ADM

Technical Bulletin

Soybean Hulls:
An Alternative Fiber Source for Dogs

Key Points

- Dietary fiber is not a required nutrient, but it plays an important role in the well-being of dogs by enhancing intestinal health.
- Fermentation and health benefits of dietary fiber are dependent on 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 nutritional quality.

Nutritional value of dietary fiber is clearly evident

through the attention and priority it receives in popular media, retail outlets and food products. While there is no specific requirement for dietary fiber, people recognize its impact on health; for instance, intestinal function, blood cholesterol level and maintaining healthy weight. Pet owners desire these same health benefits for their dogs and cats and, thus, seek pet products containing functional fiber.

Dietary fiber is the edible parts of plants or analogous carbohydrates that are resistant to hydrolytic digestion and require fermentative breakdown by resident microbiota in the large intestine. Fiber composition varies greatly by source and resulting health benefits are attributed to differences in the relative proportions of soluble and insoluble fiber (Figure 1). Soluble fiber includes oligosaccharides, pectin, β-glucans, alginate and psyllium. These fibers have high water holding capacity and form gels in aqueous environments. These functional properties delay gastric emptying which promote slower intestinal transit and glucose absorption while providing more substrate for microbial fermentation. Insoluble fiber is predominantly cellulose, hemicellulose and lignin. These fibers are not digested by animal-derived enzymes, and they are not extensively fermented due to their low water solubility. This indigestible fiber provides a laxative effect by increasing intestinal rate of passage and contributing to fecal bulk.

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

Beet pulp and cellulose are common sources of dietary fiber used in commercial dog foods. Beet pulp is composed of soluble and insoluble fibers while cellulose is predominantly insoluble fiber (Table 1). The fiber composition of beet pulp results in a moderate rate of microbial fermentation in the large intestine. Short-chain fatty acids derived from the fermentation of soluble fiber enhance intestinal health by providing energy to the intestinal cells. The insoluble fraction provides the necessary bulk to

Table 1. Typical fiber composition of different fiber sources

Dietary Fiber Source	Beet Pulp	Soybean Hulls	Cellulose
Total dietary fiber (%)	79	77	96
Insoluble fiber (%)	58	71	93
Soluble fiber (%)	21	6	3
Ratio (Insoluble:Soluble)	3:1	12:1	31:1

