and –16% soyhulls fed to sheep. As a result, feeding the two by-products improved digestible OM intake. Other studies with cattle have also shown that supplementing diets with soyhulls improved digestibility of diets and digestible OM intake

Table 4. Serum and ruminal fluid (obtained by rumenocentesis) measurements from meat goats fed by-product diets

Item	Diet				SEM	P value
	Hay with soybean meal	Soyhull mixture	Corn gluten feed mixture	Wheat midd mixture		
Serum urea N, mg/100 mL	21.55	19.25	22.83	20.37	0.99	0.11
Ruminal fluid						
pH	6.52[a]	6.41[a,b]	6.35[b]	6.23[b,c]	0.05	<0.01
NH_3, mg/100 mL	15.35[a]	11.56[a]	25.21[b]	22.98[b]	1.35	<0.01
Total VFA, m*M*	79.31	89.94	85.08	89.57	6.13	0.59
Acetate, mol/100 mol	67.60[a]	69.06[a]	61.69[b]	63.28[b]	0.70	<0.01
Propionate, mol/100 mol	22.17[a]	21.40[a]	26.06[b]	26.72[b]	0.66	<0.01
Acetate:propionate ratio	3.06[a]	3.26[a]	2.38[b]	2.38[b]	0.11	<0.01
Isobutyrate, mol/100 mol	1.06[a]	0.65[b]	0.97[a]	0.064[b]	0.08	<0.01
Butyrate, mol/100 mol	6.64	7.11	7.66	7.05	0.24	0.06
Isovalerate, mol/100 mol	1.44[a]	0.80[b]	1.41[a]	0.81[b]	0.10	<0.01
Valerate, mol/100 mol	1.09[a]	0.97[a]	2.21[c]	1.50[b]	0.06	<0.01

[a,b,c]Superscripted means within a row that do not have a common superscript differ ($P < 0.05$).

(Galloway et al., 1993; Grigsby et al.; 1993). In contrast, substitution rates in the present study were –78%, –104%, and –96% for soyhulls, corn gluten feed, and wheat midds, respectively, and digestible OM intake was not improved.

Implications

Goats readily ate soybean hulls, corn gluten feed, and wheat middlings at 1% of body weight, and all three appear to be viable feed ingredients for meat goats when diets are adequate in protein and are balanced for Ca and P. We saw no improvements in performance or digestibility because goats ate less hay when fed the by-products. More studies with goats are needed because these results are different than what would be expected based on cattle and sheep studies.

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