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Journal of International Medical Research http://imr. sagepub. com/ A Review of the Role of Soluble Fiber inHealthwith Specific Reference to Wheat Dextrin JL Slavin, V Savarino, A Paredes-Diaz and G Fotopoulos Journal of International Medical Research 2009 37: 1 DOI: 10. 1177/147323000903700101 The online version of this article can be found at: http://imr. sagepub. com/content/37/1/1 Published by: http://www. sagepublications. com Additional services and information for Journal of International Medical Research can be found at: Email Alerts: http://imr. agepub. com/cgi/alerts Subscriptions: http://imr. sagepub. com/subscriptions Reprints: http://www. sagepub. com/journalsReprints. nav Permissions: http://www. sagepub. com/journalsPermissions. nav >> Version of Record - Feb 1, 2009 What is This? Downloaded from imr. sagepub. com by guest on March 27, 2013 The Journal of International Medical Research 2009; 37: 1 – 17 A Review of the Role of Soluble Fiber in Health with Specific Reference to Wheat Dextrin JL SLAVIN1, V SAVARINO2, A PAREDES-DIAZ3\* 1 AND G FOTOPOULOS4

Department ofFoodScienceand Nutrition, University of Minnesota, St Paul, Minnesota, USA; 2 Department of Internal Medicine, Gastroenterology Unit, Genoa, Italy; 3Novartis Consumer Health, Parsippany, New Jersey, USA; 4Novartis Consumer Health, Nyon, Switzerland dextrin, based on a search of PubMed. The evidence suggests that soluble fibers help to regulate the digestive system, may increase micronutrient absorption, stabilize blood glucose and lower serum lipids, may prevent several gastrointestinal disorders, and have an accepted role in the prevention of cardiovascular disease.

It is concluded that supplementation with soluble fibers (e. g. wheat dextrin) may be useful in individuals at risk of a lower than recommended dietary fiber intake. ACIDS; Dietary fiber is widely recognized to have a beneficial role in overall health, but only at adequate levels (25 – 38 g/day for healthy adults). Wheat dextrin in particular is a soluble fiber that can easily be added to the diet and is widely used in the food industry. There is some debate about whether increased intake of soluble fibers leads to health benefits.

This paper reviews the evidence regarding the physiological effects and potential health benefits of the addition of soluble dietary fibers, with specific reference to wheat KEY WORDS: SOLUBLE FIBER; WHEAT DEXTRIN; SHORT-CHAIN FATTY PHYSIOLOGICAL EFFECTS; HEALTH BENEFITS PREBIOTICS; Introduction Fiber, the indigestible part of plants such as cereals, fruits and vegetables (Table 1), has a fundamental role in the regulation of the digestive system and may help to prevent troublesome disorders such as constipation, 1 – 3 diarrhea4 – 6 and irritable bowel syndrome. – 9 Fiber may also help to regulate the absorption of micronutrients, 3, 10, 11 stabilize glucose12 – 14 and cholesterol levels, 15 – 17 have a role in cardiovascular health18 – 20 and possibly help to prevent some forms of cancer. 21 – 23 \*Current address: 90 Possum Way, New Providence, NJ 07974, USA. Many nutrition and healthcare professionals use the terms ‘ soluble’ and ‘ insoluble’ fibers for nutrition labeling. 24 – 27 Soluble fibers dissolve in water and usually form a gel.

They are generally fermented by bacteria in the lower intestine, but they are indigestible and hence not absorbed into the bloodstream. 24, 28 Soluble fibers also ferment to form short-chain fatty acids (SCFAs) such as butyrate, acetate and propionate (Table 2). 17, 29 – 34 Short-chain fatty acids generate approximately 1 – 2 kcal/g of ingested fiber, so are used as an energy source by the intestinal Downloaded from imr. sagepub. com by guest on March 27, 2013 1 JL Slavin, V Savarino, A Paredes-Diaz et al.

The health benefits of soluble fiber TABLE 1: Classification systems for fiber based on four different fiber characteristics Dietary fibers Lignin (polyphenolic compound, in cell walls of woody plants and seeds) Cellulose (glucose polymer, in all plant cell walls) ? -Glucans (glucose polymers, in oats, barley) Hemicelluloses (polysaccharides, in plant cell walls) Pectins (viscous polysaccharides, in fruits and berries) Gums (viscous polysaccharides, in seeds; e. g. uar gum) Inulin and oligofructose (mixture of fructose chains, in plants such as onions) Resistant starch (starch in plant cell walls; inaccessible to human digestive enzymes; often found in bananas and legumes; may also be formed by food processing) Soluble fibers Wheat dextrin ? -Glucans Gums (e. g. guar gum, partially hydrolyzed guar gum) Mucilages (e. g. psyllium) Pectins Fructo-oligosaccharides Some hemicelluloses Sources: oat products, legumes (dry beans, peas, lentils) Fermentable fibers Wheat dextrin Pectins ? Glucans Guar gum Partially hydrolyzed guar gum Inulin and oligofructose Sources: oats, barley, fruits, vegetables Viscous fibers Pectins ? -Glucans Some gums (e. g. guar gum) Mucilages (e. g. psyllium) Functional fibers Resistant dextrins (e. g. wheat dextrin) (indigestible polysaccharides formed when starch is heated and treated with enzymes; includes resistant maltodextrins) Psyllium (viscous mucilage, isolated from husks of psyllium seeds; also known as ispaghula husk) Chitin and chitosan (nondigestible carbohydrate from exoskeletons of crustaceans, e. . crabs, lobsters; deacetylation of chitin gives chitosan, a nondigestible glucosamine polymer) Fructo-oligosaccharides (FOS, short synthetic fructose) Polydextrose and polyols (synthetic polysaccharides used as bulking agents and sugar substitutes in foods) Insoluble fibers Cellulose Lignin Some pectins Some hemicelluloses Sources: wheat bran, some vegetables Non-fermentable fibers Cellulose Lignin Sources: cereal fibers rich in cellulose (e. g. wheat bran)

Non-viscous fibers Cellulose Lignin Some hemicelluloses mucosa and are absorbed through the colonic wall, where they are metabolized to produce energy or transported into the general circulation. 29 SCFAs also stimulate epithelial cell differentiation and proliferation. 29 Soluble fibers can also promote the growth of colonic Downloaded from imr. sagepub. com by guest on March 27, 2013 2 JL Slavin, V Savarino, A Paredes-Diaz et al. The health benefits of soluble fiber

TABLE 2: Short-chain fatty acids (SCFA) produced by fermentable, soluble fiber17, 29 – 34 Butyrate Widely recognized as the most significant acid in terms of its documented effects in the colon The preferred nutrient for the cells lining the colonic epithelium, in particular the distal colon and rectum The preferred substrate for colonocytes Positive effects on colonic mucosal growth, crypt cell proliferation, and early-response gene expression Acetate A fuel for skeletal and cardiac muscle, kidney and the brain A substrate for fatty acid and cholesterol synthesis Propionate Metabolized by the liver Only SCFA that can be a major source of glucose (after metabolism, used for energy production) May play a role in cholesterol lowering bacterial flora (prebiotic effect). 35 – 37 Insoluble fibers, on the other and, do not dissolve in water, are generally less fermentable by colonic microflora and are indigestible, 26 so pass through the intestines almost intact. Insoluble fibers have passive water-attracting properties that help to normalize large bowel function by acting like a sponge, pulling water into the stool and making it easier to pass. 38 They may also decelerate intestinal transit time, increase fecal weight through bulk action, delay glucose absorption and help to control and balance the pH in the intestines. 39, 40 In the USA, the daily intake recommended by the American Dietetic Association (ADA) is 20 – 35 g fiber/day for healthy adults, and ‘ age plus 5 g/day’ for children. 6 The World Health Organization (WHO) recommends > 25 g/day, 41 while the British Nutrition Foundation recommends 12 – 24 g/day for healthy adults. 42 The Food and Nutrition Board of the Institute of Medicine established the Adequate Intake (AI) recommendation for fiber (both soluble and insoluble), 24 which ranges from 19 to 38 g/day for children, depending on age, and from 25 to 38 g/day for healthy adults. The majority of people, however, do not seem to achieve the recommended daily intake of fiber, and women in general seem to consume lower amounts than men. 43, 44 Wheat dextrin is a soluble fiber that has been widely used in the food industry because it has a low viscosity and so has a good consistency when added to water, beverages or soft food. 4 It is formed by heating wheat starch at high temperature, followed by enzymatic (amylase) treatment to form a resistant starch. 24, 45 It qualifies as a dietary fiber because the non-digestible glucoside linkages (Fig. 1) lead to incomplete hydrolysation, so that only a small percentage of wheat dextrin is absorbed in the small intestine and the rest is slowly fermented in the large intestine. 3 This review aims to assess the evidence regarding the physiological effects and potential health benefits of supplementing the diet with soluble fibers, with specific reference to wheat dextrin. Data source The PubMed database (US National Library Downloaded from imr. sagepub. om by guest on March 27, 2013 3 JL Slavin, V Savarino, A Paredes-Diaz et al. The health benefits of soluble fiber CH2OH O OH O OH O CH2OH O OH HO O CH2 O OH O OH O OH CH2OH O OH O OH CH2OH O OH OH O OH OH O OH O OH HO 1: 2 bond O O CH2OH O OH CH2OH O O OH OH O OH 1: 3 bond CH2OH O OH O CH2 O OH O HO CH2OH O OH 1: 6 bond O CH2 O H2 C O O CH2OH O CH2OH O OH O HO OH FIGURE 1: Chemical structure of wheat dextrin of Medicine, National Institutes of Health, Bethesda, MD, USA) was searched (to July 2007) using the terms ‘ wheat dextrin’ and ‘ soluble fiber’, and studies were selected based on whether they evaluated the physiological or clinical effects of soluble fibers.

