The Prebiotic Phenomenon : A Review

Shamika Kulkarni

T.Y.B.Tech.
Foods Engineering and Technology Department

Abstract

There is a growing awareness about the significance of appropriate diets for health in the world today. This has led to an increased demand for supplementary and proprietary foods as well. Prebiotics and probiotics, components of the food or incorporated into the food can yield health benefits. This paper lays emphasis on the prebiotics, their sources and the common prebiotics available along with the mechanisms and the health benefits of the same. It also tracks the criteria for the food being classified as a prebiotic and the advances in combinations of prebiotics and probiotics forming synbiotics.

Keywords: Prebiotics, Probiotic, Synbiotic, Mechanism, Health benefits.

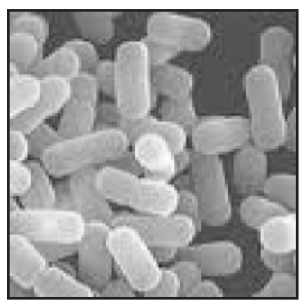
1. Introduction

The growing awareness of the relationship between diet and health has led to an increasing demand for food products that support health above and beyond providing the basic nutrition. Probiotics and prebiotics are components present in foods, or that can be incorporated into foods, which yield health benefits related to their interactions with the gastrointestinal tract (GIT). While the benefits of prebiotics have come to light in more recent years, recognition of probiotic effects dates back to the 19th century when the French scientist Louis Pasteur (1822 –1895) postulated the importance of microorganisms in human life and this was further reinforced by work done by 1908 Nobel Prize-winner Elie Metchnikoff. This paper primarily focuses on lesser known prebiotics and the role played by them in our diet. [1]

1.1 What is Prebiotic?

Prebiotics are defined as "nondigestible food ingredients that beneficially affect the host by selectively stimulating the growth of one or a limited number of bacterial species in the colon, such as Bifidobacteria and Lactobacilli, which have the potential to improve host health."[2] Prebiotics are, simply speaking, the food for beneficial bacteria that are observed in the Gastro Intestinal Tract (GIT).

Prebiotics are found to be naturally occurring in many foods, and can also be isolated from certain plants (e.g., chicory root, jerusalem artichoke, leek, etc.) or can be synthesized (e.g. enzymatically from sucrose). In order that a food ingredient be classified as a prebiotic, it has to be demonstrated, that it: (a) is not broken down in the stomach or absorbed in the GIT, (b) is fermented by the gastrointestinal micro flora and (c) most importantly, selectively stimulates the growth and/or activity of intestinal bacteria associated with health and wellbeing. Thus prebiotics enhance the functioning of the beneficial bacteria and selectively avoid growth of some pathogenic species.[3]



Source: Ref 21

1.2 History of Prebiotics

Prebiotics is a term coined by Professor Gibson and a Belgian

Examples of Probiotics and Prebiotics		
Class/Component	Source	Potential Benefit
Probiotics		
Certain species and strains of Lactobacilli, Bifidobacteria, Yeast	Certain yogurts, other cultured dairy products, and non-dairy applications	May improve gastrointestinal health and systemic immunity
Prebiotics		
Inulin, Fructo-oligosaccharides (FOS), Polydextrose, Arabinogalactan, Polyols— lactulose, lactitol	Whole grains, onions, bananas, garlic, honey, leeks, artichokes, fortified foods and beverages, dietary supplements and other food applications	May improve gastrointestinal health; may improve calcium absorption

Source: Ref 21

colleague, Dr. Marcel Roberfroid, of Louvain University in Brussels, in 1995.

2. Sources of Prebiotics [4,5,22]

Prebiotic carbohydrates are found naturally in such fruit and vegetables such as bananas, berries, asparagus, garlic, tomatoes, onions and chicory, greens (especially dandelion greens but also spinach, collard greens, chard, kale, mustard greens, and others), legumes (lentils, kidney beans, chickpeas, navy beans, white beans, black beans and others) and whole grains (wheat, oatmeal, barley, and others).

