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Review article

Role of guar fiber in improving digestive health and function

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ABSTRACT

Digestive health plays key role in our active daily life; but maintaining proper bowel movements, i.e., being free from constipation, diarrhea, irritable bowel syndrome, inflammatory bowel disease, flatulence, bloating, and abdominal pain, is complex. Dietary fibers often are recommended to maintain proper digestive health, but none seems to provide a single comprehensive solution for overall maintanance of proper digestive health. Guar fiber, however, has emerged as a credible candidate for just such a solution. This review focused on summarizing the clinically observed effects of guar fiber on digestive health. Several clinical studies suggest the guar fiber normalizes both constipation and diarrheal conditions. Also, it was effective in alleviating the symptoms associated with irritable bowel syndrome. The studies suggest that a regular intake of 5 to 10 g/d guar fiber is effective to treat most of the morbidities associated with digestive health. Guar fiber is all natural. It may offer potential protection and promotion of digestive health both alone and when combined with probiotics as a synbiotic formula.

Introduction

Digestive health plays a direct role in one's quality of life and daily performance. Digestive problems, such as irregular bowel movements, gas, bloating, and abdominal pain, may impair daily life. Irregular bowel movements such as constipation (less than 3 bowel movements per week), diarrhea (more than three bowel movements per day), irritable bowel syndrome (IBS; either constipation, diarrhea, or both associated with abdominal pain/spam), and inflammatory bowel disease (IBD) are the common morbidities associated with digestive health. Globally, >12% of the population suffers with constipation, whereas 11% suffer with IBS [1]. The World Health Organization (WHO) reported nearly 1.7 billion cases of diarrhea, of which 760 000 were in children who died annually worldwide [2]. Another report stated that IBD causes 50 000 deaths annually [3].

Although medications are sometimes indispensable for the cure of these morbidities, particularly if chronic, medical experts and dietitians often urge the use of dietary fibers for prevention and maintenance of proper digestive health [4]. Dietary fibers are available in both soluble and insoluble forms, but none are the same or equal in exhibiting their benefits due to differences in structure and function [5,6]. Insoluble fibers have mostly viscous and bulking properties that are effective in easing constipation, but they are limited in their effectiveness against other bowel morbidities [7]. Additionally, their bulking effects may cause discomfort and aggravate complications associated with bowel diseases [8–11]. Soluble fibers are fermentable to exhibit prebiotic effects by which they synthesize various amounts of short-chain fatty acids (SCFA), which are closely associated with gut health and many other physiological health benefits [12]. However, the chemical structure of the dietary fiber, their transit time in gut, the degree of fermentation, and corresponding influence on the growth of probiotics and release of SCFA greatly affects the performance of different soluble fibers [13,14].

Previous systematic reviews suggest that dietary fibers may be effective for constipation [15] and IBS [16], but they lack explanations on the efficacy of any specific dietary fiber. Most soluble fibers are helpful in the prevention or reduction of constipation but seem to have little effect on diarrhea and IBS. In this context, guar fiber, popularly known as partially hydrolyzed guar gum (PHGG; Sunfiber, Taiyo Kagaku Co Ltd, Yokkaichi, Japan), emerged as a potential soluble fiber offering prevention and cure against all bowel morbidities, including constipation, diarrhea, IBS, and IBD. Previously, guar fiber earned Grade A recommendations from a fiber consensus group for having “Level 1 evidence” (randomized trial, meta-analysis with low risk for error) in clinical use

TPR is employed by the company that produces guar fiber. However, this scientific review is written based on the scientific studies done elsewhere. The authors have no conflicts of interest to declare.

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against diarrhea and IBS and in enteral nutrition (EN) [17]. Recently, Health Canada approved guar fiber for use in childhood constipation and IBS. Also, it was approved for the alleviation of constipation and diarrhea in Japan. Therefore, the aim of this review was to summarize the clinical evidence regarding the physiological effects of soluble fibers on digestive health, with specific reference to guar fiber.

Guar gum versus guar fiber

Guar fiber is one form of guar gum having 100% guar galactomannans derived from the endosperm of *Cyamopsis tetragonolobus* L. (guar plant) seeds. The guar galactomannans are composed of mannose and galactose approximately in a 2:1 ratio. Guar gum is typically composed of very long chain galactomannans ($50–8000 \times 10^3$ units) and have high molecular weight (200–300 kDa). It forms very high viscous gel (>2000 cps with 1% of guar gum) when dissolved in liquids. Therefore, it is mostly used as a thickener in various food and industrial applications. Guar gum as a soluble fiber has shown a number of physiological benefits, such as lowering cholesterol [18–23] and attenuating postprandial glucose response [24–27]. However, its high viscosity even at low doses has limited its use as a dietary fiber in many food, beverage, dairy, and dietary supplements. In general, a minimum fiber content of 2.5 g per serving is required to declare it as dietary fiber on the label of a product in many countries. Guar gum at these dosage levels also may cause choking due its swelling properties. Therefore, a nearly non-viscous guar gum was warranted to explore its physiological health benefits fully through fortification in various foods and supplements. The demand resulted in the development of a near non-viscous guar fiber through controlled natural enzymatic hydrolysis of guar gum. Guar fiber has low molecular weight (~20 kDa) and typically is non-viscous when dissolved even at high doses (<12 cps at 5% of guar fiber), which had facilitated its use as dietary fiber in many kinds of food, beverage, and dietary supplements [28]. Guar fiber has a high dietary fiber content (>85%) in the form of a blend of short-chain (with 3~8 monomers) and medium-chain (with >9~30 monomers) galactomannans, which are within the natural range of polysaccharide length of galactomannans found in native guar gum. Although most of the soluble fibers have either short- or long-chain polysaccharides, guar fiber has a blend of short- and medium-chain–length galactomannans at a 1:7 ratio, which makes it unique among the soluble fibers. Since its development, guar fiber has been widely used in cereals, juices, shakes, yogurt, meal replacements, soups, and baked goods. It is also used as a food supplement and as a fiber source in EN and medical products [29]. In-depth safety studies (acute toxicity, subchronic toxicity, carcinogenicity, genotoxicity, and reproductive toxicity studies) as well as historical and extensive use of guar fiber have confirmed its safety. In 1991, a panel of five experts confirmed its safe use in enteral and medical foods [30]. Later, the Life Sciences Research Organization of the Federation of American Societies for Experimental Biology commissioned a panel of six experts to assess the use of guar fiber in consumer foods, and the panel concluded that a daily consumption of PHGG at levels ≤20 g/d was safe [31]. Since 1995, it is generally recognized as safe in the United States [32,33].

