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Soybean Hulls as a Dietary Fiber Source for Dogs¹

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ABSTRACT: In Exp. 1, soybean hull samples were obtained from nine sources across the United States and analyzed for nutrient content to determine their suitability for inclusion in dog diets. Compositional data revealed variation in both the amount of total dietary fiber (TDF; 63.8 to 81.2%) in the soybean hulls and the ratio of insoluble:soluble fiber (5.0:1 to 15.4:1). Crude protein content varied widely among sources, ranging from 9.2 to 18.7%. An *in vivo* trial (Exp. 2) was conducted using a premium dog diet containing 3.0, 4.5, 6.0, 7.5, or 9.0% soybean hulls (DM basis). There was a negative linear effect ($P < .05$) of soybean hull inclusion in the diet on DM, OM, TDF, and GE total-tract digestibilities, as well as on calculated ME. Crude protein and fat digestibilities were unaffected by treatment. Based on these results, ileally cannulated dogs were fed diets containing 6.0, 7.5, or 9.0% soybean hulls (DM basis) in addition to

diets containing either 0% supplemental fiber or 7.5% beet pulp (Exp. 3). Nutrient digestion at the ileum was unaffected by inclusion of supplemental fiber. Total tract digestion of DM, OM, and GE was lower ($P < .05$) for diets containing supplemental fiber when compared with the diet containing 0% fiber. Crude protein and fat digestibilities were unaffected by treatment. There was no difference in nutrient digestibility between those diets containing soybean hulls and a diet containing beet pulp. Soybean hull inclusion in the diet resulted in a negative linear effect ($P < .05$) on calculated ME, in addition to lowering ME ($P < .05$) when compared with the 0% fiber control diet. Calculated ME for dogs fed a 7.5% beet pulp-containing diet was lower ($P < .05$) than that for dogs fed the soybean hull-containing diets. Results indicate that soybean hulls can be an effective dietary fiber source in dog diets.

Key Words: Dogs, Soybean Husks, Diet, Fiber, Digestibility, Metabolizable Energy

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Introduction

The inclusion of an optimal amount of dietary fiber in canine diets can improve fecal characteristics, lipid digestibility, energy metabolism criteria, and digesta mean retention time (Sunvold et al., 1995). Beet pulp is a commonly used fiber source in premium dog diets; however, soybean hulls are being researched as an alternative fiber source, partially because soy fiber

has been shown to result in beneficial health effects in humans and other animals (Lo, 1989). These health effects result from the insoluble and the soluble fiber fractions. Insoluble fiber, which acts via physical means, can accelerate digesta passage and relieve constipation. Soluble fiber, which acts via chemical means, can improve glucose tolerance and nutrient digestibility. Because 2.4 million tons of soybean hulls per year are produced by U.S. soy-processing plants, they are readily available and economical to use (Muzilla et al., 1989).

The objective of Exp. 1 was to analyze soybean hulls from a variety of sources for total dietary fiber (TDF), insoluble fiber, and soluble fiber concentrations. The objective of Exp. 2 was to determine the effects of varying levels of soybean hull inclusion in premium-type dog diets on nutrient intake, digestibility, and fecal characteristics. Of the diets fed in Exp. 2, three were chosen for further study in a second animal experiment. The objective of Exp. 3 was to use ileally cannulated dogs to determine an optimal concentration of soybean hull inclusion in dog diets, based on

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Table 1. Composition of soybean hulls obtained from different sources (Exp. 1)

Source	DM, %	OM, %	CP, %	Fiber, %			
				TDF ¹	Insoluble	Soluble	Ratio of insoluble to soluble
A	94.3	94.8	11.7	79.6	71.4	8.2	8.7:1
B	91.3	94.7	9.2	77.3	70.0	7.3	9.6:1
C	92.0	95.1	12.3	80.7	72.2	8.5	8.5:1
D	90.0	93.9	14.1	75.3	66.1	9.2	7.2:1
E	94.7	94.8	18.7	72.4	66.3	6.1	10.9:1
F	94.7	94.7	15.5	63.8	59.9	3.9	15.4:1
G1	91.3	94.9	13.0	76.4	63.7	12.7	5.0:1
G2	91.3	94.3	14.9	75.5	68.4	7.1	9.6:1
G3	91.8	94.8	12.5	81.2	68.8	12.4	5.5:1

¹Total dietary fiber.

the total-tract and ileal digestibility values and fecal characteristics, and to compare these values with digestibility values obtained from beet pulp.

