

Probiotics and Prebiotics: Unfolding Prospects for Better Human Health

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Abstract: Some bacteria have been perceived to promote good health of the host and thus are beneficial to host health. These have been called probiotics. Probiotics are live microorganisms which when administered in adequate amounts confer a health benefit on the host. Lactic Acid Bacteria (LAB) and bifidobacteria have been identified as probiotics. These bacteria when ingested change the composition of the intestinal microflora. Various beneficial effects are attributable to the consumption of these bacteria. These include prevention of diarrhea, immune system stimulation and prevention of colon cancer. However, their presence in the gut may be transient thus requiring a permanent implantation and colonization. Thus the concept of prebiotics. Prebiotics are non digestible food ingredients that beneficially affect the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon and thus improve host health. Prebiotics selectively stimulate the growth of probiotics resident in the gut especially bifidobacteria through the production of β -fructosidase, therefore changing the colonic microflora to a healthier composition. Prebiotics are non digestible oligosaccharides especially fructooligosaccharides. Some beneficial effects attributed to consumption of prebiotics include modulation of lipid metabolism through fermentation and increasing the absorption of minerals such as Ca and Mg from the colon. However, research data available show that the growth of lactobacilli is not selectively stimulated by the prebiotics. There is therefore need to conduct more research to determine the role of bacteriocins they produce in their ability to colonize the gut.

Key words: Probiotics, prebiotics, microflora, colon, beneficial effects, humans

Probiotics

Definition of probiotics: 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 basic nutrition (IFIC, 2006). Probiotics was derived from greek words which means "for life". The term "probiotics" was first introduced in 1953 by Kollath (Hamilton-Miller, 2003). An attempt on the definition of probiotics was made in 1989 by Roy Fuller who defined it like so; A live microbial supplement which beneficially affect the host animal by improving its intestinal microbial balance (Fuller, 1989). The definition by Fuller emphasized the requirement of viability for probiotics and introduced the aspect of a beneficial effect on the host. It can also be defined as "a preparation or product containing viable, defined microorganisms in sufficient numbers, which alter the microflora of the host intestine and by that exert beneficial health effects on the host (Schrezenmier and De Vrese, 2001).

However, according to the currently adopted definition by FAO/WHO, probiotics are live microorganisms which when administered in adequate amounts confer a health benefit on the host (FAO/WHO, 2001).

History of probiotics: Probiotics have been used for centuries as natural components in health promoting

foods. Recognition of probiotic effects of microorganisms dates back to the 19th century when the French scientist Louis Pasteur postulated the importance of microorganisms in human life (IFIC, 2006). The first observation of the positive role of certain microorganisms in human health was made by the Russian scientist and Nobel laureate Eli Metchnikoff in the early 20th century. He suggested that it would be possible to modify the gut flora by replacing the harmful microorganisms with beneficial microorganisms (Metchnikoff, 1907). He introduced the notion that ageing process was as a result of the activities of putrefactive bacteria in the colon which produce toxic substances that include phenols, indoles, ammonia etc. from the breakdown of proteins. He said that these compounds were responsible for what he called "intestinal auto-intoxication", which caused the physical changes associated with old age. He had also observed that certain rural populations in Europe such as Bulgaria and the Russian Steppes who lived largely on milk fermented by lactic acid bacteria were exceptionally long lived. Based on these facts, he proposed that consumption of fermented milk would "seed" the intestine with harmless lactic acid bacteria and decrease the intestinal pH which would suppress the growth of putrefactive (proteolytic) bacteria. He then decided to introduce in his diet sour milk fermented with an organism which he called

"Bulgarian Bacillus". His friends in Paris soon followed his example and then physicians began prescribing the sour milk diet for their patients (Vaughan, 1965). However, in 1920 some workers (Cheplin and Rettger, 1920) demonstrated that Metchnikoff's "Bulgarian Bacillus" which was later named *Lactobacillus bulgaricus*, could not live in the human colon. This led to disputations on the theory of Metchnikoff. In 1935 some workers (Rettger *et al.*, 1935) found that certain strains of *Lactobacillus acidophilus* could be very active when implanted in the human digestive tract. Trials were carried out using this bacterium and encouraging results were obtained, especially in the relief of chronic constipation. By the 1960s dairy industries began to promote the use of fermented milk products containing *Lactobacillus acidophilus* and in subsequent decades other *Lactobacillus* species were introduced such as *L. rhamnosus*, *L. casei* and *L. johnsonii* because they are intestinal species with beneficial properties (Tannock, 2003).