Figure 1. Fiber classification and corresponding biological effects

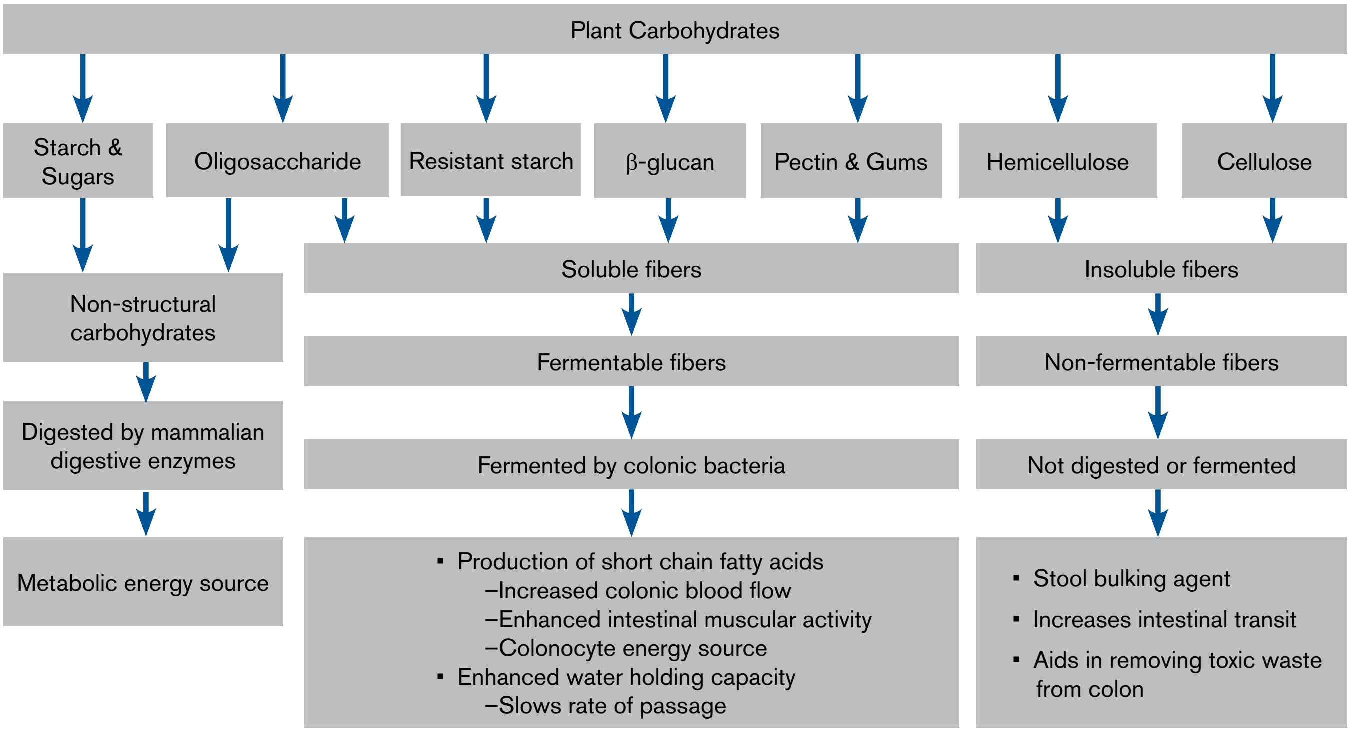


Table 2. Ingredient composition of extruded dog foods

Ingredient (%)	Low Fiber	Beet Pulp	Soybean Hulls	Cellulose
Chicken meal	31.1	31.7	30.7	33.3
Corn gluten meal	8.2	8.2	8.2	8.2
Brewers rice	46.0	28.8	31.5	33.5
Corn	4.1	4.1	4.1	4.1
Chicken fat	8.0	8.0	8.0	8.0
Beet pulp	0.0	16.6	0.0	0.0
Cellulose	0.0	0.0	0.0	10.3
Soybean hulls	0.0	0.0	15.0	0.0
Miscellaneous[1]	2.0	2.0	2.0	2.0
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}

maintain intestinal passage and desirable stool consistency. For these reasons, beet pulp is generally considered the “gold standard” source of dietary fiber used in pet foods.

Soybean hulls are a widely-available and economical source of dietary fiber. As the outer coating of individual soybeans, they are a co-product of the soybean oil extraction process. After harvesting, intact soybeans are stored, graded and cleaned. Soybeans meeting quality standards are dried, cracked and dehulled prior to conditioning and oil extraction. Resulting hulls are roasted and ground for use in animal foods. Despite their low cost and high availability, soybean hulls are rarely used in today’s pet foods because consumers assume they are an inert, non-nutritive filler. However, soybean hulls are comprised of 6% soluble fiber and 71% insoluble fiber, suggesting they are not inert filler but a potential source of functional fiber for pet food applications. The ratio of insoluble to soluble fiber in soybean hulls is intermediate to beet pulp and cellulose (12:1, 3:1, 31:1, respectively) suggesting their nutritional value should be intermediate to these common fiber sources.

As the "gold standard," beet pulp is frequently used as the comparative when evaluating the nutritional value of other dietary fiber sources. The functional health benefits of beet pulp are well-documented and accepted. This implies dietary fiber sources of similar nutritional value as beet pulp are expected to provide comparable nutritional and health benefits. In order to assess the nutritional value of soybean hulls, a feeding study was conducted using adult dogs fed extruded foods containing soybean hulls, beet pulp or cellulose.

