



Original Article

Prebiotics – A Review

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Abstract

Nutraceuticals and functional foods have become an important tool for consumers to manage their health and well-being. Pre-, pro-, and synbiotics are a part of this group of products shown to have properties that can modulate gastrointestinal problems and improve general health and well being. Prebiotics are polysaccharides that can withstand acidic and enzymatic digestion in the small intestine and can be utilized by probiotics, and gut microflora, in the large intestine for their growth and activities that benefit the host's health, e.g., by enhancing the immunity and mineral absorption, preventing colon cancer and other gastrointestinal diseases, and lowering cholesterol. Prebiotics, e.g., inulin, oligofructose, oligolactose, and lactulose, occur naturally in many plants, or may be synthesized from starch or other carbohydrates using appropriate enzymes. A number of plants from southern Thailand, e.g., palm fruit (*Borrassus flabellifer* L.), jackfruit (*Artocarpus heterophyllus* Lam.), young coconut (*Cocos nucifera* Linn.), rambutan (*Nephelium lappaceum* L.), jampadah (*Artocarpus integer* Merr.), and okra (*Abelmoschus esculentus* Moench.) contain a considerable amount of polysaccharides that have been shown to have prebiotic properties. Prebiotics may be used as ingredients in functional foods, or may be presented as nutraceuticals in the form of capsules, tablets or powder, sometimes together with probiotic cultures.

Key words: prebiotics, probiotics, southern Thailand plants, functional foods

1. Introduction

Nutraceutical and functional food (NFF) products have become an important part of today's diet as the consum-

ers are more aware of their contributions to the general health and well being. Modern lifestyle limits the time for food preparation, and with increasing prosperity the market for NFF products expands rapidly. Sloan (2002) reported an NFF product market value in the U.S. of \$47.6 billion in 2001. This has increased to \$76.1 billion in 2007 and was projected to reach \$167 billion or 5% of the total food value in the

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U.S. by 2010 (Communication, 2004). There is a wide range of NFF products designed for specific health purposes, including sport or energy drinks, high fiber products, vitamin or mineral fortified foods, and pre-, pro- and synbiotic products. Necessarily, the functional ingredient industry has become a large parallel industry producing nutraceutical and functional ingredients for the NFF industry.

Prebiotic, probiotic, and synbiotic industries form a significant part of the NFF industry. Probiotics are live microorganisms, which, when ingested, improve the intestinal microbial balance. These microorganisms consist principally of Bifidobacteria, Lactobacilli, and Eubacteria. They help to maintain gastrointestinal health and to manage inflammatory bowel diseases by protecting the digestive tract from pathogenic infection. They can also stimulate immune functions, aid digestion, and absorption of nutrients, and synthesize some nutrients such as vitamins (Panitantum, 2004). Probiotic products, like yoghurt, Yakult[®], and other fermented foods, have long been popular in Thailand. The global probiotic market is worth hundreds of millions of dollars and is expected to more than triple its value in the next six years (Martin *et al.*, 2003; Elliott and Teversham, 2004). In Asia in particular, where gastrointestinal diseases are quite common, probiotics are becoming functional food of choice for protection against these types of ailments.

Probiotic cultures must reach a certain minimum number in the guts before they can be beneficial, and gut conditions are not always conducive to the establishment and growth of these types of microflora. Prebiotics are food components that selectively stimulate the growth and activity of probiotics. They are non-digestible food ingredients consisting of short-chain carbohydrates, principally oligosaccharides such as fructooligosaccharides, galactooligosaccharides, and inulin (Gibson, 1995; Panitantum, 2004). They are not digested or absorbed in the early part of the digestive tract, but can be hydrolyzed by probiotic bacteria in the large intestine, converting them to compounds beneficial to the host's health. Prebiotics are more useful as functional food than probiotics since they can be added to more foods than probiotics, because of their ability to survive the digestive process in the upper gastrointestinal tract (Vernazza *et al.*, 2006). They have been found to reduce the risk of stomach cancer when used with probiotics and help to improve the gastrointestinal functions of seniors. Adding inulin and fructooligosaccharide at the dose of 2 g/d to baby food helps to reduce the incidences of diarrhea, vomiting, and cold in babies. A study at the Children Hospital in Texas found that children fed with orange juice and milk containing inulin and oligofructose for one year had an increased homeostasis of bone calcium; their bone mineral content increased by 15%, and bone mineral density by 45% (Silawanichnakul, 2007). Added benefits of prebiotics are that they modulate bowel habits, increase calcium absorption, and interact with lipid metabolism to reduce low density lipoprotein (LDL) cholesterol (Panitantum, 2004). A product containing both prebiotics and probiotics, which would make

