

Dietary fiber aids in the management of canine and feline gastrointestinal disease

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Dietary fiber describes a diverse assortment of nondigestible carbohydrates that play a vital role in the health of animals and maintenance of gastrointestinal tract homeostasis. The main roles dietary fiber play in the gastrointestinal tract include physically altering the digesta, modulating appetite and satiety, regulating digestion, and acting as a microbial energy source through fermentation. These functions can have widespread systemic effects. Fiber is a vital component of nearly all commercial canine and feline diets. Key features of fiber types, such as fermentability, solubility, and viscosity, have been shown to have clinical implications as well as health benefits in dogs and cats. Practitioners should know how to evaluate a diet for fiber content and the current knowledge on fiber supplementation as it relates to common enteropathies including acute diarrhea, chronic diarrhea, constipation, and hairball management. Understanding the fundamentals of dietary fiber allows the practicing clinician to use fiber optimally as a management modality.

Dietary fiber includes a diverse assortment of nondigestible carbohydrates that play a vital role in the health of animals and maintenance of gastrointestinal tract (GIT) homeostasis.¹ The main roles dietary fiber play in the GIT include physically altering the digesta, modulating appetite and satiety, regulating digestion, and acting as a microbial energy source through fermentation.¹ These functions can have widespread systemic effects, as will be highlighted in this review (**Figure 1**). Fiber function, related health benefits, reporting in pet foods, and clinical impact in dogs and cats are complex subjects. This review aims to help demystify clinically relevant aspects of fiber functions, health benefits, and keys to clinical use, as well as review the current veterinary evidence of fiber in disease management.

Because fiber types vary greatly in molecular size and structure with differing effects on the body, fiber is often categorized based on functional properties rather than its structure. The most common classification schemes for fiber types are based on physiochemical properties: fermentability, solubility, and viscosity.¹ Fermentability is defined by the speed and completeness of which a given fiber type can be fermented by microbes in the GIT. Although fermentability is a continuum, and the degree to which a given fiber type is fermented varies by the host species, fibers are typically classified in nonspecific terms, including nonfermentable, slowly fermentable, moderately fermentable,

and rapidly fermentable (**Figure 2**). Fermentation results in the production of metabolites, predominantly short-chain fatty acids (SCFAs), in the GIT. Recent research has shown that these end products of fermentation are important in understanding the bridge between processing of dietary fiber in the gut, and both the systemic and local GIT health benefits attributed to dietary fiber.² These links are still being investigated mechanistically; however, as a general rule within the GIT, as the fermentation rate of fiber increases, GI transit time decreases, fecal bulk decreases, and fecal metabolite production increases.³⁻⁵ Nonfermentable or slowly fermentable fibers (eg, cellulose and hemicellulose) pass through the GIT with little change to their structure.^{5,6} Slowly fermentable fibers have the greatest fecal bulking effects because they are typically able to bind water throughout the GIT.⁵ Rapidly fermentable fibers (eg, fruit pectins and gums) are the principle sources of SCFA production.^{1,2} Much like fermentability, dietary fiber solubility is a continuum from completely soluble to completely insoluble. The actual solubility of individual fiber sources can vary drastically, and it has been shown that fibers classified classically as soluble can be quite variable in their ability to be suspended in water.^{7,8} Last, viscosity is a measure of the fiber type's ability to thicken and form gels in solution. Viscosity can be drastically different between fiber types and most commonly is a feature attributed to soluble fibers.⁹