Criteria for use as probiotics: For a microorganism to be used as a probiotic certain criteria must be met (Fuller, 1989; Fuller, 1992). These include the following;

1. The probiotic must be capable of being prepared in a viable manner and on a large scale.
2. During use and under storage, the probiotic should remain viable and stable.
3. It should be able to survive in the intestinal ecosystem
4. The host animal should gain beneficially from harbouring the probiotic.

Also the organism must not be pathogenic to man or other animals.

Various microorganisms have been suggested for use as probiotics. They fall mainly within the group of Lactic Acid Bacteria (LAB) with strains of *Lactobacillus* sp. and *Bifidobacterium* sp. being the genera most widely used probiotic bacteria. These include *Lactobacillus acidophilus*, *L. casei*, *L. plantarum*, *L. reuteri*, *L. rhamnosus*, *L. delbrueckii*, *L. salivarius*, *L. helveticus*, *L. johnsonii*, *Lactococcus lactis*, *Bifidobacterium lactis*, *B. longum*, *B. infantis*, *B. breve*, *B. animalis* and *B. bifidum* (Gibson and Roberfroid, 1995; Sanders, 2007). Lactic acid bacteria have been used in the food industry for many years where they are used to convert carbohydrates in such food materials into lactic acid, responsible for the sour taste of some fermented dairy products such as yoghurt. This also lowers the pH to a level that prevents the growth of spoilage and pathogenic bacteria thus preventing various diseases transmissible through food such as gastrointestinal infections (Nicholas, 2007; Adams and Moss, 1999).

These bacteria are believed to assist the body's naturally occurring gut flora to re-establish themselves especially after antibiotic therapy. They are also believed to strengthen the immune system to combat allergies, excessive alcohol intake, stress, exposure to toxic substances and other diseases (Nicholas, 2007; Sanders, 2000). Maintenance of a healthy gut flora is, however, dependent on many factors, especially the quality of food intake. Including a significant proportion of a class of foods called prebiotics in the diet has been shown to support a healthy gut flora (Gibson and Roberfroid, 1995) and may be another means of achieving the desirable health benefits promised by probiotics.

Beneficial effects attributable to probiotics: There are several claims of the potential beneficial effects of probiotics. For many of the potential benefits, research is limited and only preliminary results are available. The benefits associated with probiotics are strain specific and must be shown through adequate clinical trials reflective of the dose of probiotic present in the food at the time of consumption (Gilliland and Walker, 1990; IFIC, 2006).

One area where there is good evidence for a beneficial effect is in the ability of fermented milks to alleviate the condition known as lactose intolerance (Adams and Moss, 1999; Sanders, 2000). All human infants possess the enzyme lactase (β -galactosidase). This hydrolyses lactose to glucose and galactose, thus they could be absorbed in the small intestine and metabolized. However, when the enzyme is absent the ingested lactose is not digested and will be attacked by the microbial population in the colon producing abdominal discomfort, flatulence and diarrhea. For such individuals when they take fermented milk such as yoghurt, these adverse effects are less severe or absent. This has been shown to be due to the presence of β -galactosidase in viable starter organisms (Adams and Moss, 1999).

Fermented milks (especially yoghurt) have been shown to have a strong inhibitory effect on the growth of coliforms in the stomach and duodenum of piglets and studies of human infants and adults have shown that the duration of illness (acute diarrhea and traveler's diarrhea) was shorter in those groups given yoghurt than in control groups (Adams and Moss, 1999; Reid *et al.*, 2003). Also in studies of children attending day care centres, changes in severity and duration of diarrhea after consumption of specific strains, were also observed (Weizman *et al.*, 2005). These days lactic acid bacteria such as *L. acidophilus* and bifidobacteria which can colonize the gut are now included in yoghurts and other fermented milks.

