Chapter

Prebiotic Dietary Fibers for Weight Management

Ceren Gezer and Gözde Okburan

Abstract

While all prebiotics are accepted as dietary fibers, not all dietary fibers are accepted as prebiotics. Fructo-oligosaccharides and galacto-oligosaccharides are significant prebiotic dietary fibers related with the regulation of weight management. They, selectively stimulate the growth of *bifidobacteria* and *lactobacillus*, thus help to modulate gut microbiota. Since *bifiodobacteria* population are responsible for energy scavenging they are playing a vital role in the weight management. In addition, prebiotics fermented to short chain fatty acids by gut microbiota, whose presence in the large intestine is responsible for many of the metabolic effects and prevent metabolic diseases such as obesity. Short chain fatty acids via different mechanisms also stimulate satiety hormones such as GLP-1 and PYY, and shift glucose and lipid metabolism. To conclude, prebiotic dietary fibers beneficially impact the gut microbiota thus can be effective on regulation of weight management. There is a need for further clinical trials to explain more comprehensively the effects of dietary prebiotics on weight management.

Keywords: prebiotics, dietary fiber, obesity, weight management, short chain fatty acids, gut microbiota

1. Introduction

Over the few past decades, the prevalence of obesity has been seen to increase dramatically and thus this increase lead the attention towards environment. As a result of socioeconomic development, especially in Western countries, increased sedentariness, nearby abundant presence of cheap high-energy dense foods have all been concerned as significant contributing factors [1]. In this context, the modified fatty acid composition of a Western diet, often rich in saturated and trans fatty acids, raises serum total and low density lipoprotein (LDL) cholesterol levels, increasing the risk of chronic vascular diseases. Furthermore, diets high in sodium and low in potassium can lead to a variety of chronic diseases, including hypertension and stroke. Another factor is the presence of dietary fibers such as inulin, resistant starch and beta-glucan, which are important food components that are reduced in the Western diet and can delay gastric emptying, reduce appetite and therefore help regulate dietary energy intake [2].

The dietary fiber firstly defined in 1950s as non-digestible components of plant cell wall, then in late 1970s dietary fiber defined as polysaccharides and lignin which are resistant to enzymatic digestion [3]. So, the definitions are mainly focusing on non-digestibility. During years, dietary fiber description and assessment methods has been improved. In 2001, in addition to the non-digestibility, American Association of Cereal Chemists defined dietary fiber as which is also show partial fermentation in colon. In 2008, the European Commission defined dietary fiber as carbohydrate polymers have the degree of polymerization three or more monomeric units and not digest in small intestine by enzymes. In 2009 Codex Alimentariius also defined dietary fiber as carbohydrate polymers with the degree of polymerization ten or more monomeric units which not digest in small intestine by enzymes [4]. Fiber can be classified according to chemical composition, solubility and fermentability. According to chemical composition, dietary fiber can be classified as non-starch polysaccharides, resistant oligosaccharides, resistant starch, lignin and other substances such as saponins, tannins, etc. [5]. Related with their chemical composition, solubility and fermentability of each dietary fiber type has been shown different physiological effects such as lowering gastric emptying and blood cholesterol level, production of short-chain fatty acids by fermentation. Thus, dietary fiber has been demonstrated potential prevention from chronic diseases such as cancer, cardiovascular diseases, diabetes and obesity [4]. Some fibers which fermented in colon are classified as prebiotics. Prebiotics has been defined as "substrate that is selectively utilized by host microorganisms conferring a health benefit" by International Scientific Association for Probiotics and Prebiotics in 2017 [6]. The substances has to be demonstrate three main properties to be defined as prebiotics. Firstly, it has to be resistant to digestive enzymes and gastric acidity; secondly, it can be fermented by gut microbiota and thirdly, it can be selectively stimulate the growth of beneficial gut bacteria such as *lactobacilli* and *bifidobacteria*. Therefore, while all prebiotics have been classified as dietary fiber, not all dietary fiber has been shown prebiotic properties [6, 7]. Prebiotic dietary fibers fermented to short chain fatty acids (SCFAs) such as acetate, propionate and butyrate by gut microbiota. SCFAs are responsible for many health effects by increasing *lactobacilli* and *bifidobacteria*, decreasing pathogenic bacteria, producing beneficial metabolites, decreasing protein fermentation, modulating gut barrier permeability and supporting immune system defense [8]. Thus, prebiotic dietary fibers alter gut microbiota positively to prevent metabolic diseases such as irritable bowel syndrome and crohn's disease, colorectal cancer, cardiovascular diseases and obesity. Fructo-oligosaccharides (FOSs) and galacto-oligosaccharides (GOSs) are well known prebiotic fibers which are also related with the regulation of weight management [9].

