

## **Fiber and Functional Gastrointestinal Disorders**

### **Rome Foundation Working Group for Food and Functional GI Disorders**

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**Abstract:**

Despite years of advising patients to alter their dietary and supplementary fiber intake, the evidence surrounding the use of fiber for functional bowel disease is limited. This paper outlines the organization of fiber types and highlights the importance of assessing the fermentation characteristics of each fiber type when choosing a suitable strategy for patients. Fiber undergoes partial or total fermentation in the distal small bowel and colon short chain fatty acids and gas, thereby affecting gastrointestinal function and sensation. When fiber is recommended for functional bowel disease, use of a soluble supplement such as ispaghula/psyllium is best supported by the available evidence. Even when used judiciously, fiber can exacerbate abdominal distension, flatulence, constipation, and diarrhea.

**Introduction:**

Fiber has long been used for the treatment of various gastrointestinal and non-gastrointestinal conditions including constipation (1-4), diarrhea (5-12), ulcerative colitis (13-15), obesity in children and adolescents (16,17), hypercholesterolemia (18-23), and diabetes mellitus(22,24,25). The National Academy of Sciences Institute of Medicine recommends that adults consume 20–35 grams of dietary fiber per day, but the average American's daily intake of dietary fiber is only 12–18 grams (26). While a universally accepted definition for dietary fiber does not exist, it is generally agreed that this term includes carbohydrates that are not hydrolyzed or absorbed in the upper part of the gastrointestinal tract. Moreover, it is very unlikely that such a definition will ever be agreed upon as the term dietary fiber refers to a chemically heterogeneous family of products (from various brans to pectins, gums, and

cellulose) that have different chemical and physical properties. For the purpose of communicating nutrition information to the consumer, the term dietary fiber is of great value because it clearly distinguishes between this non-digestible class of carbohydrates and digestible, glycemic carbohydrates such as sugars and starches. It has been suggested that the use of the term dietary fiber be gradually phased out (27,28), but its widespread use and popularity with the consumer has made this difficult in practice especially as the term has been useful in nutrition education and product development. In nutritional labeling, fiber is typically listed as a single category and not broken down into soluble or insoluble subtypes. Finally, the term "fiber" is something of a misnomer, since many types of so-called dietary fiber are not actually fibrous.

### *Fiber Metabolism*

Dietary fiber has a major role in the gastrointestinal tract [**Figure 1**]. Any undigested carbohydrate that reaches the colon will be fermented (partly or totally) by the gut bacteria to produce short chain fatty acids (SCFAs) and a number of gases including carbon dioxide, hydrogen and methane (29,30). SCFAs (mainly acetate, propionate, and butyrate) in turn create an osmotic load, are absorbed, and further metabolized by colonocytes, hepatocytes, or the peripheral tissues (31-33). The fermentation of fiber also influences fecal bulking in an indirect manner, by being fermented by colonic microflora thus stimulating their growth and resulting in increased microbial biomass (34). Thus, the type of fiber consumed leads to adaptation of, and changes, to the microbiome. Dietary fiber can also influence bulking directly via water retention (3,35,36). The unwanted side-effect of fiber ingestion and subsequent fermentation, however, is the production of gas. This gas is often malodorous and may in turn

cause undesirable discomfort, bloating, and flatus in many individuals. This characteristic of many fiber types may be particularly relevant for those with functional gastrointestinal disorders.

### *Types of Fiber*

The fermentability and solubility of different “fiber” types relates closely to their chemical composition (e.g., presence of cellulose, hemicellulose, gums, resistant starch, lignins, pectins). For the purpose of this review, “fiber” will be broadly divided into short chain- and long- chain carbohydrates or fiber-types, based on their solubility and fermentation characteristics [Table 1] (37-40). Short chain carbohydrates or “fiber” includes the oligosaccharides: fructo-oligosaccharides (FOS) and galacto-oligosaccharides (GOS) (eg. raffinose and stachyose). Due to their size and solubility, both FOS and GOS “fibers” are highly fermentable. The long-chain carbohydrates include four major groups: (1) soluble, highly fermentable non-starch polysaccharide fiber (e.g., resistant starch (RS), pectin, inulin, guar gum): (2) intermediate soluble and fermentable fiber (psyllium/ispaghula) and oats; (3) insoluble, slowly fermentable fiber (wheat bran, lignin (flax) and fruit and vegetables) and finally (4) insoluble, non-fermentable fiber (cellulose, sterculia and methycelullose).

The physiological characteristics (and potential health benefits) of different fiber type, in turn, depend on its proportion of soluble- and insoluble carbohydrate components. For example, fiber types that are high in soluble, viscous fiber may slow rates of glucose and lipid absorption from the small intestine. Soluble fiber (pectin, beta-glucan (from oats and barley), ispaghula/psyllium) is believed to be beneficial in lowering blood cholesterol and plaque-forming low-density lipoprotein levels (18-20). Dietary fiber can contribute to net

metabolizable energy, depending on readily it is fermented. For example, fermentable fiber contributes 8kJ/g (resistant starch (8.8 kJ/g), FOS (8.4 kJ/g ) and inulin (8.8 kJ/g)) and non-fermentable fiber contributes (0kJ/g) (41). **Table 2** lists popular commercially available fiber supplements by type of fiber.

