

JOURNAL OF ANIMAL SCIENCE

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J Anim Sci 1996. 74:2441-2449.

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Digestion Responses to Low Oligosaccharide Soybean Meal by Ileally-Cannulated Dogs

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ABSTRACT: We investigated digestion responses to conventional and low oligosaccharide soybean meal (SBM) incorporation into diets for dogs. Five female dogs were fitted with T-type cannulas at the terminal ileum and fed five diets in a 5 × 5 Latin square design. Corn grain + poultry meal-based diets containing different levels and types of SBM (0% SBM, 18.55% conventional SBM, 18.55% low oligosaccharide SBM, 37.1% conventional SBM, 37.1% low oligosaccharide SBM) were formulated. Each period consisted of 11 d (7-d diet adaptation; 4-d collection of ileal digesta and feces). Intakes of DM, OM, CP, fat, and GE were not affected ($P > .10$) by treatment. Higher ($P < .01$) starch intakes and higher ($P < .05$) total dietary fiber (TDF) intakes were noted for dogs fed diets with SBM. Digestibilities of CP ($P < .04$) and starch ($P < .002$) at the ileum were higher for dogs fed the higher

levels of SBM. Ileal digestibilities of most individual amino acids followed the CP response. Total tract digestibility of CP was higher ($P < .006$) in dogs fed the SBM diets. There were no significant differences in nutrient digestibilities between conventional and low oligosaccharide SBM. Stachyose and raffinose intakes by dogs were decreased dramatically ($P < .001$) as a result of substituting the low oligosaccharide SBM for conventional SBM at the higher dietary concentration, although sucrose intake by dogs fed low oligosaccharide SBM was higher ($P < .001$). Galactinol was present in low oligosaccharide SBM but not in conventional SBM. Total tract digestion of all oligosaccharides was near 100%. The low oligosaccharide SBM was digested as extensively, but no better than, conventional SBM.

Key Words: Digestibility, Dogs, Oligosaccharides, Poultry Meal, Soybean Meal

J. Anim. Sci. 1996. 74:2441–2449

Introduction

Soybean meal (SBM) is the supplemental protein source most widely used in animal diets. But SBM contains oligosaccharides that result in gas production in the digestive tracts of rats, dogs, and humans (Steggerda, 1968). These oligosaccharides cannot be cleaved in the digestive tract by endogenous enzymes due to the absence of α -1,6-galactosidase in the intestinal mucosa (Gitzelmann and Auricchio, 1965). The main oligosaccharides of SBM are stachyose and raffinose; these are α -linked and reduce SBM nitrogen-corrected true metabolizable energy (TME_n), fiber digestion, and transit time in chickens (Coon et al., 1990). Extraction of the stachyose and raffinose using 80% ethanol increased the TME_n value of SBM for Leghorn roosters (Coon et al., 1988).

Studies with swine have employed cannulas placed in the terminal ileum to evaluate nutrient digestion

anterior to the large bowel, thereby removing the confounding effect of microbes in the lower gut. This same technique has proven successful in studies with dogs (Walker et al., 1994).

The primary objective of this study was to determine the effect of oligosaccharide removal from SBM on nutrient intake and nutrient digestibilities, both ileal and total tract, by the ileally-cannulated dog. The low oligosaccharide SBM was selected by traditional soybean breeding techniques.

Materials and Methods

Animals and Diets. Five diets (Table 1) containing either 0% SBM (control), 18.55% conventional SBM, 18.55% low oligosaccharide SBM, 37.1% conventional SBM, or 37.1% low oligosaccharide SBM were tested in a 5 × 5 Latin square design with 11-d periods. Diets were prepared by first mixing all ingredients together, extruding using a Wenger twinscrew extruder (Wenger Manufacturing Co., Sabetha, KS), drying the mixture, and then adding the supplemental fat and the liquid digest to the surface of the extruded

¹To whom correspondence should be addressed.
Received February 23, 1996.
Accepted June 7, 1996.