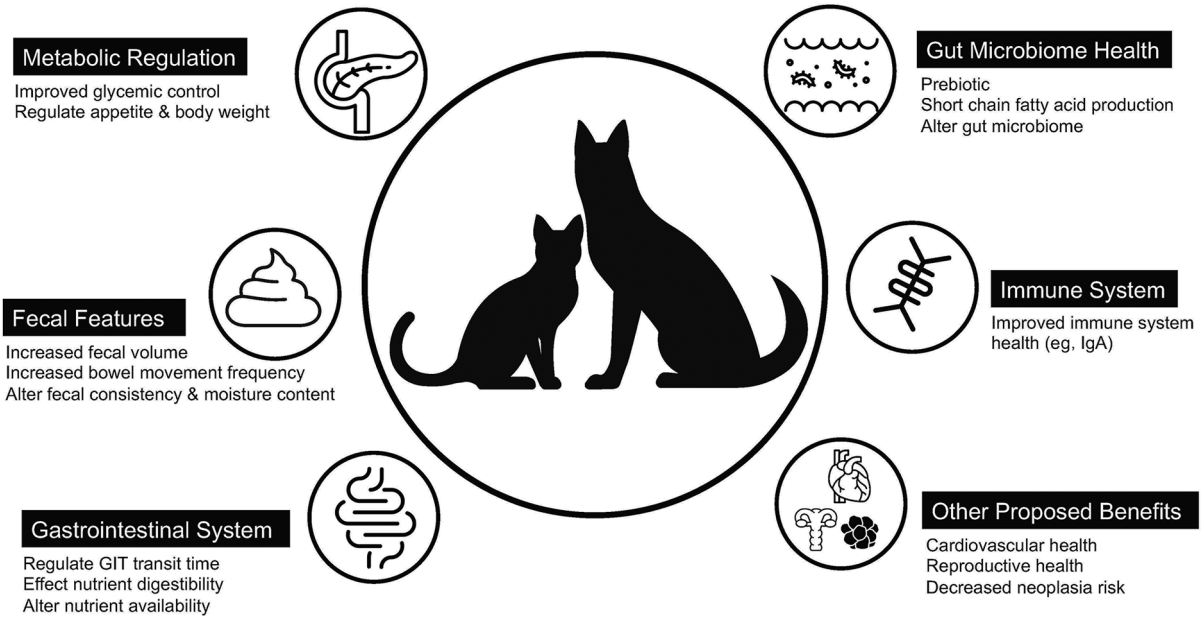


Figure 1—Dietary fiber has widespread effects within the gastrointestinal tract (GIT) and systemically. The primary effects documented in dogs and cats are highlighted in this figure. Ig = Immunoglobulin.

A

Dietary Fiber Sources		Solubility		
		High	Moderate	Low
Fermentability	High	Fructose, Galactans, Mannans, Mucilages, Apple pectin, Citrus pulp, Guar gum, Gum arabic, Soy fiber, Apple pomace, Carrot pomace, Citrus pectin		
	Moderate	Pectin, Flaxseed	Grape pomace, Tomato pomace, Pea hulls	Hemicellulose, Beet pulp, Corn bran, Pea fiber, Rice bran, Soy hulls, Wheat brans, Wheat middlings
	Low		Pistachio Psyllium	Hemicellulose, Cellulose, Soy hulls, Peanut hulls, Sunflower hulls

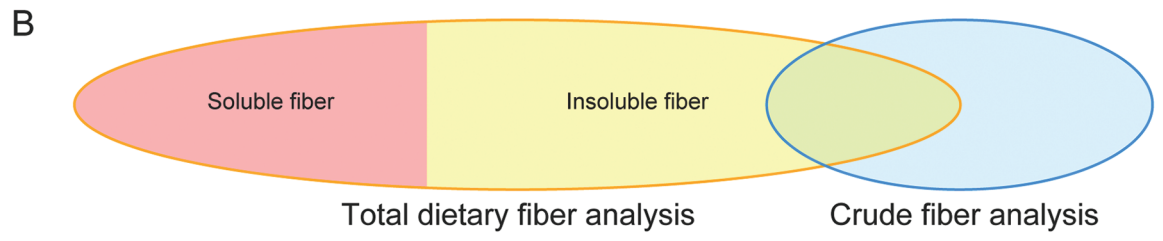


Figure 2—A—Solubility and fermentability of various dietary sources of fiber. B—Comparative meaning of total dietary fiber, crude fiber, insoluble fiber, and soluble fiber. (From Rudinsky AJ, Rowe JC, Parker VJ. Nutritional management of chronic enteropathies in dogs and cats. *J Am Vet Med Assoc.* 2018;253[5]:570–578.)

These methods of categorizing dietary fiber are used based on their applicability to many clinical situations and the modification of fiber in the diet for individual animals. There is a broad overlap between solubility and fermentability, with most rapidly fermentable fibers such as pectins and gums being the most soluble, whereas poorly fermentable fibers (cellulose, hemicellulose) are some of the most insoluble. This relationship is shown in Figure 2, which demonstrates the solubility and fermentability of select fiber sources. However, although these correlations exist between solubility and fermentability, classifying based on 1 dietary fiber property does not imply differences or similarities in other properties. This is particularly important in some effects of fiber (eg, binding mineral cations).⁸

Fiber Requirements and Reporting in Pet Foods

Dietary fiber has beneficial effects on the GIT and overall health of dogs and cats (Figure 1). However, because fiber consists of nondigestible carbohydrates and their metabolites (such as SCFAs), fiber contributes less than 5% of the energy needed in dogs and cats; thus, dietary fiber is currently not considered an essential nutrient.¹⁰ The Association of American Feed Control Officials (AAFCO) sets requirements for minimum and maximum nutrient concentrations for foods meant for dogs and cats. Currently, the AAFCO has no minimum requirement for fiber in either dogs or cats, and carbohydrate-free diets have been fed to dogs short term without adverse effects.¹¹ Fiber deficiency and excess are not major clinical concerns for most healthy dogs or cats fed commercial pet foods.¹¹⁻¹⁷ Excess dietary fiber could reduce mineral absorption, dilute caloric concentration, and, in some instances, cause diarrhea.¹²⁻¹⁸ However, this is not expected to be an issue with complete and balanced commercially available diets, and there are no published studies documenting unintended fiber-related nutritional deficiencies developing in dogs and cats fed balanced diets. Fiber deficiency can cause gastrointestinal and systemic health concerns. In these instances, fiber deficiency is relative to the animal's need rather than from an absolute deficiency. This is most commonly seen in dogs and cats that need greater amounts of dietary fiber to manage GIT dysfunction.¹⁹⁻²²

