Technical Bulletin

Soybean Hulls: An Alternative Fiber Source for Cats

Key Points

- Cats have sufficient fermentative capacity to effectively utilize dietary fiber despite being an obligate carnivore.
- Fermentation of dietary fiber is dependent on the soluble and insoluble fiber fractions.
- Soybean hulls are not inert, non-nutritive filler based on total tract nutrient digestion and fermentative end-products.
- Nutritional value of soybean hulls is similar to beet pulp, the "gold standard" of dietary fiber.
- As a functional fiber, soybean hulls can provide similar nutritional and health benefits as other fiber sources.
- Soybean hulls are a viable, cost-savings alternative to beet pulp and cellulose that will not jeopardize the nutritional quality of cat foods.

Beet pulp and cellulose are dietary fiber sources commonly used in commercial cat foods. While cats do not have a dietary requirement for fiber, it is generally accepted as a desirable pet food ingredient due its association with various health benefits. These benefits affect intestinal health, stool quality, weight maintenance and disease risk.

The ability of cats to utilize dietary fiber compared with other species is dependent on the anatomy and physiology of the digestive tract (Table 1). A resident microbial population located in the lower large intestine is primarily responsible for the fermentative breakdown of dietary fiber. As an obligate carnivore, the cat has a simple and short digestive tract which limits its ability to use dietary fiber relative to other species.

The dog is a facultative carnivore that can more effectively use plant materials due to its longer digestive tract, longer retention time, and greater hind-gut fermentative capacity. Humans are omnivores capable of digesting both plant and animal food sources.

Soybean hulls are an underutilized and overlooked source of functional fiber for pet food applications due to consumer misconceptions that they are inert filler.

Fermentation is highly dependent on the composition of dietary fiber. Total dietary fiber is comprised of soluble fiber and insoluble fiber (Figure 1). The relative proportions of these fiber types determine biological properties, fermentability and resulting nutritional and health benefits.

Table 1. Species differences in average intestinal length and fecal retention time

Species	Cat	Dog	Human
Classification	*Obligate Carnivore*	*Facultative Carnivore*	*Omnivore*
Small Intestine (ft)	5.5	12.8	23.0
Large Intestine (ft)	1.3	2.0	5.9
Total Length (ft)	6.8	14.8	28.9
Body Length (ft)	1.6	2.5	5.7
Total Length:Body Length	4:1	6:1	5:1
Mean Fecal Retention Time (hr)	13	22	38

