Dig Dis Sci (2016) 61:3140–3146
DOI 10.1007/s10620-016-4304-1

REVIEW

# Fermented Fiber Supplements Are No Better Than Placebo for a Laxative Effect

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Received: 29 April 2016 / Accepted: 7 September 2016 / Published online: 28 September 2016


**Abstract**

*Background* Misconceptions about the effects of dietary fiber and 'functional' fiber on stool parameters and constipation persist in the literature.

*Methods* A comprehensive literature review was conducted with the use of the Scopus and PubMed scientific databases to identify and objectively assess well-controlled clinical studies that evaluated the effects of fiber on stool parameters and constipation.

*Results* The totality of well-controlled randomized clinical studies show that, to exert a laxative effect, fiber must: (1) resist fermentation to remain intact throughout the large bowel and present in stool, and (2) significantly increase stool water content and stool output, resulting in soft/bulky/easy-to-pass stools. Poorly fermented insoluble fiber (e.g., wheat bran) remains as discreet particles which can mechanically irritate the gut mucosa, stimulating water & mucous secretion *if* the particles are sufficiently large/coarse. For soluble fibers, some have no effect on viscosity (e.g., inulin, wheat dextrin) while others form high viscosity gels (e.g., β-glucan, psyllium). If the soluble fiber is readily fermented, whether non-viscous or gel-forming, it has no effect on stool output or stool water content, and has no laxative effect. In contrast, a non-fermented, gel-forming soluble fiber (e.g., psyllium) retains its gelled nature and high water-holding capacity throughout the large bowel, resulting in soft/bulky/easy-to-pass stools.

*Conclusion* When considering a recommendation for a fiber supplement regimen to treat and/or prevent constipation, it is important to consider which fibers have the physical characteristics to exert a laxative effect, and which fiber supplements have rigorous clinical evidence of a significant benefit in patients with constipation.

**Keywords** Fiber · Supplement · Laxative · Placebo · Ferment · Stool

## Introduction

There are only two mechanisms by which fiber can provide a laxative effect: (1) Poorly fermentable insoluble fiber particles can mechanically irritate the gut mucosa, stimulating water/mucous secretion *if* the particles are sufficiently large/coarse (fine/smooth particles can be constipating); and (2) non-fermentable viscous/gel-forming fiber can retain its water-holding capacity throughout the large bowel to resist dehydration [1–3]. Both mechanisms require that the fiber resist fermentation to remain intact and present throughout the large bowel (must be present in stool) and that the fiber increase stool water content, which is the primary mechanism for both stool softening and increased stool bulk [1, 2]. Stool is mostly water (normal/formed stool ≈74–75 % water content), and the texture of stool is correlated with percent water content [1, 4, 5]. Relatively small changes in percent stool water content can lead to relatively large changes in stool texture: hard stool ≤72 % water content; soft/formed stool ≈76 %; loose stool ≈80 % [1, 4, 5]. The purpose of this review is to assess the laxative effect of

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fermentable isolated fibers, which comprise the majority of marketed fiber supplements.

The Institute of Medicine (IOM) published a definition of total fiber that differentiated *dietary fiber* (non-digestible carbohydrates and lignin that are intrinsic and intact in plants) from *functional fiber* (isolated, non-digestible carbohydrates that have been shown to have beneficial physiological effects in humans) [6]. Note that the isolated, non-digestible carbohydrates found in fiber supplements fall into the second category and would be considered a "functional fiber" *if* there is evidence of a beneficial physiological effect in well-controlled clinical studies. The term "fiber supplement" may lead healthcare professionals and/or consumers to believe that regular consumption will provide health benefits that may be missing from a low-fiber diet. For many fiber supplements, however, this belief is not supported by well-controlled clinical evidence of a health benefit. While most fiber supplements have a maximum daily dose of $\leq$10 g, doses up to 30 g/day will be included in this assessment for completeness. The review will be restricted to well-controlled, randomized clinical studies. Many of the clinical studies assessing the effects of fiber were conducted in healthy/non-constipated subjects with normal bowel movement frequency, so assessments of effectiveness will be based on objective measures of stool output and stool water content, and/or subjective assessments of stool consistency. An increase in bowel movement frequency without a concomitant increase in stool output and a stool softening effect means that each bowel movement produces a smaller, potentially harder stool, which is not a health benefit. It should be noted that, with a given daily dose of an effective fiber supplement, healthy subjects tend to show a greater increase in stool output than constipated patients. Exhibiting a stool effect in healthy subjects may not be predictive of a clinically meaningful effect in patients with chronic idiopathic constipation.

