Focusing on Fibre: Impact on Gastrointestinal Health and Clinical Uses in Dogs and Cats

Defining Fibre
Dietary fibre is defined as edible carbohydrate polymers with three or more monomeric units including non-starch polysaccharides, oligosaccharides, and resistant starch.[1,2] Unlike other macronutrients, such as fats, proteins and simple carbohydrates, fibre is resistant to the action of mammalian digestive enzymes and is fermented primarily in the large intestine by bacteria of the gastrointestinal (GI) microbiome.

Fibre can have ranging physiochemical properties meaning that its physiological effects upon the host can be widely variable, therefore fibre requires further definition to help categorise individual sources. Fibre is often categorised based on fermentability, solubility or viscosity,[3] with solubility referring to the ability to dissolve in water, whereas fermentability refers to the rate of microbial fermentation. Many soluble fibres are also highly fermentable (and vice versa),[4] therefore the terms are often used interchangeably.

Fibre and the Microbiome
Dietary fibre can largely impact the composition, diversity and richness of the microbiome, acting as a substrate for specific microbes that possess the necessary enzymes for fermentation of these complex carbohydrates.[2] Fibres that demonstrate an ability to specifically or selectively stimulate the growth of beneficial micro-organisms to positively influence microbiome composition and host health are termed 'prebiotics'.[3] For example, fructo-oligosaccharide and acacia gum have shown to increase levels of beneficial bacteria (e.g. *Bifidobacteria* and *Lactobacillus*) and reduce potential pathogens (e.g. *Clostridium perfringens*) in humans, dogs and cats.[5-8] Prebiotic fibres are readily fermented resulting in maximal production of beneficial metabolites including lactate and short-chain fatty acids (SCFAs).

Short-chain Fatty Acids
SCFAs are metabolites produced through the microbial fermentation of fibre, primarily butyrate, acetate, and propionate. SCFAs reduce luminal intestinal pH acting to suppress the growth of pathogens and offer a competitive advantage to beneficial bacterial species, promoting a more favourable microbiome composition.[9,10] SCFAs also enhance mineral absorption and reduce degradation of peptides into toxic compounds (e.g. ammonia, amines, phenolic compounds).[11] Butyrate acts as the preferred energy source for colonocytes, providing approximately 70–80% of their total energy requirement,[12] and is vital for the maintenance of epithelial barrier integrity. Butyrate acts as a key regulator for normal cell colonocyte renewal, enhances intestinal mucin production, promotes epithelial tight junction formation, and is a key messenger molecule, helping to regulate local and systemic immune responses.[12–17]

The importance of these metabolites becomes even more apparent when their association with disease is studied. In humans, reduced levels of faecal and intestinal SCFAs, and SCFA-producing bacteria (e.g. *Faecalibacterium prausnitzii and Roseburia intestinalis*), have been observed in patients with inflammatory bowel disease.[18] As such, research is underway to help harness this metabolomic and microbiome data in order to develop biomarkers that can predict disease onset.[19] Similarly, dogs with chronic enteropathies possess lower concentrations and abnormal patterns of faecal SCFAs, as well as reductions in important SCFA-producing bacteria (e.g. *Blautia spp., Faecalibacterium spp.*), decreased bacterial diversity and higher dysbiosis index.[20] Further research is required to fully ascertain cause and effect, however this is a promising field for future diagnostic testing and therapeutic targets.

PHYSIOLOGIC EFFECTS OF FIBRE
Gut Transit & Faecal Consistency
Dietary fibre can help to regulate gut transit time, faecal consistency and intestinal motility, exerting different actions depending upon the fibre type. In general, soluble fibres tend to delay gastric emptying and increase small intestinal transit time.[21–25] Soluble, fermentable fibres can efficiently hold water to increase stool weight and moisture, thereby acting as effective stool softeners, whilst viscous fibres can form gels to increase the viscosity of intestinal contents.[24] Fermentable fibre produces SCFAs which facilitate sodium and chloride absorption within the colon to regulate fluid homeostasis and faecal moisture.[22]