In the past two decades, several in vitro, animal, and clinical studies have confirmed its safety and physiological health benefits, which are comparable to those of normal guar gum [28,34–37]. Several human studies [38–43] suggest its digestive health benefits against constipation (Tables 1), diarrhea (Tables 2), and IBS [38–43] and animal studies against IBD [44–46]. These effects are discussed in detail in the following sections.

Reduction of constipation

Constipation varies by definition but essentially occurs when there is no fecal output for 3 to 4 d. Constipation has symptoms of hard feces causing difficulty in output and delayed transit time [47]. Other symptoms associated with it are painful defecation, hard or dry stool, abnormally small stool, or a feeling of incomplete rectal evacuation. Chronic constipation can lead to more serious complications, such as bowel perforations, fecal impaction, and other bowel diseases. It is important to eliminate toxins and reduce the risk for more serious bowel problems. Dietary fiber has been considered effective in regulating fecal transit time by reducing constipation. It may improve defecation by fecal bulking, changing fecal consistency, and increasing intestinal motility [48]. Increased bulk, softness, or pliability of colonic contents may indicate a protective effect against the development of constipation. There is a significant amount of research regarding increased fiber intake and improvement of constipation.

The influence of guar fiber on constipation was investigated in 15 women who had a fecal output occurring an average of 2.8 times/wk and associated with discomfort and abdominal pain before movements. The women took 11 g/d of guar fiber consecutively for 3 wk between 2 control (no fiber) 3-wk periods. Weekly defecation frequency, pH, weight, moisture, and bacterial flora of the feces were investigated and compared with the control periods [49]. Significant ($P < 0.05$) changes in fecal pH (from 6.87 to 6.36), moisture content (from 70% to 74.1%), and defecation frequency (from 0.46 ± 0.05 to 0.63 ± 0.05 times/d) were observed after 2 wk with fiber supplementation. These improvements disappeared after discontinuation of fiber supplementation.

Positive results also were seen in studies with men. Guar fiber (36 g/d) was given to eight healthy men for 4 wk. Fortifying their daily diet with guar fiber significantly ($P < 0.05$) increased fecal weight (from 137.8 to 195.2 g/d) and output frequency (from 0.89 to 1.13 times/d), while lowering the pH (from 6.19 to 5.54) of feces. High daily intake of guar fiber did not show any side effects except slight flatulence in the beginning of intake. The high intake also did not have an influence on fat, protein, or mineral excretion. Additionally, guar fiber significantly ($P < 0.05$) increased the fecal SCFA, especially acetic acid, and decreased total serum cholesterol. The study concluded that the intake of guar fiber increased the bulking capacity and SCFA production, but without any influence on utilization of other nutrients in normal healthy individuals [42].

In another double-blind, randomized crossover study [50], 10 healthy male volunteers were randomly assigned with supplementation of either guar fiber (21 g/L for 7 d) or control within a liquid formula for 7 d. After a 1-wk washout period, they were assigned to other treatments for another 1 wk. Although the study was examining the safety of high intake of guar fiber in a liquid form, they also observed an improvement in the consistency of hard stool with guar fiber supplementation. The high intake of guar fiber did not result in any hematologic, renal, or hepatic toxicity among the participants.

Dialysis patients are often constipated and reported to have changes in their intestinal microflora. Indoxylsulfuric acid (IS) levels rise as glomerular filtration decreases, and patients with renal failure have high IS. One study [51] investigated whether administering guar fiber can decrease IS levels while ameliorating constipation and improve the nutritional status in dialysis patients. Thirty-five patients on dialysis (mean age, 71 ± 9 y; 22 male/13 female) ingested guar fiber (10 g/d) for 6 wk. Defecation score was measured before and after guar fiber intake using a modified Constipation Assessment Scale-Long Term (Japanese version). Also, nutritional status was rated according to the Geriatric Nutritional Risk Index at respective times. IS was measured in eight patients

Table 1
Summary of clinical studies on the effects of Guar fiber against constipation

Reference	Participants	Study	Results
Takahashi et al., 1994 [49]	15 constipated but otherwise healthy women	The frequency of defecation, changes in fecal moisture and pH, and frequency of *Lactobacillus* species in feces were measured with intake of 11 g guar fiber/d for 3 consecutive wk	The intake of guar fiber significantly increased ($P < 0.05$) the defecation frequency and moisture content of feces. The pH of the feces was decreased.
Takahashi et al., 1993 [42]	8 healthy men	Fecal weight, output frequency, and feces pH was examined after intake of 36 g/d guar fiber for 4 wk	Diet with guar fiber significantly ($P < 0.05$) increased fecal weight (from 137.8 to 195.2 g/d) and output frequency (from 0.89 to 1.13 times/d) while lowering the pH (6.19 to 5.54) of feces without any influence on fat, protein, or mineral excretion.
Alam et al., 1998 [50]	10 healthy men	While examining the safety of high doses (21 g/d) of guar fiber, the stool conditions were observed	The intake of guar fiber significantly increased ($P < 0.001$) the fecal weight (from 161 to 259 g/3 d). The intake of guar fiber also changed stool consistency from hard to normal.
Maeda et al., 2012 [51]	35 dialysis patients	The effect of guar fiber intake (10 g/d) for 6 wk on improvement of constipation was observed	Constipation scores measured on the Constipation Assessment Scale-Long term suggested significant ($P < 0.01$) decreases in the score from 7.9 to 5, suggesting amelioration of constipation in dialysis patients.
Yamatoya et al., 1995 [53]	65 healthy participants	The effect of low-dose (5 g/d) or high-dose (15 g/d) guar fiber for 2 wk on stool conditions were observed	The fecal frequency was significantly ($P < 0.05$) improved by both low- (12.4 to 13.7 times/2 wk) and high-dose (10.4 to 11.4 times/2 wk) guar fiber. The frequency returned back after discontinuing guar fiber intake. Also, fecal volume was increased and fecal hardness was decreased with both treatments.
Okazaki et al., 1999 [54]	22 + 15 healthy participants	Two studies, one with or without intake of 10 g/d guar fiber (n = 22). The other study with intake of 5 g guar fiber (n = 15). Intake period was 2 wk	Fecal frequency was significantly ($P < 0.01$) increased in both studies from 6.13 to 7.14 in study 1 and from 3.67 to 5.21 times/wk in study 2. The fecal quantity in study 2 was significantly increased ($P < 0.01$); whereas no change was observed in fecal harness, smell, and defecation frequency.
Tanaka et al., 2000 [55]	46 healthy participants	Defecation frequency and other fecal features were observed with intake of 7 g guar fiber along with 250 g of rice for 2 wk	Defecation frequency and fecal volume were significantly ($P < 0.01$) increased with intake of guar fiber.
Polymeros et al., 2014 [40]	39 chronic constipated participants	Changes in bowel movement, laxative use, and abdominal pain associated with chronic constipation was observed with intake of 5 g guar fiber for 4 wk	Bowel movements (both complete and spontaneous) were increased significantly ($P < 0.01$) with intake of guar fiber. The treatment also helped to reduce laxative use and abdominal pains associated with chronic constipation.
Belo et al., 2008 [52]	64 constipated adults	The improvement in constipation and related complications were assessed with intake of a high-fiber diet (30 g) and similar diet +10 g guar fiber for 15 d	High fiber reduced constipation by 78%. The addition of guar fiber to a high-fiber diet did not add further benefit in the improvement of constipation but helped to reduce abdominal pain associated with the constipation.
Sasaki et al., 2005 [74]	34 hemodialysis patients and 8 healthy normal participants	Stool conditions in both groups were observed with intake of 10 g/d of guar fiber for 4 wk	The hard or slightly hard stool conditions in normal participants were reduced significantly from 60% to 40% with intake of guar fiber. In hemodialysis patients, the use of laxatives caused loose stools, which was significantly improved to normal with the treatment of guar fiber.
Sakata and Shimbo 2006 [56]	9 healthy participants	Changes in fecal conditions were observed with intake of 12.5 g/d of guar fiber for 2 wk	Guar fiber intake resulted in an increase of fecal bulk in 4 participants and fecal moisture in 5 of 9, but a decrease of fecal hardness in 3 participants.
Patrick et al., 1998 [57]	21 elderly participants dependent on laxative use	Observed the changes in laxative use with intake of gradual increase of guar fiber from 4 to 12 g/d in 4 wk	Regular intake of guar fiber significantly ($P < 0.001$) reduced the laxative use from 2 to <0.1 by end of treatment period, whereas no changes were observed in the number of bowel movements (1/d).
Ustundag et al., 2010 [58]	61 constipated children	Compared effects of guar fiber (3–5 g/d) with common laxative lactulose (1 mL/kg daily) on defecation frequency in 4-wk administration period	Both the treatments significantly reduced stool consistency, abdominal pain, and weekly defecation frequency compared with baseline.
Sariano et al., 2000 [59]	187 mentally and physically challenged people at a care facility	Reduction of enema usage with intake of 18 g of guar fiber for 9 mo	Enema usage was significantly ($P < 0.05$) reduced from 7 to 8 to 1 to 3 enemas/mo with intake of guar fiber