Although this non-systematic approach limits the review in that a quantitative analysis was not performed, it does allow a general and potentially useful overview of the effects of supplementation with soluble fibers. Physiological effects of soluble fibers FERMENTABILITY In vitro fermentation of wheat dextrin, inulin and partially hydrolysed guar gum (PHGG), and analysis of the resulting SCFA production over a 24-h period17 revealed that all three fibers demonstrated detectable fermentability. Acetate was the main SCFA produced by all fibers, accounting for about 50% of the total SCFA. Over 24 h, wheat dextrin produced substantially more total SCFA, propionate and butyrate than PHGG, which consistently showed lower fermentability at all time points (Fig. 2A – 2C).

To reduce gas production (which can be socially undesirable and cause uncomfortable bloating), extensive fermentation at 24 h is desirable, while fast fermentation (e. g. high values at 4 h) may be undesirable. The total amount of SCFA produced by wheat dextrin at 4 h was just over half the amount produced by glucose Downloaded from imr. sagepub. com by guest on March 27, 2013 4 JL Slavin, V Savarino, A Paredes-Diaz et al. The health benefits of soluble fiber A Concentration (µmol/ml) 120 100 80 60 40 20 0 B Concentration (µmol/ml) 16 14 12 10 8 6 4 2 0 0 4 8 12 Time since start of fermentation (h) 24 0 4 8 12 Time since start of fermentation (h) 24 C Concentration (µmol/ml) 45 40 35 30 25 20 15 10 5 0 0 4 8 12 Time since start of fermentation (h) 24 Wheat dextrin PHGG Inulin F97 Glucose

FIGURE 2: Analysis of short-chain fatty acid (SCFA) production following in vitro fermentation of wheat dextrin, partially hydrolysed guar gum (PHGG) inulin and glucose (positive control) over 24 h: (A) total SCFA production; (B) butyrate production; and (C) propionate production17 (positive control) and almost half the amount produced by inulin at the same time point (Fig. 2A). The fermentation of wheat dextrin, therefore, occurred slowly over 24 h, so its consumption was less likely to result in the gas production that can occur as a result of rapid fiber fermentation. composition towards a more beneficial distribution. 17, 46 For example, the consumption of fructo-oligosaccharides led to an increase in fecal bifidobacteria, 36, 47, 48 while ingestion of polydextrose resulted in a dosedependent decrease in bacteriodes and an increase in beneficial lactobacilli and bifidobacteria. 49 Administration of PHGG for 3 weeks increased the Lactobacillus spp count in feces. 0 Consumption of wheat dextrin led to a lower colonic pH, an increase in the fecal concentration of glucosidases, a statistically significant increase in the beneficial lactobacilli population and a statistically significant decrease in pathogenic Clostridium perfringens. 35 In another study, wheat dextrin increased the fecal concentration of glucosidase; 45, 51 increased glucosidase activity is considered beneficial to the host and is linked to substrate fermentation leading to more SCFAs and lactic acid production. PREBIOTIC EFFECT The SCFAs produced by soluble fermentable fibers are moderately strong acids (pK 4. 8)29 and so they lower colonic pH. Lowering the pH in the large ntestine may support the growth of bifidobacteria and lactobacilli because they have a strong intrinsic resistance to acid and the lower pH may help to prevent the growth of pH-sensitive pathogenic bacteria such as clostridia. 30 Many soluble fermentable fibers have demonstrated a significant prebiotic effect and alter the intestinal microflora Downloaded from imr. sagepub. com by guest on March 27, 2013 5 JL Slavin, V Savarino, A Paredes-Diaz et al. The health benefits of soluble fiber EFFECT ON LAXATION AND REGULARITY The formation of SCFAs helps to improve laxation and regularity by increasing fecal bulk and weight and increasing the waterholding capacity (and thus the hydration) of feces. 0, 46 The increase in fecal bulk and weight results from the presence of fiber, the water that the fiber holds and the partial fermentation of the fiber, which increases the amount of bacteria in the feces. 52 Studies have confirmed that consumption of the soluble fibers inulin or oligofructose result in an increase in fecal weight, 53 while inulin helped to reduce constipation2 and polydextrose increased fecal mass and sometimes stool frequency. 49, 54 Consumption of psyllium significantly increased stool frequency and stool weight, increased stool water content, improved stool consistency, increased the frequency of bowel movements and reduced pain on defecation. 55 – 59 Wheat dextrin significantly increased dry fecal output by 70% (P < 0. 02) and wet fecal output by 45% (P < 0. 05) (Fig. 3). The increase in wet fecal output was due to increased dry matter output (38%) and increased water output (62%). IMPROVED NUTRIENT/MINERAL ABSORPTION Although dietary fibers are traditionally thought to decrease mineral absorption, animal models and human studies have demonstrated that soluble fermentable fibers appear to increase the absorption of certain minerals. 3, 10, 60 – 62 For example, soluble fibers may increase calcium absorption through the increased production of SCFAs, with an increase in the villus crypt height, number of epithelial cells per crypt, cecal vein flow and mucosal-to-serosal calcium fluxes and stimulation of the expression of calbindinD9K, thereby enhancing the active calcium transport route. 3 Soluble fibers may also increase the absorption of other minerals such as magnesium, zinc and iron. 3, 10, 11 Studies in rats showed that the absorption of calcium, magnesium and/or zinc may be enhanced by guar gum, 64 inulin, 10, 65 oligofructose65 and PHGG. 11 In healthy men supplemented with either wheat dextrin or dextrose (100 g/day), ingestion of wheat dextrin significantly increased magnesium apparent absorption (50. 9%, P = 0. 001) and retention (30. 9 mg/day, P = 0. 024) and tended 80 P < 0. 02 70 60 Increase (%) 50 40 30 20 10 0 Wet fecal output FIGURE 3: Effect of wheat dextrin on fecal output3 Dry fecal output P < 0. 05 45% 70% Downloaded from imr. sagepub. om by guest on March 27, 2013 6 JL Slavin, V Savarino, A Paredes-Diaz et al. The health benefits of soluble fiber (not statistically significant) to increase calcium apparent absorption (37. 4%) and retention (111 mg/day) (Table 3). 3 prandial plasma glucose concentrations (–13 mg, P = 0. 04) and a significant reduction in the urinary excretion of glucose (P = 0. 008) compared with the low-fiber diet. 13 In fact, the effects of fiber on glucose concentrations are most evident in individuals withdiabetesmellitus and it has been suggested that diabetics should consume 25 – 50 g/day of dietary fiber, with ? 55% of their calorie intake coming from carbohydrate. 4 To assess the effect of fiber on the risk for diabetes, more than 65 000 women (40 – 65 years of age) were followed for 6 years; it was found that dietary glycemic index and glycemic load were positively associated with the development of type 2 diabetes, and dietary fiber was inversely associated. 75 Beyond the effects of fiber on post-prandial glucose and insulin, fiber alters the responses and actions of the gut hormones gastric inhibitory peptide, 76 glucagon-like peptide177 and cholecystokinin (CCK). 78 CCK is a peptide hormone and neurotransmitter that regulates gut motility, gall bladder contraction and pancreatic enzyme secretion and may mediate the post-prandial glycemic and insulinemic response to viscous fibers. A direct correlation has been reported between post-prandial CCK and subjective satiety scores following ingestion of foods with varying amounts of fiber. 79, 80 DECREASED GLYCEMIA AND INSULINEMIA