Materials and Methods

Experiment 1. Nine samples (90 kg each) of soybean hulls were obtained from seven processing plants. A portion of each was ground through a Wiley mill (Model 3375-E10, Thomas/Wiley, Swedesboro, NJ; 2-mm screen) and analyzed for DM, OM, N (AOAC, 1985), and TDF (Prosky et al., 1984). Insoluble fiber was determined using the method of Prosky et al. (1992). Soluble fiber was calculated by subtracting insoluble fiber from TDF. Values are presented in Table 1.

Experiment 2. Thirty beagles (mean body weight, 12.2 ± 2.5 kg; mean age, 5.5 yr) were grouped by weight and sex and randomly assigned to five diets (six dogs per treatment). There were 15 neutered males, 2 intact males, and 13 intact females. Dogs were housed individually in stainless steel metabolism cages in a temperature-controlled room (mean temperature, $20 \pm 1^\circ\text{C}$). A 12-h dark:12-h light cycle was used. The cages measured 1.0 m^3 . The floor of the cage was wire mesh, with urine drip trays underneath. The Institutional Animal Care Advisory Committee, University of Illinois, Urbana-Champaign, approved all animal care procedures.

Premium-type, extruded, isonitrogenous diets were tested in a completely randomized design. Soybean hulls from source G1 (Table 1), with a 5:1 insoluble:soluble fiber ratio, were chosen for inclusion in the diets. Tables 2 and 3 provide the ingredient and chemical composition of the diets, respectively. Brewer's rice was replaced by soybean hulls to obtain concentrations of 3.0, 4.5, 6.0, 7.5, and 9.0% of the DM.

A 10-d diet adaptation phase preceded a 4-d total collection of feces. Initially, all dogs received ad

libitum access to 250 g (as-fed basis) at each of two feedings (0800 and 1600). Feed refusals from the previous meal were collected and weighed immediately before the next feeding. As the adaptation period progressed, the amount of offered feed was reduced to limit the amount of feed refusals. Water was available ad libitum. Dogs were weighed at the beginning of the experiment, the beginning of the collection period, and the end of the experiment.

At each feeding during the collection period, feces were collected, weighed, and frozen. Additionally, feces were given fecal characteristic scores, following the method used by Sunvold et al. (1995). At the end of the collection phase, fecal samples were composited, lyophilized, and ground through a Wiley mill (Model 3375-E10; 2-mm screen). All feed refusals were

Table 2. Ingredient composition of diets fed to dogs in Exp. 2 and 3

Ingredient	% of DM
Poultry by-product meal	44.5
Brewer's rice ^a	36.1
Poultry fat	15.7
Dehydrated egg	2.2
Sodium chloride	.7
Potassium chloride	.4
Choline chloride	.1
Vitamin premix ^b	.1
Mineral premix ^c	.1

^aSoybean hulls were substituted for brewer's rice to obtain desired concentrations of 3, 4.5, 6, 7.5, and 9% (Exp. 2) or 0, 6, 7.5, and 9% (Exp. 3). Beet pulp was substituted for brewer's rice to obtain a 7.5% beet pulp treatment in Exp. 3.

^bProvided per kilogram of diet: vitamin A, 10,947 IU; vitamin D, 891 IU; vitamin E, 57.5 IU; vitamin K, .6 mg; thiamin, 7.6 mg; riboflavin, 11.9 mg; pantothenic acid, 18.5 mg; niacin, 93.2 mg; pyridoxine, 6.6 mg; choline, 2284.2 mg; biotin, 112.4 mg; folic acid 1142.1 μg ; vitamin B-12, 164.9 μg .

^cProvided per kilogram of diet: manganese, 17.4 mg; iron, 284.3 mg; copper, 17.2 mg; cobalt, 2.2 mg; zinc, 166.3 mg; iodine, 7.5 mg; selenium, .2 mg.