Fiber Category	Type	Brand	Serving size	Amount of Fiber per serving
Soluble highly fermentable oligosaccharides	FOS	Orafti- P95	Powder 8g/day	7.5g
Soluble highly fermentable 'fiber'	Inulin	FiberChoice Fibersure Benefiber(Canada) Metamucil Clear Choice	2 Tablets 1 teaspoon Varies	4-5g
	Wheat dextrin	Benefiber (US)	2 teaspoon powder	3g
	Partially hydrogenated guar gum (PHGG)	Benefiber (formerly)	Powder	
	Resistant starch	Hi-Maize	15-20 g powder	7-9g
Soluble intermediate fermentable 'fiber'	Ispaghula/Psyllium	Metamucil Konsyl	1 tsp Powder, caplet,	3g

	Oat Bran	Quaker Oats	wafer 40g dry	4g (2 g soluble)
Insoluble, minimally fermentable 'fiber'	Wheat Bran	available in supermarket	-15g Coarse powder	6.5g
			-19g Bran-Pellets	4.5g
Insoluble, non-fermentable 'fiber'	Methylcellulose*	Citrucel	Varies	0.5-2g
	Karaya gum/Sterculia **	Normacol Normafib	1-2 sachets daily or bid	7 g per sachet

Table 2. Commercially available fiber preparations.

\*Derivatives of insoluble fibers (eg. esters of cellulose) are generally used. These derivatives are soluble in cold water. \*\* Sterculia gum is available as granules which should be swallowed whole with plenty of water.

## How Fiber Affects GI Function and Sensation

Fiber has been advocated for improved bowel function since the early 1970s (42). In a 1980 Nature article, Stephen and Cummings demonstrated that the actions of soluble and insoluble fibers in the colon depend on the extent to which they are digested. In an elegant study they showed that insoluble fiber alters colonic function by increasing fecal water content and fecal bulk water and increasing fecal bulk (43). The mechanism for this effect was unclear, however, since insoluble fiber has no appreciable water holding capacity, is minimally fermented (no appreciable increase in biomass) and accelerates colonic transit in germ-free rats (44,45). It was later determined that insoluble fiber (e.g., wheat bran) increases fecal mass and colonic transit rate through mechanical stimulation/irritation of gut mucosa, inducing secretion and peristalsis (46). An additional study showed that both particle size and shape were important, with large, coarse particles providing greater laxative efficacy than fine, smooth particles (no effect) (47). Taken together, these data support that insoluble fiber can have a significant laxative effect, but only if the particles are of sufficient size and coarseness.

Soluble non-viscous fiber and soluble viscous fiber that is readily fermented increase stool bulk by increasing biomass and fermentation by-products, such as gas and short chain fatty acids (43). Based upon such observations, it has been proposed that fiber improves FGIDs through the acceleration of oro-anal transit and by decreasing intra-colon pressure (48,49). Of course, it is also possible that it is through secondary effects on the microbiota, low grade inflammation, or permeability that fiber exerts effects on sensation as well as transit [**Figure 1**] (50). The consumption of fiber may actually retard *gas transit*, by decreasing bolus propulsion



to the rectum (51). Thus, in addition to increasing gas production by colonic flora, fiber ingestion may elicit gaseous or bloating symptoms by promoting gas retention.

Soluble viscous fiber that is minimally fermented has a high water-holding/gel-forming capacity that is preserved throughout the large bowel, normalizing stool form (softens hard stool in constipation, firms loose/liquid stool in diarrhea) (52,53). Viscous fibers that are FDA approved for laxation include methylcellulose, calcium polycarbophil, and psyllium. Stool consistency is highly correlated with stool water content, and a relatively small change in stool water content (increase of 4.7%) can lead to a relatively large stool softening effect (4.6-fold difference in viscosity (52).

Fiber also has extra-colonic effects, but the data on gastric emptying is mixed (54-58). In general, high doses ( $\geq 7\text{g}$ ) of wheat bran, inulin and psyllium tend to delay gastric emptying, while lower doses do not show a significant effect. Delayed gastric emptying may be due to increased viscosity of gastric contents which reduce pyloric flow. Increased viscosity reduces sedimentation of solids in liquids and thus impairs the ability of the antrum to preferentially empty liquids faster than solids (59,60). This delay in gastric emptying, together with a possible impairment of nutrient absorption in the small intestine may delay intragastric redistribution, which normally occurs as nutrients enter the duodenum (61). This could explain the tendency towards the higher antral/fundal ratios seen with bran, leading to the sensation of distension and bloating (62).

