Review Article

Industrial Production, Physio-chemical properties and Potential Applications of Prebiotic in Biotech-based Products

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Abstract

Prebiotics are non-digestible short chain carbohydrates and non-digestible food components. These are non-digestible fibers that enhanced the beneficially gut bacteria that improve the health of the host. These indigestible food ingredients have beneficial effects on the selected population of gut bacteria (e.g; bifidobacteria). There may be various types of prebiotics like Polydextrose-fructans, Inulin, Fructo oligosaccharides (FOS), Galacto oligosaccharides (GOS), Lactulose, Isomalto oligosaccharide (IMO), Lactitol which are used as a food supplement. Application of prebiotics may restore the gut microbiota diversity and activity and these have broader effects on intestinal microbiota. Application of prebiotics may restore the gut microbiota diversity and activity and these have broader effects on intestinal microbiota.

Keywords: Prebiotic, microbiota fructo-oligosaccharides, galacto-oligosaccharides, bifidobacteria, lactobacillus

Introduction

Health Canada defines useful foods item as the food stuffs that have been ability to explain the benefits for physical state but have similar to traditional foods" (Shahidi, 2009). When these foods are combined with herbal products then many novel traditional useful food products have been made. Traditional herbal products are excessively used as medicine in nutritional supplements, daily foods and functional foods, for restore, and health advancement purposes in some countries (Shahidi et al., 2011). Beneficial food is a component of human nutrition according to the definition, that given an additional function (often one related to health promotion or disease prevention) by adding acceptable diet (Grajek et al., 2005). Prebiotics are non-digestible food ingredients that promotes the growth of beneficial microorganisms in the intestine and are also called resistant Short-Chain Carbohydrates (SCCs) (Quingley et al., 1999).

Occasionally these mentioned as Non Digestible Oligosaccharides that are dissolvable in 80% ethanol. A Prebiotic is inactive food component which once permit through small intestine, they range the gut, where they are partially fermented by the gut microflora (Gibson et al., 1995). Recent research has shown us that only non-digested carbohydrate (CHO) molecules behave the same way as prebiotic properties. Without being utilized by other intestinal bacteria, Prebiotics passes through small intestine and become manageable for probiotic bacteria.

The short-chain fatty acids which are used as a source of energy by the host organism are necessary end components of carbohydrate metabolism. Several plant species e.g Asparagus, onion, garlic, artichoke and chicory can be the different sources of prebiotics. The groupings of sugars with a changed degree of polymerization are oligosaccharides (Crittenden et al., 1996).

Synbiotics are actually, the mixtures of probiotics and prebiotics. This mixture (synergic effects) is often used to take advantage in application to food products. The rationale for this combination is that the prebiotics, together with probiotics, increase the level of health in general, so nearly every individual can afford to accommodate this prebiotics in their nutrition (Capela et al., 2006). Prebiotic is used to stimulate the growth of useful microbe (called "probiotics") that settle the gut microflora, thereby increasing its effectiveness.

There is a human body and the number of bacteria

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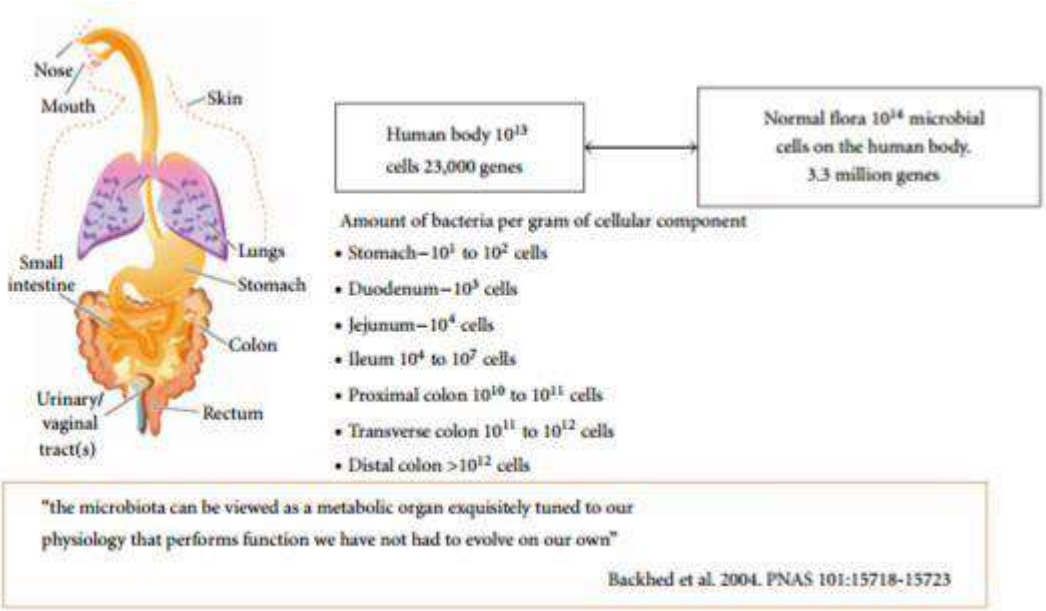

