Chapter 3

Prebiotics: Metabolism and Symbiotic Synergy with Probiotics in Promoting Health

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/64091

Abstract

Prebiotics are non-digestible food ingredients that beneficially affect the host by selectively stimulating the growth and activity of probiotic bacteria in the colon. All dietary prebiotics and/or dietary fiber provide the physiological and beneficial effects and, therefore, are considered as essential nutrients. According to the Codex Alimentarius and the Canadian Bureau of Nutritional Sciences, dietary fiber consists of carbohydrates with a degree of polymerization (DP) of three or more that naturally occur in foods of plant origin and that are not digested and absorbed by the small intestine. The same definition goes well along with the term dietary prebiotics. Food and Drug Administration (FDA)|Institute of Medicine (IOM) states that dietary fiber only comes from plant foods and anything else is regarded as "added fiber" or "novel fiber." Dietary fiber and/dietary prebiotics can be industrially produced for a broad range of food applications. They can also be processed into capsules for the purpose of microencapsulating probiotics. In this chapter, the most recognized physiological and/or beneficial effects of the prebiotics are clarified. New evidence on the concentrations of the short-chain fatty acids (SCFAs) and their metabolic relationship with better health or disease prevention in the host is provided.

Keywords: Prebiotics, Probiotics, Synbiotic, Microencapsulation, SCFA (short-chain fatty acids)

1. Introduction

All dietary prebiotics have the physiological and/or beneficial effects in humans and, thus, are regarded as essential nutrients. According to the Codex Alimentarius, Canadian Bureau of

Nutritional Sciences, IOM, and American Association of Cereal Chemistry International (AACCI), dietary fibers are identified as the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. Dietary fiber includes polysaccharides, oligosaccharides, lignin, and associated plants substances. Dietary fibers promote beneficial physiological effects including laxation and/or blood cholesterol attenuation, and/or blood glucose attenuation [1]. Ordinarily, a prebiotic is defined as a non-digestible food ingredient that confers beneficial effects in the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon and thus improves host health and well-being [2–4]. From those two descriptions, it is clear that "dietary fiber" and/or "prebiotics" are certainly a complex of many different plant sources, with different chemical and physiological properties. Collectively when ingested, they are a cohesive unit for essentiality. In the United States of America, the joint recommendation by FDA | IOM says that dietary fiber only comes from plant food (fruits, vegetables, or grains); and anything else was regarded as "added fiber" or "novel fiber." Interestingly, that FDA | IOM recommendation fits well with the terminology "dietary prebiotics". A dietary prebiotic is defined as a selectively fermented ingredient that results in specific changes in the composition and/or activity of the gastrointestinal microbiota, thus conferring benefit(s) upon host health [5]. Polymers and oligomers are the common types. Besides, a proof of the new oligomers and/or polymers about whether they confer the physiological, or beneficial effects would be required before being started to be used in the public.

The primary reason that the prebiotics transit through the stomach and small intestines undigested is because humans do not have the intestinal enzymes needed to digest them. They characteristically make their way intact to the colon, where they will be bacterially fermented, together with the unabsorbed nutrients [6]. The salivary and pancreatic α-amylases are the only enzymes needed for starch digestion. It is also necessary to emphasize here that all sources of dietary fiber are potential prebiotics, and every source of dietary prebiotics (with a few exceptions) is selectively fermented, thus mutually providing energy and simple sugars to the host through the gut microbiota. Therefore, due to similarities between these two terms, we will use the term "prebiotics" to refer to both the "dietary fiber and dietary prebiotics" throughout this chapter.

2. Whole grain, roughages, and prebiotics as essential nutrients: linked with probiotics for health

Whole grain and roughage are terms that have been easily confused with prebiotics in research and sometimes used interchangeably. Whole grains are cereal grains that consist of the intact, ground, cracked, or flaked kernel, which includes the bran, the germ, and the innermost part of the kernel or endosperm [7]. Apart from prebiotics alone, whole grains provide a variety of other nutrients too. Roughages are the coarse indigestible constituents of food or fodder, which provide bulk to the diet and promote normal bowel function. Hence, it has now become clear that where deficiency occurs, the whole-grain products can be enriched with the prebiotics or else roughages. This fortification would be necessary and may clarify some of the confusions