Table 3. Chemical composition of diets fed to dogs in Exp. 2 and 3

Item	Diet						
	Soybean hulls, % of DM						Beet pulp, % of DM
	0	3.0	4.5	6.0	7.5	9.0	7.5
Dry matter, %	94.0	95.1	93.2	94.1	94.0	94.4	96.3
	% of DM						
Organic matter	93.5	93.6	93.5	93.3	93.2	93.2	92.8
Crude protein	34.5	35.0	35.1	35.6	35.9	35.2	35.1
Fat	23.3	23.8	23.3	23.2	23.7	23.7	24.2
Total dietary fiber	.4	3.05	4.09	6.03	7.32	8.88	7.03
Gross energy, kcal/g	5.58	5.72	5.69	5.81	5.67	5.63	5.53

collected for analysis and used to calculate nutrient intakes and digestibilities. Feces and feed refusals were analyzed for DM, OM, N (AOAC, 1985), TDF (Prosky et al., 1984), and fat (Budde, 1952; AACC, 1975). Carbohydrate (**CHO**) content exclusive of fiber was calculated with the following equation: $CHO = OM - (fat + TDF + CP)$. From these values, CHO intake and digestibility values were calculated. Gross energy of feeds, feed refusals, and feces was determined with bomb calorimetry (Model 1261, Parr Instrument, Moline, IL). Metabolizable energy was calculated using AAFCO (1995) formulas. The equation used is as follows: $ME = [GE_f - GE_e - (P \times CF)] / A$, where GE_f is the gross energy of the food, GE_e is the gross energy of the feces, P is the grams of protein digested, CF is the correction factor for energy lost in the urine (1.25 kcal/g protein digested for dogs), and A is the amount of food consumed.

Data were analyzed as a completely randomized design according to the GLM procedure of SAS (1996). Treatment means were compared using orthogonal contrasts to determine linear and quadratic effects of soybean hull inclusion in the diets.

Experiment 3. Five ileally cannulated dogs were used in a 5×5 Latin square design. Due to health problems not related to the treatments, there was one missing observation in the last period. Dogs were female hound mixes (mean body weight, 24.0 ± 3.5 kg; mean age, 2.6 ± 1.1 yr) fitted with T-type cannulas following the procedure of Walker et al. (1994). The Institutional Animal Care Advisory Committee, University of Illinois, Urbana-Champaign, approved all surgical and animal care procedures. After surgery, dogs were monitored for a minimum 2-wk recovery period. Dogs were housed individually in 1.1×3.3 -m pens in a temperature-controlled room with a 16-h light:8-h dark cycle. Room temperature was maintained at $22 \pm 2^\circ\text{C}$. Periods consisted of a 6-d diet adaptation, followed by a 4-d fecal and ileal fluid collection. The 6.0, 7.5, and 9.0% soybean hull diets used in Exp. 2 also were fed in this experiment.

Dogs were offered 250 g (as-is basis) at each of two feedings each day, at 0800 and 2000. Beginning on d 3

of the period, dogs were dosed orally before each feeding with a gelatin capsule containing .5 g of chromic oxide. Water was available ad libitum. During each collection period, feed refusals were collected prior to each feeding. Ileal contents were sampled for 4 d during each period. Beginning at 0800 on d 1, contents were collected three times daily at 4-h intervals. On each day of the period, collection time was advanced 1 h. The collections were made in sterile sampling bags (Fisher Scientific, Pittsburgh, PA) attached to the cannula with a rubber band. Each collection lasted for 1 h. To encourage digesta flow, dogs were restrained only with Bite-Not collars (Bite-Not Products, San Francisco, CA) and allowed unrestricted movement. The collars were used to prevent the dogs from removing the bags. After removing the collection bag, the cannula site was rinsed thoroughly with a Betadine:warm water solution. Total feces excreted were collected from the floor of the pen on each of the four collection days. Feed refusals, ileal contents, and feces were frozen immediately after collection. At the end of each period, refusals were composited, ground through a Wiley mill (Model 3375-E10; 2-mm screen), and stored for analysis. Ileal samples were composited, refrozen, and then lyophilized. Fecal samples were lyophilized and then composited. After lyophilization, the fecal and ileal samples were ground through a Wiley mill (Model 3375-E10; 2-mm screen). All samples were analyzed for nutrient content following the procedures outlined above. The chromic oxide marker was used to determine fecal output and ileal DM flow, from which nutrient digestibilities were calculated. The concentration of chromium in the fecal and ileal samples was measured according to the method of Williams et al. (1962). Fecal samples were scored following the method outlined by Sunvold et al. (1995). Data were analyzed as a 5×5 Latin square design by the GLM procedure of SAS (1996). Means were separated using the following nonorthogonal contrasts: 1) 0% fiber vs 6.0, 7.5, and 9.0% soybean hulls; 2) 7.5% beet pulp vs 6.0, 7.5, and 9.0% soybean hulls.