Table 1. Ingredient composition of diets fed to ileally-cannulated dogs

Ingredient	Diet				
	(1) Poultry meal control	(2) 18.55% conventional SBM	(3) 18.55% low oligosaccharide SBM	(4) 37.1% conventional SBM	(5) 37.1% low oligosaccharide SBM
	% of Diet, as-is basis				
Corn grain	56.53	49.12	49.12	41.09	41.09
Poultry meal	32.39	20.06	20.06	7.81	7.81
Conventional soybean meal	—	18.55	—	37.10	—
Low oligosaccharide soybean meal	—	—	18.55	—	37.10
Poultry fat	5.75	6.58	6.58	7.43	7.43
Liquid digest ^a	3.00	3.00	3.00	3.00	3.00
Salt	.70	.70	.70	.70	.70
Calcium carbonate	.24	.83	.83	1.40	1.40
Monocalcium phosphate	.48	.87	.87	1.27	1.27
Potassium chloride	.53	—	—	—	—
Vitamin-trace mineral mix ^b	.20	.20	.20	.20	.20
Choline chloride, 60%	.18	.09	.09	—	—

^aA commercially available palatability-enhancing agent containing protein, fat, and acid and obtained from Bioproducts, Inc., Fairlawn, OH 44333.

^bConcentration per kilogram of diet contributed by vitamin-trace mineral mix: vitamin A, 12,500 IU; vitamin D, 750 IU; vitamin E, 50 IU; vitamin K, .5 mg; thiamin, 10 mg; riboflavin, 8 mg; pantothenic acid, 15 mg; niacin, 37.5 mg; pyridoxine, 10 mg; choline, 2,000 mg; biotin, .9 µg; folic acid, 600 µg; vitamin B₁₂, 15 µg; salt .02%; Mn, 9.9 mg; Fe, 75 mg; Cu, 10 mg; Co, 2 mg; Zn, 100 mg; I₂, 1.25 mg; and Se, .2 mg.

food. Five female dogs with hound bloodlines, averaging 24 ± 6 kg body weight and ranging in age from 1 to 6 yr (average age = 2.5 yr), were fitted with ileal cannulas according to Walker et al. (1994). Surgical and animal care procedures for the experiment were conducted under a research protocol approved by the Campus Animal Care Advisory Committee, University of Illinois, Urbana-Champaign. Diets were balanced to meet or exceed nutrient requirements of dogs at maintenance. Dogs were allowed a minimum of 2 wk to recover before the experiment. Dogs were housed individually in clean concrete-floor pens (1.8 × 4.6 m) in a temperature-controlled room. A 12 h dark:12 h light (1900 to 0700) cycle was used. Dogs were adjusted to their respective diets for 7 d, followed by a 4-d collection period.

All dogs were offered 250 g of their respective diet each day at 0800 and 2000 (500 g/d total). Water was available for ad libitum consumption. Chromic oxide was used as a digestibility marker. Beginning on d 3 of each period, dogs were dosed orally with .5 g of chromic oxide in a gelatin capsule at 0800 and 2000, prior to feeding, for a total of 1 g of marker per day for the duration of the period.

Three dogs were treated for subcutaneous abscesses at some point during the trial. Small abscesses around the cannula were treated topically with Panalog cream (SOLVAY Animal Health, Mendota Heights, MN); abscesses were washed daily with povidone-iodine topical solution (Becton Dickinson AcuteCare Division, Franklin Lakes, NJ) and warm water. Large abscesses required subcutaneous injections of antibiotics (Polyflex, G.C. Hanford Manufacturing Co., Syracuse, NY) twice daily.

Sampling Procedures. During the collection phase, ileal effluent and feces were collected. A 4-d collection phase was used with ileal effluent collected three times daily. Each collection was allowed to proceed for 1 h. For example, on d 1, sampling occurred at 0800, 1200, and 1600. The sampling times advanced 1 h each day for the three remaining days. Ileal effluent was collected by attaching a Whirlpak bag (Pioneer Container Corp., Cedarburg, WI) to the cannula hose clamp with a rubber band. Before attachment of the bag, the interior barrels of the cannulas were scraped clean with a spatula and initial digesta discarded. After removing the collection bags, the area around the cannula was washed with water and wiped with a paper towel. Dogs were encouraged to move around freely during the collection. Elizabethan collars were used at collection times so that dogs would not pull the bag from the cannula. Samples then were frozen in their individual bags at -4°C . Feces excreted between 0800 and 2000 on each of the 4 d were collected from the floors of the pens, weighed, composited, and frozen at -4°C . After completion of the trial, all of the effluent collected was composited for each dog in each period, mixed, and re-frozen at -4°C .