Table 2
Summary of clinical studies on the effects of Guar fiber against diarrhea

Reference	Participants	Study	Results
Hommann et al., 1994 [68]	100 patients	Effects of guar fiber 20 g/L as enteral nutrition on improvement of diarrhea	Administration of guar fiber significantly decreased incidence of diarrhea.
Spapen et al., 2001 [69]	25 patients	Effect of guar fiber 20 g/L as enteral nutrition on the improvement of diarrhea	The mean frequency of diarrhea days was significantly reduced in the fiber group compared with the control group ($8.8 \pm 10\%$ vs $32 \pm 15.3\%$; $P < 0.001$). The total number of diarrhea days was lower in patients treated with guar fiber.
Rushdi et al., 2004 [70]	20 patients	Effects of guar fiber 20 g/L as enteral nutrition for 4 d on improvement of diarrhea	The number of liquid stool episodes was reduced from 2 ± 0.9 to 1 ± 0.7 ($P < 0.01$) in the guar fiber group, whereas the number of episodes was increased from 1.2 ± 0.7 to 2.1 ± 0.8 ($P < 0.05$) in the control group in 4 d of treatment period.
Nakao et al., 2002 [72]	20 patients	The effect of incremental usage of guar fiber from 7 to 28 g/d in 4 wk on improvement of liquid diet-induced diarrhea	The DAO activity was significantly ($P < 0.001$) improved from 8.5 to 12.3 IU/L during 4 wk, but decreased to 10.8 after discontinuation of PHGG treatment. Water content ($P < 0.05$), pH of stools ($P < 0.05$), and bowel movements ($P < 0.05$) were significantly decreased in the 4 wk treatment with guar fiber but the factors were increased after discontinuation of the fiber treatment.
Nakamura et al., 2007 [38]	34 healthy subjects	The effects of guar fiber (5 and 10 g) on improvement of diarrhea induced by maltitol or lactitol	The intake of gaur fiber in both 5 and 10 g suppressed the diarrheal incidences induced by maltitol and lactitol. The cumulative suppressive effect with 10 g dosage was 82.1%.
Alam et al., 2000 [76]	150 male children (4-18 mo)	Examined the effect of guar fiber (20 g/L) supplementation together with ORS on the amelioration of acute non-cholera diarrhea	Patients supplemented with guar fiber + ORS solution had significantly reduced duration of diarrhea (from 90 to 74 h; $P < 0.03$) compared with the control group. The guar fiber supplementation also helped with reduced stool output.
Alam et al., 2005 [77]	116 children (5–24 mo of age) with persistent diarrhea	Examined the effects of guar fiber (20 g/L) supplemented with ORS on the amelioration of diarrhea	The diarrheal suppression effect of guar fiber was significantly higher compared with control diet (84 vs 62%). Stool output also significantly reduced with intake of guar fiber.

DAO, diamine oxidase activity; ORS, Oral Rehydration Solution; PHGG, partially hydrolyzed guar gum

taking guar fiber orally for an extended period of 24 wk and compared with those not on guar fiber. Constipation scores decreased from 7.9 to 5 ($P < 0.01$) and Geriatric Nutritional Risk Index increased from 95 ± 5 to 95.9 ± 5.7 ($P < 0.05$), reflecting amelioration of constipation and improved nutritional status. The IS ratio was calculated using the IS score before and after use of guar fiber. IS ratios were 1.2 ± 0.3 and 0.8 ± 0.3 ($P < 0.05$) in patients without and with guar fiber, respectively. The results indicated that guar fiber consumption ameliorated constipation, improved nutritional status, and reduced IS in dialysis patients.

Belo et al. [52] studied the effect of intake of guar fiber in the treatment of functional constipation among hospitalized patients. Sixty-four adults were placed into one of two groups, with one receiving either 30 g of guar fiber and the other an additional 10 g guar fiber for 15 d. The high-fiber diet with 30 g guar fiber reduced constipation by 78%. The addition of guar fiber to a high-fiber diet did not further elevate improvement but did reduce bowel complaints. This study showed a background diet of 30 g/d is sufficient to improve constipation, and the additional guar fiber did not have an additive effect on constipation improvement.

Although the aforementioned studies referred to the usage of high-dosage levels (>10 g/d), several other studies have indicated that a small dose (5–7 g/d) of guar fiber is sufficient and equally effective in the amelioration of constipation. In a study with 65 healthy individuals, participants were given a beverage containing 5 or 15 g/d of guar fiber for 2 wk. A significant ($P < 0.05$) increase in fecal frequency and fecal volume, and a decrease in fecal hardness was observed with both treatments. The changes in bowel movements were noticed within few days after the start of fiber supplementation [53].