Results and Discussion

Experiment 1. Nutrient composition data for the soybean hulls are reported in Table 1. Dry matter ranged from 94.7% (source E) to 90.0% (source D), OM ranged from 95.1% (source C) to 93.9% (source D), and CP ranged from 18.7% (source E) to 9.2% (source B). Total dietary fiber values ranged from 81.2% (source G3) to 63.8% (source F). The soybean hulls from source F contained much less TDF than did soybean hulls obtained from other sources, and the next lowest TDF value was 72.4% (source E). Insoluble fiber ranged from 72.2% (source C) to 59.9% (source F), and soluble fiber ranged from 12.7% (source G1) to 3.9% (source F). Calculating the insoluble:soluble fiber ratio revealed a wide range of values, from 15.4:1 (source F) to 5.0:1 (source G1). The average TDF values (75.8%) for these sources are the same as values (75.6 and 75.0%) determined by Lo (1989) and Slavin (1991), respectively. However, insoluble and soluble fiber values varied widely. Lo (1989) reported values of 59.4% (insoluble fiber) and 15.4% (soluble fiber). Slavin (1991) reported values of 71.0% (insoluble fiber) and 4.0% (soluble fiber). The average values determined from our soybean hull samples (insoluble fiber, 67.4%; soluble fiber, 8.4%) more closely approximate those values reported by Slavin (1991). In the animal experiments, the soybean hulls with the lowest insoluble:soluble fiber ratio (5.0:1) were used. This source was chosen to obtain the highest amount of soluble fiber in dog diets. The insoluble:soluble fiber ratio in soybean hulls used in

this experiment (5.5:1) is similar to that of beet pulp (7:1 for the sample used in this experiment), a commonly used fiber source in commercial dog food.

Experiment 2. The diets were formulated to represent a high-quality, premium dog food. These diets were fed to dogs to obtain nutrient intake and digestibility values. Brewer's rice was included in the basal diet at 36.1% of DM, and a portion of the brewer's rice was replaced with soybean hulls in experimental diets to obtain desired fiber concentrations (Table 2). Total dietary fiber concentrations were 3.05, 4.09, 6.03, 7.32, and 8.88% of DM (Table 3). These values were slightly overestimated, and the degree of overestimation increased with increasing levels of fiber in diets. Test diets resulted in similar CP and fat concentrations. Dry matter, OM, CP, fat, and GE intakes were numerically lower for the 6.0 and 7.5% soybean hull diets, but there were no differences among treatments (Table 4). As expected, there was a linear increase ($P < .05$) in TDF intake and a linear decrease ($P < .05$) in CHO intake. This decrease is due to the substitution of soybean hulls for brewer's rice.