Year	Event
1900	Tissier described bifidobacteria (Bacillus bifidus) in the feces of babies
1906	Tissier proposed the oral feeding of bifidobacteria to prevent infant diarrhoea
1954	Gyorgy reported that components of human milk (N-acetyl-glucosamine) promoted the growth of a Bifidobacterium strain
1957	Petuely recognized lactulose as a 'bifidus' factor
1970s-1980s	Japanese researches discovered that a number of different nondigestible oligosaccharides are 'bifidus' factors
1995	The term 'prebiotic' was coined by Gibson and Roberfroid

Source: Ref 21

The various oligosaccharides classified as prebiotics and added to processed foods and supplements include fiber gums, fructo-oligosaccharides (FOS), inulins, isomalto-oligosaccharides, lactilol, lactosucrose, lactulose, oligofructose, soy oligosaccharides, transgalacto-oligosaccharides (TOS), and xylo-oligosaccharides.

2.1 Fiber Gums

Fiber gums are water-soluble and derived from plants as acacia, carrageenan, guar, locust bean, and xanthan. They usually contain about 85% fiber, and these gums help promote production of large quantities of short-chain fatty acids (SCFA's), which are known to play several beneficial roles; like supporting the growth of intestinal bacteria such as Lactobacillus and Bifidobacteria.

2.2 Fructo-Oligosaccharides (FOS)

Fructo-oligosaccharides are composed of glucose-terminated fructose chains of 3 to 5 units in length. They are mainly derived from sugar cane via natural fermentation process. Oligofructose is a mixed FOS compound that is formulated from inulin. It consists of a mixed number of glucose and fructose-terminated chains that vary in length from 2 to 7 units in each chain. FOS are resistant to digestion in the upper gastrointestinal tract and are, therefore, able to stimulate growth of Bifidobacterium and Lactobacillus strains farther down in the large intestine.

2.3 Inulins

They are a group of non-digestible oligosaccharides belonging to a class of carbohydrates known as 'Fructans'. Fructans also include another group called 'Levans'. Levans are found in fungi and bacteria while Fructans are derived from plants.

The inulin producing plant species consist of several monocotyledonous and dicotyledonous families, including Liliaceae, Amaryllidaceae, Gramineae, and Compositae, especially chicory, onions, leeks, garlic, bananas, asparagus and artichokes. However, only chicory (Cichorium intybus) and Jerusalem artichokes (Helianthus tuberosus) are used to produce inulin commercially.

Comprised mainly of fructose units, inulins have glucose terminals and stimulate growth of Bifidobacterium in the large intestine. Because of its longer chain structure, inulins are thought to ensure longer fermentation times that are needed in the colon.

2.4 Isomalto-Oligosaccharides

These are a mixture of glucose and other saccharide molecules. Produced by various enzyme processes, isomalto-oligosacharides ultimately form several sugar molecules including isomaltose, isomaltotetraose, isomaltopentose, nigerose, isopanose and other higher branched oligosaccharides. They act to stimulate the growth of Bifidobacterium and Lactobacillus species in the large intestine. They are marketed in Japan as dietary supplements and in functional foods. They are also being developed in the United States for similar commercial uses.

2.5 Lactulose

This is a semisynthetic disaccharide comprised of lactose and fructose. Lactulose is resistant to human digestive enzymes and is fermented by a limited number of bacteria in the colon, especially Lactobacilli and Bifidobacterium. In Japan, it is marketed as a dietary supplement and for use in functional foods.

2.6 Lactitol

This is a disaccharide alcohol analogue of lactulose. In Japan, Lactitol is also used as a prebiotic because it is resistant to digestion in the upper gastrointestinal tract and is fermented by a limited number of colonic bacteria. However, it is not approved as a prebiotic in the United States. In Europe, it is used as a food sweetener.

2.7 Lactosucrose

It is a trisaccharide comprised of galactose, glucose, and fructose molecules. It is produced through action of enzymes. Resistant to digestion in the stomach and small intestine, lactosucrose acts on the intestinal microflora to significantly increase the growth of the Bifidobacterium species. Lactosucrose is widely used in Japan as a dietary supplement and in functional foods, including yogurt and is being developed in the United States for similar uses.