Research

The feeding study used eight adult female beagles averaging 4.6 ± 0.6 years of age and weighing 12.8 ± 1.7 kg. Test foods were comprised of a control food containing no supplemental fiber (low fiber) or fiber-supplemented foods with 15% soybean hulls, 16% beet pulp or 10% cellulose (Table 2). All extruded foods were formulated to be nutritionally complete for adult dogs. The foods with fiber were formulated to contain 15% total dietary fiber compared with 5% for the low fiber food. Nutrient composition based on laboratory analyses is shown in Table 3. The soluble fiber content of the complete foods was 7.2, 2.6 and 1.9% for beet pulp, cellulose and soybean hulls, respectively. The ratio of insoluble to soluble fiber was highest for soybean hulls (6.5:1) compared with beet pulp (1.4:1) and cellulose (4.6:1).

The study was conducted at a USDA-licensed facility according to Animal Welfare Act guidelines and approved by the Institutional Animal Care and Use Committee. A replicated 4x4 Latin square design was used so each dog 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 dog foods

Item	Low Fiber	Beet Pulp	Soybean Hulls	Cellulose
Dry matter (%)	90.2	93.3	94.1	95.8
Crude protein (%)[1]	31.7	31.4	30.9	32.6
Acid-hydrolyzed fat (%)[1]	11.9	13.0	13.3	15.9
Total dietary fiber (%)[1]	5.0	17.3	14.3	14.7
Insoluble (%)[1]	3.4	10.1	12.4	12.1
Soluble (%)[1]	2.6	7.2	1.9	2.6
Insoluble:Soluble (ratio)	1.3:1	1.4:1	6.5:1	4.6:1
Gross energy (kcal/g)[1,2]	5.0	5.0	5.0	5.2
Metabolizable energy (kcal/g)[1,3]	3.7	3.3	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 each day during the collection period. A 5-point assessment scale assigned 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.

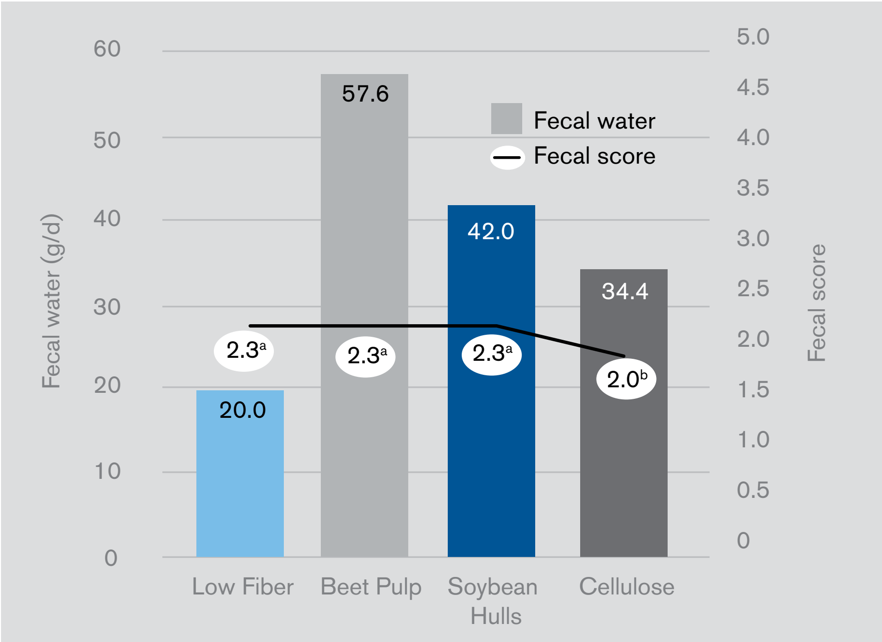
All dogs remained healthy throughout the study based on normal serum chemistries and blood counts and maintenance of body weight and body condition.