Probiotic bacteria have been reported to stimulate the immune system. Studies have shown that they possess the ability to activate macrophages and lymphocytes,

improve levels of IgA and production of gamma interferon (Reid *et al.*, 2003; Ouwehand *et al.*, 2002; Isolauri, 2001; Adams and Moss, 1999). Clinical trials have also demonstrated that probiotics may decrease the incidence of respiratory tract infections as well as dental caries in children (Hatakka *et al.*, 2001; Nase *et al.*, 2001). Certain probiotic strains have been shown to have a favourable effect on markers of the immune response to stress (Pujol *et al.*, 2000). Also a study among the elderly found an enhancement of immune function following consumption of milk supplemented with a *Bifidobacterium lactis* strain (Gill *et al.*, 2001). Some experts also believe that higher levels of bifidobacteria in the gut of breast-fed infants may be one reason why they are considered to be generally healthier than formula-fed babies (IFIC, 2006).

Probiotics have been shown to produce anti-mutagenic effects and anti tumor effects thought to be due to their ability to bind with heterocyclic amines (carcinogenic substances) formed in cooked meat (Wollowski *et al.*, 2001) and the production of high levels of IgA and interferon (Adams and Moss, 1999) which may prevent cancer cell formation. Most human trials have found that for the strains tested the possible mechanism of action may be by reduction in the activity of the enzymes β -glucuronidase, azoreductase and nitroreductase (Brady *et al.*, 2000; Adams and Moss, 1999). These enzymes, produced by components of the intestinal flora, can convert procarcinogens to carcinogens in the gut. Also lower rates of colon cancer among higher consumers of fermented dairy products have been observed in some population studies (Sanders, 2000; Saikali, 2004).

There are also some evidences showing that probiotics may reduce or lower serum cholesterol levels. It is believed that they bring about their hypocholestaemic action by breaking down bile in the gut thereby preventing their re-absorption into the blood as cholesterol. Some human trials have shown that dairy foods fermented with specific probiotics can produce modest reductions in total and LDL cholesterol levels in those with normal levels (St-Onge *et al.*, 2000;

Xiao *et al.*, 2003; Sanders, 2000). This area, however, requires further study.

Consumption of probiotics has also been reported to modestly lower blood pressure. It is thought that this is due to the ACE inhibitor-like peptides which are produced during fermentation (Sanders, 2000).

There are also reports indicating that probiotics in combination with standard medical treatments could be used in the treatment of peptic ulcers caused by *Helicobacter pylori* (Hamilton-Miller, 2003) as well as in the treatment of antibiotic associated diarrhea (Cremonini *et al.*, 2002).

Probiotic foods/supplements have also been reported to modulate inflammatory and hypersensitivity responses. These are believed to be partly due to the regulation of cytokine function (Reid *et al.*, 2003). Studies have also revealed that they can prevent the re-occurrences of inflammatory bowel disease in adults, acute gastroenteritis and improve milk allergies (Reid *et al.*, 2003; Isolauri *et al.*, 2002; Saggiro, 2004). Consumption of such foods also decreases the risk of atopic eczema in children (Kalliomaki *et al.*, 2003). It has also been suggested that probiotic lactobacilli may help in cases of malabsorption of trace minerals which occur when individuals consume foods high in phytate content (legumes, whole grains, nuts) (Famularo *et al.*, 2005).

Probiotic strains and products currently in use:

Probiotic products may come in several forms. They could be in the form of fermented milks, or they could be in the form of tablets, capsules, powders or sachets containing the bacteria in freeze dried forms. They could also be found in supplement form and as components of foods and beverages (IFIC, 2006). Today, probiotic-containing foods are commonly found and consumed in Japan and Europe (Sanders, 1999). In the USA, several probiotic-containing foods have recently been introduced into the marketplace (IFIC, 2006). Table 1 and 2 show the various probiotic strains, the producers and the proven probiotic effects observed in humans.

