Dietary fiber in irritable bowel syndrome (Review)

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Abstract. Irritable bowel syndrome (IBS) is a common chronic gastrointestinal disorder. It is widely believed that IBS is caused by a deficient intake of dietary fiber, and most physicians recommend that patients with IBS increase their intake of dietary fiber in order to relieve their symptoms. However, different types of dietary fiber exhibit marked differences in physical and chemical properties, and the associated health benefits are specific for each fiber type. Short-chain soluble and highly fermentable dietary fiber, such as oligosaccharides results in rapid gas production that can cause abdominal pain/discomfort, abdominal bloating/distension and flatulence in patients with IBS. By contrast, long-chain, intermediate viscous, soluble and moderately fermentable dietary fiber, such as psyllium results in a low gas production and the absence of the symptoms related to excessive gas production. The effects of type of fiber have been documented in the management of IBS, and it is known to improve the overall symptoms in patients with IBS. Dietary fiber acts on the gastrointestinal tract through several mechanisms, including increased fecal mass with mechanical stimulation/irritation of the colonic mucosa with increasing secretion and peristalsis, and the actions of fermentation byproducts, particularly short-chain fatty acids, on the intestinal microbiota, immune system and the neuroendocrine system of the gastrointestinal tract. Fiber supplementation, particularly psyllium, is both safe and effective in improving IBS symptoms globally. Dietary fiber also has other health benefits, such as lowering blood cholesterol levels, improving glycemic control and body weight management.

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Contents

1. Introduction

Irritable bowel syndrome (IBS) is a chronic common gastrointestinal disorder with a prevalence of 10-20% among the adult population worldwide (1-15). The diagnosis of IBS is based mainly on symptom assessment using the Rome criteria (16,17). The cardinal symptom is abdominal discomfort/pain, which is associated with altered bowel habits and abdominal bloating/distension (1,4). Patients with IBS are divided into four subtypes according to the stool pattern: diarrhea-predominant IBS (IBS-D), constipation-predominant IBS (IBS-C), mixed-diarrhea-and-constipation IBS (IBS-M) and unclassified IBS (16,17). Patients with IBS are usually diagnosed at a young age, and IBS is more common in women than in men (3-6,8,9,11, 12,14,15,18,19). Although IBS is not associated with increased mortality, it considerably reduces the quality of life (1,19-21) and is an economic burden to society (22).

Dietary fiber includes non-digestible carbohydrates and the complex polymer, lignin, which are present in plants and have physiological effects in humans (23). Dietary fiber has long been used in the treatment of several gastrointestinal conditions (24-38). It is widely believed that IBS is caused primarily by a deficient intake of dietary fiber (39). Increasing the dietary fiber intake has been the standard recommendation for patients with IBS (1). However, a systematic meta-analysis based on 12 small studies showed that increased dietary fiber consumption by patients with IBS did not improve IBS symptoms compared to placebo or a low-fiber diet (39). Other studies have shown that while consuming water-insoluble fiber does not improve IBS symptoms, consuming soluble fiber improves overall IBS symptoms (40,41). Subsequent studies have shone new light on fiber supplementation as a treatment for IBS. Several comprehensive reviews have been published recently on the role of dietary fibers in IBS (42-46). The present review aimed to discuss the efficacy of

fiber supplementation in the treatment of IBS, the type of dietary fiber that should be recommended, and the mechanisms underlying the effects of dietary fiber, particularly those concerning the interaction between fibers, microbiota, the immune system and the neuroendocrine regulatory system of the gut.