There are a variety of different analyses used to measure fiber in human and veterinary diets and foodstuffs, including crude fiber (CF), neutral detergent fiber, acid detergent fiber, total dietary fiber (TDF), amylase-treated neutral detergent fiber, insoluble dietary fiber, soluble dietary fiber, and non-starch polysaccharides.¹ The most common laboratory method for reporting fiber in pet foods is the CF method, and the AAFCO requires that the guaranteed analysis of pet foods list the maximum CF concentration. CF does not provide an estimate of

highly fermentable and soluble fiber concentration (Figure 2) because they are not included in this analysis.²³ This can result in underestimating the total fiber concentration by up to 50%.²⁴

TDF is more commonly reported for human foods and is measured with enzymatic and gravimetric processes. This method separates fibers into soluble and nonsoluble, thus including the fiber contribution missed with crude analysis (Figure 2).²⁵ TDF is gaining popularity among veterinary nutritionists to quantify fiber concentration more accurately.²³ In 2019, Fahey et al²⁴ asserted that TDF should replace CF as the required method of measuring and reporting fiber content of pet foods. Because not all commercial diets report TDF, pet owners and veterinarians should be aware of the aforementioned significant limitations of the more common CF method to assess dietary fiber concentration.

Another flaw of the current reporting standards is the inability to compare nutrient concentrations among foods of differing caloric densities and between dry and canned foods. Although not specific to dietary fiber reporting, this is an important consideration in assessing nutrient profiles. Comparing nutrient concentrations on an as-fed percentage basis does not necessarily provide an accurate comparison among diets. We authors typically recommend comparing nutrients on a caloric basis (eg, grams per 100 kcal). The amount of TDF in dog and cat food ranges greatly—from as little as 0.1 g/100 kcal to more than 11 g/100 kcal (Figure 3). For reference, when assessing veterinary therapeutic dry diets, some of the lowest fiber diets include hydrolyzed and easily digestible diets, providing approximately 1.0 to 2.5 g TDF/100 kcal. Specifically formulated fiber-enriched diets for the management of fiber-responsive enteropathies (ie, mix of soluble, insoluble, and prebiotic fibers) provide a midrange of TDF: 4.5 to 6.0 g/100 kcal and 2.6 to 2.9 g/100 kcal for dogs and cats, respectively. The highest fiber diets are typically those designed for weight management, providing 7.5 to 11.0 g/100 kcal and 4.6 to 7.6 g/100 kcal for dogs and cats, respectively. It is important to note that nutrient profiles of specific diets may vary over time; therefore, TDF should be reevaluated periodically.



Dietary fiber g/100 kcal				
	Crude fiber	TDF	Crude fiber	TDF
Low	< 1.0	< 2.0	< 0.5	< 0.5
Moderate	1.0–2.0	2.0–4.0	0.5–1.0	1.0–2.5
High	> 2.0	> 4.0	> 1.0	> 2.5
Range	0.1–6.8	0.1–11.0	0.1–4.9	0.2–7.5

Figure 3—Typical ranges of crude fiber and total dietary fiber (TDF) concentrations reported in dog and cat food.

Fiber Administration in Dogs and Cats

There are a number of veterinary therapeutic fiber-enhanced diets designed specifically for dogs and cats with fiber-responsive diseases. These diets often include a variety of fiber sources, including soluble, insoluble, and prebiotic fibers. Diets manufactured by reputable pet food companies are the ideal method of fiber supplementation for dogs and cats because of their guaranteed analysis and assurance they are complete and balanced. Specifically formulated diets ensure specific fiber sources are provided in specific amounts, and that the diet collectively is formulated to be complete and balanced. However, for a number of reasons, either veterinarians and/or pet owners may not want to feed a specific veterinary therapeutic fiber-enhanced diet. In these cases, to manage a suspected fiber-responsive disorder, it is common in clinical practice to add another source of dietary fiber to the complete and balanced diet that the patient is already consuming. This approach is considered less ideal because the additional supplemented fiber might be associated with administration issues (including variability and inconsistency of consumed fiber) as well as the potential to result in an imbalance in consumed nutrients.

Commonly administered fiber sources may include psyllium husk, cellulose, or canned pumpkin. The relative fiber concentrations of these different fiber sources vary widely (Figure 4), with psyllium providing a far more concentrated fiber source (USDA Nutrient Database).²⁶ Currently, there are limited evidence-based guidelines for fiber supplementation in dogs and cats. There is only 1 study¹⁹ that reports fiber supplementation amounts. In that study, dogs with fiber-responsive large bowel disease reportedly responded to a median dosage of 2 tablespoons/day of psyllium fiber. The full range of fiber supplementation used in that study was between 0.25 to 6 tablespoons/day. Beyond these data, additional fiber supplementation dosing is empirical and based




Fiber Source	Amount	Total Fiber ~20 grams
Psyllium husk	2 tbsp	
Canned pumpkin	3 cups	
Green beans	8 cups	

Figure 4—Relative fiber contributions totaling 20 g of fiber from various commonly used fiber sources in clinical practice.

on clinical experience. It is imperative to keep in mind that single sources of fiber supplementation may not yield the same clinical benefits as diets with a more varied mix of soluble, insoluble, and prebiotic fiber sources. It is also important to increase the amount of fiber supplemented gradually to avoid complications (eg, flatulence, bloating, abdominal cramping, changes in bowel movements) associated with rapid changes in fiber administration (Figure 5).