Nutrient digestibilities varied among diets (Table 4). Dry matter, OM, and GE digestibilities decreased linearly ($P < .05$) with increasing level of soybean hulls, and TDF digestibility increased linearly ($P < .05$). Crude protein, fat, and CHO digestibility were not affected by treatment. Total dietary fiber digestibility increased linearly across diets. The negative TDF digestibility value resulting from feeding the 3.0% soybean hull diet was due perhaps to the very

Table 4. Nutrient intakes and digestibilities by dogs fed diets containing soybean hulls (Exp. 2)

Item	Diet					SEM
	Soybean hulls, % of DM					
	3.0	4.5	6.0	7.5	9.0	
Intake, g/d						
Dry matter	288	266	226	232	267	31
Organic matter	269	249	211	217	248	28.9
Crude protein	100.6	93.4	80.4	83.4	93.9	10.93
Fat	68.5	62.0	52.4	55.1	63.2	7.33
TDF ^{ab}	8.8	10.9	13.6	17.0	23.5	7.58
GE, kcal/d ^c	1,645	1,514	1,311	1,318	1,500	176.6
Total-tract digestibility, %						
Dry matter ^b	84.8	84.8	80.6	80.9	82.5	1.19
Organic matter ^b	88.8	88.5	85.1	85.0	86.1	.92
Crude protein	83.7	84.3	81.4	82.7	83.2	1.27
Fat	95.6	95.6	95.5	95.6	96.0	.52
TDF ^{ab}	-17.4	-.8	2.4	11.1	28.5	7.57
GE ^{bc}	89.5	89.3	86.6	86.5	87.4	.85
ME, kcal/g ^{bd}	4.74	4.71	4.67	4.54	4.55	.04

^aTotal dietary fiber.

^bLinear effect of soybean hull concentration ($P < .05$).

^cGross energy.

^dCalculated metabolizable energy (AAFCO, 1995).

low concentrations of TDF in the diet and in the feces of dogs fed that diet. When converted to a percentage, values become inflated. The 9.0% soybean hull diet did not result in digestibility values statistically higher than did either the 6.0 or 7.5% soybean hull diets. Additionally, the 6.0 and 7.5% soybean hull diets resulted in DM intake values that were approximately 16% lower than those for the 3.0, 4.5, and 9.0% soybean hull diets. Because of these lower intake values, endogenous losses might account for a larger portion of excreted material, which artificially lowers nutrient digestibility calculations.

A comparison of the 7.5% soybean hull diet to similar diets used in previous research revealed that soybean hulls have a more pronounced effect on nutrient digestibility than do other fiber sources. Fahey et al. (1990a), in a study analyzing the nutritional effects of graded levels of dietary beet pulp, determined that a dietary inclusion of 7.5% beet pulp resulted in digestibility values of 86.2 (DM), 89.0 (OM), 88.8 (N), 95.4 (fat), and 56.1% (TDF). The diet containing this level of beet pulp actually provided 12.0% TDF, with other fiber-containing ingredients being used in addition to beet pulp. Fahey et al. (1992) corroborated their earlier results in a study examining the effects of beet pulp and oat fiber on nutrient digestibilities. Dietary levels of 7.5% beet pulp resulted in digestibilities of 85.8 (DM), 89.0 (OM), 87.4 (N), 97.0 (fat), and 61.1% (TDF). Dietary levels of 7.5% oat fiber resulted in digestibility values of 82.7 (DM), 85.7 (OM), 88.5 (N), 97.4 (fat), and 39.7% (TDF), which are intermediate to those values resulting from beet pulp and soybean hull inclusion. It should be noted, however, that inclusion of 7.5% beet pulp resulted in 11.2% TDF and that inclusion of 7.5% oat fiber resulted in 13.6% TDF, indicating that other dietary ingredients were supplying additional fiber. Muir et al. (1996) used a diet containing 7.5% supplemental beet pulp, which provided 8.6% TDF, in a trial studying the effects of varying fiber sources in dog food. The digestibility values resulting from feeding the beet pulp-containing diet were somewhat lower than those from previously

mentioned trials that examined this level of beet pulp inclusion. Muir et al. (1996) reported digestibility values of 81.5 (DM), 86.3 (OM), 83.9 (CP), and 94.3% (fat) that very closely resemble values resulting from feeding the control diet in the present trial. However, 35.0% TDF digestibility determined by Muir et al. (1996) was much higher than for our 7.5% soybean hull diet (11.1%).

The metabolizable energy content of the diets decreased linearly ($P < .05$). This is because brewer's rice is hydrolytically digested by the dog and is more extensively digested, whereas the major component of soybean hulls (i.e., fiber) must be fermentatively digested by microbes in the large bowel of dogs.