probiotics persist better in the gut ecosystem, is termed "synbiotics" (Vernazza *et al.*, 2006).

Oligosaccharides, such as galactooligosaccharides (GOS), and fructooligosaccharides (FOS), are used extensively as ingredients in many food products. Most of these ingredients currently available on the market are synthesized. These compounds may also be found naturally in chicory, onion, artichoke, asparagus, banana, garlic, soybean, and others, and their functionality may be enhanced further through biotechnological approaches (Gibson *et al.*, 2000). With consumer's increasing preference for products from natural origins, it is an important incentive for scientists and industrialists to seek prebiotics from natural sources.

Several plants native to southern Thailand have recently been studied for the existence, quantity, and quality of prebiotic compounds. The plants include peel and flesh of banana (*Musa sapientum* Linn.), pod of okra (*Abelmoschus esculentus* Moench.), skin, flesh, and seed of jackfruit (*Artocarpus heterophyllus* Lam.), germinated rice (*Oryza sativa* Linn.), peel, flesh, and seed of rambutan (*Nephelium lappaceum* L.), pericarp of ripe fruit, flesh of young fruit, and embryo of germinating fruit of palm fruit (*Borrassus flabellifer* L.), skin, flesh, and seed of jampadah (*Artocarpus integer* Merr.), shell of durian (*Durio ziberhinus* Merr.), hausa potato (*Coleus parvifolius* Benth.), ripe flesh, seed coat, and seed cotyledon of tamarind (*Tamarindus indica* L.), flesh of young coconut (*Cocos nucifera* Linn.), skin, flesh, and seed of mature mango (*Mangifera indica* L.), and dioscorea tuber of Hua Khao Yen (*Smilax china* Linn.). This paper reviews various kinds of prebiotics and summarizes the results of the study on Thai crops. It also briefly reviews how prebiotics work to improve human health and how they may be applied to produce functional foods.

2. Definition of prebiotics

Prebiotics should have the following properties:

1. Capable of passing to large intestine without being digested and absorbed in the upper part of gastrointestinal tract (Kolida *et al.*, 2002; Gibson, 2004).
2. Capable of being digested in the large intestine by beneficial bacteria such as *Bifidobacterium* and *Lactobacillus* (Kolida *et al.*, 2002; Gibson, 2004).
3. Capable of enhancing the growth of beneficial bacteria such as *Bifidobacterium* and *Lactobacillus*, but not pathogens causing gastrointestinal diseases such as *Clostridium perfringens* (Gibson *et al.*, 1995; Gibson and Roberfroid, 1995; Kolida *et al.*, 2002).

Gibson *et al.* (1995) fed 100 volunteers with 5-20 g/d of fructooligosaccharide and inulin for 9 weeks and found an increase in *Bifidobacterium* in their intestinal tracts.

Prebiotics must be able to withstand acid hydrolysis in the stomach, able to move to large intestine without changes or being absorbed in small intestine so that they can be utilized by the indigenous microflora in the large intestine to enhance their growth (Gibson, 2004). This benefits the host

by improving the absorption of elements such as Ca, Mg, and Fe, or preventing cancer of the large intestine (Van Loo *et al.*, 1999). Oligosaccharides that are considered prebiotics are lactose, lactulose, raffinose, stachiose, and fructooligosaccharide. There are other compounds that can be fermented by *Bifidobacterium* and *Lactobacillus* in the large intestine, e.g., resistant starch, non-starch polysaccharides, which include plant constituents such as pectin, cellulose, hemicelluloses, and xylan.