Table 1: Some probiotics in use and their effects on humans

Strain	Producer	Proven effect on humans
<i>Bifidobacterium animalis</i> subsp. lactis BB-12	Chr. Hansen	Immune stimulation, improves phagocytic activity, alleviates atopic eczema, prevents diarrhea in children and traveller's diarrhea.
<i>Bifidobacterium infantis</i> 35624	Procter and Gamble	Irritable Bowel Syndrome (IBS).
<i>Bifidobacterium lactis</i> HN019	Danisco	Immune stimulation.
<i>Lactobacillus acidophilus</i> NCFM	Danisco	Reduces symptoms of lactose intolerance, prevents bacterial overgrowth in small intestine.
<i>Lactobacillus johnsonii</i> Lal	Nestle	Immune stimulation, active against <i>Helicobacter pylori</i> .
<i>Lactobacillus reuteri</i> ATCC 55730.	BioGaia Biologics	Immune stimulation, against diarrhea.
<i>Lactobacillus rhamnosus</i> LB21	Norrmejerier	Immune stimulation, improves digestive health, reduces antibiotic-associated diarrhea.
<i>Lactococcus lactis</i> L1A	Norrmejerier	Immune stimulation, improves digestive health, reduces antibiotic-associated diarrhea.

Some are also administered as a mixture of the various probiotics. These are listed below

Table 2: Probiotic strains administered as a mixture

Strains	Producers	Proven effects on humans
<i>Lactobacillus rhamnosus</i> GR-1 and <i>Lactobacillus reuteri</i> RC-14	Chr. Hansen	Oral ingestion results in vaginal colonization and prevention of vaginitis.
Mixture of 8 strains of <i>Streptococcus thermophilus</i> , 4 <i>Lactobacillus</i> spp. and 3 <i>Bifidobacterium</i> spp. strains	Sigma-Tau Pharmaceuticals Inc.	Positive effects with intestinal ulcers and inflammation.
<i>Lactobacillus helveticus</i> R0052 and <i>Lactobacillus rhamnosus</i> R0011.	Institut Rosell.	Prevents diarrhea in children, prevents upset stomachs for patients on antibiotics, active against <i>Helicobacter pylori</i> .

Prebiotics: The large intestine is by far the most heavily colonized region of the digestive tract, with up to 10^{12} bacteria for every gram of gut content. Through the process of fermentation, colonic bacteria are able to produce a wide range of compounds that have both positive and negative effects on gut physiology as well as other systemic influences (Gibson and Roberfroid, 1995). It is therefore important to manipulate the content of the gut flora with the view to increasing the numbers and activities of the presumed probiotics and reducing those of the pathogens. This can be brought about by the supplementation of human diet with some food ingredients that have been termed prebiotics.

A prebiotic is 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 and thus improves host health (Gibson and Roberfroid, 1995). Therefore intake of prebiotics can significantly modulate the colonic microflora by increasing the number of specific bacteria and thus changing the composition of the gut bacteria to favour the probiotics (IFIC, 2006).

Criteria for food material to be a prebiotic: As was found in the probiotics, for a food material to be used as a prebiotic certain criteria must be met (Gibson and Roberfroid, 1995; Gibson, 1999). These are as follows; It must be neither hydrolyzed nor absorbed in the upper part of the gastrointestinal tract.

It must be a selective substrate for one or a limited number of beneficial bacteria commensal to the colon, which are stimulated to grow and/or are metabolically activated.

It must consequently, be able to alter the colonic flora in favour of a healthier composition.

It must induce luminal or systemic effects that are beneficial to the host health.

Based on these criteria listed, only a few groups of food ingredients qualify to be used as prebiotics. A good number of food materials because of their chemical structure are not absorbed in the upper part of the GIT or hydrolyzed by the digestive enzymes in humans. Such foods have been called "colonic foods" (Gibson and Roberfroid, 1995) i.e, foods entering the large intestine which also serve as food for the endogenous microorganisms.

Amongst these colonic foods are non digestible carbohydrates, some peptides and proteins. The use of peptides and proteins as prebiotics will have a major

problem; their anaerobic decomposition is likely to produce potentially harmful compounds such as ammonia and amines (Macfarlane and Cummings, 1991), although they may have some beneficial effects both by facilitating the intestinal absorption of cations (mainly calcium and iron) (Scholz-Ahrens *et al.*, 2001) and by stimulating the immune system (Gibson and Roberfroid, 1995; Saavendra and Tschemia, 2002; Cummings and Macfarlane, 2001).