2.8 Oligofructose

It is a sweet product derived from native inulin and is about 30-60% as sweet as sugar. It is found in the market as an oligosaccharide because it consists mainly of fructose units with some glucose-terminated chains. The unbound fructose chains have prebiotic properties, but with a different fermentation profile than either inulin or FOS. However, it is fermented by a wider variety of probiotic bacteria than inulin. Unlike inulin, oligofructose has the ability to brown, making it a valuable addition to baked products.

2.9 Pyrodextrins

These are a mixture of glucose-containing oligosaccharides derived from starch. Pyrodextrins are resistant to digestion in the upper gastrointestinal tract and help promote the growth of Bifidobacterium in the large intestine.

2.10 Soy-oligosaccharides

These are oligosaccharides found mainly in soybeans, but also be found in other beans and peas. There are two principal soy oligosaccharides: trisaccharide raffinose and tetrasaccharide stachyose. Soy oligosaccharides act to stimulate the growth of Bifidobacterium species in the large intestine. They are marketed in Japan as dietary supplements and in functional foods and are being developed in the US for similar uses.

Thus prebiotics are a very specialized form of dietary fiber, which can selectively stimulate the growth and activity of intestinal microflora associated with health and well being. As of now, only four food carbohydrates, essentially non digestible polysaccharides fulfill the criteria for prebiotics. They are inulin, oligofructose, galacto-oligosaccharides and lactulose[24].

3. Mechanism of Action

Prebiotics are not bacteria; they are food for friendly bacteria. Prebiotic is a non digestible component that affects the host by selectively stimulating the activity of colonic bacteria. The best-known of these are fructo-oligosaccharides (FOS). The principal characteristic and effect of prebiotics in the diet is to promote the growth and proliferation of beneficial bacteria in the intestinal tract, and thus, potentially yield or enhance the effect of probiotic bacteria.[6] Prebiotics have also been shown to increase the absorption of certain minerals (such as calcium and magnesium).

The gastrointestinal tract contains large numbers of bacteria, in the oral cavity predominantly Streptococcus, Neisseria and Veilonella. In the stomach and small intestine Streptococcus and Lactobacillus and in large intestine and colon, Bifidobacterium, Bacteroides, Eubacterium, etc are observed.[7] Therefore, prebiotic foods are vital to encourage probiotic organisms and the existing beneficial microflora to survive and thrive in the human gut. Thus a selective modification of the gut microflora must be carried out[24]. These bacteria must constantly be introduced in the diet and fed proper food to encourage them to adhere to the intestinal wall rather than passing through the digestive tract. This is because probiotic bacteria produce short-chain fatty acids (SCFAs) and restrict the growth and activity of less beneficial species. This "crowding out" of undesirable organisms is known as competitive exclusion, an action which promotes better gut integrity and function, increases immune system function, and improves calcium absorption and cholesterol maintenance. [8]

5. Health Benefit

Prebiotics are nondigestible food ingredients that beneficially affect the host by selectively stimulating the growth and/or activity of one or a limited number of bacterial species already resident in the colon, and thus attempt to improve host health.

5.1 Effect on Microbiota

Intake of prebiotics can significantly modulate the colonic microbiota by increasing the number of specific bacteria and thus changing the composition of the microbiota. Moreover, these prebiotics modulate lipid metabolism, most likely via fermentation products. Dietary oligosaccahrides are poorly absorbed, and can restore a predominance of beneficial Lactobacillus and Bifidobacterium species. Crohn's disease, ulcerative colitis, and pouchitis are caused by overly aggressive immune responses to a subset of commensal (nonpathogenic) enteric bacteria in genetically predisposed individuals. Clinical and experimental studies suggest that the relative balance of aggressive and protective bacterial species is altered in these disorders. [10, 11, 12]