Through the production of SCFAs, soluble fibers can stimulate pancreatic insulin release and affect liver control of glycogen breakdown, 66, 67 and so may be effective in decreasing blood glucose and insulin levels and improving glycemic and insulinemic indices. 68 Guar gum, 69, 70 inulin12 and dextrin71 were all found to improve postprandial glycemia. In healthy subjects, the glycemic index of wheat dextrin was 25% compared with dextrose and the insulin response with wheat dextrin was also low at 13% compared with dextrose. 14 Resistant dextrins led to reduced blood glucose concentrations and insulin secretion in rats after sucrose or maltose loading, 72, 73 reduced the post-prandial blood glucose concentrations in healthy men and women, 13 and significantly reduced fasting blood glucose concentrations in type 2 diabetics. 6 In patients with type 2 diabetes given a diet high (25 g soluble plus 25 g insoluble fiber) or low (8 g soluble plus 16 g insoluble fiber) in total fiber, the high-fiber diet resulted in significantly lower pre- TABLE 3: Effect of wheat dextrin supplementation (100 g/day) on the absorption and retention of magnesium and calcium in healthy men3 Dextrose diet Calcium Apparent absorption, mean, mg/day (%) Retention, mean, mg/day Magnesium Apparent absorption, mean, mg/day (%) Retention, mean, mg/day 187 (28. 8) 39. 3 65 (30. 4) –0. 3 Wheat dextrin diet 269 (37. 4) 111 117 (50. 9) 30. 9 Statistical significance (P-value) 0. 093 0. 122 0. 001 0. 024 Downloaded from imr. sagepub. com by guest on March 27, 2013 7 JL Slavin, V Savarino, A Paredes-Diaz et al.

The health benefits of soluble fiber REDUCED CHOLESTEROL LEVELS The SFCAs can suppress cholesterol synthesis by the liver and may reduce serum levels of low-density lipoprotein cholesterol (LDL-C) and triglycerides. 81 Soluble, viscous fibers are also thought to exert their hypocholesterolemic action by increasing fecal sterol excretion and stimulating hepatic bile acid synthesis. 82, 83 In a metaanalysis of 67 controlled trials, consumption of 2 – 10 g/day of fiber (i. e. pectin, oat bran, guar gum, psyllium) reduced total cholesterol by 4% and LDL-C by 7% compared with placebo. 15 No significant effect was observed on serum high-density lipoprotein cholesterol (HDL-C) and triacylglycerol concentrations.

A greater reduction in serum total cholesterol and triacylglycerol concentrations was also noted in type 2 diabetics who consumed 60 g/day resistant dextrin compared with type 2 diabetics or healthy adults who consumed 30 g/day. 16 No difference was observed in the concentration of HDL-C. A diet high in total fiber (25 g soluble plus 25 g insoluble fiber) led to significantly reduced plasma total cholesterol (P = 0. 02), very-low-density lipoprotein cholesterol (VLDL-C) (P = 0. 01) and triglyceride (P = 0. 02) concentrations compared with a low-fiber diet, indicating that high fiber intake, especially soluble fiber, improves plasma lipid profile. 3 It has also been proposed that soluble fermentable fibers may lead to a reduction of cholesterol levels via the increased amounts of propionate produced during their fermentation by the commensal bacteria, because propionate may inhibit cholesterol biosynthesis. 84 Fibers producing high amounts of SCFAs (particularly propionate), such as wheat dextrin, may help to sustain cholesterol levels within the normal range. 17 The cholesterol-lowering effects of wheat dextrin have been demonstrated in animal trials. 85 The findings suggest that its cholesterol-lowering effect is likely to be related to reduced cholesterol and bile salt absorption. However, not all soluble fibers are hypocholesterolemic agents; for example, oat bran has been shown to lower serum lipids while wheat bran did not. 81 IMMUNE FUNCTION

It is possible that SCFAs help to improve immune function, as they stimulate the production of T helper cells, antibodies, leukocytes and splenocyte cytokines, all of which have a crucial role in immune protection. 86, 87 In addition, SCFAs improve the barrier properties of the colonic mucosal layer, thus inhibiting inflammatory and adhesion irritants. 88 – 90 Lactic-acid-forming bacteria competitively inhibit and/or suppress the growth of pathogenic bacteria, and may have a positive influence on immune function. 91, 92 WEIGHT REDUCTIONObesityis associated with increased energy intake and decreased consumption of fiberrich foods, 93 while fiber intake is inversely associated with body weight and body fat. 94 – 97 Increasing daily fiber intake is an effective way of providing a satiating effect. 8 Dietary fiber also decreases gastric emptying and/or slows energy and nutrient absorption (a fiber-rich meal, which is also usually richer in micronutrients, is processed more slowly and nutrient absorption occurs over a greater period of time99), leading to lower post-prandial glucose and lipid levels. Furthermore, addition of dietary fiber to a low-calorie diet has been shown to lead to a significantly greater weight loss (8. 0 kg) compared with placebo (5. 8 kg). 100 When post-menopausal women consumed higher fiber diets, this was associated with significant weight loss. 101 A high Downloaded from imr. sagepub. com by guest on March 27, 2013 8 JL Slavin, V Savarino, A Paredes-Diaz et al. The health benefits of soluble fiber carbohydrate diet consumed ad libitum (i. e. elf-regulating), without energy restriction or change in energy intake, caused significant body weight and body fat losses in older men and women, with a significant decrease in thigh fat area (P = 0. 003). 102 A review of the effects of increased fiber (high-fiber foods or supplementation) on hunger, satiety, energy intake and body weight revealed that controlled energy intake with increased dietary fiber led to an increase in post-meal satiety and a decrease in subsequent hunger. 103 With ad libitum energy intake, increased dietary fiber (14 g/day) resulted in an average 10% decrease in energy intake and 1. 9 kg weight loss over 3. 8 months of intervention. The effects of increasing dietary fiber were reported to be greater in obese individuals.