When considering "dietary fiber" (intrinsic and intact in whole foods), it is unclear how much of an observed health effect can actually be attributed to a direct effect of the dietary fiber in the gut, versus other dietary constituents like sorbitol, a sugar alcohol with an osmotic laxative effect that is independent of fiber (e.g., prunes have both high fiber content and high sorbitol content, yet prune juice has a similar laxative effect without the fiber) [1, 7, 8]. Much of the evidence supporting the health benefits of dietary fiber is derived from epidemiologic studies, which can be useful for establishing "associations" between consumption of high-fiber diets and observed health effects (or low-fiber diets and increased risk of disease), but lack the control necessary to establish causation. An example of an association between a high-fiber diet (*dietary fiber*, not specific isolated fibers) and reduced risk of disease is the reduced risk of cardiovascular disease [6]. The IOM adequate intake (AI) guideline for dietary fiber (14 g/1000 kcal of diet, or about 25 g/day for women and 38 g/day for men) is based on this association [6]. It is a misconception that consuming the recommended levels of dietary fiber will reduce the risk of constipation. The American Gastroenterological Association made the following observation: "Constipation was associated with low dietary fiber intake in some, but not other studies. However, these associations do not necessarily indicate causation. Although it is reasonable to try and modify these risk factors, doing so may not improve bowel function." [9].

## Methods

A comprehensive literature review was conducted with the use of the Scopus and PubMed scientific databases, without limits for year of publication. Key search words included: fiber, inulin, dextrin, wheat dextrin, resistant maltodextrin, guar gum, oat, oat bran, β-glucan, barley, psyllium, ispaghula, polydextrose, soluble corn fiber, fructooligosaccharide, galactooligosaccharide, laxation, laxative, constipation, stool, stool water content, bran, wheat bran, soluble, and insoluble. Published clinical studies were identified and assessed for study design, study population, fiber dose, objective measures of stool output and/or stool water content, and subjective measures of stool consistency. The reference section of each identified publication was also searched for any studies that might have been missed in the database searches.

## Results

### Readily Fermented Soluble Fibers

*Inulin* is a naturally occurring storage polysaccharide extracted from a variety of plants, including chicory root, Jerusalem artichoke, onions, and garlic. Inulin is soluble, non-viscous, has no water-holding capacity, and is readily fermented. A total of three parallel-design, multi-week clinical studies [10–12] that assessed the effects of inulin in constipated patients ($n = 35$–100) were identified, with doses ranging from 13 to 15 g/day. None of the studies showed an effect on colonic transit time, stool consistency, and/or stool output (g/day). There were also a total of eight clinical studies (5 crossover, 3 parallel design) [13–20] in healthy subjects ($n = 6$–200), with doses ranging from 5 to 20 g/day. None of the eight studies showed a statistically significant effect on stool output, stool water content, stool consistency, and/or colonic transit time. One additional study in healthy subjects (3-week treatment crossover design, $n = 29$) [21] did not assess stool output, but showed a very small change in subjective assessment of stool consistency for the higher dose (7.5 g/day) [0.2 change on the 7-point Bristol stool scale, from 3.4 to 3.6 (normal stool consistency); $p < 0.05$]. This dose also showed a significant increase in abdominal pain, bloating, flatulence, and borborygmus, which suggests that the dose may not be well tolerated [21]. Considered together, these data show that inulin is no better than placebo for a laxative effect.