Figure 1. Human body and number of bacteria present in total microflora (Backhed et al., 2004).

which are present in total microflora of human body shown in figure 1.

Properties of Prebiotics

Some of the non-digestible oligosaccharides are inulin, fructo-oligosaccharides, galacto-oligosaccharides, soya-oligosaccharides and prodextrins etc. Inulin is extracted from chicory root and their degree of polymerization is 11-65. Different oligosaccharides are extracted from different sources. Similarly the degree of polymerization of fructo-oligosaccharides, galacto-oligosaccharides, soya-oligosaccharides and xylo-oligosaccharides are 2-10, 2-5, 3-4, 2-4 respectively.

Properties of some common non-digestible oligosaccharides are discussed in **table 1:**

Sources and types of Prebiotics

Prebiotics comprise Non-digestible carbohydrates as they come across to following standards:

- mammalian enzymes and resistance to gastric acidity
- Vulnerability to fermentation by gut bacteria
- Capacity to increase the feasibility and action of useful Microbes. (Rastall et al., 2006).

Most commonly known prebiotics are

Table 1. Properties of Prebiotics

Name	Composition	Method of manufacture	DP
Inulin	b(2–1) fructans	Extraction from chicory root	11-65
Fructo-oligosaccharides	b(2–1) fructans	Tranfructosylation from sucrose, or hydrolysis of chicory inulin	2-10 3-5
Galacto-oligosaccharides	Oligo-galactose (85%), with some glucose and lactose	Produced from lactose by b-galactosidase	2-5
Soya-oligosaccharides	Mixture of raffinose (F-Gal-G) and stachyose (F-Gal-Gal-G)	Extracted from soya bean whey	3-4
Xylo-oligosaccharides	b(1–4)-linked xylose	Enzymic hydrolysis of xylan	2-4
Pyrodextrins	Mixture of glucose-containing oligosaccharides	Pyrolysis of potato or maize starch	various
Isomalto-oligosaccharides	a(1–4) glucose and branched a(1–6) glucose	Transgalactosylation of maltose	2-8

DP, degree of polymerization; F, fructose; Gal, galactose; G, glucose.

Table 2. Types and sources of Prebiotics

Type of prebiotic	Source of prebiotic	References
Fructooligosaccharides	Asparagus, sugar beet, garlic, chicory, onion, Jerusalem artichoke, wheat, honey, banana, barley, tomato and ry	Sangeetha et al. (2005)
Isomaltulose	Honey, sugarcane juice	Lina, Jonker, and Kozianowsky (2002)
Xylooligosaccharides	Bamboo shoots, fruits, vegetables, milk,honey and wheat bran	Alonso, et al., (2000)
Galactooligosaccharides	Human's milk and cow's milk	Alander et al. (2001)
Cyclodextrins	Water-soluble glucans	Singh et al., (2002)
Raffinose oligosaccharides	Seeds of legumes, lentils, peas, beans, chickpeas, mallow composite and mustard	Johansen et al., (1996)
Soybean oligosaccharide	Soybean	Mussatto and Mancilha (2007)
Lactulose	Lactose (Milk)	Villamiel et al., (2002)
Lactosucrose	Lactose	Kawase et al., (2001)
Isomaltulose	Sucrose	Lina et al. (2002)
Palatinose	Sucrose	Lina et al. (2002)
Maltooligosaccharides	Starch	Kaneko et al. (1994)
Isomaltooligosaccharides	Starch	Kaneko et al. (1994)
Enzyme-resistant dextrin	Potato starch	Barczynska et al., (2012)