2. Dietary fibers with prebiotic properties

Fermentation of prebiotic dietary fibers by gut microbiota is related with solubility, longevity of chain and structure. Soluble fibers fermented better than insoluble fibers and oligosaccharides fermented better than polysaccharides. FOSs and GOSs are most common and proven prebiotic dietary fibers that meet the three main prebiotic properties which are resistance to digestive enzymes and acidity, fermentation by gut microbiota and selectively stimulation of the growth of *lactobacilli* and *bifidobacteria*. There is not sufficient randomized controlled clinical studies on other dietary fibers such as resistant starch 2, 3 and 4, pectins, polydextrose manno-oligosaccharides and xylo-oligosaccharides to proven them as prebiotic dietary fibers. However, there are *in vitro* and preclinical studies indicated that these fibers can be accepted as prebiotic dietary fiber candidate. While resistant starch 1 and 5, lignin and cellulose not recognized as prebiotic dietary fibers since it has not been proven that they meet the prebiotic properties [10].

Fructans are fructose polymers which has three main types, and inulin type fructans such as inulin, fructo-oligosaccharide and oligofructose are important ones. They contain β (2–1) linear chain of fructose. Degree of polymerization of fructooligosaccharide is less than 10 while inulin's polymerization degree is between 3 and 60. The degree of polymerization of oligofructose is between 2 and 20 and forming as a product of degradation of inulin [9, 11, 12]. FOSs are naturally found in asparagus, sugar beet, garlic, chicory, onion, Jerusalem artichoke, wheat, honey, banana, barley, tomato, and rye. It has been known that FOSs stimulate bifidogenic activity [13] GOSs are galactose polymers have β (1–3) and β (1–4) bonds and prebiotic GOSs have glucose as a terminal end and generally consist of 2–10 galactose and 1 glucose synthesized by β-galactosidase. GOSs are naturally found in milk. It has have been known that GOSs are stimulate bifidogenic activity [12, 13]. Therefore, FOSs and GOSs increase *bifidobacteria* [14] hence can switch glucose metabolism and show beneficial metabolic effects to control chronic diseases [15].

3. Effects of prebiotic dietary fiber in control of chronic diseases

There is an association of dietary fiber consumption with a healthy gut microbiome, also there are promising evidence which demonstrates a favorable effect of dietary fiber on body weight and overall metabolic health by reducing the risk for the development of cardiovascular disease and mortality. Moreover, there has been additional health benefits of dietary fiber such as reduction the risk of malignancy and improved colonic health [16, 17]. It has been supported by Academy of Nutrition and Dietetics in 2015 that the consumption of sufficient amount of dietary fiber reduces the risk of some chronic diseases such as diabetes, obesity and coronary heart diseases [18]. Precisely, studies have revealed that individuals with adequate intake of dietary fiber seems to be at lower risk for developing stroke, colorectal cancer, cardiovascular diseases and type-2 diabetes [19–26] Sufficient intake of dietary fiber is correspondingly related with lower blood pressure and lower serum cholesterol levels [27]. Additionally, via different mechanism through satiety or fullness regulation, adequate intake of dietary fiber is proposed to help in weight loss and weight management [28–33]. Furthermore, dietary fiber appears to improve immune function via gut health and fiber-microbiota interactions [34–36]. Increased consumption of high-fat and high-sugar diets have been shown to alter microbial ecology, leading to the impression that the gut microbiota may function as an environmental factor resulting in increased energy harvesting and obesity [2].