When evaluating the effects of 1 week of supplementation with soluble fiber (guar gum, 40 g/day) on hunger, satiety rating and energy intake, mean daily energy intake decreased significantly from 6. 7 to 5. 4 MJ, while hunger and satiety scores did not change. 104 Long-term (4 – 5 weeks) assessment of wheat dextrin (30 or 45 g/day) supplementation demonstrated a trend towards better weight maintenance; compared with baseline, body weight was increased in the control group supplemented with pure absorbable maltodextrin (+0. 87 kg; P = 0. 07), whereas body weight remained stable in the wheat dextrin-treated groups (+0. 0 kg). 35 sometimes stool frequency. 9, 54 Psyllium significantly increased stool frequency and stool weight, increased stool water content, improved stool consistency, increased the frequency of bowel movements and reduced pain on defecation. 55 – 59 Administration of PHGG for 3 weeks increased the frequency of defecation (+0. 17 /day), increased fecal moisture (+5%) and decreased fecal pH. 50 Supplementation with PHGG also helped to reduce the use of laxatives (from an average of 2. 0 to 0. 2 doses/day). 105 Wheat dextrin (100 g/day) had a positive effect on fecal output in healthy men, 3 with an average 45% increase in wet fecal weight (P < 0. 05) and 70% increase in dry fecal output (P < 0. 02) (Fig. 3). DIARRHEA Increased intake of soluble fiber may enhance recovery and improve stool consistency in diarrhea. , 5, 106 – 109 Persistent diarrhea resolved in more children taking PHGG (84%) compared with those on the control diet (62%) (odds ratio 3. 12), while the duration of diarrhea was reduced and there was a trend towards reduction in daily stool weight that reached significance on days 4 – 7. 6 Compared with non-fiber control in children, PHGG significantly reduced the mean frequency of diarrhea (8. 8% versus 32. 0%; P = 0. 001), resulted in significantly fewer days with diarrhea per total feeding days (10. 8% versus 31. 5%; P < 0. 001) and led to a significantly lower mean diarrhea score (4. 8 versus 9. 4; P < 0. 001). 110 PHGG also suppressed diarrhea caused by the ingestion of high levels of non-digestible sugar substitutes. 11 In elderly patients with diarrhea, 4-week supplementation with soluble dietary fiber (7 g/day) significantly reduced the water content of feces (P < 0. 01), the fecal pH (P < 0. 05) and the frequency of daily bowel movements (P < 0. 05). 5 In addition, the fecal characteristics improved The role of soluble fiber in disease CONSTIPATION Increased daily fiber intake can ameliorate constipation. 40, 49, 52 – 59 Consumption of inulin or oligofructose was shown to increase fecal weight, 53 inulin reduced constipation2 and polydextrose increased fecal mass and Downloaded from imr. sagepub. com by guest on March 27, 2013 9 JL Slavin, V Savarino, A Paredes-Diaz et al.

The health benefits of soluble fiber and the total level of SCFAs increased significantly (P < 0. 05). 5 In patients with fecal incontinence, significantly fewer incontinent stools were observed in those who consumed dietary fiber (psyllium or gum arabic) than those receiving placebo. 4 Improvements in fecal incontinence or stool consistency did not appear to be related to unfermented dietary fiber. However, the effects of increased soluble fiber on diarrhea are inconclusive, as a meta-analysis of randomized, controlled trials found no evidence that dietary fiber was effective in treating diarrhea. 112 randomized studies would be useful to confirm the potentially beneficial effects of soluble fiber in IBS.

DIVERTICULOSIS A diet low in fiber is thought to play a role in the pathogenesis of diverticular disease. 114 Increasing dietary fiber produces bulky, soft stools, facilitating defecation and reducing intracolonic pressure. 114 Increased fiber also helps to promote regular bowel function and is important in controlling and minimizing diverticular disease. 115 – 117 Non-viscous soluble fiber is associated with a decreased risk of diverticular disease and an improvement of bowel pain. 115 In patients with diverticulosis, it is recommended that patients consume 20 – 35 g/day of fiber either through the diet or supplementation. 118 IRRITABLE BOWEL SYNDROME

Treatment for irritable bowel syndrome (IBS) is aimed at alleviating symptoms. In patients with mild symptoms, fiber supplementation (particularly non-gelling soluble fibers) may help to relieve the severity and frequency of IBS symptoms, including abdominal pain, spasms or distension/tension, bowel dysfunction (e. g. fluctuation between constipation and diarrhea) and flatulence. 8, 9, 113 PHGG was better tolerated than wheat bran and more readily accepted by IBS patients, resulting in an improved quality of life during the treatment period. 113 PHGG also had a positive effect on evacuation frequency with a decrease in the frequency of IBS symptoms such as flatulence, abdominal tension and abdominal spasm. 13 Based on its physiological properties, wheat dextrin may also help to alleviate gastrointestinal symptoms associated with IBS through increased fecal output, 3 enhanced prebiotic capabilities35, 45 and significant but slow fermentation in the lower intestine, producing high concentrations of SCFAs but lower amounts of gas, which could be an important aspect in relieving the discomfort caused by IBS. 17 However, double-blind, HEMORRHOIDS A low-fiber diet is thought to contribute to the etiology of hemorrhoids. 119 Increasing the fiber content in the diet can have a beneficial effect in the treatment of symptomatic hemorrhoids. 120, 121 A recent meta-analysis demonstrated that increased fiber reduced the risk of bleeding and decreased the rate of recurrence of hemorrhoids, 120 while a Cochrane review found that the risk of not improving hemorrhoids and having persisting symptoms decreased by 53% with increased intake of fiber, with a significant reduction in bleeding. 121

CARDIOVASCULAR DISEASE A number of studies have consistently found that a fiber-enriched diet (14 g fiber/1000 kcal energy) is associated with a significant reduction (16 – 33%) in the risk of coronary heart disease (CHD). 19, 20, 122 – 126 A pooled analysis of studies evaluating dietary fiber Downloaded from imr. sagepub. com by guest on March 27, 2013 10 JL Slavin, V Savarino, A Paredes-Diaz et al. The health benefits of soluble fiber intake in the USA and Europe indicated that each 10 g/day increase in total fiber intake was associated with a 14% decrease in the risk of coronary events (e. g. myocardial infarction), and a 24% decrease in deaths from CHD. 9 A study on the relationship between dietary fiber and risk of cardiovascular disease (CVD) among women over a 10-year period showed that the ageadjusted relative risk for major CVD was 0. 53 for women consuming the highest amount of fiber (22. 9 g/day) compared with those on the lowest fiber intake (11. 5 g/day). 125 Although few interventional studies have specifically assessed fiber intake on the risk of CVD, increased fiber has been shown to ameliorate some of the risk factors for CVD (e. g. high cholesterol levels, high blood pressure, obesity and diabetes). For example, fiber can significantly reduce blood cholesterol levels and so may be important to cardiovascular health. 5, 16, 81, 127 Consuming foods rich in viscous soluble fibers has been shown to reduce blood levels of LDL-C by 10 – 15%, with an expected reduction in CVD events of 10 – 15%, and it has been stated that a diet including 5 – 10 g/day of viscous soluble fiber reduces CVD events and death independent of baseline risk. 18 Although the cholesterol-lowering effect of soluble (especially viscous) fibers probably contributes the most to its cardioprotective effects, other mechanisms are likely to play a role. As part of a lifestyle modification program, fiber can help to reduce blood pressure significantly, 128 supporting research that found that highfiber intake was inversely associated with the risk of high blood pressure or hypertension. 129, 130 Two intervention trials found that increased fiber intake resulted in significant reductions in blood pressure compared with placebo. 31, 132 In an analysis of the association between nutrient intake and risk of stroke, dietary fiber was inversely correlated to the incidence of stroke, a relationship that was stronger in hypertensive than normotensive men. 133 Fiber is also effective at reducing the risk of diabetes and, thus, the risk of developing CVD, and can improve glycemic and insulinemic indices12, 14, 69 – 71 and decrease blood glucose and insulin levels. 13, 16, 72 Lowfiber, high-glycemic load diets are associated with higher serum triglyceride levels and lower HDL-C levels, which are risk factors for CVD. 134, 135 Increased fiber consumption may also help control body weight and support a weight reduction program by helping to reduce obesity and, possibly, the associated risk of CVD. 94 – 104 Safety aspects of fiber supplementation

Reduced absorption of trace elements has traditionally been proposed as a potential negative effect of dietary fiber intake; 136, 137 however, it is unlikely that healthy adults who consume fiber in amounts within the recommended ranges will have problems with nutrient absorption. In fact, clinical data demonstrate that soluble fibers (e. g. inulin, fructo-oligosaccharides, wheat dextrin) may positively affect the absorption of certain minerals. 3, 10, 11, 64, 65 Fermentation of dietary fiber by anaerobic bacteria in the large intestine produces gas (including hydrogen, methane and carbon dioxide), which may be related to complaints of distention or flatulence, especially with high intakes of fiber. An increase in dietary fiber should also be accompanied by an increase in fluid intake, and fiber should be increased gradually to allow the gastrointestinal tract time to adapt.

Normal laxation may be achieved with relatively small amounts of dietary Downloaded from imr. sagepub. com by guest on March 27, 2013 11 JL Slavin, V Savarino, A Paredes-Diaz et al. The health benefits of soluble fiber fiber, and the smallest intake that results in normal laxation should be used. 138 Nevertheless, wheat dextrin has been shown to be well tolerated even up to the relatively high intake of 45 g/day. 51 Higher daily intakes (60 and 80 g) resulted in greater flatulence (P < 0. 05) and some bloating compared with placebo, but no intake resulted in diarrhea. fiber can have beneficial effects on constipation, diarrhea and the symptoms of IBS.