Ileal digesta and feces were freeze-dried in a Tri-Philizer™ MP microprocessor-controlled lyophilizer (FTS Systems, Stone Ridge, NY). After drying, food, orts, ileal effluent, and feces were ground through a 2-mm screen in a Wiley mill in preparation for chemical analyses.

Chemical Analyses. Foods, orts, ileal contents, and feces were analyzed for DM, OM, and ash content according to AOAC (1984) procedures. Crude protein was calculated from Kjeldahl N ($\text{N} \times 6.25$) for all

samples (AOAC, 1984). The total lipid content of diets, orts, ileal effluent, and feces was determined by acid hydrolysis followed by ether extraction according to AACC (1983) and Budde (1952). The method of Prosky et al. (1985) was used for determination of total dietary fiber (TDF) content. Gross energy content of diets, orts, ileal effluent, and feces was determined by bomb calorimetry (model 1261, Parr Instrument, Moline, IL). A flat-glass electrode was used to measure pH of the ileal effluent.

Starch was determined using amyloglucosidase to hydrolyze starch to glucose (Thivend et al., 1972). Amino acid analysis of food and ileal digesta was as follows: a performic acid reagent (1 mL 30% hydrogen peroxide in 9 mL 88% formic acid) was added to tubes containing 75-mg samples and placed in an ice water bath for approximately 16 h; 10 mL of water was then added and the mixture was freeze-dried (Moore, 1963) before conducting a 6 N HCl hydrolysis (Spitz, 1973) to determine sulfur amino acids. The remaining amino acids were prepared for analysis by a 6 N HCl hydrolysis alone. The amino acid composition of the resulting hydrolysate was measured on an amino acid analyzer (model 126, Beckman Instruments, Palo Alto, CA) using sodium citrate buffers and ninhydrin detection.

Chromium (Cr) content of ileal digesta and feces was determined by the technique of Williams et al. (1962). Concentrations of Cr were measured using an atomic absorption spectrophotometer (model 2380, Perkin-Elmer, Norwalk, CT). Dry matter flow (g/d) at the ileum and fecal DM output were calculated by dividing daily Cr intake (mg) by Cr concentration (mg/g) in ileal digesta or feces, respectively. Nutrient flows were calculated by multiplying DM flow by the concentration of the nutrient in ileal or fecal DM.

Sucrose, raffinose, stachyose, and galactinol contents of diets, ileal effluent, and feces were determined as follows: samples were ground in a Cyclotec model 1093 sample mill equipped with a 100-mesh screen. Samples (25 to 30 mg) were placed in a screw-cap test tube to which was added 2 mL of methanol-water (4:3) and 1 mL of chloroform. Tubes were tightly sealed with Teflon-lined caps and shaken on an Orbital shaker (model 3590, VWR Scientific, Chicago, IL) (setting #7) for 60 min. After shaking, tube contents were centrifuged for 20 min at 800 to 900 × g. A 200- μ L aliquot was taken from the top layer (methanol-water) and placed in HPLC autosampler vials. Vials then were dried at 70°C under vacuum. Liquid N was placed in the bath for a vapor trap. Drying took approximately 15 min. Water (1 mL) was added to the dried sample, the mixture vortexed vigorously for 15 to 30 s, and a 200- μ L aliquot of resuspended sample was added to 800 μ L of water and mixed well. Samples were frozen for subsequent analyses.

Sugars were analyzed using a Dionex DX-300 (Dionex, Sunnyvale, CA) ion chromatograph equipped

with a pulsed electrochemical detector. The column used was a Dionex Carbopac PA-1. The run time was approximately 11.1 min.

Statistical Analyses. Data were analyzed as a 5 × 5 Latin square by the general linear models procedure of SAS (1994). Model sums of squares were separated into effects of animal, period, and treatment. Treatment comparisons were made using the following orthogonal contrasts: 1) control (Diet 1) vs SBM-containing diets (Diets 2 to 5); 2) low level of SBM (2 and 3) vs high level of SBM (4 and 5); 3) control SBM (2 and 4) vs low oligosaccharide SBM (3 and 5); and 4) SBM level × source interaction. Ileal and total tract digestibilities of stachyose, raffinose, and galactinol were not analyzed statistically because no quantifiable amount of these carbohydrates was consumed by dogs fed certain experimental treatments.