Conversely, insoluble fibres are poorly fermented and largely retain their structure throughout the GI tract, offering little in terms of nutritional value. However, they have important physiological and functional effects, tending to promote gastric emptying, decrease intestinal transit time and help to normalise colonic motility.[23–25] The proposed mechanism of action is through their ability to increase faecal bulk, leading to colonic distention and stimulation of peristalsis; or through the action of coarse fibre particles which can increase intestinal water and mucus secretions, aiding the passage of faeces through the colon.[25,40] Decreased colonic transit time and increased faecal bulk help to reduce colonocyte exposure to toxins (e.g., bile acids, ammonia and ingested toxins) to support large intestinal health.[40]

An animal's individual response to specific fibre sources can be variable and may deviate from these general trends, therefore clinicians should be aware that not all animals will respond uniformly and trial and error with different types and levels of fibre may be necessary.[4] Potential side effects such as diarrhoea, flatulence and abdominal cramps may be seen if fibre is introduced suddenly and/or at excessive doses.[40]

Energy Metabolism and Appetite Regulation
Dietary fibre can impact metabolic health through its effects on nutrient metabolism (namely glucose and lipids) and appetite regulation, likely through both its physical presence in the GI tract but also through the action of SCFAs. (Figure 1) In fact, fermentable fibre intake has been inversely correlated with weight gain and obesity in humans, and can induce satiety and reduce bodyweight.[37]

Fibre has a relatively low energy density, meaning it contains significantly fewer calories per gram than other macronutrients such as protein, fat or carbohydrates. Research suggests that the weight of food consumed, as

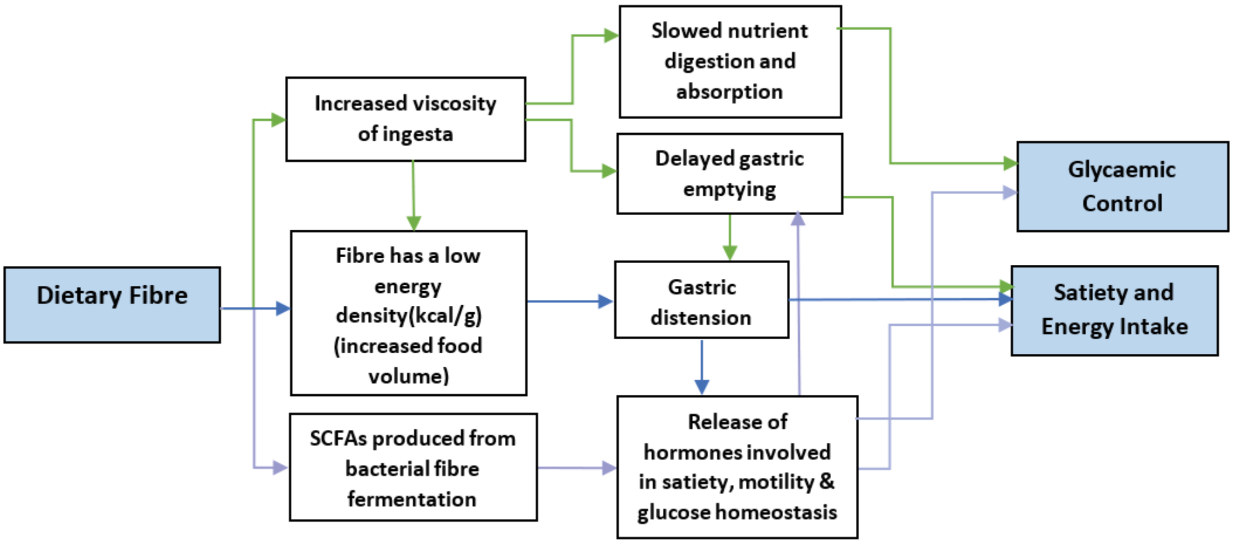

Figure 1: The Interlinking Mechanisms through which Fibre can Support Metabolic Health

opposed to the energy content, has a greater influence on eating patterns; hence to ameliorate hunger signals during weight loss, satiety can be encouraged through substitution of more energy dense nutrients with fibre.[28,29] Certain fibres possess properties (e.g. poor fermentability, high fluid-binding capacity) that increase volume of ingesta to stimulate stretch receptors in the stomach and induce early gastric signals of satiation, which appear to act via a non-cholinergic vagal pathway.[26–28]