5.2 Prevention of Colon Cancer

Ingestion of viable probiotics or prebiotics is associated with anticarcinogenic effects, one mechanism of which is detoxification of genotoxins in the gut. Ingestion of prebiotics results in a different spectrum of fermentation products, including the production of high concentrations of short-chain fatty acids. Gut flora, especially after the ingestion of resistant starch, induces the chemopreventive enzyme glutathionetransferase π in the colon of the rat and also leads to increased production of agents that deactivate toxic components. Thus prebiotics can function as viable agents for the prevention of colon cancer. [13]

5.3 Prebiotics' Effects on Mineral Absorption

Prebiotic effects on mineral absorption have been investigated, and recent human studies have confirmed that specific prebiotics, such as non-digestible oligosaccharides (NDOs) enhance calcium absorption. However, this effect varies according to the individual NDO and particular human population studied, and is thought to be due to its specific fermentation profile and the amount consumed.[14] Preliminary studies suggest that prebiotics may have a favorable effect on the immune system and provide improved resistance against infection.

5.4 Prevention of Osteoporosis

Some studies also suggest a possible benefit for reduced risk of osteoporosis through increased calcium absorption, reduced risk of atherosclerosis through decreased cholesterol and triglycerides and improved insulin response, obesity and possibly type 2 diabetes.[15]

5.5 Prevention of Hepatic Encephalopathy (HE) [18]

In order to reduce ammonia production by urease-positive bacteria it is recently hypothetized that prebiotics are new therapeutics for hepatic encephalopathy (HE), and that they may replace antibiotics. This influenced the view of the effect of antibiotics, prebiotics, e.g., lactulose, and probiotics on intestinal bacteria in the treatment of HE. Intestinal prebiotics are carbohydrate-like compounds, such as lactulose and resistant starch, which beneficially affects host's health in a different manner than normal food. In the small bowel prebiotics are not absorbed and digested, but are fermented in the colon by colonic bacteria. Fermentation of prebiotics yields lactic, acetic and butyric acids, as well as gas especially hydrogen (H_2). The massive H_2 volumes cause rapid intestinal hurry and thus massive amounts of colonic bacteria, not only urease-positive bacteria, but also deaminating bacteria, are removed and intestinal uptake of toxic bacterial metabolites, e.g., ammonia, reduced.

Prebiotics in conjunction with probiotics can significantly contribute to health. They have anticarcinogenic activity, antimicrobial activity, may lower triglyceride levels, can stabilize blood glucose levels, boost the immune system, help to improve mineral absorption and balance and help prevent constipation and diarrhea. [16]

Some pro- and prebiotics impart beneficial effects on the function of the human gut, and have been established and widely supported. Further scientific research is ongoing to substantiate their direct relationship to disease risk reduction. [17]

4. Prebiotic over Probiotics

Probiotics are viable micro-organisms which are beneficial to health by improving the microbial balance in the intestines and have been used to improve its intestinal microbial balance and to change the composition of colonic microbiota. [9] However, such changes may be transient, and the implantation of exogenous bacteria therefore becomes limited. In contrast, prebiotics are nondigestible food ingredients that beneficially affect the host by selectively stimulating the growth and/or activity of one or a limited number of bacterial species already resident in the colon, and thus attempt to improve host health. Intake of prebiotics can significantly modulate the colonic microbiota by increasing the number of specific bacteria and thus changing the composition of the microbiota. They have been shown to stimulate the growth of endogenous bifidobacteria. A study analyzed levels of friendly bacteria in stool samples of subjects before and after a probiotic or prebiotic diet. Evidence was found that a probiotic-rich diet did not increase friendly bacteria levels very much. However, there was evidence to show that maintaining a pre-biotic diet did increase the levels of friendly bacteria.