Results and Discussion

The chemical composition of the diets is presented in Table 2. Diets were isonitrogenous and isoenergetic (GE basis). Slightly more poultry fat was added to diets containing the higher amounts of SBM. Neither the soybean meals nor the poultry meal were assayed for chemical composition separately. Starch content decreased while concentration of most amino acids increased as SBM replaced corn and poultry meal in the diets. Total dietary fiber content was higher as SBM replaced poultry meal. The stachyose, raffinose, galactinol, and sucrose contents of the 18.55% conventional SBM diet were 1.1, .1, 0, and 2.1%, respectively, and those of the 37.1% conventional SBM diet were 2.7, .4, 0, and 4.9%, respectively (Table 2). Galactinol [0- α -D-galactopyranosyl-(1 \rightarrow 1)myo-inositol] is an intermediate in the synthesis of raffinose and stachyose (Dey, 1985). Nondetectable in typical soybeans, it was present in the genetically modified soybean evaluated in this experiment. Kawamura (1967a, b) determined the oligosaccharide content of six American varieties of defatted soybeans; average composition was 5.2% stachyose, 1.4% raffinose, and 6.2% sucrose. Delente and Ladenburg (1972) determined the oligosaccharides in defatted SBM to be 4.2% stachyose, .90% raffinose, and 8.9% sucrose. The amount of sucrose found in soybeans has been shown to vary considerably, primarily because hydrolysis of stachyose or raffinose may produce this disaccharide. Ninety-one percent less stachyose was present in Diet 3 compared with Diet 2 (18.55% SBM diets), whereas 85% less stachyose was present in Diet 4 vs Diet 5 (37.1% SBM diets). Diet 2 had .1% raffinose but Diet 3 had no detectable level. Diet 4 contained .4% raffinose and Diet 5 exhibited no detectable level. These values agree well with calculated projections. Hymowitz et al. (1972) reported that sucrose represented 60% of the total free carbohydrate fraction of soybeans and stachyose and raffinose represented 36 and 4%, respectively. Conkerton et al. (1983)

Table 2. Chemical composition of diets fed to ileally-cannulated dogs

Ingredient	Diet				
	(1) Poultry meal control	(2) 18.55% conventional SBM ^a	(3) 18.55% low oligosaccharide SBM	(4) 37.1% conventional SBM	(5) 37.1% low oligosaccharide SBM
	% of Diet, as-is basis				
OM	91.3	91.7	91.6	91.4	91.3
CP	30.3	30.8	31.1	32.0	31.8
Fat	14.7	14.1	14.1	12.5	13.0
Starch	40.1	35.6	35.9	30.5	28.6
TDF ^b	10.7	12.3	12.8	14.6	14.3
GE, kcal/kg	5,016.2	4,992.6	5,035.1	4,923.9	5,075.0
Amino acids					
Essential					
Arg	1.77	1.85	1.91	2.06	2.01
His	.60	.67	.69	.78	.78
Ile	1.00	1.07	1.11	1.21	1.19
Leu	2.36	2.40	2.52	2.62	2.58
Lys	1.52	1.65	1.68	1.88	1.84
Met	.42	.41	.47	.33	.44
Phe	1.25	1.36	1.41	1.56	1.54
Thr	1.20	1.20	1.25	1.30	1.29
Val	1.32	1.29	1.35	1.36	1.35
Nonessential					
Ala	1.95	1.74	1.82	1.66	1.64
Asp+Asn	2.56	2.84	2.95	3.40	3.37
Cys	.40	.41	.47	.35	.48
Glu+Gln	4.5	5.03	5.19	5.94	5.93
Gly	2.56	2.07	2.13	1.73	1.72
Pro	2.23	2.08	2.12	2.00	2.01
Ser	1.55	1.56	1.66	1.74	1.71
Tyr	.77	.78	.86	.88	.88
Sugars					
Stachyose	0	1.1	.1	2.7	.4
Raffinose	.1	.1	0	.4	0
Galactinol	0	0	.7	0	1.3
Sucrose	1.1	2.1	3.3	4.9	6.2

^aSoybean meal.^bTotal dietary fiber.

discovered that a large portion of stachyose and raffinose may be bound together in an unidentified compound. This compound, which can be cleaved during storage into sucrose and stachyose, may represent over 90% of the free carbohydrate fraction in soybeans.