Okazaki et al. [54] conducted two studies in which participants were given a jelly-like beverage either fortified with 5 g guar fiber or without fiber. In study 1, 22 healthy individuals (18–20 y of age) were given the beverage twice daily with (n = 14) or without (n = 8) guar fiber for 2 wk. In study 2, one beverage (5 g guar fiber) per day was given to 15 healthy women (22–33 y of age) for 2 wk. In the former study, with a total intake of 10 g/d guar fiber, fecal frequency was significantly ($P < 0.01$) changed from 6.13 to 7.14 after 2 wk. In the second study, with a total intake of 5 g/d, a significant ($P < 0.05$) increase from 3.67 to 5.21 was observed in fecal frequency after 2 wk. Other factors such as fecal volume were increased significantly ($P < 0.01$); however, fecal hardness, smell, and defecation feelings did not change significantly with intake of 5 g/d guar fiber.

In a crossover study, 46 healthy young women took a rice gruel (250 g) containing 7 g of guar fiber for 2 wk. At the beginning of the study, the defecation frequency in 16 of the women was <4 times/wk. The defecation frequency of the remaining 30 women was >4.5 times/wk. The defecation frequency was significantly ($P < 0.01$) increased from 3.2 to 4 times/wk in 16 women

and from 6.5 to 7.3 times/wk in the remaining 30 with guar fiber supplementation. Also, fecal volumes were significantly improved in all participants compared with baseline (no treatment period) and control (no fiber treatment) in 2 wk [55].

A study by Polymeros et al. [40] investigated the effect of guar fiber on symptoms of chronic constipation. Forty-nine patients fulfilling Rome III criteria for chronic constipation received 5 g guar fiber daily for 4 wk. During the study period, the patients recorded their daily symptoms, stool conditions, and laxative usage in their diaries. They also recorded treatment-related satisfaction against symptoms and any adverse events at the end of each week. Of the 49 patients, 39 (80%) completed the study. At the end of the study, the weekly number of complete (0 to 1.25 times/wk) and spontaneous bowel movements (from 1.5 to 4.75 times/wk) increased significantly ($P < 0.001$). Additionally, the number of bowel movements with straining decreased (from 100 to 38; $P < 0.001$) and stool form was improved ($P < 0.001$). A significant decrease from 3 to 0 days with laxative use ($P < 0.001$) and percentage of weeks with abdominal pain from 100% to 50% ($P < 0.05$) was observed with 5 g guar fiber.

Modulation of stool form

Stool form may vary (watery, loose, normal, slightly hard, or hard) with type of diet, water intake, and/or physical and medical condition of a person. Some medical treatments also may cause modifications in stool form and frequency. The studies discussed here suggested the improvement of both constipation and diarrhea in a variety of conditions; however, few studies examined the effect of guar fiber on the modulation of stool form from loose/hard to normal conditions.

Sakata and Shimbo [56] examined the effect of guar fiber on the modulation of bowel movements and stool form in healthy individuals. In two sessions (14 d each in spring and autumn), nine healthy female students followed the same strictly controlled diet regimens. During the first session, the students were not supplemented with fiber. In the second session they were given with 12.5 g/d guar fiber (equivalent to 10 g of dietary fiber) dissolved in an adequate amount of water at the end of each meal. Their feces were collected and weighed just after defection. Guar fiber intake resulted in an increase of fecal bulk for four of the women and fecal moisture for five of the nine and decreased fecal hardness in three. These results indicated that guar fiber helped improve bowel movements and stool form (hard or soft) to a more regular pattern in healthy individuals.

Reduction in use of enemas and laxatives

In addition to guar fiber's ameliorating effects against constipation, it also has been found to be effective in reducing the use of enema or laxatives in both children and adults.

Twenty-one elderly patients who regularly consume laxatives were examined on the pattern of laxative use with administration of guar fiber regularly. For the first 3 wk, the frequency of their use of laxatives without administration of guar fiber was recorded. At the beginning of the fourth week, the patients were given guar fiber and reduced (50%) the dose of their daily laxatives. The dosage of guar fiber was gradually increased from 4 to 12 g/d by the end of week 4. From the beginning of week 5, guar fiber alone was given, and the use of laxatives was restricted to only when required until the end of week 8. Of 21 patients, 16 completed the study. The dropouts were unrelated to guar fiber treatment. The use of laxatives was significantly ($P < 0.001$) reduced from 2 to <0.1 at the end of the 6-wk period, although no significant change in the number of bowel movements (1/d) was observed. The study found no difference in frequency of bowel movements, perception of stool consistency, or ease of evacuation when their regular laxatives were replaced with guar fiber [57].

Another study examined the supplementation of guar fiber for treatment of constipation in children and compared its effects with the most commonly used osmotic laxative lactulose. A randomized, prospective, controlled study with 61 patients grouped into a guar fiber group (3–5 g/d based on age, n = 31) and a lactulose group (1 mL•kg•d^{-1}, n = 30) was performed for 4 wk. Using a standardized bowel diary, defecation frequency, stool consistency, and presence of flatulence and abdominal pain were recorded. Family questionnaires about the success, safety, and side-effect profile of both treatment arms also were obtained. No significant differences were found in the baseline daily fiber (fruits and vegetables) intake between the two groups. Bowel movement frequency per week and stool consistency improved significantly in both treatment groups ($P < 0.05$). The percent of children with abdominal pain and stool withholding also decreased in both groups ($P < 0.05$). Weekly defecation frequency increased from 4 ± 0.7 to 6 ± 1.06 and from 4 ± 0.7 to 5 ± 1.7 in the lactulose- and guar fiber-treated groups, respectively ($P < 0.05$). According to the family questionnaire, parents complained of bad taste, flatulence, and need to ingest a high amount of drug in the lactulose-treatment group. In the guar fiber-group, parents were satisfied with their children's defecation frequency. The study concluded that guar fiber was as effective as lactulose treatment in relieving stool withholding and constipation-associated abdominal pain, and its use improved stool consistency. Lactulose seemed to have more side effects such as flatulence and bad taste [58]. Guar fiber appears to be a good alternative to lactulose for constipation in children, offering greater acceptability, negligible side effects, and better efficacy.

In another study, profound reduction of enema use was observed in a case-controlled study with guar fiber supplementation in residents with profound mental and physical disabilities at a care facility [59]. Baseline data on enema use in the residents was collected. One-hundred and eighty-seven residents were then given guar fiber supplement (18 g/d fiber) for up to 9 mo. After fiber supplementation, residents with higher enema usage (7–8 enemas per month) at baseline had significantly ($P < 0.05$) lower enema use (1–3 enemas monthly). These results indicate long-term administration of guar fiber supplementation is well tolerated and helps to reduce enema usage in mentally and physically disabled individuals.