*Resistant Starch*, including resistant dextrin, is a starch (e.g., wheat, corn) that has been artificially altered (e.g., heat/acid treatment) to make it resistant to enzymatic degradation in the small bowel. The process can be incomplete, leaving a percentage (e.g., 15–25 %) of the supplement readily digested/absorbed as sugar [22, 23]. Resistant starches/dextrins are soluble/non-viscous fibers and have no water-holding capacity, and the resistant portion is fermented by gut bacteria. There were no studies assessing the stool effects of resistant starches or dextrins in patients with constipation. There were three studies that assessed the effects of a dextrin in healthy subjects [24–26] ($n = 20$–38) at doses of 7.5–15 g/day. A 7-day crossover study of wheat dextrin 15 g/day [24] showed that stool output significantly *decreased*, and stool water content showed a directional decrease, consistent with a stool-hardening effect. This observation is consistent with an earlier crossover study of wheat dextrin where healthy subjects reported harder stools with consumption of wheat dextrin at the same dose of 15 g/day [23]. A crossover study ($n = 20$, 2-week treatment period) of four soluble fermentable fibers, including dextrin, pullulan, resistant starch, and soluble corn fiber, all dosed at 12 g/day for 2 weeks, showed that none of the fermentable fibers had an effect on stool output or stool consistency [26]. A 5-week (2-week baseline, 3-week treatment) parallel study of resistant maltodextrin [25] ($n = 38$), dosed at 7.5–15 g/day, showed no significant effect on bowel movement frequency, stool output, stool water content (directionally decreased versus placebo), or stool consistency. Two additional well-controlled crossover studies [27, 28] (10–21-day treatment periods) in healthy subjects ($n = 21$–36) assessed the stool effects of soluble corn fiber (dosed 20–21 g/day) and found no significant effect on stool output or stool consistency. Considered together, these data show that resistant starches/dextrins are no better than placebo for a laxative effect and that wheat dextrin can be constipating.

*Polydextrose* is a synthetic, indigestible polymer of glucose and sorbitol that is soluble, non-viscous, and readily fermented by the bacteria in the gut. Sorbitol, a sugar alcohol that provides the laxative effect observed with prunes/prune juice, exerts a dose-dependent osmotic laxative effect that is independent of a fiber effect [2–4]. No studies were identified that assessed the effects of polydextrose in a constipated population. There were a total of six studies identified in healthy subjects. Two studies assessed polydextrose at 8 g/day in healthy subjects ($n = 31$–45) and showed no effect on stool output (g/day), stool consistency, bowel movement frequency, or colonic transit time [29, 30]. Four studies provided very high doses of fermentable polydextrose (20–30 g/day) [27, 28, 31, 32], and three of the four studies showed no significant effect on stool output (g/day), stool softening, stool frequency, and/or large bowel transit time [27, 31, 32]. Only one polydextrose study (20 g/day) showed a minimal but statistically significant increase in stool output in healthy subjects, accompanied by a significant increase in flatulence and borborygmus [28]. The three studies with higher doses (21–30 g/day) failed to show an effect on stool [27, 31, 32]. Based on the totality of available clinical data, polydextrose is no better than placebo for a laxative effect.

*Gel-forming Fermentable Fibers*, including β-glucan (e.g., oatmeal), xanthan gum, and guar gum, are soluble fibers that form viscous gels with high water-holding capacity that would resist dehydration in the large bowel if the fiber remained intact, but lose that water-holding capacity when fermented/degraded [1, 2]. No studies were identified in a constipated population. There were also no well-controlled studies of β-glucan identified that assessed a dose $\leq 30$ g/day. At extreme doses (e.g., 87–100 g/day), oat bran (β-glucan) consumption resulted in a minimal effect on stool output (<1 g/g) and a *decrease* in stool water content (harder stools) in healthy subjects [33–35]. For guar gum and xanthan gum, a crossover study (1-week treatment periods) compared in vitro fermentation and in vivo stool effects of these two gelling fibers (guar gum 15 g/day, xanthan gum 15 g/day) versus a non-fermented gelling fiber (psyllium 14 g/day) in 7 healthy subjects [36]. Results showed that only non-fermented psyllium significantly increased stool output ($p < 0.05$), and psyllium was also the only fiber to retain its viscosity (retained water-holding capacity) during in vitro fermentation. Another study of guar gum was a crossover design in 11 healthy men who consumed a liquid formula with either no added fiber or 15 g/day guar gum (18-day treatment periods) [37]. The guar gum showed no effect on stool output or stool consistency. The same study also compared the 15 g of guar gum liquid diet to a self-selected regular diet with 15 g of dietary fiber and showed that the self-selected diet exhibited significantly higher stool output (161 vs. 78 g/day; $p < 0.0001$) and stool water content (73 vs. 70 %; $p = 0.008$) than guar gum [37]. The authors noted that other constituents of the diet, besides fiber, may affect stool parameters. Taken together, these data show that fermentable gel-forming fibers lose their viscosity and water-holding capacity when fermented, and are no better than placebo for a laxative effect.