*Effects of Short Chain Fatty Acids*

Using in vitro fermentation models to produce estimates of in vivo fiber fermentation, there is evidence that fermentable soluble fibers increase the rate of fermentation, increase SCFA production, lower pH, and increase hydrogen gas production (63). In fact, differences in fermentation rates, gas production, and SCFA production have been observed for various fiber preparations (wheat dextrin, psyllium, inulin) which may in turn explain their clinically observed different gastrointestinal tolerances. Of the SCFAs, butyrate is the preferred energy source for the colonic mucosa cells and exerts effects on myenteric neurons and motility (64), supporting one mechanism by which a high fiber diet accelerates colonic transit (65). Recent work has found that specific short chain fatty acids such as butyrate alter the proportion of ChAT immune reactive myenteric neurons and increase cholinergic mediated colonic circular smooth muscle contraction in animals (64). Butyrate has also been shown to suppress colonic inflammation by the inhibition of the IFN- $\gamma$ /STAT1 signaling pathway (66-68).

SCFAs have also been shown to exert effects on the GI tract outside the colon. Exposure of the proximal colon in healthy volunteers to SCFAs contributes to the regulation of gastric motility and lower esophageal function, resulting in marked dose-dependent relaxation of the proximal stomach, triggering transient LES relaxations (TLESRs) (69,70). Similar effects have been observed patients with gastroesophageal reflux disease (GERD) on a diet high in indigestible carbohydrates (10g fiber/day), significantly increasing the rate of TLESRs, number of acid reflux episodes, and symptoms of GERD (71).

#### *Interaction with Microbiota*

There is also evidence that changes in the complex gastrointestinal environment by ingested fiber influence fecal microbiota profiles, perhaps due to the varied production of SCFA

and/or decreased in colonic pH, promoting the growth of beneficial bacteria [Figure 1]. Short chain carbohydrates (inulin, FOS/GOS) and other soluble fibers are fermented in the distal small intestine and proximal colon by endogenous bacteria to energy and metabolic substrates (SCFAs), and the presence of these carbohydrates may produce quite selective changes in the composition of the microbiota, inducing different fermentation patterns. As such, carbohydrates such as inulin are regarded as prebiotics, which may stimulate or alter the preferential growth of health-promoting species already residing in the colon (especially, but not exclusively, lactobacilli and bifidobacteria) (72-76), leading to potential benefits in irritable bowel syndrome (IBS) (77).

### **Fiber for Chronic Constipation**

In addition to adequate fluid intake and exercise, a high fiber diet is often the first recommendation a patient will receive for chronic constipation, as a lack of dietary fiber is believed to contribute to constipation (78-80). Although 50% of patients think fiber does not completely relieve their constipation and most (64%) respondents are not completely satisfied with the ability of fiber to improve their quality of life (81), current guidelines recommend the use of fiber in both dietary and supplement form for in the early management of constipation (82) [Table 3 (83)]. However, it is apparent from trials identified by systematic reviews that there is a relative paucity of high quality evidence to support this approach, especially for insoluble fiber. Soluble fiber is thought to increase stool bulk and weight and therefore stool frequency (3,84). Insoluble fiber such as bran is thought to accelerate intestinal transit time, thereby increasing stool frequency (44,46,85). Finally, there is a particular lack of evidence of efficacy of fiber for individual constipation subtypes (obstructive, metabolic, neurological, diet-

related, myogenic, drug-related, pelvic floor dysfunction). Thus, the remainder of this discussion will focus on fiber as a treatment for chronic idiopathic constipation (CIC), or constipation unrelated to anatomic, medication-related, or physiologic causes.

### *Fiber Supplements*

In an attempt to make sense of the divergent data addressing the role of fiber as a treatment for constipation, a number of systematic reviews and meta-analyses with varying selection criteria have been published (2,86,87). These analyses have found that most studies suffer from small sample sizes and poor study design with non-rigorous outcomes and high risk of bias. Acknowledging the inherent heterogeneity of the data, there does appear to be a significant improvement in constipation symptoms and abdominal discomfort compared to placebo for soluble fiber (psyllium, inulin). The paucity of high quality data highlights the need for further large methodologically rigorous RCTs utilizing validated outcome measures as defined by the Rome Foundation and regulatory agencies such as the US Food and Drug Administration and the European Medicines Agency (88).

The most recent summary of available RCTs studying the effects of both soluble and insoluble fiber in patients with CIC was performed in 2011 by Soares et al (89). Six studies were found to be eligible for inclusion, including one RCT which utilized a cross-over design. It should be noted that studies that recruited patients with drug-induced constipation, institutionalized patients, or those that enrolled a heterogeneous group of patients (e.g., both CIC and IBS with constipation (IBS-C)) were excluded. None of these was at low risk of bias, the majority of them were small, and none accounted for baseline dietary fiber consumption or change in fiber consumption during the study. Amounts of fiber in these studies ranged between 10-20 grams

of fiber/day with a treatment duration from 2 to 8 weeks. The settings were mostly tertiary care centers and subjects were predominantly female. Four of the eligible trials used soluble fiber (3 psyllium,(90-92) 1 with inulin and malto-dextrin) (93). The largest was a single-blinded RCT with 201 primary care patients during a 2-week treatment period (90). Eighty-seven percent of patients allocated to psyllium reported an improvement in symptoms, compared with 47% of patients receiving placebo ( $p<0.001$ ). There was also a significant response in abdominal pain/discomfort and straining on defecation. Similar effects were seen among the other 3 trials of soluble fiber. In one study, pain with defecation was significantly reduced with psyllium, but 18% of psyllium patients reported abdominal pain as a side effect as compared to 0% of placebo (91).