Numerous classes of prebiotic dietary fibers display diverse health benefits. FOSs and GOSs have long been considered prebiotics. Nonetheless, apart from those prebiotic dietary fibers other categories (guar, lactulose, maltodextrin, etc.) propose great health benefits, although in varying ranges of efficacies [8]. It has been indicated that GOSs, FOSs and inulin alter glucose and lipid metabolism hence can reduce body weight and the risk of chronic diseases such as diabetes and cardiovascular diseases [37]. A study conducted with overweight or obese individuals indicated that especially inulin-type fructans and GOSs have beneficial properties on metabolic endotoxemia. After they get fermented in the gastrointestinal tract, especially in general inulin-type fructans and in particular FOSs produce SCFAs, thus those fermentation products favor the development of beneficial microorganisms to the detriment of other harmful population. Likewise, those SCFAs significantly increases feelings of satiety and reduces feelings of hunger and thus reduces energy intake [38]. Although it has been known for years that the metabolic benefits of dietary fiber have positive effects on human health including the prevention of diabetes and obesity, the mechanism of these beneficial effects has not been fully defined until recent years. Thus far, SCFAs and their receptors have been progressively appreciated as a fundamental mediator that relates diet and the gut microbiota to host physiology by modulating endocrine responses, development and functioning of leukocytes, and the activity of enzymes and transcription factors. Consequently, it is essential to further lighten the role of SCFA receptors concerning to the efficacy of dietary interventions and gut microbiota manipulations in the management of obesity and metabolic syndrome [39].

4. Application of prebiotic dietary fiber on weight management

Manipulation of the gut microbiome, which is mainly influenced by diet, seems to be an innovative therapeutic tool to prevent or control obesity and related diseases. Of specific concern, prebiotic dietary fiber are fermented by the gut microbiota, which consequently providing potentially beneficial health effects [6]. Based on numerous studies which were conducted in animals and humans have been suggested that fermentable prebiotic dietary fibers may increase satiety, enhance obesity-related metabolic disorders, and modulate gut-related immunity [40–42]. Suggested mechanisms to explain such effects commonly comprise bacterial metabolites such as SCFAs. Inulin-type fructans are prebiotics that support *bifidobacteria* and produces SCFAs upon fermentation; their administration can improve health outcomes, particularly in the context of obesity [2, 6].

The effects of dietary fiber on weight management may be due to the non-digestible nature of dietary fibers, which prolongs transit times in the intestinal lumen and accordingly provides greater satiety compared to simple and easily digestible polysaccharides. Moreover, dietary fiber may also play a role in prolongation of meal intervals and cause an enhanced mastication on satiety via presumable cephalic and peripheral effects. Remarkably, diets rich in dietary fiber have lesser energy bulk and could affect the flavor and palatability of foods, which can eventually lead to lower energy intake [43]. Another mechanism for the appetite-reducing effects of dietary fiber is the stimulation of glucose-dependent insulinotropic peptide (GIP) signaling by gastrointestinal satiety peptide hormones such as glucagon-like peptide (GLP-1) and peptide YY (PYY) or dietary fiber resulting from their fermentation in the large intestine by the gut microbiota [44].

Other possible mechanism which relates the mainly prebiotic dietary fiber and weight regulation is fermented products of dietary fiber which are known as SCFAs. In humans, nutrient digestion and absorption occurs mainly in the stomach and proximal small intestine. Vital source of energy for the human being is the carbohydrates, but the ability of humans to break down and use dietary mono-, oligo- or polysaccharides is very limited. Various members of the gut microbiota, known as saccharolytic microorganisms, degrade these complex glycan's and in this manner providing the host with a variety of metabolites, particularly SCFAs. SCFAs which are the products of the digestion of soluble plant polysaccharides are not only an important source of energy, but also play key roles in the regulation of food and energy intake [45]. As mentioned previously, SCFAs and their receptors have been progressively appreciated as a fundamental mediator that relates diet and the gut microbiota to host physiology by modulating endocrine responses, development and functioning of leukocytes, and the activity of enzymes and transcription factors. Free fatty acid receptor (FFAR) 3/ G protein coupled receptor (GPR) 41 and FFAR2/GPR43 represent two SCFA-specific GPRs that commonly occur on gut enteroendocrine cells, adipocytes, and immune cells. Interventional studies presented that activation of GPR41 on enteroendocrine cells stimulated secretion of the gut hormone PYY, which functions to induce satiety and reduce food consumption [46], while by promoting GLP-1 secretion GPR43 signaling was proposed to mediate host insulin sensitivity [47]. Such molecular mechanisms of