2. Types and characteristics of dietary fiber

Different types of dietary fiber are characterized by marked differences in physical and chemical structure, with the health benefits of dietary fiber being specific to each fiber type (23). Dietary fiber can be divided into soluble types (i.e., dissolving in water) and insoluble types based on their physical and chemical properties (47,48). Soluble dietary fiber can be subdivided into viscous (gel forming) and non-viscous (23,47). Dietary fiber can be divided further into short-chain and long-chain carbohydrates, and fermentable or non-fermentable types (49-53). Fermentable oligosaccharides, disaccharides, monosaccharides and polyols (FODMAPs) are closely associated with the focus of this review, and are to be considered to be the short-chain carbohydrate, soluble, and highly fermentable type of dietary fiber.

Short-chain, soluble and highly fermentable dietary fiber (e.g., oligosaccharides) results in rapid gas production that can outpace the capacity of the gastrointestinal tract to absorb gas into the bloodstream for final elimination through the lungs. This imbalance can cause abdominal pain/discomfort, abdominal bloating/distension and flatulence (23,51,54). On the other hand, long-chain, intermediate viscous, soluble and moderately fermentable dietary fiber (e.g., psyllium) results in a low gas production and the absence of the symptoms related to excessive gas production (23,54,55).

3. Mechanisms of action of dietary fiber in IBS

Laxative effects. Insoluble dietary fiber increases fecal mass and accelerates colonic transit via mechanical stimulation/irritation of the colonic mucosa with increasing secretion and peristalsis (23,56-63). Soluble dietary fiber is fermented by bacteria in the large intestine, which increases the stool bulk by increasing the biomass by fermentation byproducts, such as gas and short-chain fatty acids (61,62). The oro-anal transit time and sensation are affected by these changes and probably also through other effects on microbiota, immune cells, intestinal endocrine cell, enteric nervous system and permeability (64-75) (Fig. 1). Soluble viscous dietary fiber (e.g., psyllium) is minimally fermented and forms a gel that is preserved during its passage through the large bowel and normalizes the stool form (26,76-79).

Interaction of dietary fiber with microbiota and the immune system. There is an increasing body of evidence to indicate that dietary fiber acts as a prebiotic that influences the composition of the intestinal microbiota (80-88) (Fig. 1). Furthermore, the fermentation of dietary fiber byproducts, such as short-chain fatty acids (acetate, propionate and butyrate) and the decrease in luminal colonic pH promote the growth of beneficial bacteria, such as *lactobacilli* and *bifidobacteria* (80-88).

Butyrate is one of the short-chain fatty acids that are produced by the fermentation of dietary fiber (23,54). Butyrate has been recently reported to suppress colonic inflammation in two ways: i) by inducing T-cell apoptosis, thus eliminating the source of inflammation, and ii) by suppressing interferon-γ (IFN-γ)-mediated inflammation (Fig. 1) (89-91).

Interaction between dietary fiber and the neuroendocrine system (NES) of the gastrointestinal tract. The NES of the gastrointestinal tract comprises gastrointestinal endocrine cells and the enteric nervous system (Fig. 1). Various different types of endocrine cells are scattered between the epithelial cells of the mucosa (1,92-97). These endocrine cells constitute approximately 1% of all epithelial cells in the gastrointestinal tract (92,93,98-100) and they have specialized sensors in the form of microvilli that project into the lumen and respond to luminal stimuli by releasing hormones (101-113). The distribution, functions and modes of action of the most important gastrointestinal endocrine cells have been described in detail elsewhere (95,114,115). Briefly, each cell type secretes one or more signaling substances into the lamina propria, where these substances act directly on nearby structures (autocrine/paracrine mode), indirectly via an endocrine mode of action (by circulating in the blood to reach distant targets), and/or through a synaptic mode of action (116). The enteric nervous system comprises two plexi: the submucosal plexus and myenteric plexus. The NES regulates several functions of the gastrointestinal tract, including sensation, motility, secretion, absorption, local immune defense and food intake (22,92,93,95,117). The components of the NES interact and integrate with each other, the autonomic nervous system, and the afferent and efferent nerve fibers of the central nervous system (22,95,117,118).