Delzenne and Roberfroid (1994) have grouped non digestible carbohydrates to include resistant starch, non digestible oligosaccharides and non starch polysaccharides such as hemicellulose, pectins, gums and plant cell wall polysaccharides (Table 3).

Although these food materials get to the colon unabsorbed in the upper gastrointestinal tract and undigested by human digestive enzymes they could not be classified as prebiotics as they stimulate in the large intestine the growth and/or metabolic activity of several different bacterial species that could be beneficial and harmful to the host (Drasar *et al.*, 1976; Salysers *et al.*, 1982).

Studies on non digestible oligosaccharides have shown that the fructooligosaccharides and galactooligosaccharides are those that have been found to selectively stimulate the growth and/or metabolic activity of the potentially beneficial bacteria (probiotics) in the colon (Roberfroid *et al.*, 1998; Gibson and Wang, 1994a,b; Wang and Gibson, 1993; Rowland, 1992; Ito *et al.*, 1990). Soy bean oligosaccharides have also been studied for their prebiotic potentials (Saito *et al.*, 1992; Hayakawa *et al.*, 1990) while the oligosaccharides of the African Oilbean seeds, starchyose and raffinose have been suggested as a possible prebiotic (Crittenden and Playne, 1996).

Table 3: Classification of certain carbohydrates as colonic foods and prebiotics

Carbohydrates	Colonic food	Prebiotic
Resistant starch	Yes	No
Non-starch polysaccharides		
Plant cell wall polysaccharides	Yes	No
Hemicelluloses	Yes	No
Pectins	Yes	No
Gums	Yes	No
Non-digestible oligosaccharides		
Fructooligosaccharides	Yes	Yes
Galactooligosaccharides	Yes	?
Soybean oligosaccharides	Yes	?
Glucosaccharides	?	No

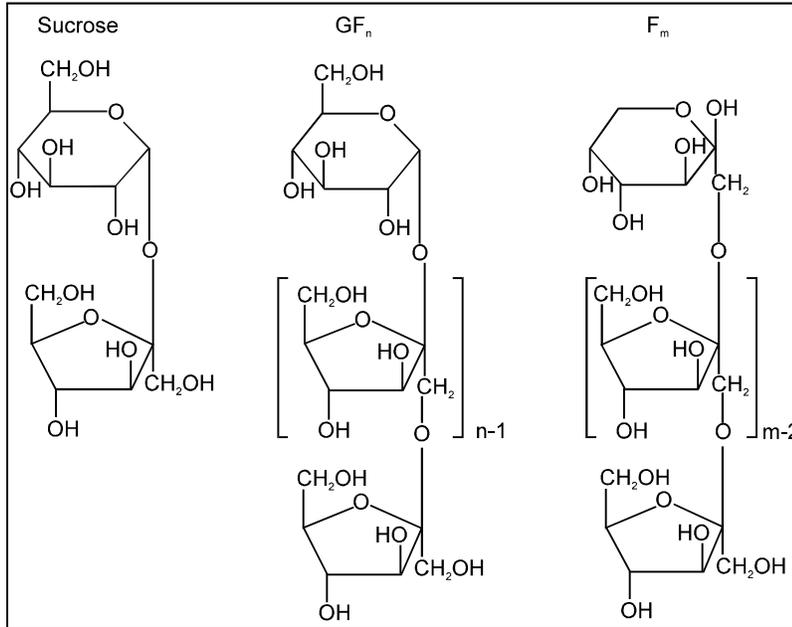


Fig. 1: Chemical structure of the various fructo oligosaccharides. G, glucose; F, fructose; n or m indicate the number of fructose moieties in the molecules

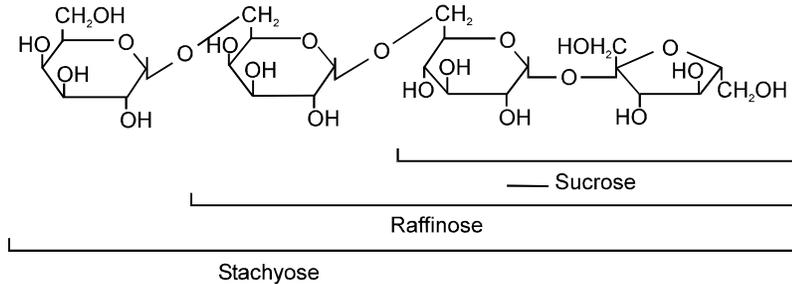


Fig. 2: Structure of some galactooligosaccharides

Chemical structure of prebiotics: Fructooligosaccharides are short- and medium-length chains of β -D fructans in which fructosyl units are bound by a β -1 fructosidic linkage.