Soluble fiber also has additional positive effects on cardiovascular health, leading to a significant risk reduction of CHD. Thus, this review of the physiological effects and subsequent health benefits of soluble fibers suggests that daily fiber supplementation could be beneficial in those individuals who are at risk of inadequate fiber in their diet. Most servings of common foods contain between 1 and 3 g of dietary fiber so it may be difficult to consume the recommended amounts of fiber. Dietary assessment programs can estimate fiber intake for different population groups, allowing the identification of groups that have deficient fiber intake.

At an individual level, fiber intake can be generally estimated based on servings of fruits, vegetables and whole grains having 2 g of dietary fiber per serving, and servings of legumes having 5 g of dietary fiber per serving. Values from high-fiber cereals or fiber supplements can be added to these totals. Wheat dextrin is one example of a soluble fiber supplement that has been shown to help normalize bowel function and is well tolerated, even at large intakes. It is slowly but extensively fermented, leading to a significantly high production of SCFAs, while its slow fermentation profile could help minimize the undesirable effects of gas production and flatulence. Wheat dextrin has also demonstrated enhanced prebiotic capabilities when used at an intake of 30 – 45 g/day.

Based on its physiological properties, supplementation with wheat dextrin should be useful in individuals that need to complete their dietary intake with a fiber in order to achieve the daily recommended dietary levels of fiber. Conclusion Review of the evidence indicates that soluble, fermentable fibers, including wheat dextrin, have positive physiological effects that may help to improve bowel regularity and result in some health benefits. Soluble fibers are fermented in the large intestine, leading to the production of SCFAs that lower colonic pH and result in a significant prebiotic effect in which the growth of beneficial intestinal microflora (e. g. ifidobacteria, lactobacilli) and fecal glucosidase concentrations are increased, while the growth of pH-sensitive pathogenic bacteria (e. g. clostridia) is prevented or suppressed. In this way, SCFAs could promote normal bowel regularity and may help to reduce serum glucose and cholesterol levels. SCFAs also positively influence the absorption and retention of certain micronutrients (e. g. calcium, magnesium, zinc), and may improve immune function by stimulating the production of immunoprotective factors (e. g. T helper cells, antibodies) and improving the barrier properties of the colonic mucosal layer. Soluble fibers that are slowly yet extensively fermented in the large intestine (e. g. heat dextrin) are tolerated more easily than those that ferment quickly, as the latter can produce larger amounts of gas in a shorter period of time, leading to bloating and flatulence. By improving digestive balance, regularity and hydration in the gut, soluble Downloaded from imr. sagepub. com by guest on March 27, 2013 12 JL Slavin, V Savarino, A Paredes-Diaz et al. The health benefits of soluble fiber Acknowledgments Editorial support was given by Deborah Nock, DPP-Cordell Ltd, Saxthorpe, UK. Funding for the review was provided by Novartis Consumer Health, Nyon, Switzerland. Conflicts of interest Alberto Paredes-Diaz and Grigorios Fotopoulos were Novartis Consumer Health, employees at the time of manuscript preparation.

The other authors had no conflicts of interest to declare in relation to this article. • Received for publication 8 September 2008 • Accepted subject to revision 9 September 2008 • Revised accepted 11 December 2008 Copyright © 2009 Field House Publishing LLP References 1 Cummings JH: The effect of dietary fiber on fecal weight and composition. In: CRC Handbook of Dietary Fiber in Human Nutrition (Spiller GA, ed), 2nd edn. Boca Raton: CRC Press, 1993; pp 263 – 349. 2 Kleessen B, Sykura B, Zunft HJ, et al: 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. Vermorel M, Coudray C, Wils D, et al: Energy value of a low-digestible carbohydrate, NUTRIOSE®FB, and its impact on magnesium, calcium, and zinc apparent absorption and retention in healthy young men. Eur J Nutr 2004; 43: 344 – 352. 4 Bliss DZ, Guenter PA, Settle RG: Defining and reporting diarrhea in tube-fed patients: what a mess! Am J Clin Nutr 1992; 55: 753 – 759. 5 Nakao M, Ogura Y, Satake S, et al: Usefulness of soluble dietary fiber for the treatment of diarrhea during enteral nutrition in elderly patients. Nutrition 2002; 18: 35 – 39. 6 Alam NH, Sarker SA, Bardhan PK, et al: Partially hydrolysed guar gum supplemented comminuted chicken diet in persistent diarrhoea: randomised controlled trial. Arch Dis Child 2005; 90: 195 – 199. Giaccari S, Grasso G, Tronci S, et al: Partially hydrolyzed guar gum: a fiber as coadjuvant in the irritable colon syndrome. Clin Ter 2001; 152: 21 – 25. 8 Bijkerk CJ, Muris JW, Knottnerus JA, et al: Systematic review: the role of different types of fibre in the treatment of irritable bowel syndrome. Aliment Pharmacol Ther 2004; 19: 245 – 251. 9 Aller R, de Luis DA, Izaola O, et al: Effects of a high-fiber diet on symptoms of irritable bowel syndrome: a randomized clinical trial. Nutrition 2004; 20: 735 – 737. 10 Coudray C, Rambeau M, Feillet-Coudray C, et al: Dietary inulin intake and age can significantly affect intestinal absorption of calcium and magnesium in rats: a stable isotope approach. Nutr J 2005; 4: 29. 1 de Cassia Freitas K, Amancio OM, Ferreira Novo M, et al: Partially hydrolyzed guar gum increases intestinal absorption of iron in growing rats with iron deficiency anemia. Nutrition 2003; 19: 549 – 552. Jackson KG, Taylor GRJ, Clohessy AM, et al: The effect of the daily intake of inulin fasting lipid, insulin and glucose concentrations in middle-aged men and women. Br J Nutr 1999; 82: 23 – 30. Chandalia M, Garg A, Lutjohann D, et al: Beneficial effect of high dietary fiber intake in patients with type 2 diabetes mellitus. N Engl J Med 2000; 342: 1392 – 1398. Donazzolo Y, Pelletier X, Cristiani I, et al: Glycaemic and insulinaemic indexes of NUTRIOSE® FB in healthy subjects. Dietary Fiber 18 – 21 May 2003 [abstract].

Brown L, Rosner B, Willett WW, et al: Cholesterol-lowering effects of dietary fiber: a meta-analysis. Am J Clin Nutr 1999; 69: 30 – 42. Ohkuma K, Wakabayashi S: Fibersol-2: A soluble, non-digestible, starch derived dietary fibre. In: Advanced Dietary FibreTechnology(McCleary B, Prosky L, eds). Oxford: Blackwell Science, 2001; pp 510 – 523. Stewart ML, Savarino V, Slavin JL: Assessment of dietary fiber fermentation: effect of Lactobacillus reuteri and reproducibility of shortchain fatty acid concentrations. Mol Nutr Food Res 2009; 53: DOI: 10. 1002/mnfr. 200700523. Shamliyan TA, Jacobs DR Jr, Raatz SK, et al: Are your patients with risk of CVD getting the viscous soluble fiber they need? J Fam Pract 2006; 55: 761 – 769.