http://dx.doi.org/10.5772/64091

among the consumers who still believe that whole grains and prebiotics are one and the same. In **Figure 1**, for example, it can be observed that the average intake of prebiotics among Americans (male and female) between 2009 and 2010 was around 18 g/day, which was far below the daily recommended intakes (DRIs). The optimum daily requirement for prebiotics is estimated to be between 35 and 50 g/day [8]. This quantity would be needed for proper intestinal functions and to adequately support the immune functions. Fascinatingly, an additional severe deficiency of the prebiotics in some foods linked to whole grain and non-whole grain can be witnessed in **Figure 2**. Yeast bread and breakfast cereals each seem to provide nearly 1/3rd of the whole-grain per serving. Others such as the grain-based snacks appear to offer about 1/5th in addition to <1/10th which appears to come from rice, pasta, quick breads, pastries, cakes, pies, cookies, and miscellaneous grains [9]. Research has further revealed that whole-grain consumers had significantly better nutrient profiles (including higher intakes of minerals and vitamins as percentages of 1989 Recommended Dietary Allowances and as nutrients per 1000 kcal, and lower intakes of total fat, saturated fat, and added sugars as % of food energy) than the nonconsumers. It was found that consumers were more likely to meet pyramid recommendations for the grain, fruit, and dairy food groups than the nonconsumers [9].

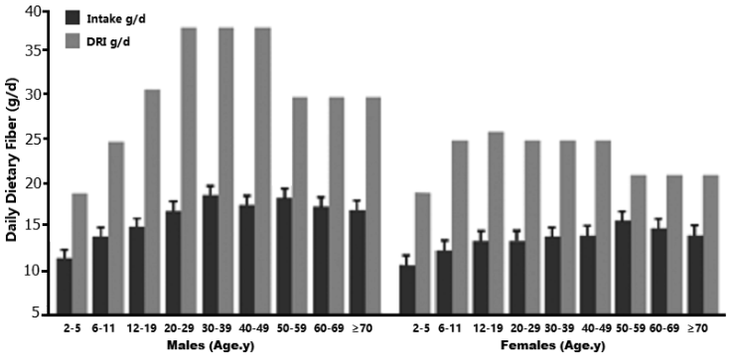

Figure 1. A parallel link of prebiotics made from the average intakes and projected daily recommended intakes or DRIs (g/day) among the American males and females, respectively. Source: Remade from Ref. [8].

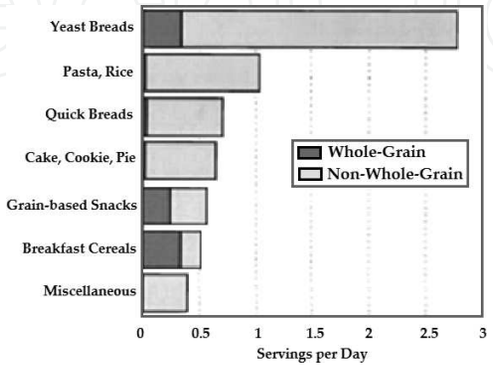

Figure 2. A comparison made between constituents of whole grain and non-whole grain as fiber representation in some common foods. Source: Modified from Ref. [9].

When the probiotic bacteria selectively ferment the prebiotics in the colon, a symbiotic synergy has been observed. During the metabolic process, that interdependent relationship exerts beneficial health effects to the host. For instance, probiotics selectively receive different prebiotics as nutrients from the host, initiate fermentation in the colon, provide the host with additional genetic and metabolic attributes, boost the immune system, and be able to harness nutrients that are otherwise inaccessible. Perceptibly, synbiotic is a mixture of both probiotics and prebiotics, which beneficially affect the host by improving the survival and implantation of live microbial dietary supplements in the gastrointestinal (GI) tract [2]. Therefore, prebiotics, probiotics, and synbiotics (combination of prebiotics and probiotics) can make up a distinct class of the essential functional ingredients in foods. Probiotics are defined as live microorganisms, which when administered in adequate amounts confer a health benefit on the host [10]. As a live microbial food supplement, probiotics have been linked to numerous beneficial effects of improving the intestinal microbial balance in humans. Naturally, the number of bacteria living in the human body and inside the gut is vast and is estimated to be 100 trillion bacteria [11, 12].