Table 4. Food intake and fecal characteristics

Item	Low Fiber	Beet Pulp	Soybean Hulls	Cellulose
Food intake (g/d, DM)	112.5[a]	117.5[a]	116.3[a]	140.5[a]
Fecal output (g/d, as-is)	35.9[a]	85.5[b]	69.2[b]	66.0[b]
Fecal output (g/d, DM)	15.9[a]	27.9[b]	27.2[b]	31.6[b]
Fecal ammonia (µmole/g)	152.2[a]	103.9[b]	147.8[a]	129.3[ab]
Fecal total phenols/ Indoles (µmole/g)	3.1[a]	0.9[b]	1.7[ab]	2.2[a]
Fecal phenols (µmole/g)	0.9[a]	0.1[a]	0.3[a]	0.7[a]
Fecal indoles (µmole/g)	2.2[a]	0.8[b]	1.4[ab]	1.5[ab]
Fecal pH	6.3[a]	5.9[b]	5.9[b]	6.6[a]

[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)

Food intake:

Level or source of dietary fiber did not affect (P>0.05) food consumption (Table 4). Dogs consumed more of the cellulose food numerically which is likely due to its higher fat content and better palatability.

Fecal characteristics:

Acceptable stool quality was maintained for all dogs based on subjective scores that ranged between 2 (semi-moist, well-formed) and 3 (soft, moist, formed). Stools were more firm and dry when dogs consumed cellulose compared with other fiber sources (P<0.05). Mean stool scores were identical (P>0.05) when dogs consumed soybean hulls, beet pulp or low fiber. As shown in Figure 2, there was no relationship between the similar stool scores (2.3) and differing fecal water content when dogs consumed beet pulp (57.6%), soybean hulls (42.0%) or low fiber (20.0%). Lower fecal moisture for dogs consuming cellulose (34.4%) corresponds to stools that were scored as drier (2.0). It was concluded that dogs fed a food with soybean hulls produced stools of comparable appearance and quality as beet pulp.

Fecal output was not different (P>0.05) for the fiber-containing foods. Beet pulp resulted in numerically more feces on an "as-is" basis, but this difference was mitigated by expressing fecal output on a dry matter basis. All fiber sources resulted in greater (P<0.05) fecal output than low fiber when expressed on "as-is" or dry matter basis. The higher "as-is" fecal output with beet pulp is attributed to its higher soluble fiber content and water holding capacity.

Nutrient digestibility:

All fiber-containing foods had similar (P>0.05) dry matter digestibility averaging 78% (Table 5). They were less (P<0.05) digestible than low fiber (85%). Protein digestibility was highest (P<0.05) for cellulose (87.1%) and the low fiber food (85.8%) and lowest (P<0.05) for beet pulp (78.8%). Protein digestibility was intermediate for soybean hulls which were different (P<0.05) from the other foods. Apparent protein digestibility does not account for fecal contributions of non-dietary protein sources. As a result, microbial protein from hind-gut fermentation reduces the estimate of protein digestibility. In all likelihood, the lower protein digestibility of beet pulp is likely due to its soluble fiber content and subsequent increase in microbial fermentation. The intermediate estimate for soybean hulls is surprising considering this food contained less soluble fiber than cellulose. This implies more hind-gut fermentation of soybean hulls than would be expected based on the fiber content of the complete food.

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

Fat digestibility was highest (P<0.05) for cellulose (94%) compared with other foods. This difference is likely an artifact of the higher fat content of this specific food. Fat digestibility was similar (P>0.05) for soybean hulls, beet pulp and low fiber food averaging 91%. Digestibility of total dietary fiber was lowest (P<0.05) for cellulose (15%) compared with other foods. Despite a two-fold difference in fiber digestibility between beet pulp (44%) and soybean hulls (22%), the difference was not significant (P>0.05). Fiber digestibility averaged 37% for the low fiber food which was similar (P>0.05) to beet pulp and soybean hulls. These fiber digestibility results are expected based on the higher ratio of insoluble to soluble fiber for soybean hull (6:1) and cellulose (4:1) relative to beet pulp (1:1). More non-fermentable fiber reached the large intestine when dogs were fed the food with cellulose vs. beet pulp.