Nutrient intakes, ileal digestibilities, and total tract digestibilities are presented in Table 3. Starch intake decreased ($P < .01$) as dietary SBM concentration increased. Total dietary fiber intake was higher ($P < .05$) as a result of SBM additions to diets. Intakes of DM, OM, CP, fat, and GE were not affected by treatment ($P > .10$).

Ileal CP digestibility of the control diet was lower ($P < .06$) than for diets containing SBM. Similarly, the 18.55% SBM diets were lower ($P < .04$) in ileal CP digestibility than the 37.1% SBM diets. A dog food that contains high-quality animal products generally will have a higher digestibility than a plant-based food (Case et al., 1995). However, the quality of animal

byproducts is quite variable. Two diets containing meat and bone meal (MBM) were compared by Donkoh et al. (1994). Relatively low digestibility coefficients were found for most of the essential amino acids of one MBM product. The differences in apparent digestibilities of N and amino acids between the two sources of MBM may have been due to differences in protein intake, as well as to the quality of the meals themselves. Our results indicate that the poultry meal used in the current experiment was not a particularly high-quality animal byproduct.

Starch digestibility data supported earlier research (Moore et al., 1980) indicating that extruded starch is highly digestible by the dog. Mean values for ileal starch digestibility were all above 97%. Dogs fed the 37.1% SBM-containing diets had higher ($P < .002$) starch digestion coefficients than did those fed the 18.55% SBM-containing diets. Also, starch digestibility of the control diet was lower ($P < .005$) than starch digestibility of the diets containing SBM.

Table 3. Nutrient intakes, digestibilities at the ileum, and total tract digestibilities by ileally-cannulated dogs^a

Item	Diet					Orthogonal contrasts			
	(1)	(2)	(3)	(4)	(5)	1	2+3	2+4	Level
	Poultry meal control	18.55% conventional SBM ^b	18.55% low oligosaccharide SBM	37.1% conventional SBM	37.1% low oligosaccharide SBM	vs 2-5	vs 4-5	vs 3-5	× source
Intake, g/d									
DM	400.9	401.7	390.3	395.4	409.4	NS ^d	NS	NS	NS
OM	366.1	368.3	357.3	361.3	374.0	NS	NS	NS	NS
CP	121.6	123.3	120.6	126.5	131.2	NS	NS	NS	NS
Fat	59.0	56.8	54.6	49.6	53.4	NS	NS	NS	NS
Starch	160.9	143.1	140.1	120.7	117.1	.01	.04	NS	NS
TDF ^c	43.5	49.5	50.8	57.6	58.6	.05	NS	NS	NS
GE, kcal/d	2,012.0	2,005.0	1,964.6	1,947.4	2,077.6	NS	NS	NS	NS
Digestion at ileum, %									
DM	66.5	62.2	58.9	59.8	63.1	NS	NS	NS	NS
OM	73.1	69.0	66.8	66.7	69.1	NS	NS	NS	NS
CP	65.1	70.8	68.0	77.4	78.3	.06	.04	NS	NS
Fat	90.0	89.6	88.6	88.6	89.9	NS	NS	NS	NS
Starch	97.3	97.6	97.8	98.7	98.6	.005	.002	NS	NS
TDF	10.0	-5.2	-13.9	-9.6	-5.5	NS	NS	NS	NS
GE	75.2	72.0	70.3	70.2	73.6	NS	NS	NS	NS
Total tract digestibility, %									
DM	77.0	77.7	79.8	78.9	76.3	NS	NS	NS	NS
OM	82.7	82.6	84.4	82.6	81.0	NS	NS	NS	NS
CP	77.2	80.3	82.9	84.6	83.2	.006	NS	NS	NS
Fat	90.6	90.6	91.2	90.8	89.8	NS	NS	NS	NS
Starch	100.0	100.0	100.0	100.0	100.0	NS	NS	NS	NS
TDF	31.0	31.3	39.6	35.4	28.8	NS	NS	NS	NS
GE	83.1	83.4	85.2	84.1	82.9	NS	NS	NS	NS

^aDogs ranged in age from 1 to 6 yr of age (average age = 2.5 yr) and weighed 24 ± 6 kg.

