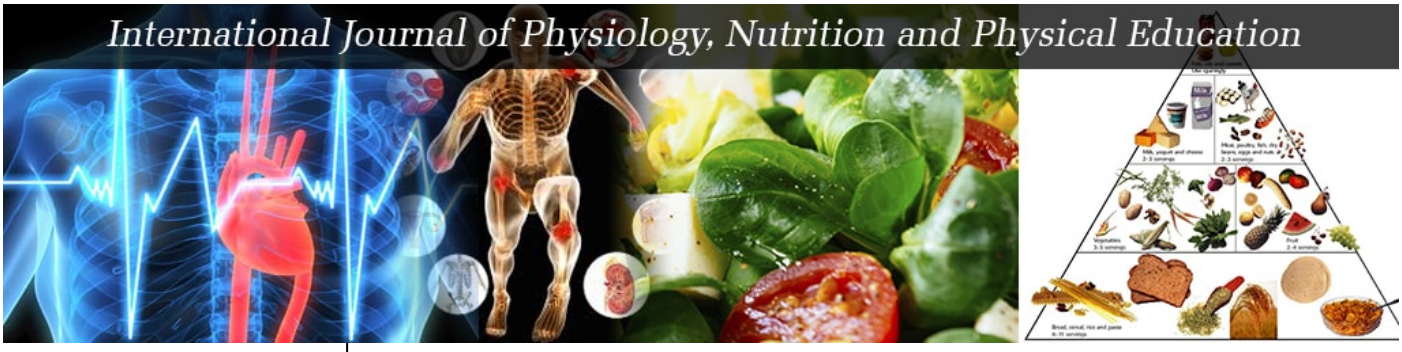

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Prebiotic activity of carbohydrates: A review

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Abstract
Prebiotics are a group of nutrients that are degraded by gut microbiota. Their relationship with human overall health has been an area of increasing interest in recent years. They can feed the intestinal microbiota, and their degradation products are short-chain fatty acids that are released into blood circulation, consequently, affecting not only the gastrointestinal tracts but also other distant organs. Fructo-oligosaccharides and galacto-oligosaccharides are the two important groups of prebiotics with beneficial effects on human health. Since low quantities of fructo-oligosaccharides and galacto-oligosaccharides naturally exist in foods, scientists are attempting to produce prebiotics on an industrial scale. Considering the health benefits of prebiotics and their safety, as well as their production and storage advantages compared to probiotics, they seem to be fascinating candidates for promoting human health condition as a replacement or in association with probiotics. This short review will emphasize on recent trend on functional food and the cocept of prebiotic as well as several potential source as a prebiotic.

Keywords: Prebiotics, gut microbiota, short-chain fatty acids, fructo-oligosaccharides, galacto-oligosaccharides

Introduction
In recent years, there is an increasing trend of consumer awareness towards the demand for functional foods, which are claimed to enhance the health of consumer. Various types of microorganisms, known as gut microbiota, are inhabitants of the human gastrointestinal tract. Trend in food science and technology has shown development of prebiotics, which are able to modulate the human gut microbiota and lead to a significant health improvement. It has been reported that there are 10^{10}–10^{12} live microorganisms per gram in the human colon [1]. The resident microbial groups in the stomach, small, and large intestine are crucial for human health. The majority of these microorganisms, which are mostly anaerobes, live in the large intestine [2]. Many studies have now confirmed that the prebiotics incorporated in the diet are valid approach to the dietary manipulation of the colonic microbiota. Although some endogenous factors, such as mucin secretions, can affect the microbial balance, human diet is the chief source of energy for their growth. Particularly, non-digestible carbohydrates can highly modify the composition and function of gut microbiota [3]. Beneficial intestinal microbes ferment these non-digestible dietary substances called prebiotics and obtain their survival energy from degrading indigestible binds of prebiotics [4, 5]. As a result of this, prebiotics can selectively influence gut microbiota [6, 7]. On the other hand, the gut microbiota affects intestinal functions, such as metabolism and integrity of the intestine. The effects of prebiotics on human health are mediated through their degradation products by microorganisms. This concept has gained global attention and is being manipulated for human health purpose. The concept has been introduced for more than a decade with inulin and oligosaccharide (Fructo-oligosaccharide, galacto-oligosaccharides and trans-galacto-oligosaccharides) being the most established prebiotics. Better understanding on the role of prebiotic on health benefits has led to search new source of prebiotics which is relatively low price as compared to commercially available prebiotics [8, 9].

2. Current trends on functional foods
In recent years, much attention has been paid to physiological function of foods due to increasing concerns for health.