3. Types of prebiotics

Current interest focuses on oligosaccharides with low molecular weight because they can be used as carbon sources for bacteria in the large intestine. When ingested, these compounds will pass through the small intestine to ileacaecal region without being digested (Oku *et al.*, 1984; Nilsson *et al.*, 1988; Ellegard *et al.*, 1997). While in the large intestine (colon), these compounds undergo microbial fermentation, causing the reduction in the pH value and the formation of short-chain fatty acids, which can inhibit pathogens (Morisse *et al.*, 1993).

Oligosaccharides occur naturally in plants, and small amounts are found in the form of free sugars or glycoconjugates in human milk and animal colostrums (Bucke and Rastall, 1990). Recent discoveries showing the effects of these compounds on the physiology of the digestive system lead to an increased interest (Van Loo *et al.*, 1999).

There are two types of prebiotics, i.e., those occurring naturally in plants such as banana, asparagus, beans, and cereals, and those synthesized from enzymatic digestion of polysaccharides, such as starch.

3.1 Naturally occurring prebiotics

3.1.1 Galactooligosaccharides

Galactooligosaccharides contain galactose in the following structure: $\text{Glu } \alpha \text{ 1-4}[\beta \text{ Gal 1-6}]_n$, where $n = 2-5$. They are found in human milk, cow's milk, yoghurt, and may be synthesized from lactose with β -galactosidase.

GOS are non-digestible by gut enzymes and can pass into the large intestine without being digested. However, they can be hydrolyzed by microorganisms in the large intestine, producing short-chain fatty acids, e.g., acetic, propionic and butyric acids, and gases, like H_2 , CH_4 , and CO_2 . There may be other compounds from the hydrolysis of GOS such as lactate, which can enhance the growth of *Bifidobacteria* and *Lactobacilli*. These microorganisms can help synthesize vitamins, stimulate immunity, and prevent stomach upset. Sofia *et al.*, (2000) reported a study on the effect of 10g/d of GOS on gut microflora in 12 volunteers, who had lower than normal population of the microorganisms and found their numbers increased. Their mineral absorption was also enhanced. Chonan *et al.* (1995) added 5% (w/v) GOS to rats' diet for 30 d and found their calcium absorption increased.

Yanahira (1997) fed 5% GOS (w/v) to rats for 14 d and found their Ca and Mg absorption enhanced. GOS also prevented colon cancer by reducing the pH value in the large intestine, which inhibited the production of secondary bile acids, which cause cancer (Wijnand, 1999). They also regulate the activities of various bacterial enzymes, e.g., β -glucuronidase and nitroreductase which are involved in the production of toxins and carcinogens (Rowland and Tanaka, 1993; Sako *et al.*, 1999). GOS are also found to reduce hazardous compounds, e.g., ammonia, indole and *p*-cresol, which stimulate the expansion of cancer (Sako *et al.*, 1999).

3.1.2 Fructooligosaccharides and Inulin

Inulin is a polysaccharide which plants store as a nutrient. It is a small-molecule FOS, containing 3-60 fructose moieties with the structure of $\text{Glu } \alpha \text{ 1-2}[\beta \text{ Fru (2-1)}]_n$, where $n = 10^{14}$. Inulin is generally found in plants, bacteria, and some fungi. It is known in more than 3,600 fruits and vegetables, especially those in the Cichorium family, e.g., chicory, banana, large onion and garlic (Bxcommerce, 2001), as shown in Table 1. Inulin is not digested in the small intestine, but parts of it may be digested in the large intestine by its microflora. Inulin and FOS can be easily dissolved in hot water (Tanya, 2002) at about 80°C (Kim and Wang, 2002), but very little in cold water and alcohol (Wang and Gibson, 1993). They are quite stable, have no undesirable sensory property except some sweetness. Therefore, they have been used in the food industry to improve sensory and physical properties of some products. For example, they help preserve freshness and moisture in cakes, and the physical stability in beverages. FOS and inulin pass into large intestine without

Table 1. Fructooligosaccharides and inulin in plants.