Figure 5—Cosmetic changes to feces after fiber supplementation. Both photos are from dogs on fiber supplementation. A—The fiber supplementation has firmed the feces from this canine colitis patient and given a fibrous/rubbery outer appearance to the bowel movement. B—Oversupplementation of fiber resulted in a pseudomembranous appearance of the feces with watery diarrhea inside consistent with the dog's initial clinical signs.

Physiologic Effects and Health Benefits of Dietary Fiber

GIT transit times

Fiber helps to regulate stool transit time through bulking effects, the regulation of GIT contents water concentration, the stimulation of mucus secretion, and bacterial metabolism (Figure 1).²⁷ The fiber type, source, and processing method all impact the effect on GIT transit times. Furthermore, the effects on GIT transit times vary based on specific regions within the GIT.²⁷ Fiber solubility and viscosity provide the most consistent predictive effect of the impact on GIT transit times. In general, soluble and viscous fiber types delay gastric emptying and increase small intestinal transit time, whereas insoluble fibers often increase gastric emptying time and decrease transit time in both the small intestine and colon.^{3-5,12,28-39}

Despite these trends, there are also exceptions to GIT transit time responses because they are not completely predictable based on fiber type. One notable exception is from comparative data from 2 studies in cats^{40,41} that showed relatively shorter gastric emptying times when healthy cats were fed a diet high in insoluble fiber compared to cats fed a diet with a lower insoluble fiber concentration.

In these 2 studies, other important variables were not controlled, including—most specifically—the other macronutrient concentrations of the diet. As such, the effect cannot be attributed definitively to the insoluble fiber content. However, similar results in contrast to the classic response to dietary fiber have been reported in humans and dogs as well.^{3,42-44} As such, clinicians should be aware that atypical clinical responses may be observed in GIT transit when dietary fiber concentration is altered. The last proposed mechanism for the fecal transit regulatory effects of fiber is related to bacterial metabolism and production metabolites such as SCFAs and microbially derived secondary bile acids.⁴⁵⁻⁴⁷ This mechanism has been documented, but not fully examined in dogs or cats, and further study is needed.^{45,46}

Laxation, fecal water concentration, and fecal volume

Dietary fiber increases fecal volume and weight, making defecation easier (Figure 1). Soluble, fermentable fibers increase stool weight, moisture concentration, and softness by increasing water retention, fecal dry matter percentage, and bacterial concentration.^{5,12,28,29,48,49} Insoluble, minimally fermentable fibers increase fecal mass through water retention and dry matter bulking capacity.⁵ The effects of fiber source and preparation on wet fecal volume and defecation frequency are variable in dogs, with some studies showing the expected effect and others resulting in no significant changes.^{28,29,48,50-53} Studies examining the effects of dietary fiber on fecal volume in cats are not available; however, review articles, reports, and proceedings reference their potential utility in clinical practice.^{53,54} As such, there is evidence in dogs that defecation frequency, fecal score, and moisture content may be altered by modifying dietary fiber, with minimal supporting evidence in cats. The effects on fecal score and cosmetics can be particularly useful because abnormalities in fecal appearance, clinical or not, can be distressing for owners.

Appetite and body weight

Dietary fiber has been used in weight management therapeutic strategies for people because of its ability to decrease caloric density of foods, alter dry and organic matter digestibility, and increase satiety.⁵⁵ Increasing the amount of fiber in a diet reduces the caloric density, allowing animals to be fed a calorically neutral, larger volume of food and improve satiation through gastric distension while eating. The addition of predominantly insoluble fiber sources results in reduced caloric consumption, weight loss, and more rapid satiation in some studies, whereas others have shown no effect in dogs.^{27,56-61} Studies in cats have shown a similar ability to decrease caloric density of diets and decrease voluntary intake.^{62,63} Importantly, many of these trials examine multiple variables, including varying macronutrient profiles and concurrent caloric restrictions, making definitive conclusions about fiber effects difficult.⁶⁴

Nutrient digestibility and availability

As fiber concentration increases, the overall digestibility of a diet decreases.^{6,51,65-68} Foods high in slowly fermentable fibers, such as cellulose, cause a greater reduction in digestibility, whereas foods with rapidly fermentable fibers have a lesser impact on digestibility.⁵ Fermentable, soluble fibers alter nutrient availability by forming gels that act as a physical barrier to enzymatic digestion of nutrients and modulation of GIT transit time, which affects the duration of enzyme-substrate interactions.⁶⁹ Fiber can also have variable impacts on the apparent digestibility of other macronutrients—in particular, protein.⁶ This is a reflection of the contribution of microbially derived nitrogen in total fecal nitrogen concentration otherwise attributed as dietary origin. Dietary fiber can potentially limit absorption of minerals, including magnesium, calcium, phosphorus, and iron (Figure 1).¹³⁻¹⁸

Fiber as a prebiotic and colonic health

Dietary fiber may function as a prebiotic fiber.⁷⁰ The definition of a prebiotic fiber from the International Scientific Association of Probiotics and Prebiotics is a substrate used selectively by host microorganisms that confers a health benefit.⁷¹ Fibers are classified as prebiotics if they are resistant to digestion by host enzymes, promote the growth of symbiotic gut microbes, and fail to promote the growth of pathogenic bacteria.⁷⁰ Many compounds have been evaluated for their prebiotic properties and effects. Several of these have been studied in dogs, including multiple fructans and oligosaccharides—mainly, mannan oligosaccharides (MOS), a yeast cell wall carbohydrate; galacto-oligosaccharides, xylo-oligosaccharides.⁷² Oligosaccharides and inulin (mainly from chicory) are the most well studied and widely used prebiotic fibers in dogs and cats.