5. Conclusion

Prebiotics have great potential as agents to improve or maintain a balanced intestinal microflora to enhance health and well being[23]. The prebiotics are beneficial to the body and should be a part of our daily diets. It is also directly or indirectly responsible for the enhancement of the functioning of the gut and systemic immune system. Experts agree that daily consumption of foods containing these functional components is beneficial. Recent research in the area of prebiotic oligosaccharides and synbiotic [19] combinations of prebiotics with probiotics is leading towards a more targeted development of functional food ingredients. Improved molecular techniques for analysis of the gut microflora, new manufacturing biotechnologies, and increased understanding of the metabolism of oligosaccharides by probiotics are facilitating development. Such developments are leading us to the time when we will be able to rationally develop prebiotics and synbiotics for specific functional properties and health outcomes. [20]

References

1. Probiotic and prebiotic foods and beverages take root in the U.S. once and for all, Nutrition Business Journal, Oct 2008.
2. Ashwell M., Concepts of functional foods (ILSI Europe Concise Monograph Series Ed Walker, R) 2002.
3. Douglas L. C., Sanders M. E., Probiotics and prebiotics in dietetics practice, Journal of the American Dietetic Association, 108, (3) March 2008, Pages 510-521.
4. Chow J. M., Probiotics and prebiotics: A brief overview, Journal of Renal Nutrition, 12 (2), April 2002, Pages 76-86.
5. Ziemer C. J., Gibson G. R., An overview of probiotics, prebiotics and synbiotics in the functional food concept: perspectives and future strategies, International Dairy Journal, 8 (5-6) 6 May 1998, Pages 473-479.
6. Duggan G. J. and Walker A.W., Protective nutrients and functional foods for the gastrointestinal tract, Journal of Nutrition. 1999; 129:1438S-1441S.
7. Gibson G. R., Dietary modulation of the human gut microflora using the prebiotics oligofructose and inulin· The Journal of Nutrition, 1999, 1 (29), Pg:1438-1441.
8. Gibson G. R., Fibre and effects on probiotics (the prebiotic concept), Clinical Nutrition Supplements, 1 (2) 2004, Pages 25-31.
9. Holzapfel W. H., Schillinger U., Introduction to pre-and probiotics, Food Research International, 35 (2-3) 2002, Pages 109-116.
10. Fooks L.J., Fuller R., Gibson G.R., Prebiotics, probiotics and human gut microbiology, International dairy journal, 1999 – Elsevier.
11. Saggiro A., Probiotics in the treatment of irritable bowel syndrome, Journal of Clinical Gastroenterolgy, 2004; 38supp. II:S104-S106.
12. St-Onge MP, Farnworth ER, Jones P. Consumption of fermented and nonfermented dairy products: Effects on cholesterol concentrations and metabolism. American Journal of Clinical Nutrition, 2000; 71 674-681.
13. Scholz-Ahrens K.E., Schaafsma G., Heuvel E., Schrezenmeir J., Effects of prebiotics on mineral metabolism, American Journal of Clinical Nutrition, 2001; 73 suppl:459S-464S.
14. Roberfroid M. B., Concepts and strategy of functional food science: the European perspective, American Journal of Clinical Nutrition, 71 (6) 1660S-1664s, June 2000.
15. Gibson G. R. and Williams C. M., Functional foods - concept to product, American Journal of Clinical Nutrition, 75 (5) 789-808, May 2002.
16. Prebiotics and probiotics: are they functional foods?, Roberfroid M. B., American Journal of Clinical Nutrition, 71 (6) 1682S-1687s, June 2000.
17. Bongaerts G., Severijnen R., Timmerman H., Effect of antibiotics, prebiotics and probiotics in treatment for hepatic encephalopathy, Medical Hypotheses, 64 (1) 2005, 64-68.
18. Rastall R. A., Maitin V., Prebiotics and synbiotics: towards the next generation, Current Opinion in Biotechnology, 13 (5) 1 October 2002, 490-496.
19. Reid G., Probiotics and prebiotics – Progress and challenges, International Dairy Journal, 18 (10-11) October-November 2008, Pages 969-975.
20. Chart adapted from International Food Information Council Foundation: Media Guide on Food Safety and Nutrition: 2004-2006.
21. Handbook of Probiotics and Prebiotics By Yuan Kun Lee, Seppo Salminen.
22. Roberfroid M., Prebiotics: the concept revisited, Journal of Nutrition 137, 2007.
23. McFarlane S., Cummings J.H., Prebiotics Revisited, Alimentary Pharmacolagy and Therapeutics.