Source	Inulin (% fresh weight)	Fructooligosaccharide (% fresh weight)
Onion	2-6	2-6
Jerusalem artichoke	16-20	10-15
Chicory	15-20	5-10
Leek	3-10	2-5
Garlic	9-16	3-6
Artichoke	3-10	<1
Banana	0.3-0.7	0.3-0.7
Rye	0.5-1.0	0.5-1.0
Barley	0.5-1.5	0.5-1.5
Dandelion	12-15	NA
Burdock	3.5-4.0	NA
Camas	12-22	NA
Murnong	8-13	NA
Yacon	3-19	3-19
Salsify	4-11	4-11
Wheat	1-4	1-4
Asparagus	1-30	5-10

Source: Van Loo *et al.* (1995)

being digested. Thus, they have the properties of prebiotics.

3.1.3 Soybean oligosaccharides (SOS)

SOS are oligosaccharides in soybean, which consist of raffinose and stachiose (Gibson, 2004). They can withstand enzymatic digestion in the stomach and small intestine and are capable of being hydrolyzed by the microflora in large intestine. They can enhance the growth of *Bifidobacteria* in the large intestine (Hayakawa *et al.*, 1990).

3.1.4 Prebiotics from selected Thai plants

Some 14 plants from southern Thailand and their parts were studied for their indigestible polysaccharide contents and prebiotic properties. The plants included banana, *Musa sapientum* Linn., (peel and flesh), okra, *Abelmoschus esculentus* Moench., pod, jackfruit, *Artocarpus heterophyllus* Lam. (skin, flesh, and seed), germinated rice (*Oryza sativa* Linn.), rambutan, *Nephelium lappaceum* L., (peel, flesh, and seed), palm fruit, *Borrassus flabellifer* L., (pericarp of ripe fruit, flesh of young fruit, and embryo of germinating fruit), jampadah, *Artocarpus integer* Merr., (skin, flesh, and seed), durian, *Durio ziberhinus* Merr., shell, hausa potato (*Coleus parvifolius* Benth.), tamarind, *Tamarindus indica* L., (ripe flesh, seed coat, and seed cotyledon), young coconut, *Cocos nucifera* Linn., flesh, mature mango, *Mangifera indica* L., (skin, flesh, and seed), and Hua Khao Yen (*Smilax china* Linn.) (dioscorea tuber). The raw materials were finely chopped and extracted with various solvents, which included water (room temperature and hot) and alcohol (50 and 95% in water). The extracts were vacuum-concentrated and freeze-dried. They were then analyzed for yields, indigestible polysaccharide contents, and prebiotic properties (growth enhancement of commercial probiotic cultures, which included *Lactobacillus acidophilus*, *Lactobacillus planta-*

rum, and *Bifidobacterium bifidum*). The extracts were also analyzed for their antioxidant, anti-allergy and antimicrobial activities, and cytotoxicity. Ten samples were then chosen for their potential as commercial prebiotics. Table 2 summarizes the chosen plants and their parts, and their indigestible polysaccharide content.

The Thai plants and their parts shown in Table 2 are ranked according to their indigestible polysaccharide content. All could enhance the growth of *L. plantarum*, eight (jackfruit skin, flesh and seed, rambutan flesh, Jampadah flesh, young coconut flesh, palm embryo and flesh) could enhance the growth of *L. acidophilus*, and only four (jackfruit flesh, young coconut flesh, okra pod, and palm flesh) could enhance the growth of *B. bifidum*. Among these 10 extracts, only rambutan flesh and okra pod have appreciable antioxidant activity ($IC_{50} = 22.6$ and 26 mg/mL, respectively), and only rambutan flesh has some antimicrobial activity against *Bacillus subtilis*. None are found to be anticarcinogen or cytotoxic (Thammarutwasik *et al.*, 2007).