Fermentation of prebiotic fiber in the colon promotes colonocyte health through modulation of microbial populations and microbial metabolites.^{2,73} SCFAs produced by bacterial fermentation of fibers act as an energy source for both the microbes in the colon and the host via the portal circulation.^{2,74} In particular, butyrate can be used as a primary energy source for colonocytes, maintain osmotic balance in the colon by facilitating the absorption of chloride and sodium, maintain a healthy epithelium by regulating proliferation, improve colonic blood flow, reduce reliance on gluconeogenesis, and prevent colonization by pathogenic bacteria (Figure 1).^{2,75-78} An additional local benefit attributed to the production of SCFAs is the lowering of the luminal pH, which inhibits the proliferation of *Clostridium* spp and other pathogenic bacteria, enhances mineral absorption, and reduces peptide degradation, which reduces the production of ammonia, amines, and phenolic compounds.^{2,72,79} Systemic health benefits of SCFAs, including the improvement in glycemic control, modulation of gene expression, immunoregulatory effects, and neuronal regeneration, have been investigated and reviewed extensively in humans.^{2,74} To date, these systemic outcomes

have not been investigated extensively in dogs and cats.^{80,81} Other microenvironment changes are recognized independent of fatty acid production, including most specifically the modulation of fecal bile acid profiles; however, this requires further investigation in dogs and cats.^{82,83} In conclusion, fibers vary greatly in their fermentability and production of SCFAs, branched-chain fatty acids, and fecal bile acids, and further research is needed.

Fiber and glycemic control

Diet composition impacts postprandial glycemia and insulin responses based on macronutrient concentration, effects on GIT function and motility, and incretin responses (Figure 1).⁸⁴⁻⁸⁶ Highly viscous, soluble fibers appear to be most effective as a result of their ability to impair glucose uptake from the fiber-induced gel formation in the intestines.²⁷ There is evidence in dogs to suggest that increasing the fiber concentration, soluble or insoluble, is associated with better glycemic control and decreased postprandial hyperglycemia through decreased GIT motility and nutrient absorption.⁸⁷⁻⁹⁰ Less research has been performed in cats exploring the effect of fiber on glycemic control. The two currently available studies^{91,92} are contradictory in that one demonstrated improved postprandial hyperglycemia in cats on a higher fiber diet whereas the other study showed a low-fiber diet might improve feline diabetes mellitus remission rates. There are no studies in diabetic dogs and cats that have shown that an overall administered insulin dose is altered by dietary fiber; however, the reduced postprandial hyperglycemia might contribute to improved clinical symptomatology.

Geriatric nutrition

As animals age, each body system experiences physiologic and metabolic changes. In the GIT, changes to the way animals' enterocyte uptake, digest, and absorb nutrients occur with age. Apparent digestibility of crude protein and fat is reduced in older animals.^{73,93} Likewise, intestinal transit time, basal metabolism, postprandial responses, intestinal and pancreatic secretions, and physical activity decrease with age.⁹⁴ Based on these reported changes, fiber supplementation has been advocated in geriatric animals to maintain intestinal transit time and gastrointestinal function, and prevent constipation and diarrhea.⁹⁴ Fiber recommendations in geriatric dogs and cats have not been established formally.⁹⁵

Additional benefits: cardiovascular, immune, and reproductive health

The gut microbiome plays a key role in maintaining gastrointestinal and immune health, and can be altered by fiber. Grieshop et al⁷⁹ demonstrated that dietary supplementation of chicory (58% inulin on a DM basis) or MOS in geriatric dogs had no impact on serum IgA, IgG, or IgM levels; however, IgA levels in the gut were not investigated. Alternatively, Swanson et al⁹⁶ found that ileal cannulated dogs supplemented with 2 g/day MOS saw an 18.5% increase in ileal IgA

concentrations. These are preliminary evaluations of the immunomodulatory aspects of fiber in canine nutrition. Further investigation is needed to explore this aspect of dietary fiber in companion animals.

In human medicine, evidence supports that fiber intake reduces the risk of neoplasia, cardiovascular disease, and coronary heart disease as well as improves effects on reproductive health status.^{72,97} Research evaluating these outcomes in association with fiber consumption are absent in the veterinary literature.