Dietary treatments resulted in some numerical variation in amount of feces produced (Table 5). As expected, the 9.0% soybean hull diet resulted in the highest fecal excretion, and the 4.5% soybean hull diet and the 6.0% soybean hull diet resulted in the lowest fecal excretion. Fecal consistency decreased linearly ($P < .05$) as soybean hull inclusion increased. Fecal scores of approximately 2.5 are considered the most desirable. The effects of fiber on fecal characteristics have no real impact on the overall health of the animal; however, most pet owners consider liquid, unformed stools (those with higher fecal scores) to be symptomatic of unhealthiness. Any fiber source included in canine diets must therefore result in good fecal characteristics in addition to having no deleterious effect on nutrient digestibility. Our data indicate that soybean hulls can be added to diets at relatively high levels with no deleterious effects on fecal characteristics.

Comparing the 7.5% soybean hull diet with diets containing 7.5% beet pulp revealed that soybean hulls result in approximately the same quantity of fecal output when DM intake is considered. Fahey et al. (1992) reported that a diet containing 7.5% beet pulp resulted in 232 g/d of wet fecal output and 63 g/d of dry fecal output. Dietary inclusion of 7.5% oat fiber resulted in a wet fecal output of 183 g/d and dry fecal output of 75 g/d. These values seem much higher than fecal output resulting from the feeding of our control

Table 5. Fecal characteristics of dogs consuming diets containing soybean hulls (Exp. 2)

Item	Diet					SEM
	Soybean hulls, % of DM					
	3.0	4.5	6.0	7.5	9.0	
Wet fecal output, g/d	125	121	111	116	152	18.9
Dry fecal output, g/d	44	41	44	43	46	5.7
Fecal consistency ^{ab}	3.0	2.7	2.4	2.5	2.5	.16

^a1 = hard, dry pellets: small, hard mass; 2 = hard, formed, dry stool: remains firm; 3 = soft, formed, moist: softer stool that retains shape; 4 = soft, unformed: stool assumes shape of container, pudding like; 5 = watery: liquid that can be poured.

^bLinear effect of soybean hull concentration ($P < .05$).

Table 6. Nutrient intakes by dogs fed diets containing soybean hulls and beet pulp (Exp. 3)

	Diet					SEM
	Soybean hulls, % of DM				Beet pulp, % of DM	
	0	6.0	7.5	9.0	7.5	
Intake, g/d						
Dry matter	332	342	322	348	338	30.0
Organic matter	311	319	300	324	313	27.9
Crude protein	114.4	121.9	115.8	122.5	118.7	10.5
Fat	77.2	79.4	76.4	82.5	81.8	7.1
TDF ^{ab}	.1	20.6	23.6	30.9	23.8	2.5
GE, kcal/d ^c	1,852	1,988	1,827	1,959	1,869	167.8

^aTotal dietary fiber.

^b0 vs 6.0, 7.5, and 9.0% soybean hulls ($P < .05$).

^cGross energy.

diet. However, the DM intake in the experiment studying beet pulp (432 g/d) and oat fiber (428 g/d) was approximately twice the DM intake of dogs fed the control diet in this experiment (232 g/d). Fahey et al. (1990a) reported similar fecal output values for a diet containing 7.5% beet pulp (252 g/d, wet fecal output; 65 g/d, dry fecal output). The DM intake (469 g/d) was more than twice that of our experimental control.

Experiment 3. Nutrient intake data are reported in Table 6. Comparison of the DM, OM, fat, CP, and GE intakes of dogs fed no soybean hulls to dogs fed the

soybean hull-containing diets revealed no differences. The 7.5% beet pulp diet resulted in 23.8 g/d TDF intake by the dogs. This closely matched the 23.6 g/d intake resulting from ingestion of the 7.5% soybean hull diet.