FIGURE 1: Typical fiber composition of different fiber sources

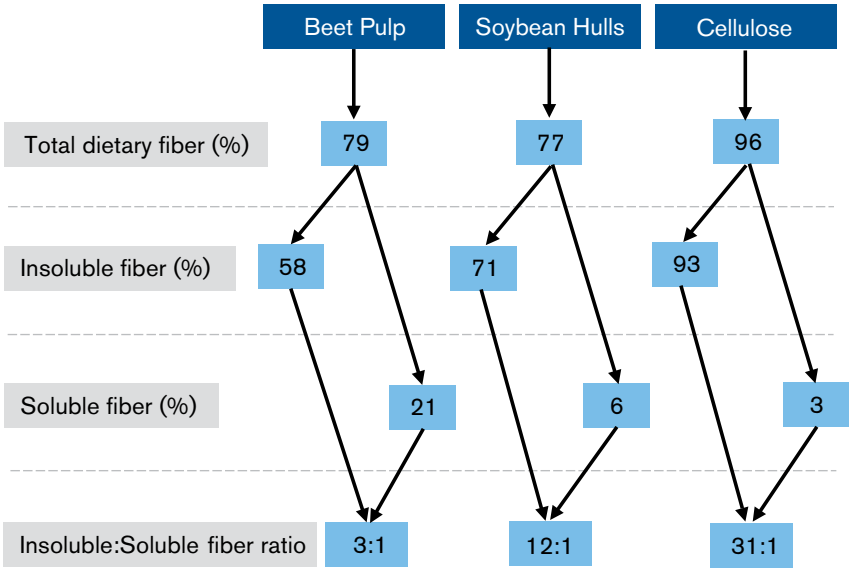


Table 2. Ingredient composition of extruded cat foods

Ingredient (%)	Low Fiber	Beet Pulp	Soybean Hulls	Cellulose
Chicken meal	29.1	29.6	28.7	31.1
Corn gluten meal	7.7	7.7	7.7	7.7
Brewers rice	43.0	26.9	29.4	31.3
Corn	3.7	3.7	3.7	3.7
Chicken fat	12.0	12.0	12.0	12.0
Beet pulp	0.0	15.5	0.0	0.0
Cellulose	0.0	0.0	0.0	9.6
Soybean hulls	0.0	0.0	14.0	0.0
Miscellaneous[1]	4.2	4.2	4.2	4.2
Vitamins & trace minerals[2]	0.4	0.4	0.4	0.4

[1]Palatant, salt, potassium chloride, choline chloride, taurine.
[2]Manganese sulfate, iron sulfate, copper sulfate, cobalt sulfate, zinc sulfate, potassium iodide, sodium selenite, vitamin A, vitamin D3, vitamin E, vitamin K, thiamine, riboflavin, pantothenic acid, niacin, pyridoxine, biotin, folic acid, vitamin B_{12}

Beet pulp is the gold standard source of dietary fiber in pet food based on its content of insoluble fiber (58%) and soluble fiber (21%). Beet pulp is a moderately fermentable fiber due to its rate of microbial fermentation in the large intestine. The soluble fiber fraction initially forms a gel in the aqueous environment of the stomach which delays gastric emptying. The slower rate of passage through the digestive tract provides a greater opportunity for hind-gut fiber fermentation. The resulting short-chain fatty acids support intestinal health by providing energy to the intestinal cells. The insoluble fiber component also provides the necessary bulk to maintain rate of passage and stool quality.

Cellulose, in contrast, is almost exclusively insoluble fiber (93%) with limited soluble fiber (3%). Dietary cellulose passes through the intestinal tract essentially undigested prior to fecal excretion. It provides a laxative effect by speeding intestinal transit time and increasing fecal bulk. Cellulose is generally used in weight control cat foods as a bulking agent to decrease total caloric density. Dietary cellulose is also used in hairball control foods to minimize hairball occurrence. Cellulose associates with ingested hair derived from grooming to move the hair through the intestinal tract for excretion in the feces.

Soybean hulls are a widely available, economical co-product of the soybean oil extraction process. Despite their low cost, they are rarely used in today's pet foods because it is assumed they are an inert filler providing no nutritional value to the animal. However, soybean hulls are comprised of 6% soluble fiber and 71% insoluble fiber suggesting they may be a cost-effective, alternative fiber source in pet food applications.

An assessment of their nutritional value is required before soybean hulls can be recommended for cat food formulations.

A feeding study was conducted to determine if adult cats can derive nutritional benefits from soybean hulls when compared to beet pulp or cellulose. Soybean hulls are hypothesized to be intermediate in nutritional value relative to beet pulp and cellulose based on ratios of insoluble to soluble fiber (12:1, 3:1, 31:1, respectively).

Research

The feeding study used eight adult male domestic shorthair cats averaging 10.5 ± 0.1 years of age and 6.1 ± 0.8 kg in body weight. Test foods were comprised of a control food containing no supplemental fiber (low fiber) or foods with 14% soybean hulls, 15% beet pulp or 9% cellulose as sources of dietary fiber (Table 2). All extruded foods were formulated to be nutritionally complete for adult cats. The low fiber contained 5% total dietary fiber while the foods with fiber were formulated to contain 15% total dietary fiber. Nutrient composition based on laboratory analyses is shown in Table 3. Soluble fiber content of the fiber-containing foods ranged from 5.9% (beet pulp) to 1.5% (cellulose) and 1.0% (soybean hulls). Ratio of insoluble to soluble fiber in the complete foods was highest for soybean hulls (15.6:1) compared with beet pulp (1.9:1) and cellulose (9.1:1).