Fiber as a Prebiotic and the Gut Microbiome

Prebiotic fibers affect the gut microbiome in dogs and cats.⁹⁸ Fibers are broken down primarily by *Bifidobacterium* spp and *Lactobacillus* spp, and remain inaccessible to other gut microbes.⁷² Increased consumption of these carbohydrates gives a competitive advantage to and promotes the growth of these bacteria, which confers host benefits in the GIT and systemically.⁷² Supplementation with either MOS or chicory (inulin) in dogs increased fecal concentration of *Bifidobacterium* spp.^{79,99,100} Colonic pH is lowered by the SCFAs produced by *Bifidobacterium* spp and other anaerobes that ferment these prebiotic fibers.^{49,101,102} The effect that a fiber has on the pH change and production of SCFAs varies between different prebiotic fibers.^{49,101,102} Flickinger et al,¹⁰³ using in vitro human fecal samples and in vivo dietary trials with ileal cannulated dogs found that alpha-gluco-oligosaccharide and maltodextrin-like oligosaccharide serve as fermentable, indigestible prebiotic fibers.¹⁰³ When compared to other prebiotics (guar gum, gum arabic, fructo-oligosaccharides, guar hydrolysate), each had different amounts of both total SCFA production and relative abundance of butyrate, acetate, and propionate.¹⁰³

The fermentation of oligosaccharides into organic acids can help to decrease the number of pathogenic bacteria and prevent the overgrowth of several pathogenic bacterial species such as *Clostridium* spp by lowering intestinal pH and preventing colonization by competitive exclusion.¹ *Bifidobacterium* spp may also produce antimicrobials that inhibit the proliferation of diarrhea-causing pathogens such as clostridia and *Escherichia coli*. Fecal concentrations of *E coli* were found to be lower in geriatric dogs supplemented with MOS than in age-matched control dogs.⁷⁷ Supplementation with 3% chicory, 1.5 g lactosucrose, and 1% scFOS all led to an increase in bifidobacteria and a decrease in clostridial species.^{100,104,105} Terada et al¹⁰⁴ found that although the concentration of lecithinase-positive *Clostridia* spp decreased by 3 log units after 2 weeks of supplementation, 1 week after the supplementation was discontinued, the bifidobacteria and clostridia levels returned to their presupplementation levels.

Limited studies are available that assess the therapeutic effects of prebiotics in companion animals. Studies reporting the effects of different

prebiotic fibers differ in their results and all their methodology. Currently, in veterinary medicine, there is no consensus on ideal delivery route, dosage, and source of prebiotic fibers, and many fibers differ in their purity levels, exacerbating differing results found by researchers. The overall health impacts of prebiotics on the health of dogs and cats is understudied, and many of the proposed benefits of prebiotic supplementation are based on human, pig, and rabbit studies.⁷⁰ Feeding studies^{68,96,106,107} with dogs have sometimes shown conflicting results. Addition of FOS to the diet of dogs was shown to increase *Bifidobacterium* spp concentration in the colon in 2 studies,^{68,96} whereas there was no significant impact in bifidobacteria concentration in 2 conflicting studies.^{106,107} Grieshop et al,¹⁰⁸ in 2002, found arabinogalactan, another prebiotic fiber, to increase lactobacilli concentrations in dogs. Information regarding dosage ranges for prebiotic supplementation and the synergistic effects of prebiotics and other dietary fibers on dog and cat health are lacking, and further research is warranted.

Fiber and Management of Clinical Gastrointestinal Disease

Acute diarrhea

There is evidence supporting the management of dogs with acute colitis using fiber-enhanced diets.¹⁰⁹ One early study¹⁰⁹ evaluated whether feeding a diet with high concentrations of soluble and insoluble fiber (TDF, 6.1 g/100 kcal) would be more effective than a diet with average fiber levels (TDF, 1.5 g/100 kcal). Twenty-two dogs were randomized into 2 groups receiving the 2 diet options in combination with metronidazole. Dogs fed the high-fiber diet had a greater proportion of improved fecal scores compared to dogs fed the standard diet in the short term.

A second study¹¹⁰ examined the response of 59 client-owned dogs with noninfectious acute colitis randomized into 3 placebo-controlled groups. The first group received an easily digestible diet in combination with placebo, the second group received an easily digestible diet in combination with metronidazole, and the final group received a psyllium-enhanced easily digestible diet in combination with placebo. Time to clinical resolution was improved with both the easily digestible diet (TDF, 1.5 g/100 kcal) as well as the easily digestible diet with psyllium fiber enhancement (TDF, 2.8 g/100 kcal) when compared to the easily digestible diet with metronidazole. Interestingly, although a significance difference between groups was not found, the number of dogs with recurrence of colitis was less for dogs receiving the fiber-enhanced diet compared to the easily digestible diet. This study demonstrated dietary management was more effective than dietary management in combination with metronidazole for management of acute colitis in dogs.

One final study²² tested the effect of 2 diets on 46 shelter puppies. The test diet in the study used soluble and insoluble fiber from multiple sources

(4.3% CF and 2.0% soluble fiber; grams per 100 kcal not reported) compared to a control diet (CF 3.3% dry matter basis and 0.3% soluble fiber; grams per 100 kcal not reported). In this group of dogs, the test diet that was higher in both CF and soluble fiber resulted in faster resolution of clinical signs and improved fecal scores.²² This study is currently only published in abstract form and, as such, limited additional information about the patient population and study diets is available. These studies provide evidence for the use of fiber as a primary therapeutic in acute diarrhea, particularly colitis.