Two studies used insoluble fiber, wheat bran in one study (94) and rye bread in the other (95). In the 24 patients recruited to receive 20 g of bran per day or placebo, no statistically significant difference in response (defined as having no further straining at stool) occurred with active treatment. For the rye bread study, 29 female participants consumed rye bread (37g/day fiber) or low fiber bread (6.6g/day fiber) over a 3 week period. Following the intervention period, the mean difference in number of stools per day was 0.3 higher for the patients randomized to rye bread compared with those assigned to low fiber bread ( $p=0.001$ ). Difficulty of defecation was also significantly reduced with rye bread ( $p<0.001$ ), and stools were softer ( $p<0.001$ ). However, there were higher symptoms scores for gastrointestinal side effects such as abdominal pain, flatulence, borborygmi, and bloating with rye bread compared with low fiber bread (mean difference in scores = 1.6,  $p<0.001$ ). Note that rye is partially

fermentable, and the high dose (37g/day) was started day 1 without a gradual introduction of fiber.

Little human data exist on other commercially available fiber preparations [Table 3]. For example, one study of methylcellulose in constipated patients resulted in statistically significant increases in stool frequency, water content, and fecal solids but this was neither randomized or placebo controlled (96).

Treatment modalities commonly used for constipation	Recommendation level and grade of evidence
Bulking agents	
• Psyllium/ispaghula	Level II; grade B
• Calcium polycarbophil	Level III; grade C
• Bran	Level III; grade C
• Methylcellulose	Level III; grade C

Table 3. Commonly used therapeutics for constipation and level and grade of evidence (83).

#### *Fiber Effects on Constipation Subtype*

Non-response to supplementary fiber may be a marker of refractory constipation or constipation subtype, though there are few studies which have assessed the efficacy of fiber for slow transit constipation or dyssynergic defecation. One non-randomized study demonstrated 88% of patients with slow transit and 63% of patients with a disorder of defecation did not respond to dietary fiber treatment (30 g of fiber per day), whereas 85% of patients without a pathological finding improved or became symptom free (97). Approximately half of patients

with symptoms refractory to supplementary fiber have a prolonged intestinal transit time (98). Thus, fiber intake is not a panacea for all CIC patients.

### *Dietary Fiber*

Patients often find fiber supplements inconvenient and unpalatable with the occurrence of gas or bloating often a reason for lack of compliance or discontinuation of therapy (99). Comparatively few clinical trials have evaluated dietary fiber that is naturally occurring as opposed to supplemental fiber, most likely because food contains not only fiber but other non-absorbable sugars (ie, polyols, fructans, galacto-oligosaccharides) or chemicals which may exert laxative effects. For example, a recent prospective, randomized-controlled 8 week single-blind cross-over study examined treatment with dried plums (prunes, 6 g/day fiber) compared to psyllium (6 g/day fiber) in 40 patients (100). Dried plums not only contain fiber but also sorbitol and fructans, non-absorbable carbohydrates which, when fermented by colonic bacteria, create an osmotic load that can dramatically alter stool frequency and consistency (101). Treatment with dried plums resulted in a greater improvement in constipation symptoms as reflected by a significant increase in the number of complete spontaneous bowel movements and in stool consistency (softer stools) when compared to treatment with psyllium. Also, more subjects reported subjective improvement in overall constipation symptoms, although the mean global constipation symptom scores were similar between groups and psyllium also improved constipation symptoms when compared to baseline.

### *Conclusion*

As there may be some benefit and little risk of serious adverse events, increasing dietary fiber or the addition of fiber supplements seems a reasonable initial strategy in the

management of CIC patients. Patients may enjoy improvements in bowel movement frequency and consistency. Effects on other symptoms commonly reported by CIC patients such as abdominal pain or bloating are more variable. Non-evidence based but practical advice on initiating therapy with fiber supplements includes starting at a nominal dose and slowly titrating up as tolerated over the course of weeks to a target dose of 20-30 grams of total dietary and supplementary fiber per day [Table 2]. It is also reasonable to recommend clearing hard stool with an osmotic laxative before initiating fiber therapy which may avoid cramping pain. Occasionally, patients will experience marked worsening of their constipation related symptoms with fiber. When this occurs, there is some data to suggest that significantly delayed colon transit or dyssynergic defecation might be present (97,98).