^bSoybean meal.

^cTotal dietary fiber.

^dNS = not statistically significant.

As anticipated, digestibilities of nutrients at the terminal ileum were lower than total tract digestibility values. Yin et al. (1993) determined the ileal and total tract digestibilities of 39 different feedstuffs and 18 mixed diets using the pig; total tract digestibility values consistently were higher than ileal digestibility values.

Intakes of most amino acids were similar among treatments (data not shown). Histidine intake was higher ($P < .04$) for SBM treatments vs control (2.9 vs 2.4 g/d) and for the higher levels of SBM vs the lower levels ($P < .03$) (3.2 vs 2.7 g/d). The same pattern occurred for lysine (7.0 vs 6.1 g/d), phenylalanine (5.9 vs 5.0 g/d), aspartic acid + asparagine (12.6 vs 10.3 g/d), and glutamic acid + glutamine (22.1 vs 17.9 g/d). Glycine intakes were lower ($P < .001$) for SBM treatments (7.6 vs 10.3 g/d for control) and lower yet ($P < .04$) at the high level of SBM inclusion (7.0 g/d). Methionine ($P < .01$) and cystine ($P < .006$) intakes were higher for dogs fed the low oligosaccharide SBM than for those fed conventional SBM (1.8 vs 1.5 g/d for methionine; 1.9 vs 1.5 g/d for cystine). Differences in intakes of individual amino acids reflect changes in amino acid composition of the diets due to changes in source of supplemental CP.

There were no significant differences between conventional SBM and low oligosaccharide SBM, nor was any level \times source interaction detected, in individual amino acid digestibilities at the ileum of dogs (Table 4). The ileal digestibility coefficients for the majority of the amino acids followed the same pattern as CP digestibility. Ileal digestibilities of most individual amino acids, total essential amino acids (TEAA), total nonessential amino acids (TNEAA), and total amino acids (TAA) were higher when SBM concentrations in diets were higher. Lower values were observed when the control diet was fed.

Apparent crude protein and amino acid digestibilities can be affected by dietary CP level and amino acid profile. Of the amino acids, arginine had the highest ileal digestibility across diets, whereas cysteine and threonine had the lowest ileal digestibility values. These results seem characteristic of most soybean products (Guilloteau et al., 1986; Sauer and Ozimek, 1986) and could be due partially to the amino acid composition of endogenous protein (Guilloteau et al., 1986). Caugant et al. (1993) fed preruminant calves both conventional and treated soybean protein and found that alcohol treatment (removal of oligosaccharides) tended to increase amino acid digestibility coefficients.

Research conducted with chickens showed that although oligosaccharides did not alter GE content of the diet, their addition to the diet reduced TME_n values (Leske et al., 1993). In order to arrive at an estimate of ME content of our diets, we used the equation of Ohshima et al. (1993), who demonstrated its reliability for the canine. The equation is: ME =

(DE) - 1.25 \times Digestible CP (DCP). Using this formula, ME intakes for our dogs were calculated to be 1,551, 1,550, 1,550, 1,506, and 1,578 kcal/d for Diets 1 through 5, respectively. These values are in agreement with ME intakes reported in NRC (1974) for dogs of this BW fed various types of diets. Removal of oligosaccharides can improve the ME value of SBM in certain species. An improvement in TME_n occurred in the chicken fed soy protein concentrate diets from which more than 80% of the stachyose was removed (Leske et al., 1993).

In Table 5, data regarding oligosaccharide intakes and digestibilities at the ileum and in the total tract are presented. Stachyose intake decreased from 4.4 g/d for dogs fed conventional SBM to .4 g/d for those fed low oligosaccharide SBM at the 18.55% dietary level, and from 10.7 g/d for conventional SBM to 1.6 g/d for low oligosaccharide SBM at the 37.1% dietary level. Raffinose intake decreased from 1.6 g/d for dogs fed conventional SBM to 0 g/d for those fed low oligosaccharide SBM at the 37.1% dietary level. The intake of sucrose was increased ($P < .001$) with the addition of SBM to the diets and when low oligosaccharide vs conventional SBM was fed.