Mechanism of action in alleviating constipation

Both insoluble and soluble fibers support the normalization of bowel movements by increasing the defecation frequency and fecal weight in constipated individuals; however, the mechanism of action (MOA) varies between the two types of fibers. Insoluble fibers generally exhibit gelling properties, which absorb water, thereby helping to soften and increase the fecal bulk to pass more easily. Insoluble fibers are effective laxative agents but have an undesirable taste and texture in some processed foods. Soluble fibers have a varying degree of fermentation and limited water-holding capacities and could act in a different MOA for its laxative effects. In the case of guar fiber, as mentioned previously, Polymeros et al. [40] examined the MOA in terms of colonic transit time (CTT), complete spontaneous bowel movements, and spontaneous bowel movement (SBM) using chronic constipated patients. They found that the intake of guar fiber (5 g/d) accelerated CTT by an average of 12 h in constipated patients. The

effects were more prominent in slow-transit patients with increase of CTT by 22 h. The defecation frequency in terms of complete spontaneous bowel movements and SBM were also normalized in all patients, including slow-transit patients. In a recent report by the American Gastroenterological Association, fibers are unlikely to respond in slow-transit patients [60]. This may be true for insoluble fibers that have bulking effects, but not for soluble fibers with limited bulking effects. Takahashi et al. [49] explained that guar fiber might have increased the water-retaining capacity and defecation frequency through an osmotic effect by increased bacterial growth and reduced pH in the intestine. Bijkerk et al. [7] suggested that soluble fibers may decrease intestinal transit time by alleviating pressures in the colon through fermentation and production of SCFAs. A detailed study may be warranted to examine effects of guar fiber on the relationship between SCFA production and bowel movements during constipation for further clarity on its MOA. Based on the studies just mentioned, guar fiber at a recommended dosage of 5 g/d could be considered a potential substitute for insoluble fibers, laxatives, and medicines to treat constipation without any side effects.

Reduction of diarrhea

In humans, dietary fibers are mainly fermented in the large intestine by intestinal microflora, and in this process SCFAs are produced. SCFAs are absorbed in the colon, stimulating sodium transport in several species, including humans [61,62]. This effect may be particularly important in acute diarrheal diseases in the colon and may cause colonic dysfunction [63]. SCFA levels in the colon, therefore, may influence the clinical course of acute diarrheal conditions. Fiber added to tube-feeding formulas may aid in reduction of diarrhea, but this is dependent on both the physical and chemical characteristics of the fiber.

Several studies suggest that guar fiber has the ability to produce significantly high amounts of SCFA compared with other soluble fibers [13,64–67]. This specific effect was mainly attributed to its ability to transit through the gut slowly with a high degree of fermentation. Thus, guar fiber may be an effective treatment for diarrhea. Diarrheal conditions generally emerge with malnutrition, high consumption of sugar alcohols, cholera, and certain treatments like EN, hemodialysis, and laxative use. The following clinical studies evaluated the effects of guar fiber in the treatment of diarrhea induced by the these conditions.

Diarrhea with EN

The first study to our knowledge, to demonstrate the effect of guar fiber on diarrhea was conducted by Homann et al. [68]. It was a prospective, double-blind trial with 100 patients receiving total or supplemental EN. The patients were randomly divided into two groups. One group was given a standard liquid diet and the other the same diet but with the addition of 2% guar fiber (20 g/1000 mL). Thirty patients received total EN postoperatively, and 70 patients received enteral supplementation. Without any relevance to either total or supplemented EN, the incidence of diarrhea significantly decreased with guar fiber administration compared with the standard diet.

A double-blind study examined fiber supplementation through enteral feeding in patients with severe sepsis and septic shock [69]. Twenty-five patients who were mechanically ventilated on EN through nasogastric tube were given two treatment regimens-13 patients on guar fiber and 12 on control treatments. The fiber group received 25 g guar fiber added to their EN feeding. Patients in the guar fiber and control groups were tube fed for a mean duration of 11 ± 4 and 12 ± 5 d (non-significant difference), respectively. The mean frequency of diarrhea days was significantly less in the fiber-treated group than in the control group (8.8 ± 10% versus 32 ± 15.3%; $P < 0.001$). There were fewer diarrhea days in the group of patients treated with guar fiber. In this group, diarrhea occurred on 16 of 148 feeding days (10.8%) compared with 46 of 146 feeding days (31.5%) in the control group ($P < 0.001$). More patients in the control group had diarrhea score (>12) for ≥1 d. The guar fiber group had lower mean diarrhea score than the control group (4.8 ± 6.4 versus 9.4 ± 10.2; $P < 0.001$). The study concluded that total EN supplemented with guar fiber is beneficial in reducing the incidence of diarrhea in tube-fed and mechanically ventilated septic patients.

Another double-blind controlled study examined the effects of guar fiber on 20 patients (>20 y of age) who were on EN with persistent diarrhea with at least three liquid stool episodes per day. The patients were randomized to receive an EN containing either 2% guar fiber (n = 10) or control (fiber free; n = 10) for 4 d consecutively. The number of liquid stool episodes were reduced from 2 ± 0.9 to 1 ± 0.7 ($P < 0.01$) in the guar fiber group, whereas the number of episodes increased from 1.2 ± 0.7 to 2.1 ± 0.8 ($P < 0.05$) in control group during the 4 d of treatment. The patients fed with guar fiber were able to tolerate a high dosage. There were more side effects in the control group than in the fiber group, but not to a significant degree [70].

Homann et al. [71] examined the beneficial effects of guar fiber during EN in medical and surgical patients. One-hundred patients recovering from surgical and medical illnesses were randomized and equally divided into two groups. In each group, 15 patients were on total EN and 35 were on supplementation of regular food. One group received the above nutrition formulas supplemented with guar fiber (20 g/L). The diarrhea and number of days with diarrhea was lower in patients who received guar fiber.