Pereira MA, O’Reilly E, Augustsson K, et al: Dietary fiber and risk of coronary heart disease: a pooled analysis of cohort studies. Arch Intern Med 2004; 164: 370 – 376. Mozaffarian D, Kumanyika SK, Lemaitre RN, et al: Cereal, fruit, and vegetable fiber intake and the risk of cardiovascular disease in elderly individuals. JAMA 2003; 289: 1659 – 1666. Wakai K, Date C, Fukui M, et al: Dietary fiber and risk of colorectal cancer in the Japan collaborative cohort study. Cancer Epidemiol Biomarkers Prev 2007; 16: 668 – 675. Bingham SA, Day NE, Luben R, et al: Dietary fibre in food and protection against colorectal cancer in the European Prospective Investigation into Cancer and Nutrition (EPIC): an observational study. Lancet 2003; 361: 1496 – 1501. 12 13 14 15 16 7 18 19 20 21 22 Downloaded from imr. sagepub. com by guest on March 27, 2013 13 JL Slavin, V Savarino, A Paredes-Diaz et al. The health benefits of soluble fiber 23 Pelucchi C, Talamini R, Galeone C, et al: Fibre intake and prostate cancer risk. Int J Cancer 2004; 109: 278 – 280. 24 Institute of Medicine: Dietary, functional, and total fiber. Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids (Macronutrients). Washington, DC: National Academies Press, 2005; pp 339 – 421. 25 Shikany JM, White GL: Dietary guidelines for chronic disease prevention. South Med J 2000; 93: 1157 – 1161. 6 Marlett JA, McBurney MI, Slavin JL: Position of the American Dietetic Association: health implications of dietary fiber. J Am Diet Assoc 2002; 102: 993 – 1000. 27 US Food and Drug Administration: Health claims: soluble fiber from certain foods and risk of heart diseases. Code of Federal Regulations 2001; 21: 101. 81. 28 Cho SS, Dreher ML (eds): Handbook of Dietary Fiber. New York: Marcel Dekker, 2001. 29 Cummings JH, Rombeau JL, Sakata T (eds): Physiological and Clinical Aspects of Short-Chain Fatty Acids. Cambridge: Cambridge University Press, 2004. 30 Topping DL, Clifton PM: Short-chain fatty acids and human colonic function: roles of resistant starch and nonstarch polysaccharides. Physiol Rev 2001; 81: 1031 – 1064. 1 Wong JM, de Souza R, Kendall CW, et al: Colonic health: fermentation and short chain fatty acids. J Clin Gastroenterol 2006; 40: 235 – 243. 32 Drozdowski LA, Dixon WT, McBurney MI, et al: Cellular proliferation and gene expression. J Parenter Enteral Nutr 2002; 26: 145 – 150. 33 Vogt JA, Wolever TM: Fecal acetate is inversely related to acetate absorption from the human rectum and distal colon. Hum Nutr Metab Res Comm 2003; 133: 3145 – 3148. 34 Khattak MMAK: Physiological effects of dietary complex carbohydrates and its metabolites role in certain diseases. Pak J Nutr 2002; 1: 161 – 168. 35 Pasman W, Wils D, Saniez M-H, et al: Long term gastrointestinal tolerance of NUTRIOSE®FB in healthy men. Eur J Clin Nutr 2006; 60: 1024 – 1034. 6 Tuohy KM, Kolida S, Lustenberger AM, et al: The prebiotic effects of biscuits containing partially hydrolysed guar gum and fructooligosaccharides – a human volunteer study. Br J Nutr 2001; 86: 341 – 348. 37 Okubo T, Ishihara N, Takahashi H, et al: Effects of partially hydrolyzed guar gum intake on human intestinal microflora and its metabolism. Biosci Biotechnol Biochem 1994; 58: 1364 – 1369. 38 American Dietetic Association: Position of the American Dietetic Association: health implications of dietary fiber. J Am Diet Assoc 1997; 97: 1157 – 1159. 39 Gibson GR, Roberfroid MB: Dietary modulation of the human colonic microbiota: introducing the concept of prebiotics. J Nutr 1995; 125: 1401 – 1412. 40 Stephen AM, Cummings JH: Mechanism of action of dietary fibre in the human colon. Nature 1980; 284: 283 – 284. 1 World Health Organization: Diet, nutrition and the prevention of chronic diseases. Report of a Joint FAO/WHO Expert Consultation. 2003. Geneva, WHO, WHO Technical Report Series 916. 42 British Nutrition Foundation: Nutrient Requirements and Recommendations, 2004. Available at http://www. nutrition. org. uk/ upload/Nutritient%20Requirements%20and %20recommendations%20pdf(1). pdf [accessed 22 September 2008]. 43 Elmadfa I, Weichselbaum E (eds): Energy and nutrient intake in the European Union. European Nutrition and Health Report 2004. Forum Nutr. Basel: Karger, 2005, Vol 58, pp 19 – 46. 44 Variyam JN: Factors affecting the macronutrient intake of US adults.

Washington DC: US Department of Agriculture, Technical Bulletin Number 1901, April 2003. 45 Van den Heuvel EGHM, Wils D, Pasman WJ, et al: 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. 46 Giannini EG, Mansi C, Dulbecco P, et al: Role of partially hydrolyzed guar gum in the treatment of irritable bowel syndrome. Nutrition 2006; 22: 334 – 342. 47 Bouhnik Y, Vahedi K, Achour L, et al: Shortchain fructo-oligosaccharide administration dose-dependently increases fecal bifidobacteria in healthy humans. J Nutr 1999; 129: 113 – 116. 8 Buddington RK, Williams CH, Chen S-C, et al: Dietary supplementation of neosugar alters the fecal flora and decreases activities of some reductive enzymes in human subjects. Am J Clin Nutr 1996; 63: 709 – 716. 49 Jie Z, Bang-Yao L, Ming-Jie X, et al: Studies on the effects of polydextrose intake on physiologic functions in Chinese people. Am J Clin Nutr 2000; 72: 1503 – 1509. 50 Takahashi H, Wako N, Okubo T, et al: Influence of partially hydrolyzed guar gum on constipation in women. J Nutr Sci Vitaminol (Tokyo) 1994; 40: 251 – 259. 51 Van den Heuvel EGHM, Wils D, Pasman WJ, et al: Short-term digestive tolerance of different doses of NUTRIOSE®FB, a food dextrin, in adult men. Eur J Clin Nutr 2004; 58: 1046 – 1055. 2 Kurasawa S, Haack VS, Marlett JA: Plant residue and bacteria as bases for increased stool weight accompanying consumption of higher dietary fiber diets. J Am Coll Nutr 2000; 19: 426 – 433. 53 Gibson GR, Beatty ER, Wang X, et al: Selective stimulation of bifidobacteria in the human colon by oligofructose and inulin. Gastroenterology 1995; 108: 975 – 982. 54 Tomlin J, Read NW: A comparative study of Downloaded from imr. sagepub. com by guest on March 27, 2013 14 JL Slavin, V Savarino, A Paredes-Diaz et al. The health benefits of soluble fiber 55 56 57 58 59 60 61 62 63 64 65 66 67 68 the effects on colon function caused by feeding ispaghula husk and polydextrose. Aliment Pharmacol Ther 1988; 2: 513 – 519.

Ashraf W, Park F, Lof J, et al: Effects of psyllium therapy on stool characteristics, colon transit and anorectal function in chronic idiopathic constipation. Aliment Pharmacol Ther 1995; 9: 639 – 647. McRorie JW, Daggy BP, Morel JG, et al: Psyllium is superior to docusate sodium for treatment of chronic constipation. Aliment Pharmacol Ther 1998; 12: 491 – 497. Burton R, Manninen V: Influence of psylliumbased fibre preparation on faecal and serum parameters. Acta Med Scand Suppl 1982; 668: 91 – 94. Dettmar PW, Sykes J: A multi-centre, general practice comparison ispaghula husk with lactulose and other laxatives in the treatment of simple constipation. Curr Med Res Opin 1998; 14: 227 – 233. Prior A, Whorwell PJ: Double blind study of ispaghula in irritable bowel syndrome. Gut 1987; 28: 1510 – 1513.

Holloway L, Moynihan S, Abrams SA, et al: Effects of oligofructose-enriched inulin on intestinal absorption of calcium and magnesium and bone turnover markers in postmenopausal women. Br J Nutr 2007; 97: 365 – 372. Abrams SA, Griffin IJ, Hawthorne KM, et al: A combination of prebiotic short- and long-chain inulin-type fructans enhances calcium absorption and bone mineralization in young adolescents. Am J Clin Nutr 2005; 82: 471 – 476. Tahiri M, Tressol JC, Arnaud J: Five-week intake of short-chain fructo-oligosaccharides increases intestinal absorption and status of magnesium in postmenopausal women. J Bone Miner Res 2001; 16: 2152 – 2160. Scholz-Ahrens KE, Schrezenmeir J: Inulin, oligofructose and mineral metabolism – experimental data and mechanism. Br J Nutr 2002; 87(suppl 2): S179 – S186.