Besides commensal bacteria, probiotics, such as bifidobacteria, enterococci, streptococci, and lactobacilli, must co-exist with their host and must evade or endure the diversity of responses that the host has already developed to eliminate pathogenic bacteria while at the same time selectively ferment all the prebiotics. All these functions are mutually coordinated and provide a significant synergy to the host. An advancement of intestinal microbiota including bifidobacteria (representing some of the probiotic bacteria) in early childhood from birth to 24 months is being demonstrated in **Figure 3** [13]. In fact, an understanding on how the human immune system could differentiate between probiotics and harmful bacteria is no longer a serious challenge as it used to be in the past [12, 14].

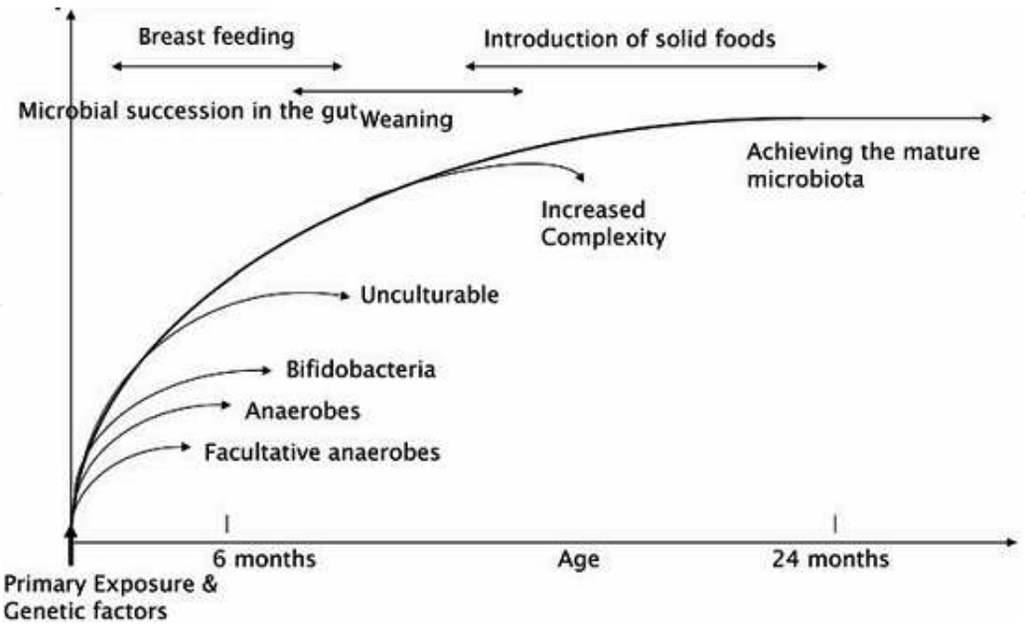

Figure 3. Succession flows of gut microbiota in a healthy infant from birth. Source: From Ref. [13].

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3. The most quintessential beneficial effects of the prebiotics

The most recognized physiological and beneficial effects of the prebiotics are as follows: improving laxation or regularity by increasing stool bulk; reducing blood glucose and/or low-density lipoprotein (LDL)-cholesterol levels; increment of high-density lipoprotein (HDL)-cholesterol; reducing post-prandial blood glucose and/or insulin levels; providing energy-yielding metabolites through colonic fermentation; enhancing feeling of satiety; reducing energy intake (which results in weight management especially in combination with probiotics); having positive effects on immune system (e.g., less risk for allergy in both infants and adults especially in combination with probiotics), and others (see **Figure 4**). However, among those, only two quintessential properties of all prebiotics are historical and common, specifically to promote intestinal function (laxation), and to serve as the primary energy source of the gut microbiota. Both functions are synergistic and essential for the development of the immune system. Furthermore, these quintessential properties as "physiological and beneficial effects" of prebiotics are cumulative and also increase with a rise of prebiotics intake every day. However, an appropriate dose of probiotics in addition to the prebiotics would be required because bacterial overgrowth in the small intestine may lead to SIBO (small intestinal bacterial overgrowth) and, subsequently, a compromised immune system [11].