**Table 1** Clinically demonstrated laxative/regularity effects of fiber supplements

| | No water-holding capacity | | | | Water-holding capacity | | |
|---|---|---|---|---|---|---|---|
| | Insoluble | Soluble low/no viscosity | | | Viscous | Gel-forming | |
| | Wheat bran | Wheat dextrin | Inulin | Partially hydrolyzed guar gum | Methylcellulose | β-glucan | Psyllium |
| Source | Wheat | Chemically treated wheat | Chicory root | Guar beans | Chemically treated wood chips | Oats, barley | Plantago ovata |
| Degree of fermentation | Poorly fermented | Readily fermented | Readily fermented | Readily fermented | Non-fermented | Readily fermented | Non-fermented |
| Constipation/ stool softener | +[a] | | | | ±[b] | | + |
| Diarrhea/stool normalizer | | | | | | | + |

[a] If particle size is sufficiently large/coarse to mechanically stimulate the gut mucosa

[b] Methylcellulose has an OTC indication for relief of constipation, but there are no well-controlled clinical studies in constipated patients to support this indication

## Discussion

The totality of published evidence from well-controlled clinical studies supports a conclusion that fermentable fibers are no better than placebo for constipation (Table 1). It is therefore a misconception that an increase in gut bacteria associated with fermentable fiber (e.g., a "prebiotic" effect) is a mechanism for a significant increase in stool output. For an isolated fiber to exert a laxative effect, it must resist fermentation, thereby remaining intact throughout the large bowel [1, 2, 36], and it must increase stool water content, which is the primary mechanism for increased stool output and mechanically softer stools [1–5]. When fermentable fibers are degraded by bacteria in the gut, the fiber does not remain intact and present to affect stool volume or stool form. This conclusion is supported by studies that assessed fecal recovery of inulin, which showed that no inulin was recovered from the stool, consistent with complete fermentation [38–40].

The isolated fibers in marketed supplements are polymers of sugar molecules linked together by bonds that resist degradation by digestive enzymes in the small bowel. Isolated fibers have unique characteristics based on the types of sugars, as well as the way in which the polymer chains interact with one another (e.g., straight chain versus highly branched chain; Fig. 1). A branched polymer with irregular branches does not pack in a regular array and, therefore has little effect on viscosity or water-holding capacity (e.g., inulin, polydextrose, wheat dextrin) [2]. In contrast, a linear polymer (e.g., methylcellulose) consists of a long straight chain of carbon–carbon bonds between sugar molecules, and the longer the chain, the greater the effect the fiber can have on viscosity (Fig. 1) [2]. Some straight chain polymers have the added capacity to form cross-links with adjacent polymers, forming a gel with high water-holding capacity (e.g., guar gum, psyllium, β-glucan) (Fig. 2). Metabolic health benefits, including cholesterol lowering and improved glycemic control, are gel-dependent phenomena in the small bowel, and efficacy is highly correlated with the viscosity of the gelling fiber (Fig. 2) [41, 42]. Insoluble fibers (e.g., wheat bran) and non-viscous soluble fibers (e.g., inulin, wheat dextrin) do not provide these gel-dependent health benefits [42, 43].


**Fig. 1** Linear versus branched polymers. Drawings representing linear and branched polysaccharides. Viscosity is a function of the volume of a molecule as it rotates in water (effective hydrodynamic size), so the longer the straight chain, the greater the effect the linear fiber can have on viscosity. The volume "swept out" by a fully extended linear fiber is much greater than a fiber with the same molecular weight but with a "bush-like," highly branched configuration

A viscous, gel-forming fiber can provide metabolic health benefits by its activity in the small bowel, but if it is fermented in the large bowel (e.g., β-glucan, guar gum), it loses its viscosity and water-holding capacity and, like non-viscous fermentable fibers, has no significant effect on stool output or stool water content/stool consistency (Table 1) [1, 36]. In contrast, a gel-forming fiber that resists fermentation will retain its high water-holding

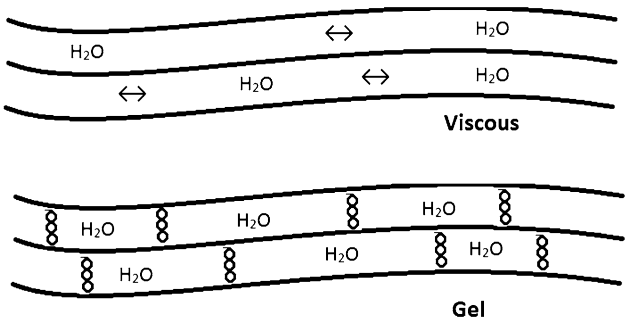


**Fig. 2** Viscous and gel-forming linear polymers. Drawings representing viscous linear polymers (*top*) and gel-forming linear polymers (*bottom*). Long-chain linear polymers orient parallel to adjacent fibers and increase viscosity in a concentration-dependent manner. Some long-chain linear polymers also can form cross-links that create a gel in a concentration-dependent manner (behave as a viscoelastic solid). Gel formation is an important driver of several metabolic health benefits for dietary fiber supplements, including cholesterol lowering, improved glycemic control, and stool normalization (soften hard stool in constipation and firm loose/liquid stool in diarrhea)