Fermentable fibre likely induces satiety largely through the actions of SCFAs; local interactions with the neuroendocrine system leads to the release levels of satiety-related gut hormones, such as glucagon-like peptide-1 (GLP-1), peptide YY (PYY) and leptin.[35] These hormones can act on appetite centres in the brain to reduce hunger, whilst also impacting intestinal motility to decrease gastric motility and emptying, promoting feelings of physical 'fullness'.[35–37]

Viscous fibres in particular appear to have beneficial effects on metabolic parameters of glycaemia and lipidaemia via a number of proposed mechanisms. First, through delaying gastric emptying which encourages a more gradual delivery of nutrients into the small intestine, helping to improve post-prandial glucose control.[30–33] Secondly, gelatinous fibres can trap other nutrients (such as fats and carbohydrates) within their matrix; this limits nutrient-enzyme interactions thereby reducing the speed of digestion, whilst also physically reducing diffusion of nutrients from the lumen to the mucosal epithelium for absorption.[32–34] Finally, SCFAs are absorbed into hepatic, portal and peripheral blood, where they influence cholesterol, lipid and glucose metabolism.[35,36] SCFAs regulate fatty acid metabolism, increasing oxidation in multiple tissues and decreasing storage in white adipose tissue, whilst also normalising plasma glucose, increasing glucose handling and acting to reduce plasma cholesterol levels.[35] Hence, SCFA's appear to play a key role in regulation of energy homeostasis and, in turn, body composition and metabolic health.

CLINICAL USES OF FIBRE

Constipation

In humans, the use of both insoluble and soluble fibres in the management of constipation has been extensively reviewed and is widely advised by numerous medical authorities.[38,39] Given that the physiochemical properties of fibre form the basis of this clinical effect, results from human medicine are likely to be transferable to other species. In dogs, fibre is documented as a dietary intervention for the management of constipation,[40,43] with multiple studies demonstrating its efficacy. One study assessing the efficacy of 2% psyllium in dogs with conditions that predisposed to constipation (including perineal hernia, pelvic facture, spinal disease, prostatic enlargement), found stool consistency improved from 'dry' or 'hard' to 'normal' or 'pasty' in 62.5% of patients.[41] Another study found that a high fibre fig paste significantly increased faecal quantity and reduced colonic transit time in experimentally induced constipation in healthy beagles.[42] Similarly in cats, fibre is recommended for the management of constipation.[40,43] One study demonstrated that a moderate fibre diet enriched with psyllium significantly improved faecal consistency in 93% of cats and resulted in a significant reduction in use of cisapride and lactulose.[44] Constipation in cats is generally associated with other comorbidities that lead to dehydration, such as chronic kidney disease (CKD), diabetes mellitus and hyperthyroidism.[45] Whilst increasing dietary fibre and moisture intake is recommended in the management of mild to moderate constipation cases, highly digestible diets are recommended for animals with megacolon associated with colonic dysmotility or obstipation (severe end-stage megacolon).[40] In these patients colonic motility is absent, therefore the stimulatory effect of high fibre diets or supplements are no longer effective. In fact, such foods can contribute to obstipation therefore diets containing <5% DM crude fibre are recommended in the literature.[40]

Diarrhoea

Acute Diarrhoea

Numerous studies have been published which support the efficacy fibre-enhanced diets in the management of acute large bowel diarrhoea in both dogs and cats.[46–49] Shelter dogs that presented with acute colitis had significantly improved faecal scores ($P < 0.04$) when fed a high fibre diet compared to those fed a standard diet.[46] Similarly, two abstracts by Frantz & Yamka reported that implementation of a multi-source high fibre diet in shelter puppies and kittens with acute diarrhoea resulted in faster resolution of clinical signs compared to animals receiving a control diet, with the canine study also demonstrating improved faecal scores.[47,48] Finally, Rudinsky *et al.* found that dogs with acute diarrhoea supplemented with a highly digestible diet alone or in combination with psyllium demonstrated significantly improved time to resolution ($P < 0.01$) compared to the same diet with metronidazole (5 days vs. 8.5 days respectively).[49] Reoccurrence of colitis occurred at a lower rate in the psyllium-supplemented group compared to dogs on the highly digestible diet alone, possibly explained by the widely-accepted intestinal benefits of dietary

fibre and SCFAs. This supports the increasing rationale that antibiotic therapy is rarely indicated in the management of acute diarrhoea, and that nutritional interventions can even offer superior benefits.