Twenty bed-ridden individuals (10 male and 10 female; 79.3 ± 5.1 y of age) with diarrhea due to long-term liquid nutrition management were treated with guar fiber for 4 wk. The initial dose was 7 g/d of guar fiber in the first week. The dose was gradually increased with the addition of 7 g each week. At the end week 4, the patients consumed 28 g/d. After 4 wk, the treatment with guar fiber was stopped for 2 wk to examine the post-treatment effects of guar fiber. The frequency of bowel movements, water content in the stools, fecal pH, total number of bacteria, total amount of SCFAs, and serum diamine oxidase activity (DAO; a biomarker for morphologic changes in intestinal mucosa) were observed at weekly intervals. The initial serum DAO activity in the patients was significantly lower compared with the control group. DAO activity was significantly improved from 8.5 to 12.3 IU/L ($P < 0.001$) during the 4-wk treatment period with guar fiber, but the activity was significantly ($P < 0.001$) decreased to 10.8 after discontinuation of guar fiber treatment. Similarly, the water content ($P < 0.05$), pH of the stools ($P < 0.05$), and bowel movements ($P < 0.05$) were significantly decreased in the 4-wk treatment period with guar fiber but increased after its discontinuation. Total amounts of SCFAs ($P < 0.05$) were significantly increased in the 4-wk treatment period. Although there was no change in the counts of total and/or anaerobic intestinal flora, the counts of aerobic flora were significantly ($P < 0.05$) decreased during the guar fiber treatment period. The study suggests that the administration of guar fiber is useful for controlling spontaneous, favorable bowel movements by improving the symptoms of small intestinal mucosal atrophy and normalizing the intestinal microflora [72].

Diarrhea with hemodialysis

Constipation is a common phenomenon observed in patients on hemodialysis due to restricted water and diet intake [73]. As a

result, laxatives often are employed, which can lead to watery or loose stool (diarrheal) conditions in these patients. Sasaki et al. [74] examined the effects of guar fiber on the improvement of stool conditions in a group of patients on hemodialysis. Thirty-four patients (20 male; 14 female, 65 ± 13.1 y of age) and 8 non-hemodialysis patients (control) were given 10 g/d of guar fiber (8 g dietary fiber) for 4 wk. Before fiber supplementation, stool conditions were mostly watery or loose (>60%; due to laxative use) in the patients on hemodialysis and mostly hard to slightly hard in the control group. After initiation of fiber supplementation, a gradual improvement in stool conditions was observed. In the patients on hemodialysis, the loose and watery stool conditions were decreased; in the control group, the hard to slightly hard stool conditions were normalized at the end of the 4-wk treatment.

Cholera-induced diarrhea

Alam et al. [75] examined the effect of guar fiber in the treatment of cholera-induced diarrhea in adults. In a randomized controlled study, 195 men (29 ± 9 y of age) were equally divided into two treatment regimens (25 and 50 g guar fiber; n = 65 each) along with WHO-Oral Rehydration Solution (ORS) and compared with an equal number of control individuals (n = 65). Cholera affects the fluid and electrolyte balance in the small intestine and may cause severe diarrhea. The treatment effects were not observed in the stool output; however, in a subgroup analysis excluding very high purging (stool weight >10 kg in first 24 h), stool weight was significantly ($P < 0.01$) reduced in both guar fiber-treated groups compared with the control group.

Diarrhea with malnutrition in infants and children

In the following studies, guar fiber was found to be effective in the treatment of diarrhea induced by varied non-hygienic food and diet conditions in infants and children.

A double-blind, randomized controlled clinical trial with 150 boys 4 to 18 mo of age who had acute non-cholera diarrhea for <48 h. The children were randomly assigned to receive a WHO-ORS standard diet or the WHO-ORS diet supplemented with 2% guar fiber. Patients supplemented with guar fiber had significantly reduced duration of diarrhea (from 90 to 74 h; $P < 0.03$) compared with the control group. The guar fiber supplementation group also showed less stool output [76].

The results of the study were supported by an additional trial in which 116 children (5–24 mo of age) with persistent diarrhea were randomized to a diet of comminuted chicken supplemented with WHO-ORS enriched with guar fiber (n = 57; 2% guar fiber) or without guar fiber (n = 59; control). Results demonstrated a significantly greater resolution of diarrhea before the end of 7 d in 84% of the children supplemented with guar fiber compared with 62% of those on the control diet. Stool output was significantly reduced on days 4 to 7, and there was a reduction in the duration of diarrhea with the guar fiber. This study shows the therapeutic potential of guar fiber in the recovery of persistent diarrhea in children [77].

Recently, the efficacy of guar fiber in the treatment of severely malnourished children with watery diarrhea was examined in a randomized, double-blind controlled study [78]. One hundred twenty-six severely malnourished children (6–36 mo of age) with acute diarrhea for <7 d were equally divided into fiber (WHO-ORS with guar fiber; 15 g/L) and no-fiber (WHO-ORS only) groups. The mean duration of diarrhea hours in the children given with guar fiber was significantly shorter (57 + 31 versus 75 + 39; $P < 0.01$) compared with those in the no-fiber group. The number of children whose diarrheal episodes stopped within 70 h was higher in the guar fiber group (29 of 63; 46%) than in the no-fiber group (19 of 63; 30%) Also, there was tendency for a decrease of stool weight every day in the fiber group.

Diarrhea with sugar alcohols

Although the studies just described examined the effects of guar fiber in adults and children with persistent diarrhea caused by various treatments and malnutrition, Nakamura et al. [38] examined the effect of different doses of guar fiber (5 or 10 g) on maltitol- and lactitol-induced diarrhea in 34 healthy individuals. The stepwise, increased intake of ≤45 g of maltitol caused diarrhea in 29 of the participants (85.3%), whereas the ingestion of the same amount of lactitol caused diarrhea in 22 (65%) of participants. The intake of guar fiber (5 g) suppressed maltitol-induced diarrhea in 10 of 28 (35.7%) participants and lactitol-induced diarrhea in 7 of 19 (36.8%). The addition of 10 g of guar fiber strongly suppressed maltitol-induced diarrhea in 13 of 18 participants (72.2%), with cumulative suppressive ratio of 82.1% (23 of 28).

MOA in alleviating diarrhea

Although guar fiber decreased the CTT in individuals with constipation, the CTT was increased in those with diarrhea. Meier et al. [79] found a slower CTT when guar fiber was given in a liquid diet to patients with diarrhea and the slower CTT was apparently correlated with increased production of cholecystokinin. This process facilitates the prolonged fermentation, which increases the luminal concentration and absorption of SCFA in the colon, thereby promoting the mucosal turnover and improved absorption of sodium and water by colonocytes [61,80,81]. Deprivation of luminal nutrition of mucosa increased watery stools due to increased fluid secretion [81]. The colonic cells use butyrate as preferential source of energy [61], where the high butyrate-producing property of guar fiber may help to restore colon, ileum, and mucosal functions [45,82]. Serum DAO activity, an index of morphologic change in small intestinal mucosa, was found to be increased with intake of guar fiber and apparently the increase was associated with a decrease in watery stools [72,82]. The same study by Nakao et al. [72] also suggested an increase of butyrate production with intake of guar fiber. Although the MOA in preventing acute diarrhea caused by EN and malnutrition was explained previously, the mode of action in preventing hyperosmotic-transitory diarrhea induced by sugar alcohols is not yet clear. Thus, the mode of action in reduction of cholera-induced diarrhea, which may cause a high purging effect leaving little time for fermentation and SCFA production, was little known. This warrants further detailed studies.