Ileal digestibilities of stachyose, raffinose, and galactinol were quite variable and relatively low. Some negative values were noted, reflecting the detection of more oligosaccharide in the feces than in the food ingested. Hill (1995) noted that soy carbohydrates were poorly digested in the small intestine. The ileal digestibility of sucrose was nearly 100% for dogs on all treatments.

Digestion of oligosaccharides in the total tract was high, and all sugars were nearly 100% digested. This high oligosaccharide digestibility may be the cause of low TME_n for conventional SBM fed to poultry in previous studies, which resulted in more gas production and acidity of the lower gut (Cristafaro et al., 1974; Rackis, 1975; Reddy et al., 1984) and more rapid intestinal transit of digesta (Hellendoorn, 1978, 1979). Lower oligosaccharide concentrations slow transit time of digesta, permitting the microbial population to hydrolyze polysaccharides to short-chain fatty acids in the lower gastrointestinal tract. Coon et al. (1990) demonstrated that removal of oligosaccharides by alcohol extraction resulted in a slower passage rate and an improvement in hemicellulose and cellulose digestibilities by chickens. Hemicellulose and cellulose total tract digestibilities using conventional SBM diets were 9 and 10%, respectively, compared with values of 62 and 35%, respectively, when alcohol-extracted SBM diets were fed. Perhaps other antinutritional factors were removed from SBM by alcohol extraction, thus contributing to this increase in fiber digestion.

In conclusion, low oligosaccharide SBM incorporated into dog diets at the 18.55% and 37.1% levels dramatically decreased stachyose and raffinose contents but did not improve nutrient digestibilities at

Table 4. Amino acid digestibilities (%) at the ileum of cannulated dogs^a

Item	Diet										Orthogonal contrasts			
	(1) Poultry meal control	(2) 18.55% conventional SBM		(3) 18.55% low oligosac- charide SBM		(4) 37.1% conventional SBM		(5) 37.1% low oligosac- charide SBM		SEM	1 vs 2-5	2+3 vs 4+5	2+4 vs 3+5	Level × source
		80.0	84.8	85.3	90.5	90.5	90.5	90.5	90.5					
Essential amino acids														
Arg	80.0	84.8	85.3	90.5	90.5	90.5	90.5	90.5	2.0	.003	.01	NS	NS	
His	66.5	74.8	74.9	83.0	83.0	83.3	83.3	83.3	3.4	.004	.02	NS	NS	
Iso	69.3	76.9	77.0	83.9	83.9	84.5	84.5	84.5	3.2	.005	.04	NS	NS	
Leu	73.4	78.6	79.2	84.6	84.6	85.0	85.0	85.0	3.0	.02	.06	NS	NS	
Lys	74.9	76.6	77.8	85.6	85.6	85.7	85.7	85.7	4.0	NS ^e	.05	NS	NS	
Met	67.3	68.4	58.5	72.6	72.6	79.4	79.4	79.4	6.8	NS	.08	NS	NS	
Phe	60.6	67.6	68.2	73.2	73.2	76.5	76.5	76.5	4.8	.06	NS	NS	NS	
Thr	56.7	62.8	64.1	70.1	70.1	72.9	72.9	72.9	5.1	.08	NS	NS	NS	
Val	65.9	72.2	72.1	78.7	78.7	79.6	79.6	79.6	3.9	.04	.09	NS	NS	
Nonessential amino acids														
Ala	73.6	76.3	76.3	80.5	80.5	81.6	81.6	81.6	3.3	NS	NS	NS	NS	
Asp+Asn	47.3	61.1	60.8	75.5	75.5	76.5	76.5	76.5	5.0	.001	.007	NS	NS	
Cys	16.5	16.7	28.6	29.7	29.7	46.7	46.7	46.7	10.0	NS	NS	NS	NS	
Glu+Gln	70.5	78.6	78.6	86.5	86.5	86.8	86.8	86.8	2.9	.001	.01	NS	NS	
Gly	68.5	69.0	68.4	73.7	73.7	75.3	75.3	75.3	4.2	NS	NS	NS	NS	
Pro	68.1	72.9	73.0	79.3	79.3	80.7	80.7	80.7	3.6	.05	.07	NS	NS	
Ser	52.0	58.4	59.6	69.4	69.4	71.9	71.9	71.9	5.5	.05	.05	NS	NS	
Tyr	67.1	74.0	70.8	75.6	75.6	78.0	78.0	78.0	4.2	NS	NS	NS	NS	
TEAA ^b	69.7	75.0	75.7	81.8	81.8	82.9	82.9	82.9	3.4	.03	.05	NS	NS	
TNEAA ^c	64.2	70.7	70.7	79.2	79.2	80.3	80.3	80.3	3.8	.02	.03	NS	NS	
TAA ^d	66.5	72.5	72.8	80.3	80.3	81.4	81.4	81.4	3.6	.02	.04	NS	NS	