capacity throughout the large bowel, with the potential to exert dual effects by softening hard stool and firming loose/liquid stool (Table 1) [2]. An example is psyllium, which resists fermentation to remain intact and present throughout the large bowel [1, 8, 36] and acts to normalize stool form by softening hard stool in constipation [1, 3–5, 43, 44], firming loose/liquid stool in diarrhea [45–48], and reducing fecal incontinence episodes [49]. A semisynthetic soluble viscous fiber that resists fermentation is methylcellulose (chemically treated wood pulp), and while it is marketed as a fiber supplement for regularity, no randomized well-controlled clinical studies were identified in the literature to support a laxative effect versus placebo. It is important to note that observed increases in stool output for constipated patients will typically be lower than those observed for healthy subjects at the same fiber dose, so an increase in stool output in healthy subjects may not be predictive of a laxative effect in chronic constipation. For example, psyllium showed an increase in stool output of 4–5 grams per gram of fiber consumed (g/g) by healthy volunteers and a lower but clinically meaningful increase (1.4–3.7 g/g) in patients with chronic idiopathic constipation [5, 44, 50, 51].

The second mechanism by which an isolated fiber can have a significant effect on stool parameters is mechanical stimulation/irritation of the gut mucosa by insoluble fiber particles. Insoluble fiber (e.g., wheat bran) is poorly fermented, so it remains relatively intact and present throughout the large bowel [1]. The observation that coarse wheat bran had a greater laxative effect than fine wheat bran [52] suggested that the size/shape of the insoluble particles had a direct effect on the large bowel. This led to studies comparing the effects of insoluble wheat bran to inert plastic particles ("plastic" effect) on stool parameters [51]. Plastic particles have no water-holding capacity and are not fermented by bacteria, so any observed laxative effect should be purely mechanical in nature. In a randomized, 3-way crossover study, 12 healthy volunteers consumed their normal diet with or without 15 grams of coarse insoluble fiber (wheat bran) or 15 grams of plastic particles (vinyl tubing cut to match the size of the coarse wheat bran particles) [51]. Stool output increased for both coarse wheat bran (4 g/g) and smooth plastic tubing (3 g/g). Both the wheat bran and the plastic particles showed similar reductions in whole-gut transit time (−10 h, $p < 0.05$), increased bowel movement frequency, and a similar stool softening effect [51]. Subsequent studies explored the effects of different particle sizes and shapes and determined that the size and shape of the plastic particles had a greater effect than the number of particles [53, 54]. One study showed that finely ground wheat bran (15 g/day), with no mechanical stimulatory effect and no water-holding capacity, had no significant effect on whole-gut transit time or stool output and caused a decrease in percent water content (harder stools) by adding only to the dry mass of stool [55]. This decrease in stool water content is consistent with reports from the healthy subjects of difficult/uncomfortable bowel movements during the fine wheat bran treatment period (constipating effect) [55]. There appears to be a limit to the mechanical stimulatory effect of insoluble fiber in that consumption of 20 g/day wheat bran for 6 days resulted in a rapid (within 38 h) increase in mean stool output (150 g/day with placebo, 246 g/day with bran, $p < 0.05$), yet consumption of wheat bran 40 g/day did not increase stool output above that observed with the 20 g/day dose [56].

In summary, fermentable fibers (e.g., "prebiotics") are no better than placebo for a laxative effect. It is therefore important to understand the physical attributes of isolated fibers that may be the underlying mechanism for a laxative effect: (1) fiber must resist fermentation to remain intact and present throughout the large bowel and (2) increase stool water content to bulk/soften stools. The two mechanisms by which an isolated fiber can increase stool water content are by (1) the mechanical irritation of the gut mucosa by coarse insoluble fiber (e.g., coarse wheat bran) and (2) the water-holding capacity of a gel-forming fiber (e.g., psyllium). Readily fermented fibers (e.g., inulin, wheat dextrin, guar gum, β-glucan) do not remain intact and present throughout the large bowel and do not increase stool output or stool water content. Further, isolated fibers that add only to the dry mass of stool can cause a decrease in the percent water content, leading to harder stools (e.g., wheat dextrin, fine wheat bran), providing one rationale for why there is an inconsistent association between dietary fiber consumption and constipation in epidemiologic studies.