3.2 Synthesized prebiotics

3.2.1 Lactosucrose (LS)

Lactosucrose is produced by combining lactose and sucrose using β -fructofuranosidase. Ohkusa *et al.* (1995) fed LS to three volunteers at the dose of 3 g/d and found their *Bifidobacteria* content increased by 0.7 times and hazardous microorganisms reduced by 0.6 times. In addition, short-chain fatty acids, e.g., acetic and butyric acids, were also increased.

3.2.2 Lactulose

Lactulose is produced from lactose having the structure in the form of Gal β 1-4 Fru. It is soluble in water,

Table 2. Solvent used, extract yield, and indigestible polysaccharide content of selected Thai plants and their parts.

Rank	Plant	Part	Solvent	Extract yield (% dry weight)	Indigestible polysaccharide (mg/g dry extract)
1	Palm fruit	Pericarp	Et 95%	51.69	705.80
2	Jackfruit	Skin	Et 95%	71.54	689.08
3	Jackfruit	Flesh	Et 95%	59.43	605.76
4	Rambutan	Flesh	Et 50%	55.73	566.83
5	Jampadah	Flesh	Et 95%	34.11	542.56
6	Young coconut	Flesh	CW	22.66	513.87
7	Okra	Pod	Et 50%	12.39	460.73
8	Palm fruit	Embryo	Et 50%	26.54	409.85
9	Jackfruit	Seed	Et 50%	16.00	403.44
10	Palm fruit	Flesh	Et 95%	44.94	334.87

Source: Thammarutwasik *et al.* (2007); Et = ethanol, CW = cold water

slightly soluble in methanol and insoluble in ether. It is not hydrolyzed and absorbed in the small intestine, but can be fermented by bacteria in the large intestine, which increased the population of the native microorganisms. This has been found to help prevent colon cancer, reduce pathogens and enhance immunity. Very little lactulose is found in natural food; therefore, it has been added to various foods, e.g., yoghurt, cookie, cake, and chocolate as a functional ingredient to improve their nutritional value.

3.2.3 Isomaltooligosaccharide (IMO)

Isomaltooligosaccharide is produced from starch using enzymes. Part of it, i.e., isomaltose, can be digested in the small intestine (Kolida *et al.*, 2000). Olano-Martin *et al.* (2000) found that giving 20 g/d of IMO to test subjects increased the Bifidobacteria content in their large intestine, and the fermentation of IMO with lactic bacteria produced butyrate.

3.2.4 Glucooligosaccharides

Glucooligosaccharides are synthesized with glucosyl transferase, which is produced by *Leuconostoc mesenteroides*, or may be extracted from β -glucan of oak tree. They are accepted as a functional food. GOS can be fermented by Bifidobacteria, except *B. bifidum*, and can be hydrolyzed by Bacteriodes and Clostridia, but not by Lactobacilli. Asahara *et al.* (2001) studied the effect of GOS in rats on the activity of *Bifidobacterium breve* and found that they could reduce *Salmonella* contamination.

3.2.5 Xylooligosaccharides (XOS)

The structure of xylooligosaccharides consists of xylose molecules joined together by β 1-4 linkage. XOS can be hydrolyzed by Bifidobacteria and Lactobacilli, and were found to be more effective than FOS in increasing the population of the probiotics and in decreasing the number of harmful bacteria.

Some of the synthesized prebiotics and their production methods are listed in Table 3.

4. Effects of pro- and prebiotics on human health

Consumers have become increasingly more aware of the effects of diet on their health. Thus, foods such as those containing high fiber and fermented dairy products are enjoying increased sales. Probiotics in the fermented dairy products are thought to be the causes of improved consumer's health. Breastfeeding is also gaining popularity owing to the greater immunity passed on from mother to infant through the milk. Oligosaccharides, which have been found to help to increase the baby's immunity against various diseases, are found in mother milk. Thus, more research efforts are currently directed to the studies on how pro- and prebiotics work to improve health and well being.