### **Fiber for the Irritable Bowel Syndrome**

Historically, increasing dietary fiber intake has been a standard recommendation for patients with IBS, but the efficacy of fiber for IBS is more nuanced than appreciated by most clinicians. Ever since Burkitt et al. first suggested that fiber might protect people in rural areas from certain gastrointestinal disorders (42), the practice of advising fiber supplementation in FGIDs has become widespread and remains standard operating procedure. However, the use of fiber for IBS has historically been, and still remains, controversial. While some believe that the highly processed, low fiber western diet is at the root of IBS, others believe that “roughage” can exacerbate or even cause IBS symptoms (42,102). These divergent views are likely the result of the inherent heterogeneity of IBS, confusion as to what we refer to as fiber, the paucity of high quality studies, and conflicting historical data. In 1977, Manning et al examined



the effect of a 6 week high or low fiber diet on abdominal pain and bowel frequency in 26 IBS patients (103). Participants in this single-blind randomized controlled trial (RCT) ingested an additional 20 grams of wheat bran per day on the high fiber diet. The investigators found significant improvement in pain frequency ( $p < .05$ ) and pain severity ( $p \sim .01$ ). Bowel habit was regarded as “improved” in the high fiber group ( $p < .05$ ), and bowel frequency improved modestly as well ( $p < .02$ ). Another seminal RCT of psyllium in 80 IBS patients significantly improved constipation ( $p = 0.026$ ) and transit time ( $p = 0.001$ ) but did not significantly improve bloating and abdominal pain (104). A subsequent non-randomized study investigated the utility of “high-fiber” diets (30 grams of fiber/day) for the treatment in 72 IBS patients (all subtypes) reported improvement in hard stools, bowel frequency, and urgency but no change in abdominal distension, diarrhea, or flatulence (105). Finally, an often-cited patient survey of 100 IBS patients found that 55% of felt worse and only 10% felt better on bran (106).

#### *Fiber Intake in IBS*

A recent survey found that most general practitioners believe that fiber deficiency is the main cause of IBS symptoms and 94% would institute dietary therapy based on this assumption (107). However, patients with FGIDs do not seem to consume less dietary fiber than healthy controls, suggesting symptoms are unlikely to be related to altered diet composition (108). A recent Swedish abstract that compared the nutrition intake in patients with IBS with the general population actually found the intake of dietary fiber to be higher in the IBS group (19 v 16 g/day,  $p < .001$ ) compared to controls (109). The authors concluded that although IBS patients may have a self-imposed limited diet and avoid trigger foods, their mean average daily

fiber intake is essentially similar to that of a matched healthy control population and in accordance with current nutrition recommendations.

#### *Fiber Supplements (Soluble and Insoluble) in IBS*

The use of fiber or bulking agents for treatment of IBS has been summarized in two meta-analyses (110,111), four systematic reviews (39,112-114), and two comprehensive narrative reviews (115,116). All noted significant quality shortcomings in the published studies, including heterogeneous patient populations, varied outcome measures, different types of fiber supplements, small sample size, and difficulties with blinding. Other widely variable factors included the amount of soluble (5-30 g) and insoluble (4.1-36 g) fiber added to the diet and the duration of study intervention (3-16 weeks). Most of the trials that report the use of these agents do not adhere to the recommendations made by the Rome foundation for the design of treatment trials for the functional GI disorders (88), although this is largely because the majority of these trials were conducted long before these guidelines were in place. Finally, most studies evaluated supplementary fiber and not increased dietary fiber, and rarely reported on IBS subtype or baseline dietary fiber consumption.

The most recent Cochrane analysis concluded that bulking agents were not beneficial for the treatment of IBS (113). This analysis, which included 12 papers with an intervention period lasting 4 to 16 weeks, reiterated the problems with the quality of available data. The authors' conclusions from the pooled data suggested that bulking agents do not provide any benefit for the treatment of IBS. The studies either showed no significance or did not address specific outcomes, including abdominal pain, improvement in global assessment, and IBS symptom scores. Only 7 of the included studies had more than 30 patients and all studies had

quality limitations (i.e., method of randomization, double-blinding, concealment of treatment allocation, description of withdrawals).

In a systematic review and meta-analysis by Ford et al, 12 trials and 591 patients were included that evaluated the efficacy of various forms of fiber with placebo or, in one study, a low fiber diet as treatment for IBS (110). Only 3 of these 12 studies reported on IBS subtype. Two of the studies included only IBS-C patients and another had 49% IBS-C patients. The fiber preparations used included bran (5 studies), ispaghula/psyllium (6 studies), and one unspecified. Overall, 52% of IBS patients assigned to fiber had persistent symptoms or no improvement in symptoms after treatment compared with 57% assigned to placebo or a low fiber diet (relative risk (RR) 0.87, 95% confidence interval 0.76 to 1.00,  $P=0.05$ ). There was no statistically significant heterogeneity detected between studies ( $I^2=14.2\%$ ,  $P=0.31$ ). The number needed to treat (NNT) with fiber to prevent one patient with persistent symptoms was 11 (95% confidence interval 5 to 100). There was no evidence of funnel plot asymmetry, suggesting no publication bias. However, only seven of the 12 studies scored 4 or more on the Jadad scale. When only these seven higher quality studies were included in the analysis, the borderline treatment benefit for fiber was no longer evident (RR of persistent symptoms (0.90, 95% CI = 0.75 to 1.08).