Galactooligosaccharides (GOS), fructooligosaccharides (FOS) and inulin. Galactooligosaccharides are non-digestible, that are derived from lactose. Lctose consist of chains of galactose monomers and occurs naturally in mammalian milk. Various foods such as asparagus, chicory, tomatoes and wheat have naturally occurring prebiotics and breast milk also have prebiotics naturally (Roberfroid et al., 2005). Several types of prebiotics and their sources are summarized in a given table 2.

Functions of Gut Microbiota

An infant has a germ free gut which is colonized by microbes (bacteria) from the baby's surroundings or environment and from the mother. The bacterial cells are 10 times more in, and on, the whole body of grownup human as related to entire human cells. The human Microbiome is very complicated. Human body is home-based to about hundred trillion bacteria and other microbes known as microbiome. The arrangement and number of microbiome altered from the nose and mouth to the distal colon and rectum. When the baby is discouraged to solid foods then the arrangement of their gut microbiota May vary.16S ribosomal RNA (rRNA) gene-sequence-based metagenomics techniques are developed that is the advancement used for defining the population of gut microbiota. This16S ribosomal RNA (rRNA) gene-sequence-based metagenomics technique is used to showing that 90% of the bacteria belongs to two phyla, (namely, the Bacteroidetes and Formicates). In the intestinal morphology, the gut microbiota play a major role. The mucin secretion and degradation are in the intestinal mucus layer. The barrier to pro-inflammatory compounds and uptake of antigen are created by the mucin layer. The colon defense barrier is shown by this mucin layer. The gut microflora play a role in the growth of cells and tissues. Comparatively, the cell development and differentiation are regulated by butyrate, a peptide chain fatty acid which is secreted by the colonic microorganisms (bacteria).

Selective modifications of Gut Microbiota

When Inulin, FOS, galacto oligosaccharides and are take in the nutrition in comparatively minor quantity that is 5–20 g/day that stimulates the development of health-promoting species which belonged to the genus that may be bifidobacteria and Lactobacillus. Anyhow, their effects on the worldwide arrangement of the vegetation are less well supported at the present. In general, whichever carbohydrate that reached to the huge bowel will affect the metabolic activities and their growth and will offer a substrate for the commensal microbiota. This will happen with additional substrate like resistant starches, lactose and sugar alcohol and has been exposed for non-starch polysaccharides (NSP). The growth of bifidobacteria and lactobacilli is related to the particular properties of prebiotics at the amount of other groups of gut bacteria. Selectivity it has been defined both in the quantitative and qualitative terms. In this manner, the increase in some

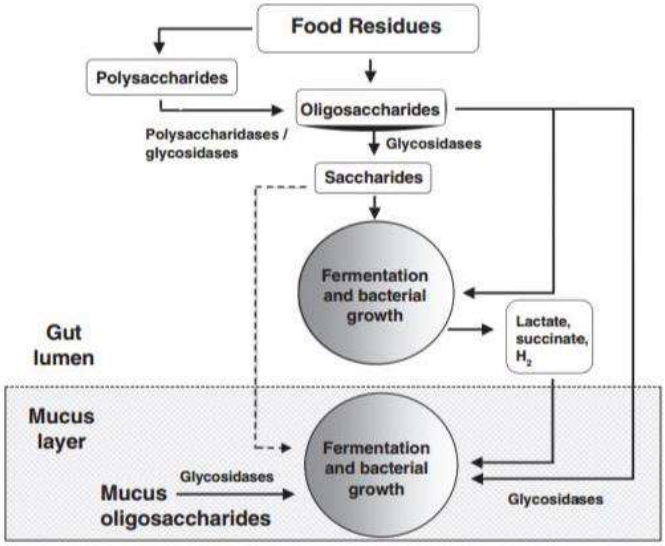

Figure 2. Mechanism whereby dietary substrates become available for mucosa-associated microbiotas in the large intestine (Macfarlane et al., 2006).

genera of bacteria like Roseburia with well-established prebiotics like inulin have been shown by some investigations. One consequence is that the comprehensive special effect of prebiotics on the assembly of the microbiota are not known yet.