In some of the molecules the initial moiety is glucose. This results from the transfer of a fructosyl moiety between two sucrose molecules during synthesis in plant cells (Edelman and Dickerson, 1966). Some workers (Stone-Dorshow and Levitt, 1986; Rumessen *et al.*, 1990) have shown that the β -1 fructosidic linkage including the first glucose-fructose bond is not hydrolyzed to a great extent by any mammalian digestive enzymes. Thus this accounts for its resistance in the digestive tract of humans.

Fructooligosaccharides can be classified into either oligofructose or inulin depending on the degree of polymerization. Oligofructose has a Degree of Polymerization (DP) of <9 (average DP=4.8) while inulin has DP of up to 60 (average DP=12) (Gibson and

Roberfroid, 1995). Inulin is obtained industrially by hot water extraction of fresh chicory roots (Gibson *et al.*, 1994) while oligofructose is produced by partial enzymatic hydrolysis of native inulin to give a product with an average DP of 4-5. Various other food materials have high content of oligofructose and inulin. These include artichoke, onion, garlic and asparagus (Van Loo *et al.*, 1995).

Galactooligosaccharides have chemical structures made up of fructose, glucose and galactose molecules. These are linked together by β -fructosidic and β -galactosidic linkages. Fructose is usually the starting molecule in the oligosaccharide (Salunkhe *et al.*, 1992). The most common types of galactooligosaccharides are stachyose, made up of one fructose, one glucose and two galactose molecules and raffinose made up of one fructose, one glucose and a galactose molecule (Iwe, 2003). These are common constituents of various legumes such as soy bean, African Oilbean and African Bread Fruit (Iwe, 2003).

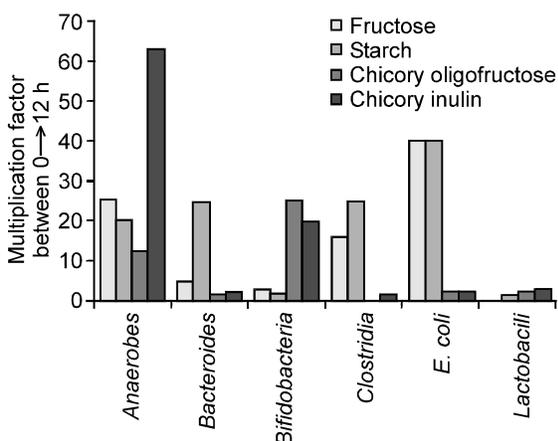


Fig. 3: Changes in the numbers of various bacteria of human faeces after the *in vitro* incubation for 12 h in the presence of 7 g/L of fructose, starch, oligofructose and inulin

Specificity of prebiotics: Bifidobacteria have been identified as preferred target microorganisms for prebiotics (Gibson *et al.*, 1995). Experimental evidences using human faecal bacteria *in vitro* have shown that fructooligosaccharides (and galactooligosaccharides) are fermented by gut bacteria with a resultant decrease in pH of the medium during anaerobic fermentation (Gibson and Wang, 1994b; Wang and Gibson, 1993). Also studies by Wang and Gibson (1993) have shown that fructooligosaccharides in comparison with other simple and complex carbohydrates (fructose and starch) are selectively fermented by most strains of bifidobacteria (Fig. 3) and were found to increase in population while other bacteria (bacteroides, clostridia and coliforms) decreased in number. Some workers have demonstrated that the specificity of the bifidobacteria to utilize fructooligosaccharides may likely be due to the presence of β -fructosidases or 2,1 β -fructanohydrolase (Roberfroid *et al.*, 1998).