Similarly, there is support for fiber-enhanced diets for cats with acute colitis as well. Sixty-four shelter kittens with colitis were randomized into 2 groups, with one group receiving a test diet consisting of soluble and insoluble fiber from multiple sources (3.0% CF and 1.6% soluble fiber; grams per 100 kcal not reported) and the other group receiving a control diet (CF 1.1% dry matter basis and 0.2% soluble fiber; grams per 100 kcal not reported). As was seen in the canine study, the test diet resulted in fewer days to resolution of diarrhea in cats.²¹ However, similar fecal scores were ultimately reported between the 2 diets. This study is also only published in abstract form and, as such, limited additional information about the patient population and study diets is available.

In all aforementioned studies,^{21,22,109} no adverse effects or complications associated with dietary therapy for acute diarrhea were noted. Furthermore, no deleterious impact on the fecal microbiome, as measured by the canine dysbiosis index, was noted when acute colitis was treated with a fiber-enhanced diet versus fiber-enhanced diet with metronidazole.¹¹⁰ Collectively, these studies provide evidence for the use of fiber-enhanced diets for the management of acute colitis in dogs and cats, with improved outcomes compared to traditional empirical management options.

Chronic diarrhea

There are multiple studies investigating nutritional management of chronic diarrhea in dogs and cats with fiber-enhanced diets. The majority of these studies are specific to animals with colitis signs; however, some include animals with enteritis or enterocolitis clinical signs. In dogs, 3 studies^{111,112} (H. Charles, DVM, Royal Canin, email, June 30, 2020), compared the effects of different diet types compared to fiber-enhanced diets. Simpson and Markwell¹¹¹ examined the effects of 3 diets (low fat, high fiber, or restricted antigen) with concurrent anti-inflammatory steroid therapy administered in the initial few weeks of therapy.¹¹¹ In their study, without concurrent medications, there was an 85% response rate with the restricted-antigen diet. The high-fiber diet was also effective in controlling clinical signs in approximately 75% of cases. The dogs on the low fat diet exhibited a lower response rate at 18%.

A second retrospective study¹¹² in 25 dogs with chronic colitis revealed that a change to a fiber-enhanced diet was the most common dietary

modification to result in resolution of clinical signs. Proportionally fewer dogs responded to highly digestible diets and hypoallergenic diets. However, importantly, this was not a randomized controlled study, and comparison between diet response rates is not possible. There is also an uncontrolled study (H Charles, DVM, Royal Canin, email, June 30, 2020), using a commercially available diet in dogs in which feeding fiber-enhanced diets resulted in a colitis response. Collectively, these studies demonstrate proof of concept for fiber-enhanced diets in chronic diarrhea dogs. An additional study¹¹³ supported the role of fiber in management of chronic gastrointestinal disease; however, it was not designed specifically to investigate the role of fiber in the treatment response. Current evidence in veterinary medicine emphasizes the importance and feasibility of using fiber-enhanced diet trials in canine chronic colitis.

There are also studies^{19,114} supporting the use of fiber-enhanced diets in both noninflammatory and idiopathic chronic colitis. Leib¹⁹ reported the response of 27 dogs with chronic, noninflammatory colitis to predominantly soluble fiber supplementation with various base diets (easily digestible, low fat, or limited ingredient). In that population, an excellent or good clinical response was seen in 26 of 27 dogs.¹⁹ The second study¹¹⁴ examined 2 separate commercially available diets enhanced with mostly insoluble fiber. Many of the dogs in that study were administered concurrent therapies; however, response was attributed to dietary modification in 12 of the 19 dogs in the study.¹¹⁴ One important finding from these studies is that dogs appear to respond to both soluble and insoluble fiber sources. In addition, in both of these studies,^{19,114} after implementing fiber supplementation, adjunctive medical treatments were able to be tapered or discontinued in some dogs. These studies emphasize the potential utility of diets enhanced with both soluble, insoluble, and mixed fiber sources in canine idiopathic large bowel diarrhea.

Last, the ability of fiber-enhanced diets not only to improve clinical signs but also parameters of gastrointestinal and systemic health has been investigated. In addition to standard signs of colitis, studies have reported improvements in stooling behaviors and quality of life. The test diet in 1 study¹¹⁵ increased metabolites associated with saccharolytic fermentation, decreased putrefactive metabolites, and increased antioxidant and anti-inflammatory effects. The authors proposed that these compounds could contribute to long-term health as well as the observed rapid resolution and decreased recurrence of chronic diarrhea.¹¹⁵

Overall, these studies indicate that the prognosis for dogs with fiber-responsive chronic gastrointestinal disease is good. In 1 study,¹⁹ the clinical response to long-term soluble fiber treatment was reported to be at least good in 96% of dogs. In the study¹¹⁵ using predominantly insoluble fiber diets, 63% of dogs responded to diet as opposed to other treatment. Long-term follow-up indicated that if fiber supplementation were removed or tapered, there was a chance that clinical signs would recur, indicating the need for long-term supplementation.¹⁹ Last, similar

to the acute studies,¹¹⁵ the therapeutic diets and fiber supplementation were safe and well tolerated by dogs.