^aDogs ranged in age from 1 to 6 yr (average age = 2.5 yr) and weighed 24 ± 6 kg.

^bTEAA, total essential amino acids.

^cTNEAA, total nonessential amino acids.

^dTAA, total amino acids.

^eNS = not statistically significant.

Table 5. Oligosaccharide intakes, digestion at the ileum, and total tract digestibilities by ileally-cannulated dogs^a

Item	Diet					SEM	Orthogonal contrasts				Level × source	
	(1) Poultry meal control	(2) 18.55% conventional SBM ^b	(3) 18.55% low oligosac- charide SBM	(4) 37.1% conventional SBM	(5) 37.1% low oligosac- charide SBM		1 vs 2-5	2+3 vs 4+5	2+4 vs 3+5			
Intake, g/d												
Stachyose	0	4.4	.4	10.7	1.6	.3	.001	.001	.001	.001	.001	.001
Raffinose	.4	.4	0	1.6	.04	.04	.04	.001	.001	.001	.001	.001
Sucrose	4.4	8.4	12.9	19.4	25.4	.6	.001	.001	.001	.001	.001	NS
Galactinol	0	0	2.7	0	5.3	.2	.001	.001	.001	.001	.001	.001
Digestion at ileum, %												
Stachyose	— ^c	20.9	-551.9	60.8	-69.2	252.2	—	—	—	—	—	—
Raffinose	44.3	-147.5	—	33.8	—	22.8	—	—	—	—	—	—
Sucrose	100.0	100.0	99.7	100.0	100.0	.1	NS ^d	NS	NS	NS	NS	NS
Galactinol	—	—	48.4	—	57.3	—	—	—	—	—	—	—
Total tract digestibility, %												
Stachyose	—	100.0	100.0	100.0	100.0	0	—	—	—	—	—	—
Raffinose	100.0	100.0	—	100.0	—	0	—	—	—	—	—	—
Sucrose	100.0	100.0	100.0	100.0	100.0	0	NS	NS	NS	NS	NS	NS
Galactinol	—	—	98.9	—	100.0	—	—	—	—	—	—	—

^aDogs ranged in age from 1 to 6 yr (average age = 2.5 yr) and weighed 24 ± 6 kg.

^bSoybean meal.

^cDashes indicate that no digestibility coefficient was calculated because there was no oligosaccharide in the diet.

^dNS = not statistically significant.

the ileum or total tract digestibilities. Both conventional and low oligosaccharide SBM had higher CP and amino acid digestibilities than poultry meal. However, SBM-containing diets resulted in higher fecal moisture concentrations (60, 67, 65, 73, and 73% for Treatments 1 through 5, respectively) and greater fecal volumes (94, 113, 99, 127, and 124 g wet feces excreted/dog/12 h period for Treatments 1 through 5, respectively) than did the poultry meal control treatment.

Implications

Although much lower oligosaccharide concentrations were present in genetically altered soybean meal, no differences were noted between conventional and low oligosaccharide soybean meal in any of the criteria measured in this experiment. If gas production in the lower gut were reduced by low oligosaccharide soybean meal inclusion in diets, then perhaps a positive role for this genetically modified plant protein source would be evident for dogs as noted previously for other species. In some instances, soybean meal will result in higher protein and amino acid digestibilities than will poultry meal.

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