The data would suggest that all types of fiber supplementation are not created equally, at least not as it pertains to the treatment of IBS. In five studies (221 patients) which compared insoluble bran with placebo or a low fiber diet, bran failed to improve overall IBS symptoms (RR of persistent or unimproved symptoms 1.02, 95% CI = 0.82 to 1.27) (110). On the other hand, six studies (321 patients) evaluated soluble fiber (ispaghula/psyllium) vs. placebo. Ispaghula was

effective at improving overall IBS symptoms (RR of persistent or unimproved symptoms 0.78, 95% CI = 0.63 to 0.96). The NNT for ispaghula to prevent one patient from experiencing persistent symptoms was 6 (CI = 3 to 50). There was no evidence of funnel plot asymmetry and 5/6 studies scored 4 or more on the Jadad scale.

One key difference between the Ford and Cochrane reviews was the method of analysis (110,113). Both analyses had similar strict inclusion criteria, but Ford et al. did not use an intention-to-treat analyses, and used persistent symptoms after treatment as an outcome measure. Therefore, this may have been a reason as to why this group found psyllium to have a small but statistically significant benefit for IBS.

The most recent comparative effectiveness trial evaluated the relative efficacy of psyllium/ispaghula, 10 g ( $n = 85$ ), bran, 10 g ( $n = 97$ ), or rice flour (placebo) ( $n = 93$ ), twice daily (mixed with food, preferably yogurt) over 12 weeks in 164 primary care IBS patients (117). This study was not included in the reviews mentioned above. At one month, 57% of patients taking psyllium experienced adequate symptom relief for 2/4 weeks of treatment compared to 40% with bran (NNT = 6, 95% CI = 4-104) and 35% with placebo (NNT = 5, 95% CI = 3-15). The difference, however, was no longer significant at 3 months. Bran provided benefits only at 3 months. Over 60% of subjects randomized to psyllium or bran reported moderate adverse events, the most common of which were constipation and diarrhea. Interpretation of the results at 2 and 3 months of treatment are complicated by the high drop-out rates (29% and 40%, respectively). The overall likelihood of side effects was similar among the 3 groups.

It is important to recognize that most of the data on the efficacy of fiber for IBS come from referral centers. Studies conducted in referral centers are likely to be biased against fiber

supplementation as patients who improve with fiber are less likely to be referred to a tertiary care center. Thus, it is possible that results of trials evaluating from referral centers could underestimate the benefits of fiber for IBS. Only a few studies have included primary care patients exclusively (106,117), and only one has addressed this potential difference in response specifically. Miller et al. recruited consecutive patients meeting Rome I criteria for IBS from primary and secondary clinics until 100 had completed questionnaires (118). Twenty-seven percent of primary care patients said that bran had improved their symptoms compared with 22% who claimed it had made them worse. Ten percent of secondary care patients attributed improvement to bran, with 55% of these patients attributed it to exacerbation of symptoms. About half of primary care patients (51%), reported that bran had no positive or negative effect on their symptoms compared to 33% of secondary patients reporting no change. In primary-care, psyllium led to improvement in 25%, deterioration in 19% and no change in 56% which was not significantly different to secondary-care. The authors concluded that while the approach of advising bran for patients with IBS is not especially beneficial, it may be better tolerated in primary care settings.

While few adequately powered, methodologically rigorous studies have examined the role of commercially available fibers other than psyllium for the treatment of IBS symptoms, there are some data to suggest that preparations such as partially hydrolyzed guar gum (formerly Benefiber, Novartis Consumer Health Inc., Parsippany, NJ, USA) and calcium polycarbophil (Fibercon, Pfizer, New York, NY, USA) may be helpful and well tolerated (119-121). It should be noted that each caplet of calcium polycarbophil contains roughly 0.5 g of fiber, thus multiple pills may be required to see an appreciable effect.

### *Dietary Fiber*

In contrast to the larger number of studies of fiber supplementation, few studies have examined the effect of increasing fiber intake in the form of ordinary foods (122-124). There are reports of improvement of IBS symptoms on both high-fiber and low-fiber diets, a result attributed to a placebo or Hawthorne effect. In fact, a number of contrarian studies had suggested that popular sources of dietary fiber such as bran and other cereals, and vegetables and fruits, might actually aggravate symptoms in IBS as these foods may also contain large amounts of FODMAPs (e.g., fructans, excess fructose, GOS and sugar polyols) (125). The symptoms that appeared to be aggravated most commonly were flatulence, bloating, and abdominal pain.

### **Conclusion**

Success in finding an effective treatment strategy for treating constipation-predominant IBS is a challenging area of clinical management. One of the aims of this review was to highlight the importance of assessing the fermentation characteristics of each fiber type when choosing a suitable strategy for patients. When fiber is recommended for FGIDs, use of a soluble supplement such as ispaghula/psyllium is best supported by the available evidence. In constipated patients, hard stool should be eliminated (e.g., with an osmotic laxative) before initiating fiber therapy. Fiber should be started at a nominal dose and slowly titrated up as tolerated over the course of weeks to a target dose of 20-30 grams of total dietary and supplementary fiber per day. Even when used judiciously, fiber can exacerbate problems with abdominal distension, flatulence, constipation and diarrhea (106,126,127). It is clear that

rather than extrapolating from the studies undertaken in healthy individuals, further research in functional GI patients should be performed with rigorous endpoints, strict inclusion criteria, and IBS subtype in mind.