**Author's contributions** JWM is the guarantor of the manuscript. JWM collected the data and drafted the manuscript. WDC reviewed and edited the manuscript and contributed to the discussion. JWM and WDC approved the final version of the article.

**Compliance with ethical standards**

**Conflict of interest** JWM is a full-time employee of the Procter & Gamble Company, which markets a fiber product (Metamucil). WDC has no conflict of interest.

## References


1. McRorie J. Evidence-based approach to fiber supplements and clinically meaningful health benefits, part 2: what to look for and how to recommend an effective fiber therapy. *Nutr Today*. 2015;50:90–97.
2. McRorie J, Fahey G. Chapter 8: fiber supplements and clinically meaningful health benefits: identifying the physiochemical characteristics of fiber that drive specific physiologic effects. In: Wallace TC, ed. *The CRC Handbook on Dietary Supplements in Health Promotion*. Florence, KY: CRC Press, Taylor & Francis Group LLC; 2015. ISBN:9781482210347.
3. Eswaran S, Muir J, Chey WD. Fiber and functional gastrointestinal disorders. *Am J Gastroenterol*. 2013;108:718–727.
4. McRorie J, Pepple S, Rudolph C. Effects of fiber laxatives and calcium docusate on regional water content and viscosity of digesta in the large intestine of the pig. *Dig Dis Sci*. 1998;43:738–745.
5. McRorie J, Daggy B, Morel J, Diersing P, Miner P, Robinson M. Psyllium is superior to docusate sodium for treatment of chronic constipation. *Aliment Pharmacol Ther*. 1998;12:491–497.
6. Institute of Medicine, Food and Nutrition Board. *Dietary Reference Intakes: Energy, Carbohydrates, Fiber, Fat, Fatty Acids Cholesterol, Protein and Amino Acids*. Washington, DC: National Academies Press; 2002.
7. McRorie J, Zorich N, Riccardi K, et al. Effects of olestra and sorbitol consumption on objective measures of diarrhea: impact of stool viscosity on common gastrointestinal symptoms. *Regul Toxicol Pharmacol*. 2000;31:59–67.
8. McRorie J. Clinical data support that psyllium is not fermented in the gut. Letter to the editor. *Am J Gastroenterol*. 2013;108:1541.
9. Bharucha A, Pemberton J, Locke G. American gastroenterological association technical review on constipation. *Gastroenterology*. 2013;144:218–238.
10. Waitzberg L, Alves Pereira C, Logullo L, et al. Microbiota benefits after inulin and partially hydrolized guar gum supplementation: a randomized clinical trial in constipated women. *Nutr Hosp*. 2012;27:123–129.
11. Marteau P, Jacobs H, Cazabiel M, Signoret C, Prevel J, Housez B. Effects of chicory inulin in constipated elderly people: a double-blind controlled trial. *Int J Food Sci Nutr*. 2011;62:164–170.
12. Kleessen B, Sykura B, Zunft H, Blaut M. Effects of inulin and lactose on fecal microflora, microbial activity, and bowel habit in elderly constipated persons. *Am J Clin Nutr*. 1997;65:1397–1402.
13. Slavin J, Feirtag J. Chicory inulin does not increase stool weight or speed up intestinal transit time in healthy male subjects. *Food Funct*. 2011;2:72–77.
14. Costabile A, Kolida S, Klinder A, et al. A double-blind, placebo-controlled, cross-over study to establish the bifidogenic effect of a very-long-chain inulin extracted from globe artichoke (*Cynara scolymus*) in healthy human subjects. *Br J Nutr*. 2010;104:1007–1017.
15. Gibson G, Beatty E, Wang X, Cummings J. Selective stimulation of bifidobacteria in the human colon by oligofructose and inulin. *Gastroenterology*. 1995;108:975–982.