Similar to dogs, there is limited information on nutritional management of diarrhea in cats with fiber, with the majority of evidence from a few studies. An early study¹¹⁶ of 12 cats with chronic diarrhea found the majority responded either to diet alone or to diet in addition to ancillary medications. The investigators reported that the most common diets used in that study were either high in fiber or supplemented with fiber.¹¹⁶ An additional crossover study²⁰ in 19 cats evaluated the response of a mixed-source soluble fiber diet in cats with chronic diarrhea. The test diet was greater in both crude and soluble fiber than the control diet. When cats given the fiber-enhanced test diet in comparison to the control diet, improvement in fecal scores and less-frequent soft stools were noted.²⁰ Last, a third study¹¹⁷ using anti-inflammatory, antioxidant-producing fiber sources was shown to have better outcomes when compared to traditional dietary fiber sources in cats with diarrhea. Collectively, these studies support the concept of fiber-responsive diarrhea in cats. In conclusion, there is strong evidence for using fiber-enhanced diets or fiber supplementation in the management of chronic diarrhea in dogs and cats, with the majority of evidence supporting its use in colitis cases.

Hairball Vomiting

Hairballs may result in vomiting, anorexia, and abdominal pain, and, in extreme cases, intestinal obstruction. Increasing dietary fiber is one of the primary nutritional recommendations for hairball management, presuming that fiber might stimulate hair excretion in the feces. The majority of studies^{38,118-121} investigating this premise have documented a benefit of dietary fiber in hairball management. Two studies^{119,121} have documented a benefit of sugarcane fiber with or without other additives. In the first study,¹¹⁹ sugarcane fiber reduced fecal hairball elimination in cats without other intervention. In the second study,¹²¹ sugarcane fiber was co-administered with keratinolytic enzymes. The sugarcane fiber was identified as the main effector in the study findings showing reduction in hairball excretion in cats.

Psyllium husk has also been investigated for controlling hairball vomiting. The results of this study¹²⁰ supported that psyllium fiber affected fecal hair excretion in longhair cats but not in shorthair cats. Dietary psyllium concentration of 11% or 15% TDF was reported to be most effective compared to a diet with lower TDF.¹²⁰ Another study¹²² examined the effects of 3 diets varying in fiber concentrations. The test diet with 14.2% TDF improved fecal hair excretion compared to the positive control diet at 11% TDF and the negative control diet at 6.9% TDF.¹²² Last, the effects of *Miscanthus* grass as a fiber source indicated less total hair weight and hair clumps per gram of dry feces when compared to a control diet without *Miscanthus* grass.¹¹⁸ Studies^{38,119} on beet pulp and cellulose in diets did not demonstrate a reduction in hairball outcome measures. Importantly,

the methods for hairball control outcome measures were not consistent across studies and may influence results. None of the studies used clinical signs of vomiting hairballs as an outcome measure.

Constipation

Both soluble and insoluble fiber sources have been advocated for use in constipation management. However, these recommendations have largely been extrapolated from human data, based on expert opinion, in vitro tissue studies, or studies on fiber effects in healthy animals.¹²³ The basis of the recommendation for soluble fiber is its ability to form gels that facilitate fecal passage.⁵⁴ In addition, highly soluble and fermentable fibers are associated with SCFA production and increased fecal water.^{124,125} SCFAs have been linked to a prokinetic effect in the colon of animals.⁴⁶ In contrast, it has also been recommended to use insoluble or nonfermentable fibers because these are more likely to increase fecal bulk and dilute luminal toxins.⁵⁴

Constipation is a common problem in cats. One study¹¹⁷ assessing the clinical outcomes in cats with constipation demonstrated that fiber sources rich in antioxidant and anti-inflammatory compounds improved constipation clinical signs. A second study¹²⁶ evaluated a diet enriched in multiple fiber sources, predominantly psyllium, in cats with constipation. Some cats were treated with diet alone, and a second group was treated with both diet and adjunctive medications. Bowel movement consistency improved in both groups of cats, but there were no differences between groups. These studies demonstrate that fiber-enhanced diets might be effective in feline constipation. Last, it is critical to remember that in cats with advanced colonic dysmotility, fiber is contraindicated because of the lack of function in megacolon cases.

The laxative effects of fiber in experimentally induced constipation in dogs has also been investigated. Administration of fiber in the form of fig paste increased fecal passage in constipated dogs.¹²⁷ There were no complications associated with fiber administration.¹²⁷ Another study¹²⁸ evaluated the effects of a symbiotic, using the prebiotic inulin, on fecal characteristics in healthy dogs. A laxative effect of the administered symbiotic was observed that could prove useful in constipation management.¹²⁸ Importantly, this study was conducted in healthy dogs; the effects in constipated dogs is unknown. Additional research is needed to document the effects of fiber in canine constipation management.

Conclusion

Fiber is a complex component of canine and feline nutrition. Understanding the basics of fiber-related health benefits, fiber concentration reporting in pet foods, fundamentals of fiber characterization (eg, fermentability), as well as clinical indications are useful to practicing clinicians. Canine and feline

gastrointestinal disease can often be managed effectively with fiber-enhanced diets, and in many cases offers advantages over alternative treatment options. For most gastrointestinal diseases, more trials are needed to examine whether specific types or amounts of fiber are ideal for disease management. Dietary fiber concentration and manipulation should remain a focus during treatment planning in companion animals experiencing gastrointestinal dysfunction.

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