SCFA-receptor-mediated metabolic responses were further established in human studies by the outcome that obese individuals who have administrated propionate increased the secretion of PYY and GLP-1 with significantly reduced adiposity and overall weight gain [48].

In support of the hypotheses outlined above, Jovanovski et al. aimed to summarize and quantify the effects of viscose fiber on body weight, body mass index (BMI), waist circumference, and body fat independent of calorie restriction, through a systematic review and meta-analysis of randomized controlled trials. Their results indicated that with an ad libitum diet, viscous fiber reduce the mean body weight, BMI and waist circumference while there was no change in body fat. Especially greater reductions in body weight was revealed in overweight and those with diabetes and metabolic syndrome. As they concluded, they stated dietary viscous fiber significantly improved body weight and other adiposity parameters independently of calorie restriction [49]. Another meta-analysis by Miketinas et al. supported the previous meta-analysis and they indicated that their primary aim was to assess the role of dietary fiber as a predictor of weight loss in participants who consumed calorie restricted diet for 6 months (−750 kcal/d from estimated energy requirement). Their results pointed out that dietary fiber intake, independently of macronutrient and energy intake, endorses weight loss and dietary adherence in adults with overweight or obesity consuming a calorie-restricted diet [50]. Salleh et al. carried out a systematic review which examined the effects of soluble dietary fiber using randomized controlled trials. As their study mentioned consumption of soluble fiber is advised since they slows gastric emptying, increases perceived satiety and acting a noteworthy role in appetite regulation. In their study, randomized controlled clinical studies conducted with different types of soluble fiber were examined in order to determine which type of fiber is more effective on weight loss. Their results indicated that polydextrose as a prebiotic dietary fiber candidate showed a significant reduction in energy intake yet compared to other types it was consumed in a higher doses (25 g) which prepared in liquid meal. This study shows that not all soluble fibers produce the same effect. They emphasized that further interventional studies are needed to determine whether combinations of these soluble fibers will have greater effects than individual fibers [51]. In another meta-analysis, specific species of prebiotics were evaluated and the efficiency of FOS and GOS prebiotics on body weight, BMI and fat mass were examined. According to the results, subjects consuming prebiotics demonstrated a significant reduction in body weight [52]. Another systematic review of randomized controlled trials indicated that, 5 (42%) of the 12 randomized controlled trial studies provided to the subjects nonviscous but fermentable fiber supplements in the form of manno-oligosaccharides, GOSs, and FOSs. According to the study results, soluble fiber supplementation reduced BMI, body weight, body fat compared with the effects of placebo treatments. Their study results concluded that soluble fiber supplementation improves both anthropometric and metabolic outcomes in overweight and obese adults [53]. Also the meta-analysis of randomized controlled trials indicated that viscous fiber within a calorie-restricted diet decreased body weight and body fat [54]. Overall, prebiotic dietary fibers modulate gut microbiota by increasing SCFAs and show effects in relation with adipose tissue, liver, brain, and pancreas. Thus, SCFAs stimulate satiety hormones such as GLP-1 and PYY, and shift glucose and lipid metabolism [55].