The study was conducted at a USDA-licensed facility according to Animal Welfare Act guidelines as approved by an Institutional Animal Care and Use Committee. A replicated 4x4 Latin square design was used so each cat received each test food and served as its own control for statistical purposes. Each phase consisted of a 10-day food adaptation period followed by a 4-day sample collection period. Food intake was measured daily. Body weight and body condition were measured weekly. Daily fecal and urine samples were quantitatively collected during each 4-day collection period. Excreta samples were used to determine fecal output, stool quality, total tract macronutrient and energy digestibility, metabolizable energy, and fecal fermentative end-products.

Table 3. Nutrient composition of extruded cat foods

Item	Low Fiber	Beet Pulp	Soybean Hulls	Cellulose
Dry matter (%)	92.2	93.9	94.8	95.4
Crude protein (%)[1]	30.8	30.2	30.7	31.9
Acid-hydrolyzed fat (%)[1]	13.7	14.5	15.2	16.4
Total dietary fiber (%)[1]	4.5	17.1	16.6	15.1
Insoluble (%)[1]	2.7	11.2	15.6	13.6
Soluble (%)[1]	1.8	5.9	1.0	1.5
Insoluble:Soluble (ratio)	1.5:1	1.9:1	15.6:1	9.1:1
Gross energy (kcal/g)[1,2]	5.2	5.2	5.2	5.3
Metabolizable energy (kcal/g)[1,3]	3.8	3.4	3.4	3.5

[1]Dry matter basis
[2]Measured by bomb calorimetry
[3]Calculated as metabolizable energy = 8.5 kcal/g fat + 3.5 kcal/g crude protein + 3.5 kcal/g nitrogen-free extract

Pet food manufacturers seeking to reduce formulation costs without jeopardizing nutritional quality should consider soybean hulls as they are generally 8- to 10-fold less expensive than beet pulp.

Stool quality was subjectively evaluated daily during the 4-day collection period. A 5-point assessment scale was used to assign individual scores as:

1= hard, dry, crumbly
2 = semi-moist, well-formed, retains shape
3 = soft, moist, formed
4 = soft, viscous, moist, unformed
5 = watery diarrhea.

All cats remained healthy throughout the study as indicated by normal serum chemistries and blood counts and the maintenance of body weight and body condition.

Food intake:

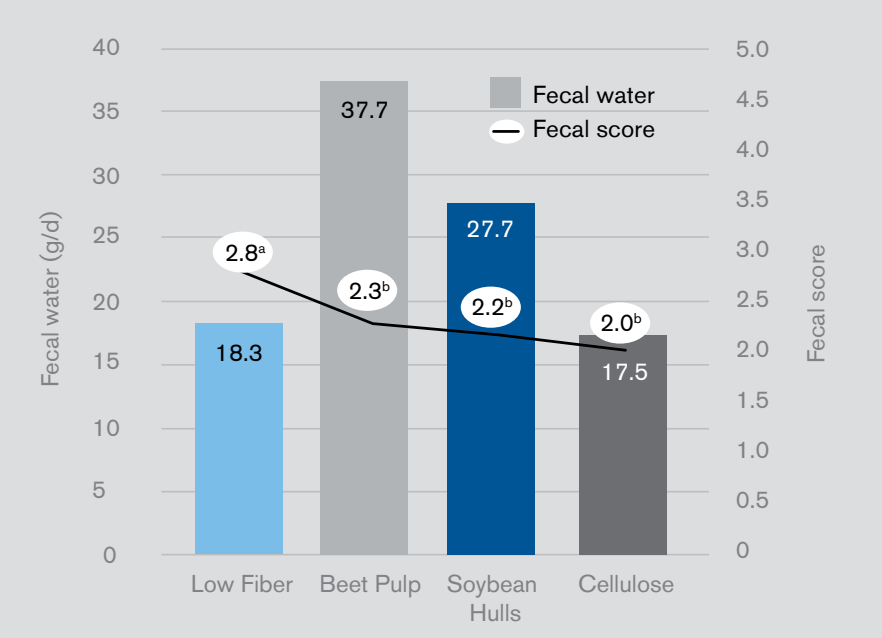
Food consumption was significantly lower ($P<0.05$) for the food with beet pulp compared with soybean hulls (Table 4). Foods containing soybean hulls, cellulose and low fiber were not different ($P>0.05$) averaging 70 g/d.