Dietary fiber appears to improve the global symptoms in patients with IBS, abdominal discomfort/pain, abdominal bloating/distension and altered bowel habit, probably by affecting the NES. Changes in the luminal intestinal pH and pressure can stimulate the release of the hormone serotonin, which is known to play a pivotal role in visceral sensitivity (95). The short-chain fatty acids produced by the fermentation of dietary fiber appear to affect several intestinal hormones, such as peptide YY (PYY) and glucagon-like peptide-1 (119-122). PYY is known to stimulate the absorption of water and electrolytes, and regulate the 'ileal brake' (123-128). Furthermore, PYY inhibits prostaglandin E2 and vasoactive intestinal polypeptide, which stimulate intestinal fluid secretion (129-131). This can explain the effect of dietary fiber on gastrointestinal transit and secretion. It has recently been reported that changing from a typical Norwegian diet to a FODMAP-reduced diet is accompanied by changes in densities of the gastrointestinal endocrine cells in patients with IBS (132-138). Since FODMAPs by definition constitute dietary fiber, these observations show that changing the dietary fiber intake is associated with changes in the gastrointestinal endocrine cells.

Short-chain fatty acids, particularly butyrate, produced by the fermentation of dietary fiber have been found to affect neurons of the enteric nervous system (119,139). Whether this is a direct effect on the enteric nervous system or involves indirect effects on the gastrointestinal endocrine cells remains to be determined.

4. Fiber supplementation in the treatment of IBS

Physicians (particularly those in the primary care system) usually recommend patients with IBS to increase their intake