A Healthy Microbiota

Healthy microbiota is measured to be one that is mainly saccharolytic and consist of bifidobacteria and lactobacilli. Two kinds of bacteria like lactobacillus and Bifidobacterium are predominantly carbohydrate fermenting bacteria and these bacteria do not have any known pathogen. Primarily, short-chain fatty acids (SCFA) which are the products of carbohydrate fermentation are beneficial to host health, whereas the phenol, sulphide and ammonia which are in the fermentation of amino acid and breakdown of protein not beneficial to host health. In gut exhaustive examination of the effects of prebiotics on the microbial association have been described by some investigations.

Mucosal Microbiota

Utmost lessons on the colonic microbiota have been attentive on fecal substantial. Anyhow, cumulative sign proposes that the diverse bacterial association are heavily colonized on the epithelial surface. Some bacteria are very important in regulating the immune system reactiveness and likely to be grow in biofilms of colonic mucosa which occur in close vicinity to the host. Some investigation shows that the inflammatory conditions like Ulcerative colitis (UC) and Crohn's disease (CD) are changed by mucosal communities. The fact that the deep properties on the mucosal microbiota open up the option of emerging curative strategies for blocking bacteria-linked gut diseases by the small additions to the diet.

There is mechanism whereby dietary substrates become available for mucosa-associated microbiotas in the large intestine described in figure 2.

Industrial Production of Prebiotics

Inulin and oligo fructose are separated and purified for utilization and these are used as nutritional supplements. Now, both oligo fructose and inulin are used in the unpolluted form as food components in many foodstuffs (Frank, 2002). Non-digestible carbohydrates that are non-digestible are produced from natural foods through hydrolyzing polysaccharides, enzymatic and chemical amalgamation from disaccharide and direct withdrawal by using industrial production methods to produce soybean oligosaccharides (Mussato et al., 1997). There are some important prebiotics which are produced on industrial level are discussed in table 3:

Applications of Prebiotic in Food Products

The utilization of prebiotics as food supplements have multiple advantages, so these enhance sensory feature and provide a stable composition of nutrition (Frank et al., 1997). Due to their jellifying qualities, prebiotics enhance low fat foods without any harsh effect on taste or texture of the food products and the food products which are important such as table sugars, butter products, dairy spreaders and cheese creams (Zimeri et al., 2003).The prebiotics are addicted during fruit preparation develops mouth-feel and presents a synergistic taste effects when combined with aspartame and acesulfame K, without increasing the caloric content (Miremadi et al., 2012).