People have turned to natural food sources such as plants and herbs for these enhancers, rather than artificial substances. The high consumer demand has resulted in emerging of various health promotimg products in the market. They are called dietary supplements, designer foods, super food, nutraceutical as well as functional foods. These terms are actually referred to foods that beneficially affect the human health [10]. There are actually hundreds of defination describing the cocept of functional food. The Foundation for Healthy Food, explained: "A functional food can be a natural product that contains useful biological components or a food obtained through a technological intervention that increases its level of biologically active compounds. Biologically active compounds are components of foods that act positively on key body functions that are relevant to health. They reduce the risk of developing diseases such as atherosclerosis, hypertension, myocardial infarction, diabetes, etc. "8

This showed that consumers are more aware on what they eat and drink as they have become more proactive in improving their health. There are lot of products containing functional ingredients in the market- infant milk formulae, bakery products, chocolates, dairy products and health drinks etc. Apart from other food ingredients, prebiotics are among those which have attracted much attention recently [11].

3. Concept of prebiotic

The term prebiotic was actually introduced by Gibson and Roberfroid [12] as "a non-digestible food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon." This definition was being updated [13] as "selectively fermented ingredients that allow specific changes, both in the composition and/or activity in the gastrointestinal microbiota that confers benefits upon host well-being and health". The following criteria are used to classify a compound as a prebiotic: (i) it should be resistant to acidic pH of stomach, cannot be hydrolysed by mammalian enzymes, and also should not be absorbed in the gastrointestinal tract, (ii) it can be fermented by intestinal microbiota, and (iii) the growth and/or activity of the intestinal bacteria can be selectively stimulated by this compound and this process improves host's health [14]. Although not all the prebiotics are carbohydrates, the following two criteria can be exploited to distinguish fiber from carbohydrate-derived prebiotics: (i) fibers are carbohydrates with a degree of polymerization (DP) equal or higher than 3 and (ii) endogenous enzymes in the small intestine cannot hydrolyze them. It should be taken into account that the fiber solubility or fermentability is not crucial [15, 16].

Ingestion of prebiotic was believed to enhance immune function, improve colonic integrity, decrease incidence and duration of intestinal infections, down-regulated allergic response as well as improve digestion and elimination of faeces [17]. The effect of prebiotics was actually indirect due to changes in the gastrointestinal microbiota compositions (bifidobacterias, lactobacilli, as well as the histolyticum subgroup; bacteroides and clostridia) that give rise to the prebiotics effect [18]. A positive effect of prebiotic reflects significant increase in numbers of bifidobacteria and lactobacilli, while retarding the development of histolyticum subgroup [19]. Gibson, Beatty, Wang, and Cumming [20] have shown that bifidobacteria was able to stimulate the immune system. Produce vitamin B, inhibit pathogen growth, reduce blood ammonia and blood cholesterol levels as well as help to restore the normal flora after antibiotic therapy, while the lactobacilli aid digestion of lactose inlactose-intolerant individuals, reduce constipation and infantile diarrhea, help to resist infections such as salmonellae and help to relieve irritable bowel syndrome.

4. Types and sources of prebiotics

It can be considered that non-digestible carbohydrate working as prebiotic if they achieve the following criteria (A) resistance to gastric acidity and mammalian enzymes; (B) susceptibility to fermentation by gut bacteria; and (C) ability to enhance the viability and/or activity of beneficial microorganisms [21] (Rastall & Gibson, 2006). Galactooligosaccharides (GOS), fructooligosaccharides (FOS) and inulin are the prebiotics most commonly known. GOS are non-digestible and are derived from lactose that occurs naturally in mammalian milk and consist of chains of galactose monomers. Inulin and inulin-type fructans, are known soluble dietary fibres (Roberfroid, 2005) [22]. Additionally, dietary fibre containing several non-starch polysaccharides, such as cellulose, dextrins, pectins, beta-glucans, waxes, and lignin can adjust the transfer time through the gut, thus offering the same useful effects as those of inulin-type fructans (Napolitano *et al*., 2009) [23]. Naturally occurring prebiotic can be found in various foods, including asparagus, chicory, tomatoes and wheat, and it is a natural constituent of breast milk.

5. Important criteria of prebioticand several potential sources

Wang [11] has pointed out the important criteria of prebiotic (Fig.1.).