Hara H, Suzuki T, Kasai T, et al: Ingestion of guar gum hydrolysates, a soluble fiber, increases calcium absorption in totally gastrectomized rats. J Nutr 1999; 129: 39 – 45. Raschka L, Daniel H: Mechanisms underlying the effects of inulin-type fructans on calcium absorption in the large intestine of rats. Bone 2005; 37: 728 – 735. Katoh K, Tsuda T: Effects of acetylcholine and short-chain fatty acids on acinar cells of the exocrine pancreas in sheep. J Physiol1984; 356: 479 – 489. Mineo H, Hashizume Y, Hanaki Y: Chemical specificity of short-chain fatty acids in stimulating insulin and glucagon secretion in sheep. Am J Physiol Endocrinol Metab 1994; 267: E234 – E241. Wolever TM, Jenkins DJ: Effect of dietary fiber and foods on carbohydrate metabolism.

In: CRC Handbook of Dietary Fiber in Human Nutrition (Spiller GA, ed), 2nd edn. Boca Raton: CRC Press, 1993; pp 111 – 152. 69 Williams JA, Lai C, Corwin H, et al: Inclusion of guar gum and alginate into a crispy bar improves postprandial glycemia in humans. J Nutr 2004; 134: 886 – 889. 70 Prieto PG, Cancelas J, Villanueva-Penacarrillo ML, et al: Short-term and long-term effects of guar on postprandial plasma glucose, insulin and glucagon-like peptide 1 concentration in healthy rats. Horm Metab Res 2006; 38: 397 – 404. 71 Asp ML, Hertzler SR, Chow J, et al: Gammacyclodextrin lowers postprandial glycemia and insulinemia without carbohydrate malabsorption in healthy adults. J Am Coll Nutr 2006; 25: 49 – 55. 2 Wakabayashi S, Ueda Y, Matsuoka A: Effects of indigestible dextrin on blood glucose and insulin levels after various sugar loads in rats. J Jpn Soc Nutr Food Sci 1993; 46: 131 – 137. 73 Wakabayashi S, Kishimoto Y, Matsuoka A: Effects of indigestible dextrin on glucose tolerance in rats. J Endocrinol 1995; 144: 533 – 538. 74 Anderson JW, Randles KM, Kendall CW, et al: Carbohydrate and fiber recommendations for individuals with diabetes: a quantitative assessment and meta-analysis of the evidence. J Am Coll Nutr 2004; 23: 5 – 17. 75 Salmeron J, Manson JE, Stampfer MJ, et al: Dietary fiber, glycemic load, and risk of noninsulin-dependent diabetes mellitus in women. JAMA 1997; 277: 472 – 477. 6 Tseng CC, Kieffer TJ, Jarboe LA, et al: Postprandial stimulation of insulin releases by glucose-dependent insulinotropic polypeptide (GIP): effect of a specific glucose-dependent insulinotropic polypeptide receptor antagonist in the rat. J Clin Invest 1996; 98: 2440 – 2445. 77 Van Dijk G, Thiele TE: Glucagon-like peptide-I (7-36) amide: a central regulator of satiety and interoceptivestress. Neuropeptides 1999; 33: 406 – 414. 78 Bourdon I, Olson B, Rackus R, et al: Beans, as a source of dietary fiber, increase cholecystokinin and apolipoprotein B48 response to test meals in men. J Nutr 2001; 131: 1485 – 1490. 79 Burton-Freeman B, Davis PA, Schneeman BO: Plasma cholecystokinin is associated with subjective measures of satiety in women. Am J Clin Nutr 2002; 76: 659 – 667. 0 Bourdon I, Yokoyama W, Davis P, et al: Postprandial lipid, glucose, insulin, and cholecystokinin responses in men fed barley pasta enriched with ? -glucan. Am J Clin Nutr 1999; 69: 55 – 63. 81 Anderson JW, Gilinsky NH, Deakins DA, et al: Lipid responses of hypercholesterolemic men to oat-bran and wheat-bran intake. Am J Clin Nutr 1991; 54: 678 – 683. 82 Marlett JA: Dietary fiber and cardiovascular disease. In: Handbook of Dietary Fiber (Cho SS, Dreher ML, eds). New York: Marcel Dekker, 2001: pp 17 – 30. 83 Trautwein EA, Kunath-Rau A, Erbersdobler HF: Downloaded from imr. sagepub. com by guest on March 27, 2013 15 JL Slavin, V Savarino, A Paredes-Diaz et al. The health benefits of soluble fiber 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98

Increased fecal bile acid excretion and changes in the circulating bile acid pool are involved in the hypocholesterolemic and gallstone-preventive actions of psyllium in hamsters. J Nutr 1999; 129: 896 – 902. Anderson JW, Deakins DA, Bridges SR: Soluble fiber: hypocholesterolemic effects and proposed mechanisms. In: Dietary Fibre – Chemistry, Physiology, and Health Effects (Kritchevsky D, Bonfield C, Anderson JW, eds). New York: Plenum Press, 1990; pp 339 – 363. Juhel C, Tosini F, Steib M, et al: Cholesterollowering effect of non-viscous soluble dietary fiber Nutriose® FB in hypercholesterolemic hamsters. Ann Nutr Metab 2007; 15(suppl 1): 259.

Pratt VC, Tappenden KA, McBurney MI, et al: Short-chain fatty acid-supplemented total parenteral nutrition improves nonspecific immunity after intestinal resection in rats. JPEN J Parenter Enteral Nutr 1996; 20: 264 – 271. Sanderson IR: Short chain fatty acid regulation of signaling genes expressed by the intestinal epithelium. J Nutr 2004; 134: 2450S – 2454S. Roediger WE: Utilization of nutrients by isolated epithelial cells of rat colon. Gastroenterology 1982; 83: 424 – 429. Koruda MJ, Rolandelli RH, Bliss DZ, et al: Parenteral nutrition supplemented with shortchain fatty acids: effect on the small bowel mucosa in normal rats. Am J Clin Nutr 1990; 51: 685 – 689. Mariadason JM, Barkla DH, Gibson PR: Effect of short-chain fatty acids on paracellular permeability in Caco-2 intestinal epithelium model.

Am J Physiol 1997; 272: G705 – G712. Blum S, Schiffrin EJ: Intestinal microflora and homeostasis of the mucosal immune response: implications for probiotic bacteria? Curr Issues Intest Microbiol 2003; 4: 53 – 60. Schiffrin EJ, Rochat F, Link-Amster H, et al: Immunomodulation of human blood cells following the ingestion of lactic acid bacteria. J Dairy Sci 1995; 78: 491 – 497. Lissner L, Lindroos AK, Sjostrom L: Swedish obese subjects (SOS): an obesity intervention study with a nutritional perspective. Eur J Clin Nutr 1998; 52: 316 – 322. Kimm S: The role of dietary fiber in the development and treatment ofchildhood obesity. Pediatr 1995; 96: 1010 – 1014. Alfieri