4.1 Probiotics

Probiotics are native microflora in the digestive system, which are beneficial to the host's health. They help maintain microbial balance in the gut and are resistant to acids and bile salts in the intestine. Probiotics consist mainly of Lactobacilli and Bifidobacteria, which are found in the human digestive tract capable of lactic fermentation. Some probiotics can produce antimicrobial compounds such as bacteriocins, and can help to improve the general health and well being of humans and animals through increased regularity of bowel movement (Paraksa, 1970; Kontula *et al.*, 1998). Table 4 shows some probiotic cultures and their effects on health.

Probiotics possess the following characteristics:

1. Able to withstand acidity in the stomach (Kontula *et al.*, 1998). Stomach excretes HCl to help digest food, causing the pH value in the stomach to be as low as 1-3. Therefore, probiotics must be able to withstand these pH levels to be able to survive.
2. Able to withstand bile salts, since liver secretes bile salts into the small intestine to digest fatty foods at a concentration of 0.15-0.30% (Erkkila and Petaja, 2000).
3. Able to colonize the intestinal wall to prevent colonization by pathogens, and resist the peristalsis of the food in the intestine, making the digestion and absorption of food more normal (Fuller, 1993).

Table 3. Synthesized prebiotics and their production methods.

Prebiotic	Production Method
Inulin [Fructooligosaccharides (FOS)]	Hot water extraction from chicory root followed by enzymatic hydrolysis, or polymerization of fructose monomers
Galactooligosaccharides (GOS)	Enzymatic lactose transgalactosylation
Xylooligosaccharides (XOS)	Enzymatic hydrolysis of plant xylans
Isomaltooligosaccharides (IMO)	Transglucosylation of liquefied starch
Lactulose	Isomerization of lactose

Source: Vernazza *et al.* (2006)

Table 4. Selected probiotics and their effects on health.

Probiotic culture	Effect on health
<i>Lactobacillus rhamnosus</i> GG (ATCC 53103)	Prevent stomach upsets in children, increase immunity
<i>Lactobacillus johnsonii</i> (<i>acidophilus</i>) LJ-1 (La1)	Increase immunity
<i>Bifidobacterium lactis</i> Bb-12	Prevent stomach upsets, increase immunity
<i>Saccharomyces boulardii</i>	Prevent stomach upsets, inhibit <i>Clostridium</i> in digestive tract
<i>Lactobacillus plantarum</i> DSM9843(299v)	Increase short-chain fatty acids

Source: Saarela *et al.* (2002)

4. Able to inhibit pathogenic growth by
- Compete with pathogens in the colonization of the intestinal wall,

- Compete with pathogens for food,
- Produce inhibitive compounds such as organic acids, H₂O₂, and bacteriocins (Fuller, 1993).

5. Able to stimulate the host's immunity. *Lactobacillus* has been found to stimulate production of γ -globulin and γ -interferon, and enhance the macrophage activities in removing pathogens from the body (Fuller, 1993).

6. Able to reduce the risk of colon cancer by reducing the cancer-causing enzymes, e.g., β -glucuronidase, azoreductase, nitrate reductase, and β -glucosidase (Kontula *et al.*, 1998).

7. Able to reduce blood cholesterol. Buke and Gilliland (1990) isolated *Lactobacillus acidophilus* from the stool of nine volunteers to study cholesterol absorption. They found that *L. acidophilus* strains 016 and C14 could absorb 50.9 mg/mL and 47.1 mg/mL of cholesterol, respectively.

4.2 Native microflora in digestive tract

In the digestive tract there are many different types of native or normal microflora. From the ingestion, there exist a number of facultative and strict anaerobes such as *Streptococcus*, *Bacteriodes*, *Lactobacillus*, and yeasts (Saarela *et al.*, 2002). In the stomach, there are *Lactobacillus*, *Streptococcus*, *Helicobacter pylori*, and *Candida albicans* numbering about 10⁴ colony forming units per gram (CFU/g). The population of the microorganisms in different parts of the small intestine varies greatly. For example, there are about 10³-10⁴ CFU/g in duodenum, 10⁵-10⁷ CFU/g in jejunum, 10⁷-10⁸ CFU/g in ileum, while the large intestine has the greatest microbial concentration of about 10¹⁰-10¹¹ CFU/g (Isolauri *et al.*, 2004).