Gibson and Wang (1994a) have been able to demonstrate that under anaerobic conditions obtainable in the gut chicory fructooligosaccharides, but not glucose, could selectively stimulate the growth of bifidobacteria over other species present. Using continuous chemostat cultures inoculated with 160 g/L

of faecal slurries they showed that these bacteria (bifidobacteria) were almost three orders of magnitude higher than bacteroides while glucose as substrate produced two orders of magnitude higher than bifidobacteria (Table 4).

Gibson *et al.* (1995) have conducted *in vivo* studies using human volunteers. These volunteers were fed on strictly controlled diets to which chicory fructooligosaccharides were added as supplements at the rate of 15 g per day for 15 days. This they reported significantly modified the composition of the bacteria in the gut with marked increase in the number of bifidobacteria. They observed a marked decrease in the numbers of other bacteria (clostridia, bacteroides and fusobacteria) when oligofructose was administered. Kleessen *et al.* (1994) and Kleessen *et al.* (1997) also have demonstrated that supplementation of diet with 20 g per day and 40 g per day of inulin significantly ($p < 0.01$) increased the population of bifidobacteria in faeces of the elderly from $10^{7.9}$ to $10^{8.8}$ and $10^{9.2}$, respectively.

The effect of ingestion of milk fermented with *Bifidobacterium* sp. on human health with or without inulin has been studied by Bounhik *et al.* (1996). Those that contained inulin were administered at the rate of 18 g per day. They concluded that bifidobacterium fermented milk substantially increased the population of the bifidobacteria in the gut, but the concurrent administration of inulin did not enhance the effect. Interestingly two weeks after stopping the consumption of the fermented milk the volunteers who received inulin had a significant increase in the number of bifidobacteria compared with those that received the fermented milk only, although they did not study the effect on the population of other bacteria present. Roberfroid *et al.* (1998) therefore stated that the study tried to study a "symbiotic" effect rather than a prebiotic effect. The theory of symbiosis has been proposed by Gibson and Roberfroid (1995).

Other workers (Roberfroid, 1997) have also reported significant increase in faecal bifidobacteria counts with concomitant decrease in *Bacteroides* sp. in humans fed with controlled diets supplemented with 8g per day of chicory oligofructose. Thus this shoes that oligofructose has bifidogenic effect in the gut of humans. Some mechanisms have been proposed as to how the bifidobacteria bring about the inhibition of other bacteria.

Table 4: Composition of the microflora of human faecal slurries after six turnovers in single-stage continous fermenters containing glucose, oligofructose or inulin as the growth substrate (10 g/L)(log₁₀ of viable bacteria per litre of medium)

	Glucose	Chicory oligosaccharides	Chicory inulin
Anaerobes	13.4	12.6	12.1
Bacteroides	12.0	9.4	9.3
Bifidobacteria	10.0	12.7	12.1
Clostridia	9.9	8.4	9.6
Coliforms	5.3	5.5	5.3
Lactobacilli	10.5	7.3	<8
Difference Log ₁₀ Bifidobacteria-Log ₁₀ Bacteroides	-2.0	+3.3	+2.8

These include the decrease in pH of the growth medium due to the production of various organic acids mainly acetate and lactate (Gibson and Roberfroid, 1995). Another mechanism is the production of bacteriocin-type substances which inhibit various bacteria such as *Clostridium* and *E. coli*. Some workers have also worked on synthetic fructooligosaccharides (Mitsuoka *et al.*, 1987; Bouhnik *et al.*, 1994; Buddington *et al.*, 1996). In all they reported an increase in the bifidobacterial counts in faeces after administering their oligosaccharides at 4, 8 and 12.5 g per day, although no information was given on the effect of the supplementation on the other types of bacteria present. Therefore the results could not conclusively prove that they are selective in their action. This doubt has also been expressed by Roberfroid *et al.* (1998).