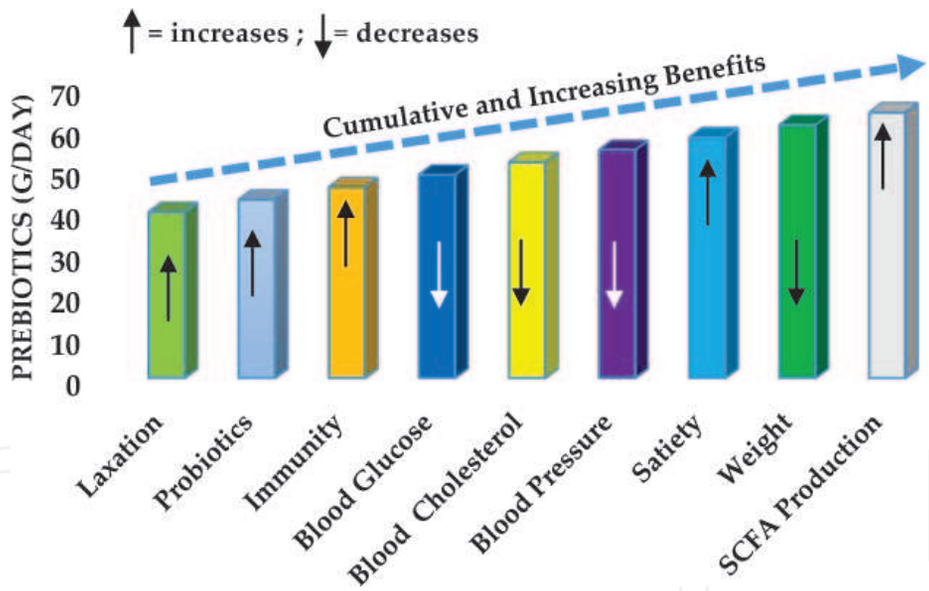

Figure 4. A classical model of the well-documented physiological and beneficial effects of adequate and continual intake of prebiotics in individuals.

Individual types of prebiotics, their beneficial roles, and additional characteristics are given in **Table 1**. Oligosaccharides (such as inulin and its derivatives), fructooligosaccharides (FOS), and others are some of the food ingredients recognized to meet the prebiotics' criteria. These low molecular weight carbohydrates naturally occur in artichokes, wheat, onions, chicory, garlic, leeks, and, to a lesser extent, in banana and cereals. Other oligosaccharides such as raffinose, stachyose, and verbascose are the major prebiotics in beans and peas. Interestingly,

these simple molecules of soluble dietary fiber can be produced industrially, and more novel prebiotics continue to be developed as functional foods in the food industry (see **Table 2**). Various methods can be applied to produce prebiotics. These include an enzymatic method [e.g., galactooligosaccharides (GOS), FOS, and oligofructose]; extraction method (e.g., inulin and soy oligosaccharides from vegetable sources); chemical synthetic method (e.g., lactulose and polydextrose); and a combination of both chemical and enzymatic techniques (e.g., resistant maltodextrin). Inulin, GOS, and FOS, for instance, have been increasingly added to foods in many parts of the world. The practice started in Japan and some European countries a few decades ago. In Canada, pulses, peas, and others are acceptable in foods as "added fibers" and more ways to put prebiotics in different kinds of diets keep emerging with new technology.

Prebiotics	**Fermentability**	**Primary source**	**Beneficial role‡**
Cellulose/hemicellulose/lignin/waxes	Low	Plant foods	Laxation
Guar gum	High	Guar bean (legume)	Viscofier, blood lipid lowering, attenuates blood glucose response
Inulin/oligofructose/FOS	High	Chicory root, wheat, Jerusalem artichoke, banana, onions, leeks, garlic, can be synthesized from simple sugars	Prebiotic effects, calcium absorption, attenuates total cholesterol Rises HDL-cholesterol
Chitooligosaccharides (COS)	Low	Derivative of chitin	Rises HDL-cholesterol, attenuates total cholesterol
Galactooligosaccharide (GOS)	High	Human and cow's milk, synthesized from lactose	Prebiotic effects, calcium absorption, lipid profiles improvement
Xylooligosaccharides (XOS)	High	Corn cobs, rice hulls, straws, bagasse, malt cakes, and bran	Blood lipid lowering
Soybean oligosaccharides	High	Soybean	Blood lipid lowering, attenuates total cholesterol
β-Glucan and oat bran	High	Oats and barley	Blood lipid lowering, attenuates blood glucose response
Pectin, gums	High	Plant foods	Blood lipid lowering, attenuates blood glucose response, emulsifier, thickener
Polydextrose	High	Synthesized from dextrose (glucose)	Laxation, bulking agent, prebiotic effects
Psyllium	High	Psyllium husk (plant)	Laxation, blood lipid lowering