Ileal digestibility coefficients for selected nutrients varied numerically, but there were no differences among treatments (Table 7). The 7.5% soybean hull diet resulted in nutrient digestibility values that were very similar to those values for the 7.5% beet pulp treatment. Both the 7.5% soybean hull diet and the 7.5% beet pulp diet resulted in the lowest ileal TDF

Table 7. Nutrient digestibilities by dogs fed diets containing soybean hulls and beet pulp (Exp. 3)

Item	Diet					SEM
	Soybean hulls, % of DM				Beet pulp, % of DM	
	0	6.0	7.5	9.0	7.5	
Ileal digestibility, %						
Dry matter	76.6	80.8	73.0	72.4	70.9	4.83
Organic matter	81.8	84.4	77.7	77.2	76.1	3.98
Crude protein	71.1	78.2	70.9	71.4	68.5	5.11
Fat	94.5	95.7	94.4	94.4	91.6	1.93
TDF ^a	—	18.9	-.7	8.4	-2.0	17.91
GE ^b	83.7	87.0	81.6	81.1	79.1	3.38
Total-tract digestibility, %						
Dry matter ^{cd}	87.8	81.1	82.6	80.2	82.2	1.30
Organic matter ^{cd}	91.8	85.4	86.4	84.1	86.6	1.08
Crude protein	85.8	85.2	84.3	82.0	81.8	1.56
Fat	95.9	94.2	95.2	93.6	94.8	.66
TDF ^a	—	4.7	22.8	22.3	34.1	7.51
GE ^{bc}	92.2	87.5	88.0	86.0	87.0	.82
ME, kcal/g ^{cde}	4.77	4.72	4.61	4.48	4.46	.04

^aTotal dietary fiber.

^bGross energy.

^c0 vs 6.0, 7.5, and 9.0% soybean hulls ($P < .05$).

^d7.5% beet pulp vs 6.0, 7.5, and 9.0% soybean hulls ($P < .05$).

^eCalculated metabolizable energy.

Table 8. Fecal characteristics of dogs consuming diets containing soybean hulls and beet pulp (Exp. 3)

Item	Diet					SEM
	Soybean hulls, % of DM				Beet pulp, % of DM	
	0	6.0	7.5	9.0	7.5	
Wet fecal output, g/d	97	135	125	141	155	15.8
Dry fecal output, g/d ^a	39	64	55	70	64	5.8
Fecal consistency ^b	3.5	3.3	3.1	3.2	3.0	.1

^a0 vs 6.0, 7.5, and 9.0% soybean hulls ($P < .05$).

^b1 = hard, dry pellets: small, hard mass; 2 = hard, formed, dry stool: remains firm; 3 = soft, formed, moist: softer stool that retains shape; 4 = soft, unformed: stool assumes shape of container, pudding like; 5 = watery: liquid that can be poured.

digestibility values (-.7 and -2.0%, respectively). Total dietary fiber digestibility data for the 0% diet were not reported because only .1 g/d of TDF was consumed.

A comparison of the 7.5% beet pulp diet with a similar diet used in previous research revealed that, in this trial, beet pulp had a similar effect on nutrient digestibility. Muir et al. (1996), using a diet containing 7.5% supplemental beet pulp, reported ileal digestibility values of 67.8 (DM), 74.9 (OM), 70.9 (CP), 93.2 (fat), and 79.2% (GE), which very closely resemble those digestibility values obtained in this study. The 0% supplemental fiber diet used by Muir et al. (1996) contained 2.6% TDF, compared with the .4% TDF in our control. Muir et al. (1996) reported ileal digestibility values for DM (76.6%), OM (83.6%), fat (95.0%), and GE (85.6%) in her control diet that closely resembled ileal digestibility values obtained for the 0% fiber diet in our study.

As expected, the 0% fiber diet resulted in the highest total-tract digestibility coefficients. Compared with the 0% fiber diets, the treatments containing supplemental fiber resulted in lower nutrient digestibilities. Dry matter, OM, fat, and CHO digestibility were not affected by treatment. Total dietary fiber digestibility increased from 4.7% (6.0% soybean hull diet) to 22.8 and 22.3% (7.5 and 9.0% soybean hull diets, respectively). With the exception of TDF, the digestibility values obtained for the 7.5% beet pulp treatment very closely resembled those values obtained for the 7.5% soybean hull treatment. It is likely that the difference in TDF digestibility between the 7.5% soybean hull diet and the 7.5% beet pulp diet was influenced by the different insoluble:soluble fiber ratios in soybean hulls and beet pulp used in this experiment.