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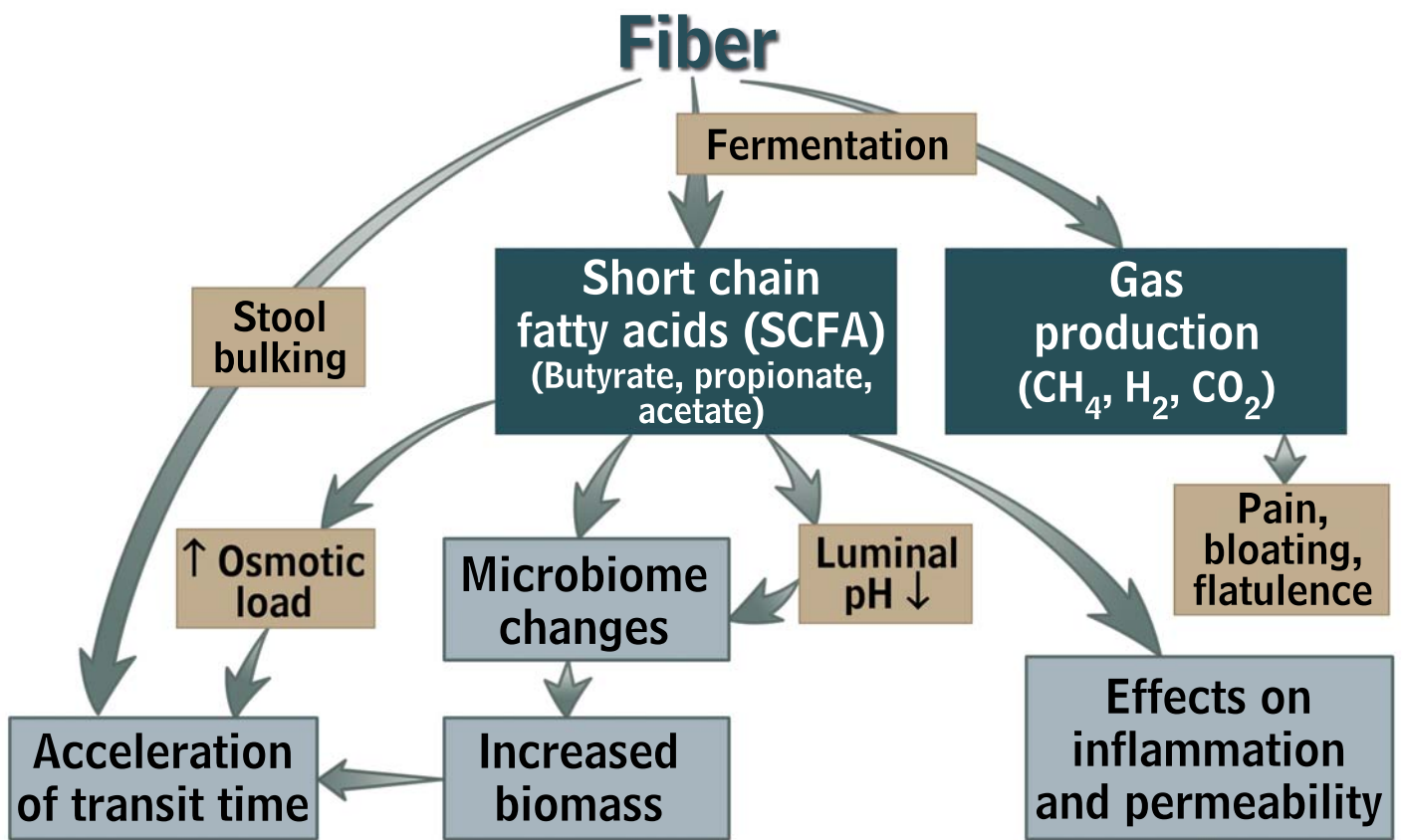
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Likely mechanism of action of fiber on intestinal transit time and visceral hypersensitivity