Types and numbers of microorganisms in the small and large intestine vary from person to person. Both, the small and large intestine, contain beneficial microorganisms, e.g., Bifidobacteria and Lactobacilli. If harmful microorganisms are present, but the number of beneficial microorganisms is predominant, the growth and activities of the pathogens may be suppressed, thus the health of the host can be maintained. The reverse, of course, will be detrimental to the host.

Parts of the food ingested will be digested and absorbed as nutrients in the small intestine. The parts that are not digested in the small intestine will pass into the large intestine to be utilized by beneficial microorganisms (probiotics). When this part of the food (prebiotics) is fermented by probiotics a large amount of lactic acid is produced causing the reduction of the pH value, which results in the inhibition of pathogens. At the same time, short-chain fatty acids, e.g., acetic, propionic, and butyric, are produced and absorbed by the host. Butyric acid can assist the intestinal cell wall to fight against the progression of cancer cells. Other useful compounds, e.g., vitamin B, are also produced during prebiotic fermentation.

Types of prebiotics affect their usefulness occurring in the human bodies. Prebiotics that can be fermented quickly have lower benefit to health than those fermented more slowly. Moreover, a fast rate of fermentation produces a large amount of gases, which causes discomfort to the host.

5. Application of prebiotics in nutraceutical and functional food

Health benefits from prebiotics may be obtained by incorporating them into products such as nutraceuticals and functional foods. The following are some examples of the products that have taken advantage of prebiotics.

1. Functional beverages containing inulin and oligofructose to improve the efficiency of the digestive system, strengthen the bone, and increase immunity against diseases.

2. Breakfast cereals with an increased amount of dietary fibers through the addition of prebiotics increase the efficiency of the digestive system and enhance the growth of probiotics.

3. Infant food with an addition of prebiotics improves the efficiency of the digestive system and increases the immunity against diseases. Addition of inulin, oligofructose and galactooligosaccharides, individually or in combination, to infant food has been shown to increase the numbers of Bifidobacteria and Lactobacilli in infant's digestive system from 31 to 59% of total gut microflora during their first six weeks, similar to breastfeeding (Anonymous, 2007).

4. Dairy product, e.g., fermented dairy beverages and yoghurt containing probiotics, which become known as synbiotics when prebiotics are added. Among other things,

they help to improve Ca absorption.

5. Nutraceuticals, where prebiotics are made into tablets or capsules; some also contain probiotics. They are taken daily to increase the amount of pro- and/or prebiotics in the gastrointestinal system.

6. Other products, e.g., weight management products, where sugar is replaced by prebiotics; some have a similar sweetness than sugar.

Special care must be taken in using prebiotics as ingredients in food products. The compatibility of these ingredients with the products in terms of physical (particle size, solubility, viscosity), sensory (color, taste, flavor), and nutritional (health benefits, potential hazards, dosage, stability) properties must be well understood. Properly used, they can be an additional tool to combat ailments and to improve the health and well being of consumers.

6. Summary

Prebiotics, natural or synthetic, can enhance the growth and activities of probiotics, and gut microflora, which are beneficial to the health and well being of humans and animals. They are polysaccharides that are capable of surviving acidic and enzymatic digestion in the small intestine, and can be fermented by probiotics in the large intestine to produce short-chain fatty acids, vitamins, and other compounds, which can normalize bowel movement, increase immunity against diseases, prevent cancer, improve mineral absorption, and lower cholesterol. Examples of prebiotics are inulin, oligofructose, galactooligosaccharides, and lactulose. Thai plants, e.g., palm fruit, jackfruit, young coconut, rambutan, jampadah, and okra contain significant amounts of polysaccharides possessing prebiotic properties. Prebiotics may be incorporated as nutritional ingredients into various functional foods, or presented as nutraceuticals in the form of tablets or capsules, sometimes with probiotic cultures, for the benefit of consumer's health.

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