Effects on IBS

IBS is the most common disease diagnosed by gastroenterologists, with a prevalence rate of 3% to 25% in various countries. IBS is not a disease, but a functional disorder characterized by the symptoms of abdominal pain, bloating, flatulence, and bowel dysfunction. IBS could be varying with type: diarrhea-predominant (IBS-D), constipation-predominant (IBS-D), and alternating diarrhea–constipation (IBS-A). IBS-D is more common in men (48%) and IBS-C and IBS-A in women (39% and 48%, respectively) [83]. IBS alters physiological function; consequently, it is difficult to diagnose by a specific abnormality. Because it is not clear what causes IBS, treatment largely focuses on the relief of symptoms so that one can live as normally as possible. Medicines or specialized nutrition are recommended to contain the specific symptoms that

Table 3
Summary of clinical studies on the effects of guar fiber against IBS

Reference	Participants	Study	Results
Giaccari et al., 2001 [84]	134 obese and normal IBS participants	Examined the effects of guar fiber (5 g/d) for 12 wk on improvement of IBS-related symptoms	Guar fiber significantly reduced the symptoms of flatulence (−55.6%), abdominal tension (−4.7%), and abdominal spasm (−35%) after 3 wk of consumption in both normal and obese IBS patients.
Parisi et al., 2002 [39]	188 IBS participants	Compared effects of guar fiber (5 g/d) with wheat bran (30 g/d) in amelioration of IBS symptoms over 12 wk	Guar fiber showed greater success than wheat bran (60 vs 40%) in relieving symptoms associated with IBS
Parisi et al., 2005 [85]	86 IBS participants	Effects of administration of low-dose (5 g/d) and high-dose (10 g/d) guar fiber for 12 wk on IBS symptoms	Both treatments were effective in significantly reducing GI, psychological, and quality-of-life symptoms compared with baseline.
Russo et al., 2011 [86]	30 IBS-C participants	The sex differentiation on effects of guar fiber (5 g/d) on GI symptoms and laxative use	Sex difference was observed in the improvement of abdominal bloating in men and decrease of laxative use in women <45 y of age and BMI <25 kg/m^2. CTT was decreased without any sex differences.
Paul et al., 2011 [89]	46 children with IBS	Effects of guar fiber on amelioration of IBS symptoms in a 6- to 8-wk period	IBS-A and IBS-D symptoms were improved by 82% and 58% with guar fiber, respectively. Abdominal pain associated with IBS was improved by 68%.
Furnari et al., 2012 [87]	40 IBS methane-producing adults	Severity of IBS symptoms and methane production were monitored with intake of 5 g/d of guar fiber up to 4 mo	The methane concentration in feces and IBS symptoms were significantly ($P < 0.001$) reduced with intake of guar fiber.
Romono et al., 2013 [41]	60 children with IBS	Severity of IBS symptoms, abdominal pain, and bowel habits were monitored with intake of 5 g/d guar fiber up to 8 wk	Guar fiber showed better efficacy than control in reducing IBS (43 vs 5%; $P < 0.05$), abdominal pain scores (0 vs 4; $P < 0.05$), and bowel habits (40 vs 13.3%; $P < 0.05$).
Niv et al., 2016 [88]	108 IBS adults, predominantly with bloating symptoms	Severity of IBS symptoms, especially bloating and bloating + gas production associated symptoms were monitored with intervention of 6 g/d guar fiber for 12 wk	Bloating and bloating + gas production scores were significantly improved ($P < 0.035$) with intake of guar fiber.

BMI, body mass index; CTT, colonic transit time; GI, gastrointestinal; IBS, irritable bowel syndrome; IBS-A, alternating diarrhea–constipation irritable bowel syndrome; IBS-D, diarrhea-predominant irritable bowel syndrome

disrupt normal daily activities. A change in daily lifestyle also may help in the management of IBS symptoms.

Guar fiber has proven effective in softening and increasing bulking capacities (fecal weight, frequency of defecation, and fecal excretory feeling) in constipated individuals [42,49,53] and in reducing the frequency of defecation in those with diarrhea [38,75–78]. Various studies have examined its effects on IBS and IBS-related symptoms. The studies and their outcomes were summarized below and in the tables 3.

Effects of guar fiber on IBS in adults

In a study [84], 134 obese and normal subjects (average age 43.12 y) with IBS who had between 2 and 35 mean weekly evacuations were recruited and grouped according to body mass index (BMI). The participants were provided with balanced, low, or normal diet supplemented by 5 g/d of guar fiber for 24 wk. After 12 wk of intake, evacuation frequency in both groups was significantly improved and normalized. All participants reported reduced symptoms of flatulence (−55.6%), abdominal tension (−4.7%), and abdominal spasm (−35%) after 3 wk of fiber consumption.

In another study [39], supplementation of guar fiber (5 g/d) was compared with supplementation of wheat bran (30 g/d), which is normally recommended for IBS. In a multicentered, randomized open trial, 49 men and 139 women diagnosed with IBS were given either 5 g/d guar fiber or 30 g/d wheat bran for 12 wk. This was an open trial, and participants were allowed to switch treatment groups after 4 wk, based on their perception of treatment. Of the patients who decided to switch, 82.1% moved into and 17.9% moved out of the guar fiber group. Regardless of symptoms of constipation or diarrhea, participants perceived improved bowel habits with guar fiber compared with wheat bran. Conversely, a greater success rate was observed in the guar fiber group (60%) than in the wheat bran group (40%). The results suggest that guar fiber was better tolerated and preferred for the relief of IBS symptoms.

Eighty-six IBS patients (average age 45.9 y) [85] were studied for the effects of guar fiber on gastrointestinal (GI) symptoms (Gastrointestinal Symptom Rating Scale), quality of life (Short Form-36), and psychological symptoms (Hospital Anxiety and Depression Scale). The effects of two doses of guar fiber were compared: 10 g/d in 40 participants and 5 g/d in 46 for 12 wk. There was no placebo group. The participants in both groups reported significant improvement in all symptoms after 1 mo compared with baseline. The improvements lasted for 6 mo (3 mo after study period) compared with baseline but became less prominent than at the end of the treatment. The study suggested a dose of 5 g/d is adequate to improve IBS symptoms.