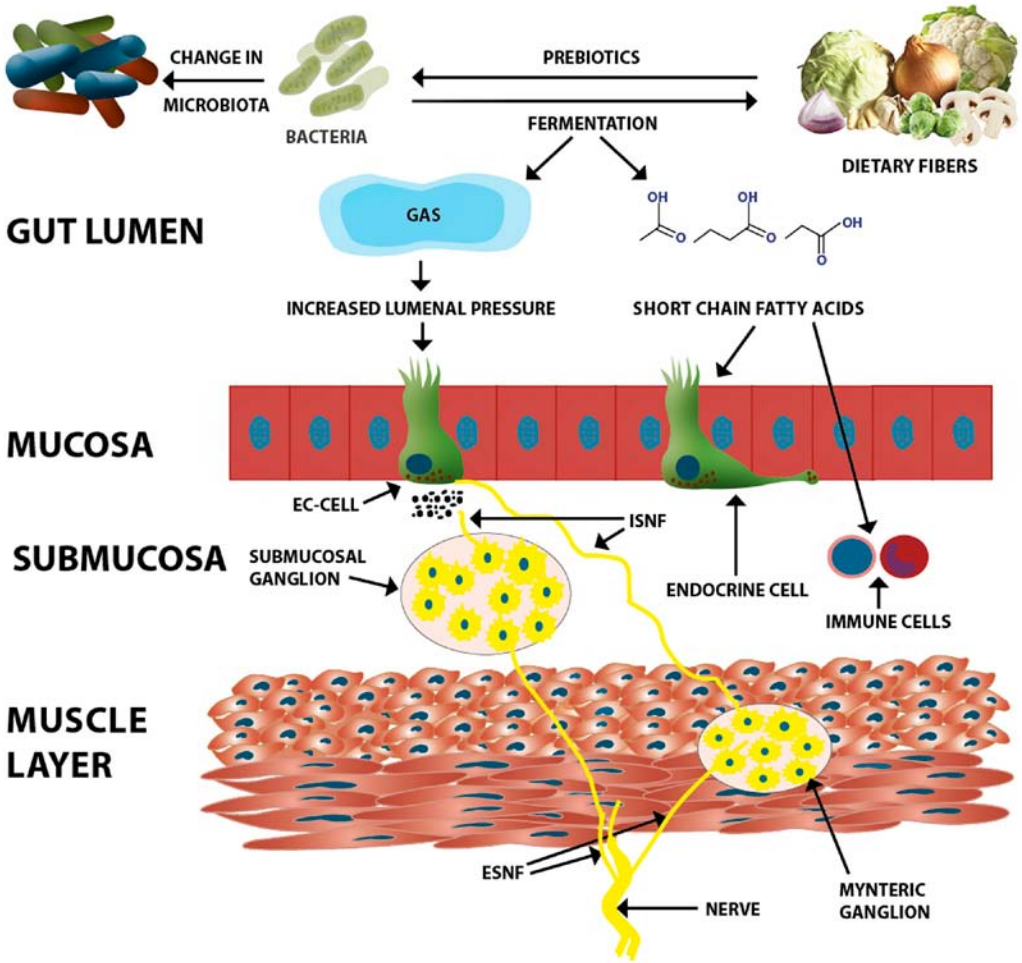

Figure 1. Likely mechanisms through which dietary fiber affects the functions of the gastrointestinal tract. Dietary fiber acts as a prebiotic to intestinal microbiota that causes changes in their composition and induces the growth of beneficial bacteria. The intestinal microbiota in turn causes the fermentation of the dietary fiber, producing gas, short-chain fatty acids, and other byproducts. The gas production increases the fecal mass and increases the luminal pressure. These mechanisms together with lowering of the luminal pH stimulate the secretion of serotonin from the EC-cell. Serotonin plays an important role in visceral sensitivity. Short-chain fatty acids act on intestinal endocrine cells and/or the neurons of the enteric nervous system to change gastrointestinal motility and secretion. Short-chain fatty acids act also on immune cells and thereby reduce inflammation. EC-cell, enterochromaffin cell; ISNF, intrinsic sensory nerve fibers; ESNF, extrinsic sensory nerve fibers.

of dietary fiber to 20-35 g daily in order to regulate the stools and reduce abdominal pain and meteorism (140-143). Supplementation with long-chain, intermediate viscous, soluble and moderately fermentable dietary fiber such as psyllium improves the global symptoms of IBS (26,144-147). A recent meta-analysis that evaluated dietary fiber supplementation in 14 randomized controlled trials involving 906 patients with IBS found that fiber supplementation (especially with psyllium) was effective in improving global IBS symptoms compared to placebo (46).

Dietary fiber supplementation seems to be safe (46,147), although transient abdominal bloating/distention can occur if it is introduced too rapidly (23,148). Recommending fiber supplementation to patients with IBS is also inexpensive while having documented effects on IBS symptoms and other health benefits (23,147,149).

5. Conclusion

Dietary fiber affects the bowel habits through increasing the stool bulk with mechanical stimulation of the colonic mucosa. The fermentation of dietary fiber by intestinal microbiota lowers the luminal pH and has several byproducts, such as gas and short-chain fatty acids. The gas increases the luminal pressure while short-chain fatty acids, particularly butyrate, affect the NES and consequently affect gastrointestinal secretion and motility. Dietary fiber has additional health benefits such as lowering the blood cholesterol level, improving glycemic control, and body weight management (23,54,55).

The different types of dietary fiber exhibit marked differences in physical and chemical properties, and not all types of fiber are beneficial for patients with IBS. A general recommendation to increase fiber intake in this group of patients would be inappropriate since it could worsen the symptoms (39). Long-chain, intermediate viscous, soluble, and moderately fermentable dietary fiber (e.g., psyllium) has documented affects in the management of IBS, and can improve the overall symptoms of patients with IBS (23,41,46,51,54). Supplementation with this type of dietary fiber should be recommended to patients with all of the IBS subtypes, namely IBS-D, IBS-M, and IBS-C. When beginning a fiber supplementation regimen, a transient period of abdominal bloating/distension, discom-

fort, and change in the bowel habits may occur (150). Fiber supplementation should therefore be started gradually, with the intake increased by no more than 5 g/day each week (23).

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