Irritable Bowel Syndrome

Table 3. Industrial production of Prebiotics

Type of prebiotic	Industrial production of prebiotic	References
Raffinose oligosaccharides	It can be directly isolated from plant materials using water or aqueous methanol or ethanol solutions	Johansen et al. (1996)
Galactooligosaccharides	It is produced from lactose and in the industrial production process of galactooligosaccharides, a highly concentrated solution of lactose, which is usually purified from cow's milk whey	Sako et al. (1999)
Lactosucrose	Is produced using lactose and sucrose as raw material	Kawase et al. (2001)
Fructooligosaccharides	Is produced into two clases: in first one , they are produced from disaccharides sucrose and second one is the controlled enzymatic hydrolysis of the polysaccharide, which can be isolated from chicory roots	Crittenden and Playne, (1996)
Isomaltulose, also referred to as palatinose	Naturally occurring disaccharides manufactured from sucrose by enzymatic rearrangement of the glycosidic linkage from (1,2)-fructoside to (1,6)-fructoside followed by crystallization	Lina et al. (2002)
Glycosylsucrose	Is a trisaccharide manufactured from the disaccharides maltose and sucrose through the trans glycosylation action	Crittenden and Playne, (1996)
Cyclodextrins	They are produced from starch using cyclodextrin glucosyltransferases, a group of amylolytic enzymes produced naturally by different strains of bacilli and other species of bacteria	Munro, Newberne, Young, and Bar (2004)
Gentiooligosaccharides	They are produced from acid or enzymatic hydrolysis of starch	Crittenden and Playne (1996)
Soybean oligosaccharides	Are extracted directly from raw material. Soybean whey , a by-product from the production of soy protein isolate and concentrate, contain the oligosaccharides raffinose, stachyose and verbascose	Karr-Lilienthal, Kadzere, Grieshop, and Fahey (2005)
Xylooligosaccharides	Production from feed stocks: (a) enzyme treatments of native xylan-containing lignocellulosic material (b) chemical fractionation of a suitable lignocellulosic material to isolate xylan (c) hydrolytic degradation of xylan to xylooligosaccharides by steam, water or dilute solutions of mineral acids	Vazquez, Alonso, Dominguez, and Parajo (2000)

Various investigations using probiotics would be seen by various benefits while the complications of IBS can stimulate the uses of prebiotics in this state. So it is proved that IBS effect various different pathogenesis of physical state and it is not only a single syndrome. By using Polymerase Chain Reaction (PCR), various changes may be visible in microbial load of faeces in Irritable Bowel Syndrome patients. Some known abilities prebiotics increase the number of Bifidobacterium and lactobacillus both are faecal microbiota (Malinen et al., 2005). Bifidobacterium and lactobacillus do not produce gases (Macfarlane et al., 1996).

Antibiotic-associated Diarrhoea

Probiotics have an important role in the prevention of Antibiotic-Associated Diarrhoea, and so it may be expected that prebiotics would also be effective in some circumstances or in prevention of some diseases. Bifidobacterium and lactobacillus cause changes in the composition of the microbiota and should increase colonization resistance in the gut (Gibson et al., 2005).

Calcium Absorption in Bones

Lactose is responsible to increase the calcium absorption in diet but it is not effective in healthy humans persistently (Abrams et al., 2005). Most importantly, increase in absorption leads to increased bone mineral density and prevents osteopenia. Calcium absorption from the colon takes place by vitamin D and energy dependent transport process, mostly in the intestinal parts. Mostly, non-soluble paracellular transport also takes place in the colon and it is passive transport, that is 1, 25(OH) 2D3 responsive (Civitelli et al., 1994). However prebiotics increase the process, mostly in adults and lesser increase in younger people and post-menopausal females while the large bowel play a prominent role in the absorption of calcium ions.