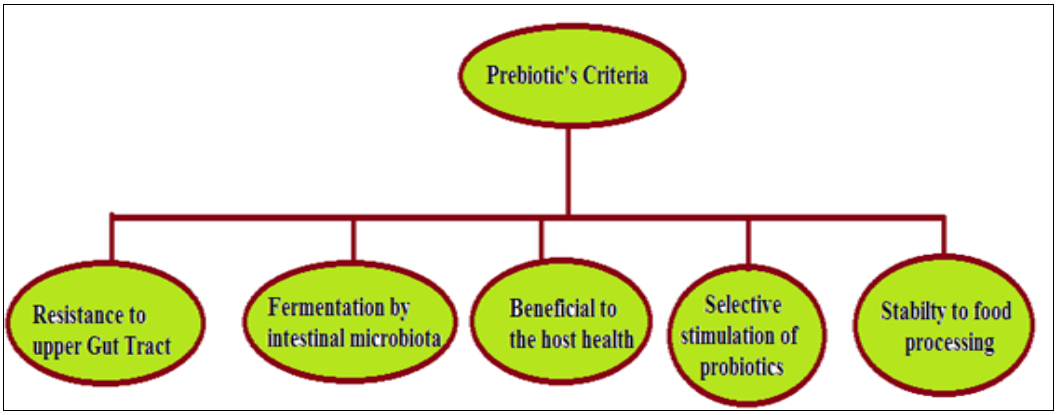

Fig 1: Criteria for classification of a food ingredient as prebiotic

The first criteria for prebiotics, which is resistant to upper gut tract is actually to ensure that the prebiotics can withstand digestive processes before they reach the colon, thus stimulate the beneficial bacteria, bifidobacteria and lactobacilli effectively [24, 25]. Some of the non-digestible oligosaccharides presently available or in the development as food ingredients include carbohydrates in which the monosaccharide unit is fructose, galactose, glucose and/or xylose. Today, only bifidogenic, non-digestible oligosaccharides (particularly inulin, its hydrolysis product oligofructose, and (Trans) galactooligosaccharides), fulfil all the criteria for prebiotic classification [26]. In the last few years, successful attempts have been reported to make infant formula more breast-milk-like by the addition of fructo- and (primarily) galactooligosaccharides. Other criteria of prebiotics are selective fermentation by potentially beneficial bacteria in the colon [27]. The effects of this fermentation may lead to an increase in the expression or change in the composition of short-chain fatty acids, increased fecal weight, a mild reduction in luminal colon p^H, a decrease in nitrogenous end products and reductive enzymes, an increased expression of the binding proteins or active carries associated with mineral absorption and immune system modulation [28], which is beneficial to the host health, requirement for the third criteria. Selective stimulation of the growth and/or activity of intestinal bacteria potentially associated with health and well-being is considered as one of the criteria of prebiotics [29]. Last but not least, a prebiotic must be able to withstand food processing conditions so that they remain intact non-degraded or chemically altered and available for bacterial metabolism in gut [30]. As a result, the gastrointestinal health of human can be improved. Huebner *et al*. [31] has tested a few commercial prebiotics over several processing conditions. It has conclusively shown that only heating at low p^H caused significant reduction in prebiotic activity of inulin, ahile fructooligosaccharides (FOS) contained product was observed to be the least stable.

Digestive enzymes secreted by the pancreas or brush border of vertebrates, and mammals in particular, are not able to hydrolyze β-glycosidic bond of carbohydrates, making them non-digestible [33]. The non-digestible property of mushroom carbohydrate leads to consider them as apotential source of prebiotics. However, intense studies need to be carried out, before such claim could be made because not all dietary carbohydrates are prebiotics. Synytsya *et al.* [34] gave a positive overview that glucans (branched 1,3-1,6-glucans and linear 1,3-glucans) isolated from fruit bodies of cultivated mushrooms *Pleurotus ostreatus* and *Pleurotus eryngii* were able to stimulate the growth of prebiotics-Lactobacillus ssp. (4 strains: Lac AeD), Bifidobacterium ssp. (3 strains: Bifi A-C) and Enterococcus faecium (2 strains: Ent A and B)- to some extent.It was found that glucan from *Pleurotus eryngii* support the growth of Lactobacillus strains better than that of *Pleurotus ostreatus*. Lactobacillus-B and C showed the highest production of short chain fatty acid (SCFA), while Bifidobacterium-A showed the lowest amount of SCFA when supplemented with both glucans.

6. Prebiotic safety

Prebiotics are assumed to lack life-threatening or severe side effects. Intestinal enzymes cannot break down oligosaccharides and polysaccharides. They are transported to the colon to be fermented by the gut microbiota. Therefore, the side effects of prebiotics are mostly the result of their osmotic functions. In this regard, osmotic diarrhea, bloating, cramping, and flatulence could be experienced in prebiotic recipients. The prebiotics chain length is an influential parameter for the development of their side effects. The prebiotics chain length is an influential parameter for the development of their side effects. Interestingly, prebiotics with shorter chain length may have more side effects. The possible explanation for this phenomenon is that shorter inulin molecules are metabolized primarily in the proximal colon and are more rapidly fermented; whereas, longer chain ones are fermented later and slower in the distal colon. This means that prebiotics within their therapeutic doses can cause mild to moderate side effects. Most products of prebiotics in the market have doses of 1.5–5 g per portion [35].

7. Conclusion

Prebiotics have a significant effect on human health and have greater possibilities for incorporation into a wide range of common foodstuffs. Their role is played by fermentable carbohydrates, which stimulate, preferentially, the growth of probiotic bacteria (bifidobacteria and lactic acid bacteria), thus enhancing the gastrointestinal and immune systems. In addition, prebiotics have been shown to increase the absorption of calcium and magnesium, influence blood glucose levels and improve plasma lipids. Long terms clinical trials are required to confirm the health benefits of prebiotics in human.

Therefore, designing particular, population-specific prebiotics with regard to the resident gut microbiota specific to each community may ultimately contribute to the reduction of certain disorders in each society as a standardized approach. This concept provides the potential to stop the huge prebiotic controversies and can be recommended in future guidelines from the FAO and/or the WHO on prebiotics.

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