Table 4. Food intake and fecal characteristics

Item	Low Fiber	Beet Pulp	Soybean Hulls	Cellulose
Food intake (g/d, DM)	69.7[ab]	55.2[b]	70.8[a]	70.6[ab]
Fecal output (g/d, as-is)	28.1[a]	50.5[b]	45.6[bc]	33.5[ac]
Fecal output (g/d, DM)	9.8[a]	12.8[ab]	17.9[b]	16.0[ab]
Fecal ammonia (µmole/g)	125.5	126.0	130.5	94.9
Fecal total phenols/ Indoles (µmole/g)	1.7	2.6	1.9	1.1
Fecal phenols (µmole/g)	0.5	1.2	0.5	0.4
Fecal indoles (µmole/g)	1.2	1.4	1.4	0.7
Fecal pH	5.5	5.7	5.7	6.0

[a,b,c] Means within row with different superscripts differ (P<0.05)

FIGURE 2: Relationship between fecal moisture content and subjective fecal scores[a]



[a] Fecal scores: 1= hard, dry, crumbly; 2 = semi-moist, well-formed, retains shape; 3 = soft, moist, formed; 4 = soft, viscous, moist, unformed; 5 = watery diarrhea
[a,b] Means with different superscripts differ (P<0.05)

Increasing total dietary fiber generally reduces food consumption, but this response was not observed in this study. Consumption of the food with beet pulp was likely reduced due to its higher soluble fiber content.

Fecal characteristics:
Acceptable stool quality was maintained for all cats based on subjective scores ranging from 2 (semi-moist, well-formed) to 3 (soft, moist, formed). Cats fed the low fiber food produced stools that were softer and more moist (P< 0.05) than stools from the fiber-containing foods (Figure 2). Fecal water content declined as the dietary fiber source changed from beet pulp to soybean hulls to cellulose. The change in fecal water content is attributed to differences in soluble fiber content of each food. Despite changes in fecal water content, subjective fecal scores remained unchanged indicating soybean hulls did not negatively impact fecal appearance relative to beet pulp or cellulose.

Fecal output on an "as-is" basis reflects the greater water-holding capacity of the soluble fiber content of beet pulp and soybean hulls. Cats consuming beet pulp and soybean hulls produced more (P<0.05) feces relative to the low fiber food. Fecal output was intermediate for cats fed cellulose and not different (P>0.05) from other foods. The high "as-is" fecal output for cats fed beet pulp was mitigated when total fecal excretion was expressed on a dry matter basis. Dried fecal output was higher (P<0.05) for cats fed soybean hulls compared with low fiber food, but not beet pulp or cellulose.

Nutrient digestibility:
Dry matter digestibility was similar (P>0.05) for all fiber-containing foods

(Table 5). These foods were significantly (P<0.05) less digestible than the low fiber food. Protein digestibility was highest (P<0.05) for cellulose (88.5%) and low fiber food (84.9%) and lowest (P<0.05) for beet pulp (77.2%). Protein digestibility of the soybean hull food (81.7%) was intermediate and different (P<0.05) from cellulose and beet pulp. These differences can be attributed to varying levels of soluble fiber in each food impacting hind-gut fermentation. Increasing soluble fiber is associated with more microbial fermentation which results in greater fecal excretion of microbial protein and reduction in apparent protein digestibility.

Table 5. Apparent total tract nutrient digestibility

Item	Low Fiber	Beet Pulp	Soybean Hulls	Cellulose
Dry matter (%)	85.5[a]	74.5[b]	75.4[b]	78.4[b]
Crude protein (%)[1]	84.9[ab]	77.2[c]	81.7[b]	88.5[a]
Acid-hydrolyzed fat (%)[1]	89.9[ab]	86.9[b]	88.6[b]	92.9[a]
Total dietary fiber (%)[1]	8.5[a]	33.7[b]	18.0[ab]	15.1[a]
Digestible energy (%)[1]	88.6[a]	78.6[b]	79.9[b]	83.7[b]
Metabolizable energy (%)[1]	82.3[a]	70.9[b]	73.6[bc]	78.2[ac]