Chronic Diarrhoea

The efficacy of high fibre diets in dogs and cats with chronic diarrhoea (> 3 week duration) has been assessed in several studies, primarily in animals presenting with symptoms of chronic colitis.[50–52] Retrospectively, Livet *et al.* found that high fibre dietary interventions were most likely to result in resolution of clinical signs of chronic colitis in dogs.[51] Simpson *et al.*[50] found fibre-enhanced diets to have a reasonably similar response rate for clinical sign resolution compared to a restricted antigen diet (75% vs 85% respectively) when used in combination with steroid therapy. When looking specifically at chronic idiopathic large bowel diarrhoea, there are further studies to support the use of fibre supplemented diets.[52–54] In a recent study, highly-strung working police dogs were supplemented with psyllium (a mixed, viscous fibre) for one month. Treatment response was classed as 'good' or 'very good' in 90% of patients, stool consistency was scored as 'normal' in 90% of dogs and there was a significant reduction in defaecation frequency.[52] Another study assessed the effect of a highly digestible diet supplemented with psyllium in dogs with an average 32-week history of chronic colitis symptoms. Following the dietary intervention, 96% of dogs achieved a 'good' or 'excellent' clinical response, some dogs were able to taper down or discontinue adjunctive therapies, and many relapsed once psyllium supplementation ceased.[53] Evidence in cats is more limited, however a small study reported that diet alone, or in combination with adjunctive medication, appears highly successful in resolving clinical signs of chronic colitis, with high fibre diets or supplementation being the most common intervention used by the investigators.[55] The currently available evidence presents a strong case for the selection of high-fibre diets or supplements as efficacious and feasible options for patients presenting with chronic large bowel symptoms.

Diabetes Mellitus

Increasing dietary fibre (including soluble and/or insoluble fibre types) can be a useful tool for the management of diabetes mellitus (DM) in dogs, helping to improve glycaemic control through mechanisms previously described. Several studies have reported positive results in dogs fed high fibre diets including reductions in postprandial glycaemia, urinary glucose excretion, serum fructosamine levels, and improved quality of life.[56–60] Interestingly, the available research does not suggest that high fibre diets will alter insulin dose requirements on a bodyweight basis, therefore implementation of such diets in diabetic patients should not have a destabilising effect and may contribute to improved clinical symptoms.[23]

As the storage of excessive adipose tissue contributes to insulin resistance, abnormalities in glucose/lipid metabolism, and ongoing metabolic dysfunction, weight loss is key for the successful management of overweight, diabetic patients.[61] For animals that require calorie-restricted diets, increased fibre intake can be useful due to its satiating effect and may elicit greater weight loss than those receiving low or moderate fibre diets.[62–64] High-fibre diets may not be suitable for underweight diabetic patients or those experiencing DM-associated weight loss.[65] Rather, prioritising palatability and increased energy density (often through increased fat content) with diets <10% DM crude fibre is important to promote weight gain or maintenance.[66]

In contrast to dogs, the nature of diabetes in cats is often non-insulin dependent with remission occurring in 50–70% of cats with appropriate dietary and pharmacological management.[22] Whilst diabetic cats have shown improved glycaemic control with high fibre diets,[67] the most recent ISFM consensus guidelines recommend low carbohydrate diets due to higher remission rates observed.[68] However, for every surplus kilogram of body weight a 30% decline in insulin sensitivity is seen,[69] therefore increased fibre intake may still be a useful tool to support weight loss and improve glycaemic control so long as other macronutrient levels are considered simultaneously.

Anal Sac Disease

Although there is no specific experimental data on the effects of fibre on the occurrence or prevention of anal sac impaction, the use of fibre supplementation is widely reported in the veterinary literature for this indication.[4,70–72] Whilst further studies are required, certain deductions can be made from looking at the available data.