5. Conclusion

While all prebiotics are accepted as dietary fibers but not all dietary fibers are accepted as prebiotics. FOSs and GOSs are well known prebiotic dietary fiber since

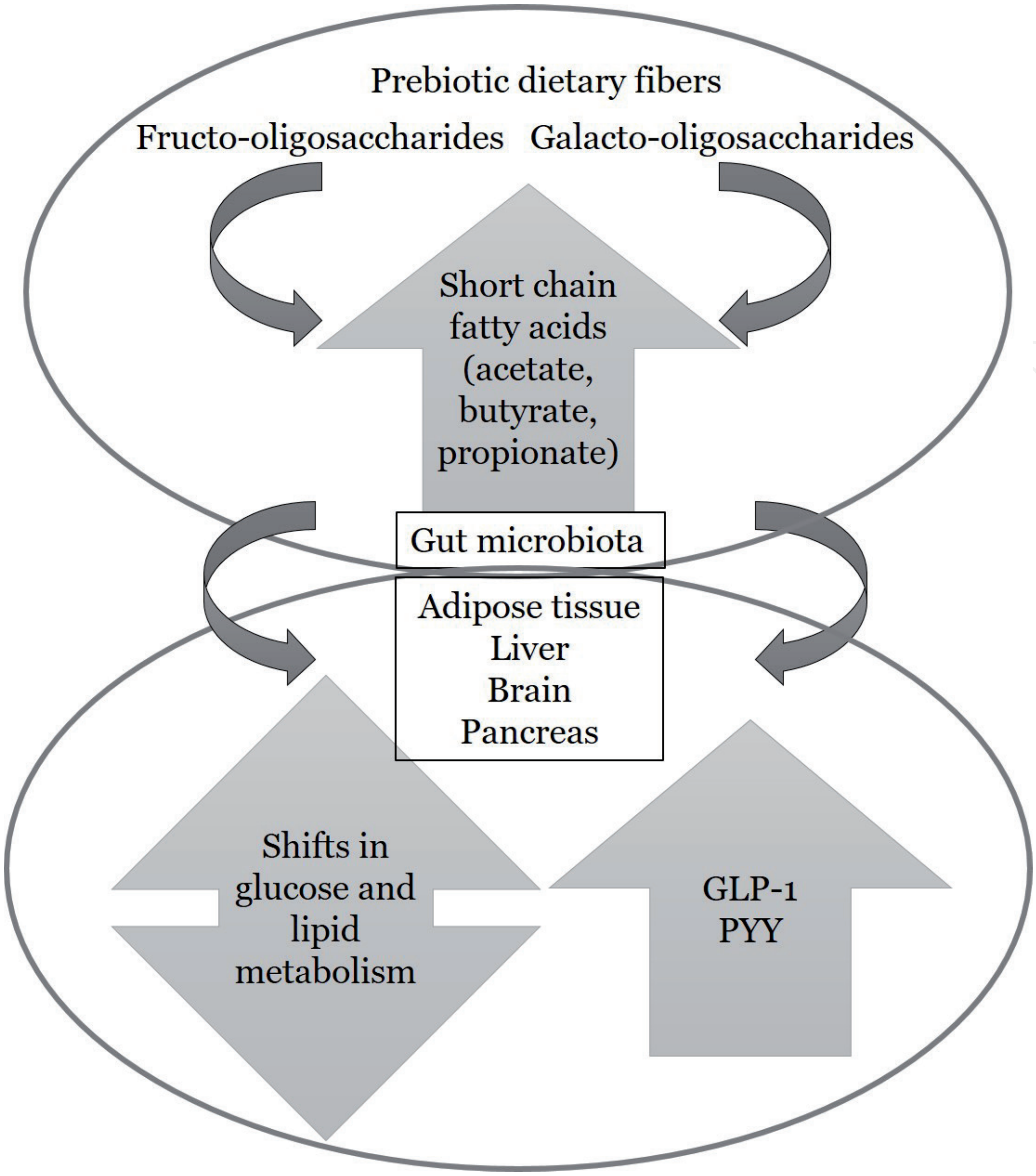

Figure 1.
Basic action of mechanisms of prebiotic dietary fibers on weight management.

studies mostly focus on them. These prebiotic dietary fibers has shown effect on weight management by increasing SCFAs thus modulating gut microbiota. SCFAs while modulating gut microbiota also stimulate satiety hormones such as GLP-1 and PYY, and shift glucose and lipid metabolism (**Figure 1**). Nevertheless, there is a need to further clinical trials to explain more comprehensively the effects of prebiotic dietary fibers on weight management.

Conflict of interest

The authors declare no conflict of interest.

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