[1] Dry matter basis.
[a,b,c] Means within row with different superscripts differ (P<0.05)

Fat digestibility was highest (P<0.05) for cellulose compared with soybean hulls and beet pulp. There was no difference (P>0.05) in fat digestibility for soybean hulls, beet pulp, or the low fiber food. The digestibility of total dietary fiber was highest for beet pulp (33.7%) which was significantly greater (P<0.05) than cellulose (15.1%) and the low fiber food (8.5%). Fiber digestibility for the soybean hulls food was intermediate (18.0%) and not different (P>0.05) than the other foods. These differences are also attributed to the ratio of insoluble to soluble fiber for each fiber source. Soluble fiber increases fiber fermentation while insoluble fiber is not well digested and is excreted in the feces to reduce apparent fiber digestibility.

Digestible energy was similar (P>0.05) for all fiber-containing foods, but these foods contained less (P<0.05) digestible energy than the low fiber food. Metabolizable energy was significantly (P<0.05) lower for beet pulp compared with the low fiber food. Foods with soybean hulls and cellulose contained similar metabolizable energy that was not different (P>0.05) from the other foods. These results likely reflect a general dilution effect of dietary fiber, and the subsequent impact on overall digestibility.

Fermentative end-products:
Certain end-products of microbial fermentation are generally associated with offensive fecal odors (Table 4). In this study, there were no differences (P>0.05) in fecal concentrations of ammonia, indoles and phenols. Similarly, fecal pH was not different (P>0.05) for any food group. These results imply there are no differences in fecal odor with the consumption of soybean hulls, beet pulp or cellulose.

Cats consuming the food with beet pulp produced more (P<0.05) total short-chain fatty acids than other foods (Figure 3). This response is attributed to higher (P<0.05) levels of acetate and propionate for beet pulp. In contrast, butyrate was proportionally highest (P<0.05) for the low fiber food and lowest (P<0.05) for cellulose. Fecal butyrate was intermediate for soybean hulls and not different (P>0.05) than other fiber sources. Fecal excretion of total branched chain fatty acids was lowest (P<0.05) for cellulose compared with other foods (Figure 4). Cats fed soybean hulls excreted greater (P<0.05) concentrations of isobutyrate and isovalerate than cellulose. Beet pulp was intermediate and not different (P>0.05) than soybean hulls. Fecal valerate was similar across all foods. Fermentative end-products reflect substrates used by the microbes as short-chain fatty acids are generally derived from carbohydrates while branched chain fatty acids are derived from protein. Overall, these results imply more hind-gut fermentation of soybean hulls and beet pulp compared with cellulose. Greater fermentative capacity with soybean hulls and beet pulp can be associated with improved intestinal functionality and whole-body health benefits.

Summary

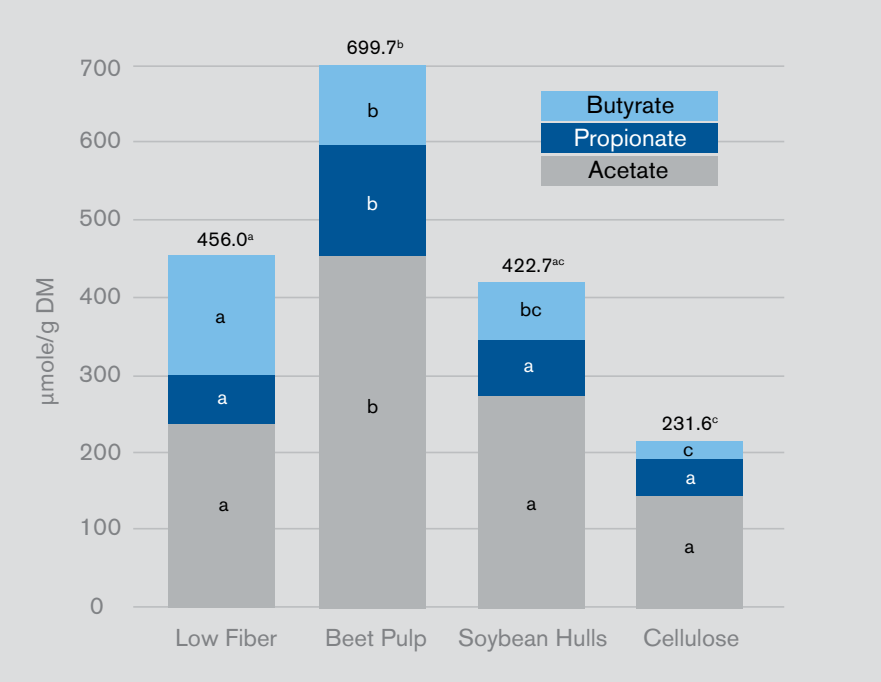
It is generally assumed cats have limited capacity to utilize dietary fiber as obligate carnivores. However, results of this study demonstrate cats can effectively utilize various sources of dietary fiber. The ability of cats to use soybean hulls, beet pulp and cellulose is influenced by their varying levels of insoluble and soluble fiber. Overall, the nutritional value of soybean hulls is more similar to beet pulp than cellulose based on macronutrient digestion and fermentative end-products. Contrary to industry assumptions, it is readily apparent soybean hulls are not an inert, non-nutritive filler when fed to cats. In fact, soybean hulls can provide the cat with similar nutritional benefits as beet pulp.