Table 5. Apparent total tract nutrient digestibility

Item	Low Fiber	Beet Pulp	Soybean Hulls	Cellulose
Dry matter (%)	85.4[a]	76.2[b]	79.6[b]	77.2[b]
Crude protein (%)[1]	85.8[a]	78.8[b]	83.3[c]	87.1[a]
Acid-hydrolyzed fat (%)[1]	90.9[a]	91.2[a]	91.9[a]	94.3[b]
Total dietary fiber (%)[1]	37.8[a]	48.2[a]	22.7[a]	15.1[b]
Digestible energy (%)[1]	89.0[a]	81.3[b]	81.2[b]	82.8[b]
Metabolizable energy (%)[1]	83.4[a]	75.0[b]	74.8[b]	77.4[b]

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

Digestible energy and metabolizable energy values were similar (P>0.05) for soybean hulls, beet pulp and cellulose, averaging 81% and 75%, respectively. In contrast, digestible energy and metabolizable energy were higher (P<0.05) for the low fiber food (89% and 83%, respectively) implying a dilution effect of dietary fiber on the total caloric density of the food.

Fermentative end-products:

Ammonia, indoles and phenols are substances known to contribute to fecal odor (Table 4). The production of these putrefactive compounds was generally similar (P>0.05) for the fiber-containing foods. Fecal ammonia was the only factor that was higher (P<0.05) for soybean hulls compared with beet pulp. All compounds were higher (P<0.05) in the low fiber food compared with beet pulp only.

Fecal levels of short-chain fatty acids are generally derived from the hind-gut fermentation of carbohydrates. In this study, total levels were greater (P<0.05) for beet pulp and soybean hulls compared with cellulose and low fiber (Figure 3). These differences can be attributed to relative proportions (P<0.05) of fecal acetate and propionate for beet pulp and soybean hulls. Fecal butyrate was highest for beet pulp and lowest for cellulose (P<0.05). Butyrate levels were intermediate for soybean hulls and low fiber which were not different (P>0.05) from any group. Branched-chain fatty acids excreted in feces are derived from protein fermentation. Total branched-chain amino acids were higher (P<0.05) for the low fiber food compared with the fiber-containing foods (Figure 4). The differences were driven by higher (P<0.05) levels of isobutyrate and isovalerate when dogs consumed low fiber. For the fiber-containing foods, total concentrations and isobutyrate were similar (P>0.05). In contrast, beet pulp was associated with lower isovalerate and higher valerate compared (P<0.05) with soybean hulls and cellulose. Overall, these responses represent a beneficial shift in fermentation end-products with soybean hulls that mirrored the response of beet pulp but not cellulose. These shifts in fermentative end-products are important for maintaining intestinal health and its link to whole-body health benefits.

Summary

Adult dogs fed an extruded food with soybean hulls produced stool characteristics and nutrient digestibilities that were more similar to beet pulp than cellulose. These foods also resulted in similar levels and profiles of fermentative end-products, implying similar hind-gut fermentation of soybean hulls as beet pulp. These results demonstrate a similar nutritional value for soybean hulls and beet pulp. This demonstrates that the consumption of soybean hulls provides the same nutritional health benefits as beet pulp.