M, Pomerleau J, Grace DM, et al: Fiber intake of normal weight, moderately obese and severely obese subjects. Obes Res 1995; 3: 541 – 547. Nelson LH, Tucker LA: Diet composition related to body fat in a multivariate study of 293 men. J Am Diet Assoc 1996; 96: 771 – 777. Kromhout D, Bloemberg B, Seidell JC, et al: Physical activity and dietary fiber determine population body fat levels: the Seven Countries Study. Int J Obes Relat Metab Disord 2001; 25: 301 – 306. Slavin J, Green H: Dietary fibre and satiety. Nutr Bull 2007; 32: 32 – 42. 99 Jenkins DJ, Wolever TM, Rao AV, et al: Effect on blood lipids of very high intakes of fiber in diets low in saturated fat and cholesterol. N Engl J Med 1993; 329: 21 – 26. 00 Birketvedt GS, Aaseth J, Florholmen JR, et al: Long-term effect of fibre supplement and reduced energy intake on body weight and blood lipids in overweight subjects. Acta Medica (Hradec Kralove) 2000; 43: 129 – 132. 101 Mueller-Cunningham WM, Quintana R, Kasim-Karakas SE: An ad libitum, very low-fat diet results in weight loss and changes in nutrient intakes in postmenopausal women. J Am Diet Assoc 2003; 103: 1600 – 1606. 102 Hays NP, Starling RD, Liu X, et al: Effects of an ad libitum low-fat, high-carbohydrate diet on body weight, body composition, and fat distribution in older men and women. Arch Intern Med 2004; 164: 210 – 217. 103 Howarth NC, Saltzman E, Roberts SB: Dietary fiber and weight regulation. Nutr Rev 2001; 59: 129 – 139. 04 Pasman WJ, Saris WHM, Wauters MAJ, et al: Effect of one week of fibre supplementation on hunger and satiety ratings and energy intake. Appetite 1997; 29: 77 – 78. 105 Patrick PG, Gohman SM, Marx SC, et al: Effect of supplements of partially hydrolyzed guar gum on the occurrence of constipation and use of laxative agents. J Am Diet Assoc 1998; 98: 912. 106 Schiller LR: Chronic diarrhea. Curr Treat Options Gastroenterol 2005; 8: 259 – 266. 107 Meier R, Burri E, Steuerwald M: The role of nutrition in diarrhea syndromes. Curr Opin Clin Nutr Metab Care 2003; 6: 563 – 567. 108 Alam NH, Meier R, Schneider H, et al: Partially hydrolyzed guar gum-supplemented oral rehydration solution in the treatment of acute diarrhea in children. J Pediatr Gastroenterol Nutr 2000; 31: 503 – 507. 09 Homann HH, Kemen M, Fuessenich C, et al: Reduction in diarrhea incidence by soluble fiber in patients receiving total or supplemental enteral nutrition. JPEN J Parenter Enteral Nutr 1994; 18: 486 – 490. 110 Spapen H, Diltoer M, Van Malderen C, et al: Soluble fiber reduces the incidence of diarrhea in septic patients receiving total enteral nutrition: a prospective, double-blind, randomized, and controlled trial. Clin Nutr 2001; 20: 301 – 305. 111 Nakamura S, Hong R, Moji M, et al: Suppressive effect of partially hydrolyzed guar gum on transitory diarrhea induced by ingestion of maltitol and lactitol in healthy humans. Eur J Clin Nutr 2007; 61: 1086 – 1093. 12 Yang G, Wu X-T, Zhou Y, et al: Application of dietary fiber in clinical enteral nutrition: a meta-analysis of randomized, controlled trials. World J Gastroenterol 2005; 11: 3935 – 3938. 113 Parisi GC, Zilli M, Miani MP, et al: High-fiber diet supplementation in patients with irritable bowel syndrome (IBS): a multicenter, randomized, open trial comparison between Downloaded from imr. sagepub. com by guest on March 27, 2013 16 JL Slavin, V Savarino, A Paredes-Diaz et al. The health benefits of soluble fiber wheat bran diet and partially hydrolyzed guar gum (PHGG). Dig Dis Sci 2002; 47: 1696 – 1704. 114 Deckmann RC, Cheskin LJ: Diverticular disease in the elderly. J Am Geriatr Soc 1993; 41: 986 – 993. 15 Aldoori WH, Giovannucci EL, Rockett HR, et al: A prospective study of dietary fiber types and symptomatic diverticular disease in men. J Nutr 1998; 128: 714 – 719. 116 Smits BJ, Whitehead AM, Prescott P: Lactulose in the treatment of symptomatic diverticular disease: a comparative study with high-fibre diet. Br J Clin Pract 1990; 44: 314 – 318. 117 Brodrib AJ: Treatment of symptomatic diverticular disease with a high-fibre diet. Lancet 1977; i: 664 – 668. 118 Marlett JA, McBurney MI, Slavin JL: Position of the American Dietetic Association: health implications of dietary fiber. J Am Diet Assoc 2002; 102: 933 – 1000. 119 Burkitt DP: Varicose veins, deep vein thrombosis and haemorrhoids: epidemiology and suggested aetiology. Br Med J 1972; 2: 556 – 561. 20 Alonso-Coello P, Mills E, Heels-Ansdell D, et al: Fiber for the treatment of hemorrhoids complications: a systematic review and metaanalysis. Am J Gastroenterol 2006; 101: 181 – 188. 121 Alonso-Coello P, Guyatt G, Heels-Ansdell D, et al: Laxatives for the treatment of hemorrhoids. Cochrane Database Syst Rev 2005, Issue 4 Art No: CD004649. DOI: 10. 1002/ 14651858. CD004649. pub2. 122 Khaw KT, Barrett-Connor E: Dietary fiber and reduced ischemic heart disease mortality rates in men and women: a 12-year prospective study. Am J Epidemiol 1987; 126: 1093 – 1102. 123 Rimm EB, Ascherio A, Giovannucci E, et al: Vegetable, fruit, and cereal fiber intake and risk of coronary heart disease among men. JAMA 1996; 275: 447 – 451. 24 Todd S, Woodward M, Tunstall-Pedoe H, et al: Dietary antioxidant vitamins and fiber in the etiology of cardiovascular disease and allcauses mortality: results from the Scottish Heart Health Study. Am J Epidemiol 1999; 150: 1073 – 1080. 125 Wolk A, Manson JE, Stampfer MJ, et al: Longterm intake of dietary fiber and decreased risk of coronary heart disease among women. JAMA 1999; 281: 1998 – 2004. 126 Bazzano LA, He J, Ogden LG, et al: Dietary fiber intake and reduced risk of coronary heart disease in US men and women: the National Health and Nutrition Examination Survey I Epidemiologic Follow-up Study. Arch Intern Med 2003; 163: 1897 – 1904. 27 Jenkins DJA, Vuksan V, Kendall CWC, et al: Physiological effects of resistant starches on fecal bulk, short chain fatty acids, blood lipids and glycemic index. J Am Coll Nutr 1998; 17: 609 – 616. 128 Elmer PJ, Obarzanek E, Vollmer WM: Effects of comprehensive lifestyle modification on diet, weight, physical fitness, and blood pressure control: 18-month results of a randomized trial. Ann Intern Med 2006; 144: 485 – 495. 129 Ascherio A, Rimm EB, Giovannucci EL, et al: A prospective study of nutritional factors and hypertension among US men. Circulation 1992; 86: 1475 – 1484. 130 Ascherio A, Hennekens C, Willett WC, et al: Prospective study of nutritional factors, blood pressure, and hypertension among US women. Hypertension 1996; 27: 1065 – 1072. 31 Keenan JM, Pins JJ, Frazel C, et al: Oat ingestion reduces systolic and diastolic blood pressure in patients with mild or borderline hypertension: a pilot trial. J Fam Pract 2002; 51: 369. 132 He J, Streiffer RH, Muntner P, et al: Effect of dietary fiber intake on blood pressure: a randomized, double-blind, placebo-controlled trial. J Hypertens 2004; 22: 73 – 80. 133 Ascherio A, Rimm EB, Hernan MA, et al: Intake of potassium, magnesium, calcium, and fiber and risk of stroke among US men. Circulation 1998; 98: 1198 – 1204. 134 Ford ES, Liu S: Glycemic index and serum high-density lipoprotein cholesterol concentration among US adults. Arch Intern Med 2001; 161: 572 – 576. 35 Liu S, Manson JE, Stampfer MJ, et al: Dietary glycemic load assessed by food-frequency questionnaire in relation to plasma highdensity-lipoprotein cholesterol and fasting plasma triacylglycerols in postmenopausal women. Am J Clin Nutr 2001; 73: 560 – 566. 136 Walker AR: Dietary fibre and mineral metabolism. Mol Aspects Med 1987; 9: 69 – 87. 137 Torre M, Rodriguez AR, Saura-Calixto F: Effects of dietary fiber and phytic acid on mineral availability. Crit Rev Food Sci Nutr 1991; 30: 1 – 22. 138 Slavin JL, Greenberg NA: Partially hydrolyzed guar gum: clinical nutrition uses. Nutrition 2003; 19: 549 – 552. Author’s address for correspondence Dr Joanne L Slavin Department of Food Science and Nutrition, University of Minnesota, 1334 Eckles Avenue, St Paul, MN 55108, USA. E-mail:[email protected]edu Downloaded from imr. sagepub. com by guest on March 27, 2013 17