Pet owners must be educated that soybean hulls provide nutritional health benefits comparable to beet pulp.

Application

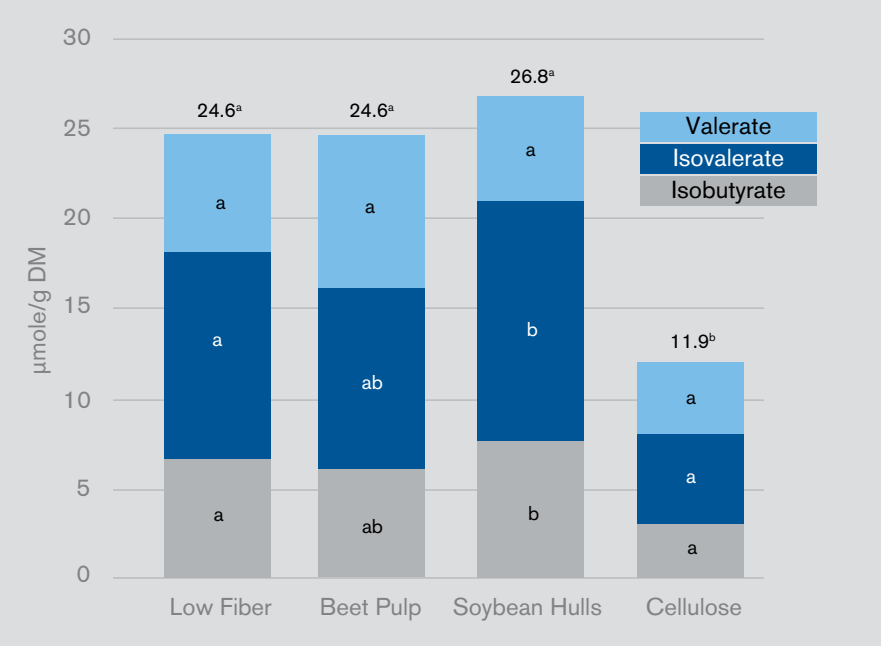
Soybean hulls are an economical source of dietary fiber for the cat. From a cost perspective, soybean hulls are generally 8- to 10-fold less expensive than beet pulp. A significant opportunity exists to leverage soybean hulls as a high-quality alternative to beet pulp in pet foods. As such, pet food manufacturers should consider soybean hulls when seeking alternative ingredients to reduce formulation costs without jeopardizing the nutritional quality of their products. Pet owners must also be educated that soybean hulls are not inert filler but provide nutritional health benefits comparable to beet pulp. ■

FIGURE 3: Fermentative end-products: Short-chain fatty acids



a,b,c Different superscripts within a short-chain fatty acid are different (P<0.05).

FIGURE 4: Fermentative end-products: Branched-chain fatty acids



a,b Different superscripts within a branched-chain fatty acid are different (P<0.05).

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