Prebiotics	Fermentability	Primary source	Beneficial role‡
Resistant dextrin	High	Corn and wheat	Blood lipid lowering, attenuates blood glucose response
Resistant starch	Intermediate†	Plant foods	Laxation/fermentation
Soluble corn fiber	High	Corn	Laxation
Sialyllactoses (SLs)	High	Human milk	SCFA production, bifidogenic effect

† Most of the beneficial roles have been repeatedly confirmed by many authors in the literature and as the results of that, the references were neglected; † The classification of resistant starch has been a challenging task because it seems to be the only prebiotics that differs in individuals especially by means of the regulatory body controls (such as its mobility and amount of enzymes required) and, inhibitors also varied greatly. The source of resistant starch plays a significant role in its characterization as well.

Table 1. Individual prebiotics, their sources, and other properties.

Prebiotics	Manufacturer	Product name	Flavor and/or application
Inulin	Kraft	Cottage cheese	Plain, pineapple, mixed berry
Inulin	Attune	Wellness bars	Chocolate crisp, cool mint chocolate, blueberry vanilla, yogurt and granola strawberry bliss, yogurt and granola wild berry, and yogurt and granola lemon crème
Inulin	General mills	Yo-Plus yogurt	Strawberry, cherry, vanilla, peach
Inulin	Sensus, NL	Frutafit®	Applied in beverages, infant foods, confectionaries, ice creams, bakery products, and others
Inulin	Cosucra, B	Fibruline®	Tasteless, odorless, can be applied in beverages, confectionaries, bakery products, breakfast cereals, and others
Inulin	Orafti, B	Beneo®	Can be applied from beverages to baby food, from dairy to bakery, from confectionary to cereals and from soups to sauces
Oligo fructose	Sensus, NL	Frutalose®	Can be applied in beverages, infant foods, confectionaries, ice creams, bakery products, and many more
Oligo	Cosucra, B	Fibrulose®	Can be applied from beverages to baby food,

Prebiotics	Manufacturer	Product name	Flavor and/or application
fructose			from dairy to bakery, from confectionary to cereals and from soups to sauces
Oligo fructose	Orafti, B	Beneo	Can be applied from beverages to baby food, from dairy to bakery, from confectionary to cereals and from soups to sauces
GOS	Friesland Campina	Vivinal® GOS	For dairy products

Table 2. Samples of some of the prebiotic-enhanced foods available in the international market.

The Food scientists appear to be on the verge of being capable of manipulating the gut situations by diet control, thus possibly increasing an individual's health. It is also known that diets consisting of different components that are fermentable by gut microbiota are substrates for various kinds of probiotic bacteria in the gut. Moreover, the fact that minerals absorption and vitamin synthesis have been observed in the host confirms the symbiotic synergy of the prebiotics with probiotics in promoting health and suggests the existence of a multifunctional metabolism that directly involve a collective participation of many systems.

4. Prebioticious materials for encapsulation

Various kinds of prebiotics today are being processed into capsules (thickness: μm—mm) for the purpose of microencapsulating live and/or lysate probiotic cells. If both probiotic cells and prebiotics are combined, then the product becomes a synbiotic. Microencapsulation is the process by which viable and/or lysate probiotic cells are packed within a wall (an outer packaging) material for the purpose of shielding them from the surrounding environment. The standard load capacity of viable cells in the encapsulation materials varies from product to product. Usually, the viable cells occur at the concentration of 10^7–10^{12} CFU/g, while lysate cells are being measured in milligrams (mg). Most of the commercial yogurts or probiotic supplements contain 1–9 registered probiotic strains. In the case of multiple strains, the proportion of each probiotic strain in a package varies from batch to batch too. It is important to emphasize here that different combinations of probiotics are more likely to ferment all the prebiotics selectively and provide the host with the most significant needs. To achieve constant probiotical colonization in human or animal colon, microencapsulation is so far the best approach. Microencapsulation protects probiotics against O_2 toxicity [15], stomach's acid [16], and bile in the small intestines [16].