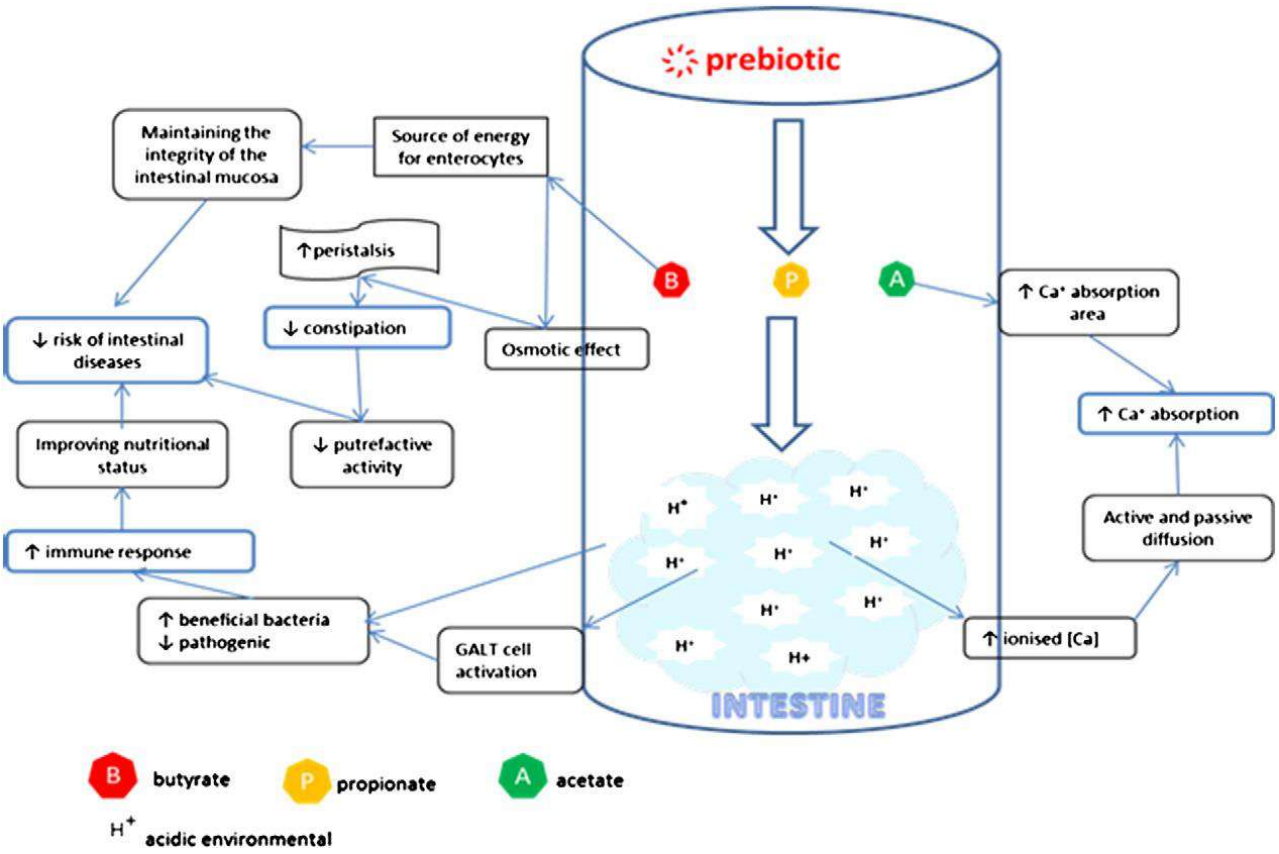

Figure 3. Possible mechanism of action of prebiotics on the elderly (Marlane et al., 2013)