	Fiber Type	Nat'l Foods	Potential Benefits for IBS	Potential Risks for IBS
<b>SHORT CHAIN CARBOHYDRATES</b>	Soluble highly fermentable oligosaccharides (includes FOS, GOS). 	<ul style="list-style-type: none"> <li>• Legumes/pulses</li> <li>• Nuts and seeds</li> <li>• Wheat, rye</li> <li>• Onions, garlic, artichoke.</li> </ul>	<ul style="list-style-type: none"> <li>• <u>Laxation</u>: Weak laxative effect.</li> <li>• <u>Transit Time</u>: Does not hasten transit time.</li> <li>• <u>Balance of bacteria</u>: selective growth of certain microbiota eg. Bifidobactia.</li> <li>• <u>SCFA</u>: very rapidly fermented in terminal ileum and proximal colon to produce SCFA.</li> <li>• <u>Gas production</u>: high</li> </ul>	<ul style="list-style-type: none"> <li>• In patients with IBS the rapid fermentation may contribute to gas, flatus and gastrointestinal symptoms.</li> <li>• A number of studies have been undertaken in IBS – with mixed results [37].</li> </ul>
<b>LONG CHAIN CARBOHYDRATES</b>	Soluble highly fermentable 'fiber' (e.g. RS, pectin, guar gum, inulin) 	<ul style="list-style-type: none"> <li>• Legumes/pulses</li> <li>• Rye bread, barley</li> <li>• Firm bananas</li> <li>• Buckwheat groats (kashi), millet, oats</li> <li>• Cooked and cooled-pasta, potato and rice.</li> </ul>	<ul style="list-style-type: none"> <li>• <u>Laxation</u>: Mild laxative effect.</li> <li>• <u>Transit time</u>: Does not hasten gut transit. Can slow absorption from the small intestine.</li> <li>• <u>Balance of bacteria</u>: Increases overall bacterial species but not selective for bifidobacteria.</li> <li>• <u>SCFA</u>: Rapidly fermented in proximal colon to produce SCFA. RS is good an excellent substrate for the production of the SCFA butyrate.</li> <li>• <u>Gas production</u>: moderate</li> </ul>	<ul style="list-style-type: none"> <li>• In patients with IBS the rapid fermentation may contribute to gas, flatus, and gastrointestinal symptoms</li> <li>• No well-designed studies have been undertaken in IBS.</li> </ul>
<b>LONG CHAIN CARBOHYDRATES</b>	Intermediate soluble fermentable 'fiber' (psyllium/ispaghula) and oats. 	<ul style="list-style-type: none"> <li>• Seed of the plant <a href="#"><i>Plantago ovata</i></a>, and oats</li> </ul>	<ul style="list-style-type: none"> <li>• <u>Laxation</u>: Good laxative effect.</li> <li>• <u>Transit time</u>: Does hasten transit time.</li> <li>• <u>Balance of bacteria</u>: Increases overall bacterial species but little evidence for selective growth</li> <li>• <u>SCFA</u>: Moderately fermented along length of colon to produce SCFA.</li> <li>• <u>Gas production</u>: moderate.</li> </ul>	<ul style="list-style-type: none"> <li>• In patients with IBS studies have shown some positive effect on laxation.</li> <li>• Side-effects of gas/flatus has produced mixed results for some patients with IBS [38].</li> </ul>

<p><b>LONG CHAIN CARBOHYDRATES</b></p>	<p>Insoluble slowly fermentable 'fiber' (e.g. wheat bran, lignin (flax), fruit and vegetables)</p> 	<ul style="list-style-type: none"> <li>• Some vegetables and fruit</li> <li>• Wheat bran</li> <li>• Wholegrain cereal</li> <li>• Rye</li> <li>• Brown rice, wholemeal pasta, quinoa</li> <li>• Flax seed.</li> </ul>	<ul style="list-style-type: none"> <li>• <u>Laxation</u>: Good laxative effect.</li> <li>• <u>Transit time</u>: Does hasten transit time.</li> <li>• <u>Balance of bacteria</u>: Increases overall bacterial species but little evidence for selective growth</li> <li>• <u>SCFA</u>: Slowly fermented to produce SCFA along the length of the colon.</li> <li>• <u>Gas production</u>: moderate-high</li> </ul>	<ul style="list-style-type: none"> <li>• In patients with IBS wheat bran has not been shown to be effective. A major side-effect has been excessive gas/wind and bloating [39]. This may be due to the presence of high quantities of fructans also associated with the wheat bran [40].</li> <li>• Symptoms associated with wheat bran may not be acceptable to many patients.</li> </ul>
<p><b>LONG CHAIN CARBOHYDRATES</b></p>	<p>Insoluble, non-fermentable 'fiber' (e.g. cellulose, sterculia, and methylcellulose)</p> 	<ul style="list-style-type: none"> <li>• high fiber grains and cereals</li> <li>• nuts, seeds</li> <li>• skins of fruit and vegetables.</li> </ul>	<ul style="list-style-type: none"> <li>• <u>Laxation</u>: Good laxative effect.</li> <li>• <u>Transit time</u>: Does hasten transit time.</li> <li>• <u>Balance of bacteria</u>: no evidence for selective growth.</li> <li>• <u>SCFA</u>: poorly fermented.</li> <li>• <u>Gas production</u>: Low</li> </ul>	<ul style="list-style-type: none"> <li>• Less gas/<u>wind</u> forming properties</li> <li>• This fiber type may have better characteristics for treating constipation in IBS patients. However, few well designed studies have been conducted.</li> </ul>

\*Using standard (not excessive) doses of these carbohydrates.

IBS (irritable bowel syndrome), GOS (galacto-oligosaccharides), FOS (fructo-oligosaccharides), SCFA (short chain fatty acids), RS (resistant starch)