So far, the prebiotics in the make include oligofructose-enriched inulin [17], pullulan/starch-blended edible-films [18], denatured whey protein–alginate [19], alginate/chitosan/carboxy-methyl chitosan [20], resistant starch, carrageenan, chitosan, alginate, cellulose acetate phthalate, gellan gum, pectin, gum arabic, xanthan gum, guar gum, locust bean [21–23], starch/

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spherulites [24, 25], and many others. Interestingly, a comparison was made between cocoa butter (lipid) and starch encapsulation materials, and a lipid system was found to be more effective at protecting the probiotics [25]. Whether the prebiotics are blended or used individually, they are all made to be harmonious mediators of probiotical or synbiotical microencapsulation. The selected materials (either oligomers or polymers) may also be used for the formation of microcapsules and body weight control in humans and animals. Moreover, high survival rates of encapsulated probiotics have been found in Cheddar cheese (6 months of storage period) [26] and in yogurt (4 weeks of storage period at 4°C [27].

5. Body weight management

All prebiotics appear to have a tremendous impact on body weight control in both animal models and humans. It has been found that the body fat in rats fed with a diet high in prebiotics was significantly lowered than the ones fed with a diet high in protein and control diet [28]. In similar studies on humans, it has also been shown that the increase in prebiotics intake was associated with weight loss due to a decrease in energy intake [11, 29]. Also, none of the polyols or sugar substitutes (sweeteners) were shown to have exerted any negative effect on the viability of the starter or probiotic cultures in cheese [30]. Apart from microencapsulation, it has also been indicated that the fat in cottage cheese provides some protection to the probiotics as they strive to survive the gastric and intestinal transit to confer health benefits in the terminal ileum and colon of the human GI tract [31]. Therefore, the inclusion of the adequate amount of prebiotics in every meal would be effective in controlling the current epidemic of overweight and few other digestion problems.

Noticeably, the speedy solution of weight control seems to be more in the lower fermentable prebiotics (such as lignin, waxes, cellulose, and hemicellulose) in combination with the probiotic strains which selectively favor them. Resistant starches are somewhat characterized between the lower and higher fermentability as part of the prebiotics (see Table 1). The prebiotics permitted in Canada include acacia gum, barley bran, oat bran, corn bran, β-glucan, fructooligosaccharide, galactooligosaccharide, inulin, modified wheat starch, oat hull fiber, partially hydrolyzed guar, pea hull fiber, polysaccharide complex (glucomannan, xanthan gum, sodium alginate), psyllium seed husk, sieved barley meal, sugar beet fiber, wheat bran, edible parts of traditional fruits, veggies, legumes, resistant maltodextrin (Fibersol-2), and many others [32].

6. SCFAs and monosaccharides homeostasis

Probiotics have been recognized to hydrolyze and selectively ferment prebiotics to generate the SCFAs and monosaccharides which can be absorbed and utilized as energy by the host. The three predominant SCFAs in the human gut are acetate, propionate, and butyrate. These have been reported with high levels in the colon. Propionate and butyrate are respectively

utilized by the liver and colon, whereas acetate enters the systemic circulation and reaches the peripheral tissues [33]. Further literature highlights that the vast influence of these SCFAs on the host physiological benefits is through the nutri- and immuno-modulatory functions [34]. For example, butyrate expresses its potential in improving immune functions, intestinal barrier, and oxidative stress through silencing the histone deacetylation of nuclear factor kappa B (NF-κB), interferon-γ, peroxisome proliferator-activated receptor-γ (PPARγ), and glutathione-*S*-transferase (GST) [35].

It is well documented that the two endogenous ligands, G-protein coupled receptor 41 (GPR-41) and GPR-43 mediate the signaling actions of the SCFAs [36]. GPR-41 and GPR-43 are known proteins from the GPRs superfamily within the mammalian genome. They are particularly expressed in the adipocytes and identified as receptors for the fatty acids [37]. Acetate, preferentially, activates GPR-43 in vitro, whereas butyrate is more selective for GPR-41. Ordinarily, propionate displays most of the potent effect on both GPR-41 and GPR-43 [38]. It is important to highlight that GRP-41 has been associated more with a strong influence on the body weight and glucose homeostasis through increasing the enteroendocrine cell hormone known as peptide YY (PYY). The literature reported PYY as actually a key factor involved in energy homeostasis as well as in glucose metabolism [39, 40].