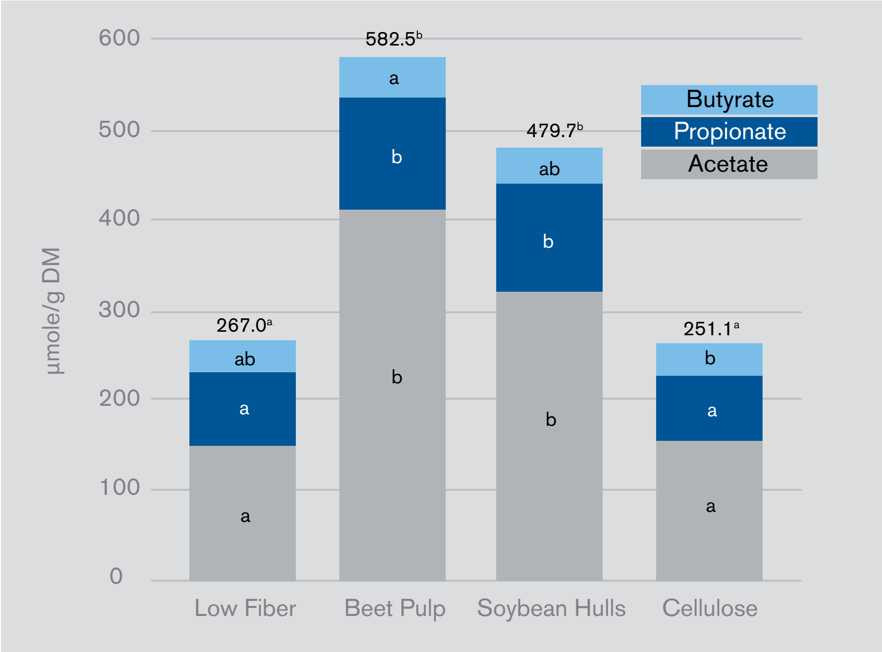
Application

Nutritional value of soybean hulls is more similar to beet pulp than cellulose based on macronutrient digestion, fermentative end-products and stool quality.

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.

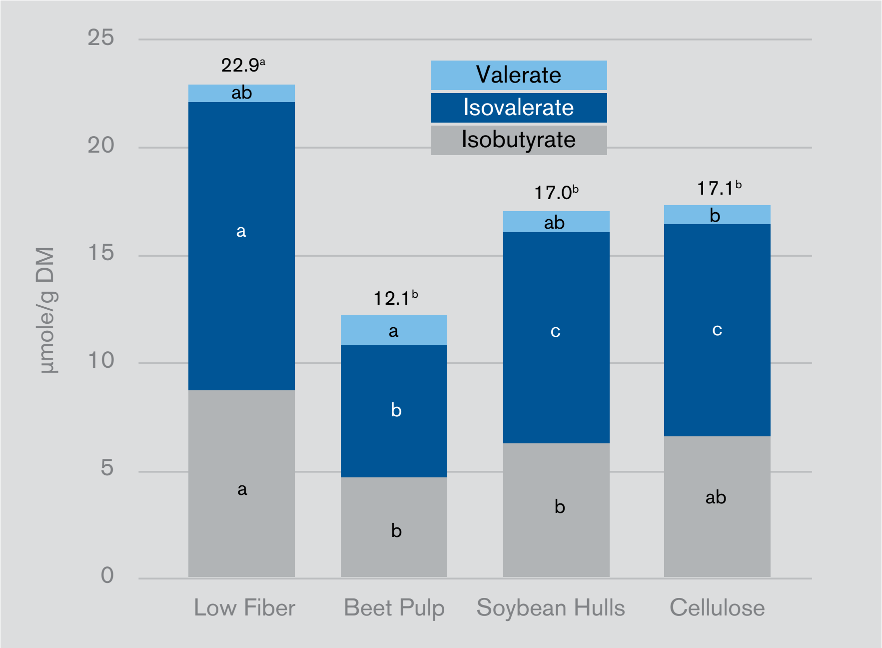
Pet owners must be educated regarding their misconceptions that soybean hulls are inert filler that provide no nutritional value to dogs or cats. This comparative study demonstrates soybean hulls contain functional fiber that is fermented by intestinal microbiota which provide nutritional health benefits comparable to beet pulp. ■

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



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

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



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

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