One study examined the sex difference of the effects of guar fiber on IBS symptoms [86]. Thirty IBS patients (22 women and 8 men) selected according to Rome III criteria were provided with 5 g/d guar fiber for 4 wk after a 2-wk run-in period. The patients recorded their daily GI symptoms, namely, abdominal pain/discomfort, bloating, and the sensation of incomplete evacuation on a visual analog scale (VAS) scale. The number of evacuations per day, laxative requirements, and stool consistency also were evaluated. CTT was evaluated at baseline and at the end of the study. The authors observed differences in the improvement of abdominal bloating in men and a decrease in laxative use in women <45 y of age with a BMI <25 kg/m^2. Regardless of sex, the CTT was decreased.

In another study, Furnari et al. [87] examined the effect of 5 g/d guar fiber administration for 4 mo on IBS-related complications, in

particular methane excretion. Forty IBS and methane producers (mean age 53 y) were given guar fiber or no fiber treatment for 4 mo. They performed 50 g glucose breath test and measured bowel habits on the Bristol stool scale. IBS symptoms were evaluated by means of a questionnaire. Methane concentration was significantly ($P = 0.001$) reduced from 29 to 19 ppm after 1 mo and to 13 ppm after 4 mo. Similarly, IBS symptoms were reduced significantly ($P < 0.001$) from 3 to 14 to 0 to 14 within 1 mo.

A recent randomized, double-blind placebo-controlled study [88] was conducted in Israel with 108 IBS patients (guar fiber, n = 49; placebo, n = 59), where 60% of the participants were suffering with IBS-associated symptoms of bloating and bloating plus gas. A 12-wk intervention of 6 g/d guar fiber significantly improved ($P < 0.035$) both conditions compared with placebo.

Effects of guar fiber on IBS in children

In an observational, single-center cohort study, 46 children (1–18 y of age) were administered Optifiber (100% guar fiber) for 6 to 8 wk [89]. The results demonstrated that 82% of the children showed improvement in IBS-A, 58% showed improvement in IBS-D, and overall 68% also showed significant improvement in abdominal pain.

In another randomized, double-blind study, 60 children (8–16 y of age) with functional bowel disorders such as chronic abdominal pain (CAP) and IBS were administered either 5 g/d guar fiber or placebo for 4 wk [41]. The severity of IBS symptoms (Birmingham IBS questionnaire), CAP (Wong-Baker Face Pain Rating Score), and bowel habits (Bristol stool scale) were measured at baseline and 2, 4, and 8 wk. Guar fiber showed better efficacy than placebo in IBS (43;% versus 5%;, $P = 0.025$), CAP (0 versus 4; $P = 0.025$), and bowel habits (40 versus 13.3%; $P = 0.025$). The results suggest that guar fiber was well tolerated and effectively alleviated the symptoms of IBS in children.

Two recent reviews [90,91] suggest guar fiber is a better-tolerated dietary fiber than traditionally used wheat bran or psyllium husk for normalizing bowel habits and for alleviating IBS symptoms.

Mechanism of action in reliving IBS symptoms

IBS is a complex syndrome with multifaceted bowel disorders associated with abdominal pain and discomfort, which would greatly influence the quality of life. Therefore, it is unlikely that all disorders associated with IBS can be treated with a single medication. Considering the dual action of guar fiber against constipation and diarrhea, its MOA may be helpful against IBS symptoms. Slow fermentation of guar fiber, which prevents rapid production of gases [66] and methane [87], results in less bloating. Guar fiber has strong prebiotic effects and reduces harmful bacteria such as *Clostridium* species [49,92,93]. Guar fiber fermentation also leads to production of SCFAs, in particular butyrate, which is major source of energy for the colonocytes [67,94,95] and which may have a significant effect on the GI tract functions and immunity in IBS patients. Additionally, guar fiber's antioxidant [96], wound healing via activation of RhoA and ERK1/2 [44], and inhibition of small intestine bacterial overgrowth [97] effects also may play a role in the suppression of IBS symptoms, such as abdominal pain and bloating.

Prebiotic effect of guar fiber and digestive health

The gut microbiome has emerged as a crucial regulator of digestive health [98,99]. It has been found that the composition of microbiota differs between healthy and diseased individuals, wherein the ratio of good bacteria often is compromised in diseased cases [100–102]. The good microbiome consist mainly of *Lactobacillus* and *Bifidobacterium* spp and are effective against digestive disorders such as constipation [103–105], diarrhea [106–109], and IBS [110]. Prebiotics support the growth of these bacteria because of their specific substrate is readily available for fermentation [111]. The fermentation results in increased production of SCFAs, which may induce propulsive contractions and accelerate transit or enhance fluid and sodium absorption in the colon [112], as well as lower the luminal pH. Low pH intestinal conditions provide an ideal environment for the growth of these beneficial bacteria and for reducing formation of harmful bacterial metabolites [113–115]. Guar fiber, similar to guar gum, increases the probiotics in gut [116].

Several in vitro [14,65,66,93,94,117] and animal [82,118] studies demonstrated that guar fiber provides a favorable environment for the *Lactobacillus* and *Bifidobacterium* bacterium growth. A recent study suggests the ability of guar fiber in increasing the number of probiotics in particular *Bifidobacterium* species, as well as butyrate-producing and immunity-enhancing bacteria in humans [95]. Guar fiber has the ability to ferment for longer periods in the gut due to its chain length, composed mostly of more than 9 monomers, which makes it as an ideal dietary fiber to produce more amounts of SCFAs than other fibers [14,65,66).

Although guar fiber alone offers preventive and curative effects against digestive disorders, a synbiotic approach with a combination of specific/multiple probiotics may offer additional benefit [119] and should be thoroughly investigated.

Conclusions

Guar fiber, commonly known as partially hydrolyzed guar gum, is a non-viscous soluble dietary fiber that is effective for the treatment of constipation, diarrhea, and IBS. Fourteen clinical studies with 631 participants suggest improvement of constipation with guar fiber. Eight of 14 studies evaluated a dose <10 g/d (3.5–10 g). Therefore, the effective dose of guar fiber for constipation could be considered <10 g/d. In the case of diarrhea, seven clinical studies with a total of 465 participants were performed. Five of the studies were performed with a liquid diet including 20 g/L of guar fiber. All studies showed significant improvement in diarrheal conditions in both adults and children. One study with healthy participants suggests the prevention of sugar-alcohol-induced diarrhea with 5 to 10 g/d of guar fiber. These studies provide evidence to suggest a recommended daily dose of <10 g for prevention of diarrhea and 20 g for the reduction of diarrhea. Guar fiber also was found effective for the improvement of quality of life in IBS patients. Eight clinical studies with total of 692 participants suggest that guar fiber at a daily dose of 5 g is effective in the suppression of symptoms and in improving the quality of life for these patients. Overall, guar fiber is effective in the prevention and treatment of constipation, diarrhea, and IBS and could be considered an effective soluble fiber for comprehensive management of digestive health. It also may be useful as a delivery system for specific probiotics to form a potential synbiotic to offer a dual-action treatment for digestive disorders.

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