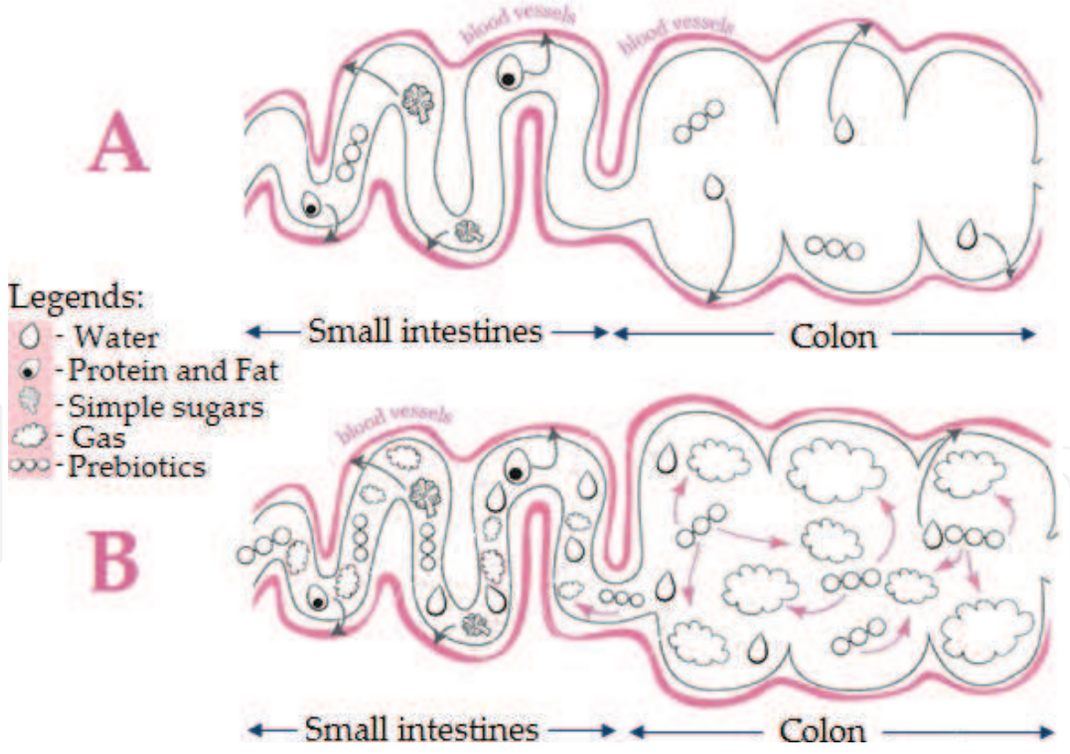

Figure 5. A represents a classical model of a normal digestion process; B represents a challenging digestion process due to an excessive intestinal fermentation of prebiotics. Source: Modified from Ref. [11].

Under a normal circumstance, the macronutrients are sensed in different parts of the small intestines. Also, the diverse types of gut hormones (such as PYY, cholecystokinin or CCK, and

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glucagon-like peptide-1 or GLP-1) control gastric emptying and the motility of food through the whole digestive tract. Gastric emptying is, in fact, the main controller of viscosity and the rate of nutrients delivery to the body. Up to now, no any in vitro technique can account for that sensation. A recent in vitro study revealed that some of the prebiotics (if not all) are slightly hydrolyzed—first in the stomach and small intestinal conditions—and then fermented in the colon [41]. In the same study, the SCFAs with lactate were synthesized and bifidobacterial population also significantly increased.

The GPR-43 as another sensor of metabolic homeostasis suppresses fat accumulation in the adipose tissue through insulin signaling pathway. Also, GPR-43 promotes the metabolism of unincorporated lipids and glucose in other tissues [40]. Apart from the amounts and proportions of those SCFAs during the fermentation stage of prebiotics, probiotics also simultaneously play other physiological benefits. Those include the balance of microbiological changes, locations of fermentation, and rates of fermentation for each prebiotic, locations of gas production, and pH changes throughout the digestion process. Naturally, all these parameters are difficult to measure in a real life situation. The batch systems which have been used in many experiments do not reflect the true interactions of a synbiotic community (combination of probiotics and prebiotics) in the host.

7. Implications of excessive bacteria and highly fermentable prebiotics in the small intestines

Probiotics too should be able to provide health benefits when administered in sufficient quantity. However, the recent data support that, beyond prebiotics being able to meet the nutritional benefits, options of food selection also may regulate various functions in the body and may play detrimental or beneficial roles in some diseases. For the prebiotics to meet the beneficial dietary effects, their fermentability status in the colon plays a significant role, especially to the commensal bacteria when all start to compete for nutrients. For example, flatulence is often a complaint when large doses of FOS are taken, which suggest that perhaps there is a tolerance limit for each prebiotics. Additionally, an overgrowth of bacteria in the small intestines (including those that for some reasons migrated from the colon) may cause digestion problems and poor overall health [11].