As expected, DM, OM, CP, and GE digestibilities at the ileum were lower than total-tract digestibility coefficients. Ileal and total-tract digestibilities of fat were virtually identical. Differences indicate that these nutrients are primarily digested hydrolytically by the animal. In the case of protein, however,

considerable activity takes place in the large bowel. There was a much larger difference in TDF digestibility, which was virtually undigested before reaching the terminal ileum. The higher total-tract TDF digestibility coefficients were due to fermentation by colonic bacteria.

Calculated ME decreased as soybean hull level increased from 4.77 kcal/g (0% soybean hull diet) to 4.48 kcal/g (9.0% soybean hull diet). Beet pulp inclusion at the 7.5% level also lowered ME when compared with the diets containing soybean hulls. Also, inclusion of soybean hulls lowered ME when compared with the diet containing no soybean hulls.

Total-tract digestibility coefficients obtained with dogs fed the soybean hull-containing diets very closely resemble the results obtained in Exp. 2 (Table 4). The 6.0 and 7.5% soybean hull diets used in Exp. 2 resulted in slightly lower DM, OM, CP, TDF, and GE digestibilities, as well as lower calculated ME, than the same two diets fed in Exp. 3. The 9.0% soybean hull diet in Exp. 2 resulted in slightly higher digestibilities of DM, OM, CP, fat, TDF, and GE than the same diet fed in Exp. 3.

Sunvold et al. (1995) reported an ME value of 4.64 kcal/g, and Fahey et al. (1990a,b, 1992) reported ME values of 4.35, 4.30, and 4.45 kcal/g, respectively. These values are similar to the calculated ME (4.46 kcal/g) for the 7.5% beet pulp diet in this study.

Dietary treatment resulted in some numerical variation in amount of feces produced (Table 8). The 0% soybean hull diet resulted in the lowest fecal excretion and the highest fecal consistency score. Of the soybean hull diets, the 9.0% soybean hull diet resulted in the highest fecal excretion (wet, 141 g/d; dry, 70 g/d) and the lowest fecal consistency score (3.0). The 7.5% beet pulp diet resulted in the greatest quantity of as-is fecal excretion (155 g/d) but only 64 g/d dry fecal excretion. Dry fecal output increased linearly ($P < .05$) as soybean hull inclusion level increased, and the 0% soybean hull diet was lower ($P < .05$) than that for the soybean hull-containing diets. There was no difference between the soybean hull-

containing diets and the 7.5% beet pulp diet.

Despite the difference in nutrient intake, in both trials the 9.0% soybean hull diet resulted in the highest output of both wet and dry feces, and the 7.5% soybean hull diet resulted in the lowest dry fecal output. Fecal consistency scores were higher in Exp. 3 than in Exp. 2. The difference ranged from .6 (7.5% soybean hull diet) to .9 unit (6.0% soybean hull diet).

Beet pulp is a commonly used fiber source in premium dog diets. However, alternative fiber sources are increasingly being researched as possible replacements for beet pulp. Even though little work had been done examining the efficacy of soybean hulls in dog diets, compositionally they seemed to be an effective substitute for beet pulp. Our *in vivo* studies confirmed this. Indeed, ileal digestion of nutrients was 1 to 3 percentage units higher when 7.5% supplemental soybean hulls was incorporated into dog diets compared with 7.5% beet pulp. And even the highest soybean hull inclusion level (9%) did not seriously hinder ileal digestion of nutrients. In addition, less wet and dry feces were produced when soybean hulls were used as the fiber source in comparison with beet pulp, with nearly identical fecal consistency scores.

Implications

Soybean hulls are an efficacious source of dietary fiber for dogs. Their compositional characteristics and their lack of negative effects on nutrient digestion at the ileum or in the total tract, as well as their lack of negative effects on fecal characteristics, allow them to be included in premium dog foods in concentrations ranging from 7.5 to 9.0% of diet dry matter.

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