Anal sac impactions may occur due to an altered rectal faecal transit, inadequate faecal bulk, poor muscle tone or obesity, all resulting in retention of anal sac contents.[73,74,79] Therefore, high fibre diets that are well-known to increase faecal bulk, volume and moisture content should theoretically aid natural expression. Furthermore, it is well-documented that loose stool consistency or low fibre diets are possible predisposing factors for the development of anal sacculitis.[73–78] One study found that 60% (180/300) of dogs presenting with anal sacculitis were receiving all-meat/raw diets (i.e. low crude fibre), with their stools described as 'poorly-formed' or 'strap-like'.[78] Whilst 75% of dogs had a history of diarrhoea between 7 and 21 days before the onset of clinical signs and diagnosis of anal sacculitis. These findings suggest a causal association between reduced faecal bulk and normal anal sac expression, therefore the rationale for fibre supplementation seems logical given its recognition as an effective stool bulking agent.

Weight Management and Satiety

In the UK, epidemiological studies estimate that approximately 60% of dogs and 40% of cats are overweight or obese,[80,81] predisposing them to numerous conditions including osteoarthritis, diabetes and chronic inflammation. Implementation of high fibre diets for the prevention of obesity should be considered, due to the previously discussed impact of fibre on energy regulation and appetite control. Begging, scavenging and other food-seeking behaviours can make it extremely difficult for pet owners to adhere to weight loss regimes. Fibre's satiating effects means that dietary manipulation of this nutrient can be a useful tool for mitigating such behaviours, encouraging greater owner and pet compliance. Evidence in pigs and horses demonstrates that implementation of high-fibre diets can help to reduce stereotyped behaviour, which often results from high feeding motivation (i.e. hunger).[28]

Several studies have evaluated the effect of dietary fibre on satiety, voluntary food intake (VFI) and feeding behaviour in dogs and cats.[62,63,82–90] Bosch *et al.* reported that when fed high fibre diets, dogs demonstrated increased inactivity and lower levels of arousal, which can be associated with increased satiety.[82] Whilst Weber *et al.* found that a high protein high fibre (HPHF) diet reduced VFI in dogs to a greater extent than either macronutrient alone.[83] A similar dietary intervention was employed in a different study, with the HPHF diet generating greater and faster weight loss in client-owned obese dogs than an isocaloric high-protein, medium fibre diet.[84] Both Jewell & Toll[62] and Jackson *et al.*[63] documented reduced daily energy intake in dogs fed a high or moderate fibre diet; in the former study, when dogs were presented with a subsequent meal 75 minutes after the first meal, a further reduction in energy and dry matter intake was observed suggesting a prolonged satiating effect.[62] Another trial in beagles found that satiety (measured through food intake) was similar between the control diet and a diet high in insoluble fibre, however, significantly fewer calories were consumed on the latter diet which supported more efficient weight loss.[29] Conversely, a study assessing the impact of soya hulls on food intake and feeding behaviour found no significant effect.[85] Likewise, Butterwick & Markwell reported no significant effect of soluble or insoluble fibre on food intake, however the dogs were overweight and subject to marked energy restriction to induce weight loss.[86] Therefore it seems that when physiological hunger signals are high, fibre's satiating effects can be negated.

Despite differing feeding behaviours in cats, alteration of dietary macronutrients (either by substitution of dietary protein for fibre or through fibre supplementation) can reduce spontaneous food intake through mechanisms which appear to be exclusive of diet palatability.[87,88] In fact, for each 1% change from protein to fibre, VFI intake reduced by 1 g/day.[89] Conversely, another study in cats assessing dry kibble diets with differing energy and fibre contents, found those fed high fibre diets employed compensatory mechanisms to increase food intake and achieve similar energy consumption overall.[89] In cats, finding the ideal protein to fibre ratio for optimising food intake may be more difficult to achieve, as very high protein diets can increase VFI, whilst very high fibre diets may present palatability issues.[90] Drawing on the conclusions from these studies, it appears that the properties of a fibre source in terms of water-binding capacity, effect on gastric emptying, viscosity and fermentability, may all impact the degree to which it can induce satiety due to the mechanisms previously discussed.

Conclusion

Dietary fibres can offer a varied range of physiochemical properties, reflected by the different effects the nutrient can exert on host physiology. Inclusion of dietary fibre appears to be integral for metabolic and GI health, both from a functional perspective and through its impact on microbiome composition and SCFA production. Manipulation of dietary fibre levels can offer a fundamental tool for the nutritional management of many clinical conditions in both dogs and cats.

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