Figure 5(B) represents an example of excessive intestinal prebiotics fermentation. Here, it can be observed that the excess bacteria in the small intestines may result in the fermentation of undigested carbohydrates (starches and oligosaccharides) before being metabolized. Then again, some of the prebiotics may absorb much water from the rest of the body into the small intestine through osmosis, which can result in watery diarrhea. Fermentation of the undigested carbohydrates in the small intestine and an excessive fermentation of prebiotics in the colon create gas. When this happens, the pressure from an abnormal amount of gas inside the small intestine and colon, respectively, can cause bloating, abnormal pain, flatulence, diarrhea, or even constipation [11].

Unlike in the colon, excess gasses generated by excess bacteria in the small intestine cannot be easily expelled by passing it out and so the result is bloating. Apparently, if the excess bacteria produce methane (CH_3), this gas tells the intestines to move upwards, causing the content in the intestine to stall or to back up. In contrast, hydrogen (H_2) gas in the small intestines is associated with diarrhea. Furthermore, the unabsorbed monosaccharides in the small intestines can result in osmotic responses [11]. Another author has reported that about 84% of people with irritable bowel syndrome (IBS) have a bacterial overgrowth in the small intestine [42]. So, if this estimate is correct, people who complain of bloating, flatulence, diarrhea, or constipation are encouraged to take probiotics at appropriate doses to balance the intestinal bacterial structure, content viscosity, and to restore the beneficial and physiological activities in the intestines. Just like prebiotics, probiotics is as important as multi-vitamins and multi-minerals too, and all should be taken daily.

Figure 5(A) represents a normal process of digestion with balanced gut flora. Here, proteins, fats, and monosaccharides (such as glucose, fructose, and galactose) are absorbed from the small intestines, while water is absorbed from the colon into the bloodstream. The unabsorbed prebiotics (cellulose, hemicellulose, polyols, fructans, galactans, and others) do not cause any problem. Thus, diet control can be used to favor the growth of some selected gut inhabitants [43].

It is necessary to state here that the small intestines are a mysterious and largely inaccessible part of the body. Endoscopy tests are reported to have only shown about 60 cm of what is exactly happening inside of that part of the GI tract. Besides, a colonoscopy that goes through the rectum also shows extremely little of the other end of the small intestine. Therefore, it would be wise for individuals to ingest strong probiotic bacteria that survive and transit the stomach acid and bile salts during the digestion process. As discussed earlier on, the use of prebioticious materials for probiotic microencapsulation appears to be one of the best practices, and other similar kinds of materials continue to be developed. Usually, the probiotics that pass through the small intestine will meet on other extreme the commensal bacteria that migrated from the colon before they start prebiotic fermentation and compete for the nutrients (usually the monosaccharides) meant for assimilation by the host in a synergetic manner.

8. Conclusion

Prebiotics, either as occurring naturally in fruits, grain products, roughages, vegetables, legumes, soy, nuts, other foods or as added fibers, they all provide the physiological and/or beneficial effects in a symbiotic relationship with probiotics. Whole grains are not prebiotics. Both whole and refined grains need to be enriched with the prebiotics to meet the estimated daily requirement of 35–50 g/day. The benefits of dietary prebiotics are cumulative and increase with an increasing intake of the prebiotics in combination with the multi-vitamins, multi-minerals, and probiotic strains. While probiotic bacteria are easily found in capsules as dietary adjuncts, the consumers are also advised to opt for foods which provide more prebiotics for the overall health. Each prebiotic appears to have its tolerance limit. Beyond such a

tolerance limit, metabolism problems might occur. Diets consisting of different fermentable prebiotics are substrates for different probiotics in the gut. Furthermore, more evidence about the SCFAs to have a relationship with better health in the host has been provided. Extra care must also be taken into account when dealing probiotics and prebiotics relationship because the action of excess commensal bacteria in the small intestine may be detrimental in some disease. The involvement of excess anaerobic bacteria in the small intestine leads to prebiotic fermentation of which should only take place in the large intestines.

Acknowledgements

We are grateful to Ms. Dajana Pemac and the entire staff of InTech for helpful advice and the opportunity given to us to express our views. All the speakers on the Food, Health, & Nutrition Track at the Annual IFT Meetings, Chicago Ill., 2013 & 2015, are also gratefully acknowledged.

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