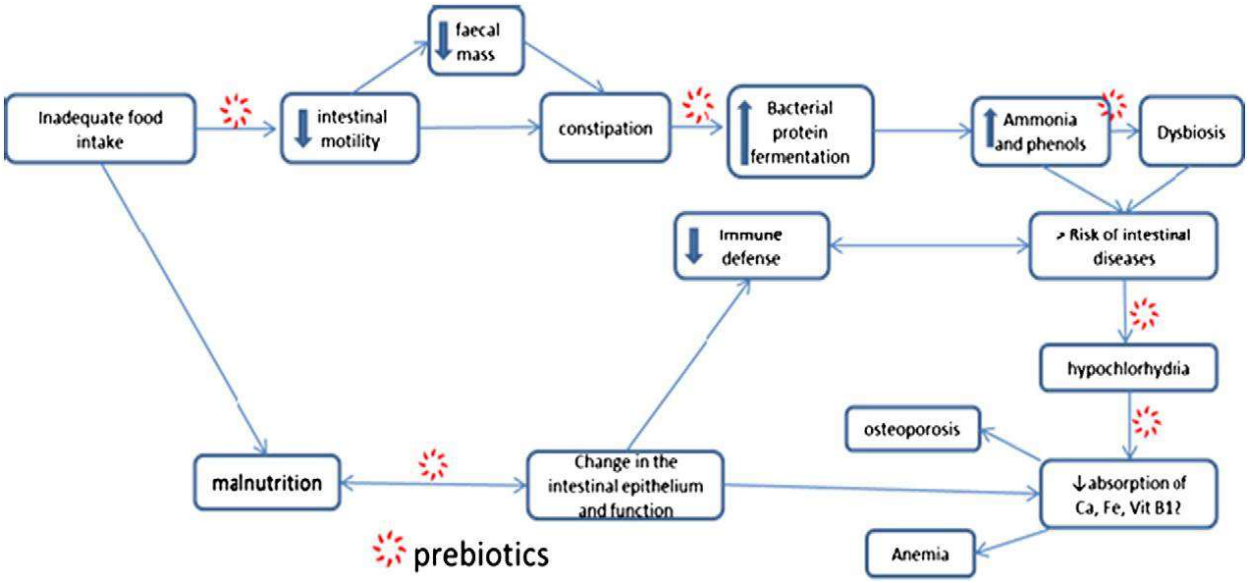

Figure 4. Physiological changes in the elderly and possible sites of action of prebiotics (Marlane et al., 2013)

Prebiotics also play an important role to enhance the uptake of others metal ions from the GIT. These results are supported in human trials. Various probiotics and prebiotics are given by an investigation in 66 transplant patients of liver post operatively shows no beneficial effects for FOS, but major reduce of infectious diseases like urinary tract infections, with probiotics (Ducros et al., 2005).

Functional effects of Prebiotics on the health of elderly

The effects of prebiotics that promote the health of host, the growth of harmful microbe is inhibited, and helpful microbes are promoted (Choque-delgado et al., 2011). Physiological changes are used to characterize the age in the GIT with proper imbalance of intestinal microbiota. Intestinal microbiota structure and composition are

changed which are related to diseases that are common in the elder people (Biagi et al., 2009). Changes in intestine can may compromise the elderly health during aging. Hypochlorhydria results from gastric atrophy which find in the elder people(Russel, 1992).The decrease in food intake (Murphy et al., 2009) which combined with the low ringing of motility of the intestine which results in lowered faecal weight and constipation (Woodmansey, 2007), which lead to less excretion capacity of bacteria metabolites (Roberfroid et al., 1998). The gastrointestinal diseases occurred due to increase in stay time of faeces that is related to large fermentation of amino acids and regularly enhance the level of ammonia and phenols which is obtained through putrefaction intestine. The degradation of residual polysaccharides from diet through the amount of bactericides decreases by aging and enhance the number of clostridia (Roberfroid et al., 2010). Various factors like lesser the quantity and type of consumed food, because of less perception, may change or alter the epithelium of intestine and alter in function of intestine caused malnutrition in elder people. These factors also resulted in lowering the intestinal immune homeostasis and nutrients absorption, due to which loss of appetite, less intake of food and increase in malnutrition. Some complications also takes place through human aging. Food is the important component which may affect the immune system in the gastrointestinal tract and the concentration of microbiota of intestine and its metabolites also added in this. The function and enhancement of intestinal immune system and systemic immune system are benefitted through dietary supplements which are present in small intestine (Rowland et al., 2008). The bifidobacterial effect of prebiotics is due to non-digestible food products and fermentation in the gut through beneficial microbes and is also concerned with lowering in pH and changing the pattern of SCFA (Rayed, 2007). Prebiotics also concerned with Different metabolic processes like absorption of mineral, metabolism of lipid, modification of intestinal microbiota modification may be modulate through prebiotics, by their beneficial effects of the immune system (Puthanapura et al., 2011). The load of bifidobacteria is enhanced which is calculated by detecting the growth population level of bifidobacteria in flora of gut, irrespective of the dose of Fructo-oligosaccharides (Roberfroid et al., 1998). With these, dietary components which contain prebiotic has been acted differently to elder people (Roberfroid et al., 1998).

The possible mechanism of action of prebiotics on elderly is shown in figure 3. There are some physiological changes takes place in elder people due to their diet disturbance like inadequate intake of food. Some possible sites of action of prebiotics are shown in figure 4.

Conclusion

Prebiotics are short chain carbohydrates (non-digestible oligosaccharides). These are non-digestible fibers that enhance the growth of beneficial bacteria in gut. The bacteria (e.g; bifidobacterium and lactobacilli) have beneficially effect on the health of host. The functional properties of prebiotics have developed the food products and use of food with these nutrients to inhibit the growth of harmful bacteria and stimulate the growth of beneficial bacteria which reduce the chances of diseases among population.

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