16. Brighenti F, Casiraghi M, Canzi E, Ferrari A. Effect of consumption of a ready-to-eat breakfast cereal containing inulin on the intestinal milieu and blood lipids in healthy male volunteers. *Eur J Clin Nutr*. 1999;53:726–733.
17. van Dokkum W, Wezendonk B, Srikumar T, van den Heuvel E. Effect of nondigestible oligosaccharides on large-bowel functions, blood lipid concentrations and glucose absorption in young healthy male subjects. *Eur J Clin Nutr*. 1999;53:1–7.
18. Ramnani P, Gaudier E, Bingham M, van Bruggen P, Tuohy K, Gibson G. Prebiotic effect of fruit and vegetable shots containing Jerusalem artichoke inulin: a human intervention study. *Br J Nutr*. 2010;104:233–240.
19. Kleessen B, Schwarz S, Boehm A, et al. Jerusalem artichoke and chicory inulin in bakery products affect faecal microbiota of healthy volunteers. *Br J Nutr*. 2007;98:540–549.
20. Kolida S, Meyer D, Gibson G. A double-blind placebo-controlled study to establish the bifidogenic dose of inulin in healthy humans. *Eur J Clin Nutr*. 2007;61:1189–1195.
21. Holscher H, Bauer L, Gourineni V, Pelkman C, Fahey G, Swanson K. Agave inulin supplementation affects the fecal microbiota of healthy adults participating in a randomized, double-blind, placebo-controlled, crossover trial. *J Nutr*. 2015;145:2025–2032.
22. Pasman W, Wils D, Saniez M, Kardinaal A. Long-term gastrointestinal tolerance of NUTRIOSE in healthy men. *J Clin Nutr*. 2006;60:1024–1034.
23. van den Heuvel E, Wils D, Pasman W, Bakker M, Saniez M, Kardinaal A. Short-term digestive tolerance of different doses of NUTRIOSE FB, a food dextrin, in adult men. *Eur J Clin Nutr*. 2004;58:1046–1055.
24. van den Heuvel E, Wils D, Pasman W, Saniez M, Kardinaal A. Dietary supplementation of different doses of NUTRIOSE-FB, a fermentable dextrin, alters the activity of faecal enzymes in healthy men. *Eur J Nutr*. 2005;44:445–451.
25. Fastinger N, Karr-Lilienthal L, Spears J, et al. A novel resistant maltodextrin alters gastrointestinal tolerance factors, fecal characteristics, and fecal microbiota in healthy adult humans. *J Am Coll Nutr*. 2008;27:356–366.
26. Stewart M, Nikhanj S, Timm D, Thomas W, Slavin J. Evaluation of the effect of four fibers on laxation, gastrointestinal tolerance and serum markers in healthy humans. *Ann Nutr Metab*. 2010;56:91–98.
27. Boler B, Serao M, Bauer L, et al. Digestive physiological outcomes related to polydextrose and soluble corn fibre consumption by healthy adult men. *Br J Nutr*. 2011;106:1864–1871.
28. Timm D, Thomas W, Boileau T, Williamson-Hughes P, Slavin J. Polydextrose and soluble corn fiber increase five-day fecal weight in healthy men and women. *J Nutr*. 2013;143:473–478.
29. Hengst C, Ptok S, Roessler A, Fechner A, Jahreis G. Effects of polydextrose supplementation on different fecal parameters in healthy volunteers. *Int J Food Sci Nutr*. 2009;60:96–105.
30. Costabile A, Fava F, Roytio H, et al. Impact of polydextrose on the faecal microbiota: a double-blind, crossover, placebo-controlled feeding study in healthy human subjects. *Br J Nutr*. 2012;108:471–481.
31. Achour L, Flourié B, Briet F, Pellier P, Marteau P, Rambaud J. Gastrointestinal effects and energy value of polydextrose in healthy nonobese men. *Am J Clin Nutr*. 1994;59:1362–1368.
32. Tomlin J, Read N. A comparative study of the effects on colon function caused by feeding ispaghula husk and polydextrose. *Aliment Phamacol Ther*. 1988;2:513–519.
33. Chen H, Haack V, Janecky C, Vollendorf N, Marlett J. Mechanisms by which wheat bran and oat bran increase stool weight in humans. *Am J Clin Nutr*. 1998;68:711–719.

34. Spencer H, Norris C, Derler J, Osis D. Effect of oat bran muffins on calcium absorption and calcium, phosphorus, magnesium and zinc balance in men. *J Nutr*. 1991;121:1976–1983.
35. Kirby R, Anderson J, Sieling B, et al. Oat-bran intake selectively lowers serum low density lipoprotein cholesterol concentrations of hypercholesterolemic men. *Am J Clin Nutr*. 1981;34:824–829.
36. Tomlin J, Read N. The relation between bacterial degradation of viscous polysaccharides and stool output in human beings. *Br J Nutr*. 1988;60:467–475.
37. Lampe J, Effertz M, Larson J, Slavin J. Gastrointestinal effects of modified guar gum and soy polysaccharide as part of an enteral formula diet. *J Parenter Enteral Nutr*. 1992;16:538–544.
38. Cummings J, Macfarlane G, Englyst H. Prebiotic digestion and fermentation. *Am J Clin Nutr*. 2001;73:415S–420S.
39. Molis C, Flourié B, Ouarne F, et al. Digestion, excretion, and energy value of fructooligosaccharides in healthy humans. *Am J Clin Nutr*. 1996;64:324–328.
40. Alles M, Hautvast J, Nagengast F, Hartemink R, Van Laere K, Jansen J. Fate of fructo-oligosaccharides in the human intestine. *Br J Nutr*. 1996;76:211–221.
41. Jenkins D, Wolever T, Leeds A, Gassull M, Haisman P, Dilawari J. Dietary fibres, fibre analogues, and glucose tolerance: Importance of viscosity. *Br Med J*. 1978;1:1392–1394.
42. Wolever T, Tosh S, Gibbs A, Brand-Miller J. Physicochemical properties of oat β-glucan influence its ability to reduce serum LDL cholesterol in humans: A randomized clinical trial. *Am J Clin Nutr*. 2010;92:723–732.
43. McRorie J. Evidence-based approach to fiber supplements and clinically meaningful health benefits, part 1: what to look for and how to recommend an effective fiber therapy. *Nutr Today*. 2015;50:82–89.
44. Ashraf W, Park F, Lof J, Quigley E. Effects of psyllium therapy on stool characteristics, colon transit and anorectal function in chronic idiopathic constipation. *Aliment Pharmacol Ther*. 1995;9:639–647.
45. Eherer A, Santa Ana C, Fordtran J. Effect of psyllium, calcium polycarbophil, and wheat bran on secretory diarrhea induced by phenolphthalein. *Gastroenterology*. 1993;104:1007–1012.
46. Qvitzau S, Matzen P, Madsen P. Treatment of chronic diarrhoea: loperamide versus ispaghula husk and calcium. *Scand J Gastroenterol*. 1988;23:1237–1240.
47. Wenzl H, Fine K, Schiller L, Fordtran J. Determinants of decreased fecal consistency in patients with diarrhea. *Gastroenterology*. 1995;108:1729–1738.
48. Washington N, Harris M, Mussellwhite A, Spiller R. Moderation of lactulose-induced diarrhea by psyllium: effects on motility and fermentation. *Am J Clin Nutr*. 1998;67:317–321.
49. Markland A, Burgio K, Whitehead W, et al. Loperamide versus psyllium fiber for treatment of fecal incontinence: the Fecal Incontinence Prescription (Rx) Management (FIRM) randomized clinical trial. *Dis Colon Rectum*. 2015;58:983–993.
50. Chaplin M, Chaudhury S, Dettmar P, Sykes J, Shaw A, Davies G. Effect of ispaghula husk on the faecal output of bile acids in healthy volunteers. *J Steroid Biochem Mol Biol*. 2000;72:283–292.
51. Brodribb A, Groves C. Effect of bran particle size on stool weight. *Gut*. 1978;19:60–63.
52. Tomlin J, Read N. Laxative properties of indigestible plastic particles. *Br Med J*. 1988;297:1175–1176.
53. Lewis S, Heaton K. The intestinal effects of bran-like plastic particles: is the concept of ‘roughage’ valid after all? *Eur J Gastroenterol Hepatol*. 1997;9:553–557.
54. Lewis S, Heaton K. Roughage revisited: the effect on intestinal function of inert plastic particles of different sizes and shapes. *Dig Dis Sci*. 1999;44:744–748.
55. Wrick K, Robertson J, von Soest P, et al. The influence of dietary fiber source on human intestinal transit and stool output. *J Nutr*. 1983;113:1464–1479.
56. McRorie J, Kesler J, Bishop L, et al. Effects of wheat bran and olestra on objective measures of stool and subjective reports of GI symptoms. *Am J Gastroenterol*. 2000;95:1244–1252.