Beneficial effects of prebiotics: Some beneficial effects have been attributed to the consumption of these prebiotics. It is believed that their beneficial effects result from the metabolism of these compounds. Fermentation of these oligosaccharides results in the production of various organic acids and CO₂. Delzenne and Roberfroid (1994) have stated that the balance of such a complex process is likely to produce 40% Short Chain Fatty Acids (SCFA), 15% lactic acid and 5% CO₂. Therefore based on this calculation Delzenne and Roberfroid (1994) and Roberfroid *et al.* (1993) have proposed that the caloric value of fructooligosaccharides must be on the order of 4.2-6.3 KJ/g (1.0-1.5 kcal/g) or 25-40% that of a digested fructose molecule. Thus such generated SCFA and lactic acid can be absorbed from the colon of the host for generation of energy. For example, butyrate is utilized by the colonic epithelium, propionate, L-lactate and acetate (partly) by the liver and acetate (partly) by muscle and other peripheral tissues (Schumann *et al.*, 1991; Demigne *et al.*, 1986; Remezy and Demigne, 1983).

Some workers have also suggested that highly fermentable carbohydrates could, possibly through production of SCFA and lactate in the colon, improve the metabolic absorption of various ions such as Fe, Ca and Mg (Scharrer and Lutz, 1992; Shulz *et al.*, 1993; Scholz-Ahrens *et al.*, 2001), in fact Delzenne and Roberfroid (1994) have been able to demonstrate that consumption of such oligosaccharides (oligofructose and inulin) can produce up to 60-65% intestinal uptake of these ions. However, this effect varies according to the individual non-digestible oligosaccharide and particular human population studied and the amount consumed as well as its specific fermentation profile (Saggiro, 2004).

Some workers have also suggested that acetate and propionate, possibly in combination with l-lactate may be involved in regulating lipid and cholesterol metabolism (Gibson and Roberfroid, 1995; Demigne *et al.*, 1986). Some workers have also demonstrated in rats that

consumption of feed supplemented with 10-15% fructooligosaccharides induced a significant reduction in total body carcass fat deposition, triglyceridemia (by 25%) (Delzenne *et al.*, 1993; Fiordaliso *et al.*, 1995). The reduction has been suggested to be due to the reduction of circulating VLDL particles. Thus the hepatic metabolism of lipids in the rats may have been modified (Gibson and Roberfroid, 1995). Thus in hyperlipidemic subjects, when a prebiotic effect is seen, it is a reduction in cholesterol whereas in normal-lipidemic subjects, any noted effects are on serum triglycerides (Pereira and Gibson, 2002).

While some of the prebiotic beneficial effects on the function of the human gut have been established and their favourable impact on health widely supported, further scientific research is ongoing to substantiate their direct relationship to disease risk reduction (IFIC, 2006; Roberfroid, 2000).

Conclusion: From all the data available it could be noted that fructooligosaccharides selectively stimulate the growth of bifidobacteria especially the oligofructose. These bacteria (bifidobacteria) are able to utilize them through the process of fermentation since it has been observed that their growth is accompanied with drop in pH of faecal slurries (Gibson and Wang, 1994b). The supplementation of such bifidobacteria in fermented milk products is likely to increase their ability to outgrow other species in the gut especially when prebiotics are provided. Thus the concept of "synbiotics" which is a combination of the probiotics and prebiotics as advanced by Gibson and Roberfroid (1995) could be explored. Some products are, however, available that contain *Bifidobacterium sp.* (Sanders, 2007). It is also observed that in all the experiments no mention was made of the lactobacilli resident in the gut or those consumed in fermented foods. This therefore calls to question the use of these lactobacilli in fermented milks, whether they will be able to really colonize the gut upon implantation even when fructooligosaccharides are administered. What this means is that there has to be a constant consumption of such fermented milks to maintain a relatively high population of the lactobacilli for them to be able to exert their probiotic effects. Since these fructooligo-saccharides are not selectively utilized by the lactobacilli (Wang and Gibson, 1993) they will be open to the stiff competition that goes on in the large gut, unless they have other means of outwitting other competitors in the gut. Thus it may be that their ability to produce bacteriocins could help them outgrow their competitors and colonize the gut. It is therefore necessary that studies be conducted in vivo using human volunteers to determine the role of these bacteriocins in their ability to outgrow competitors and colonize the gut. In fact one of such lactobacilli, *Lactobacillus reuteri*, a natural

inhabitant of the human gut has been found to produce reuterin and reuteri-cyclin when they grow. This bacterium has been targeted a special probiotic because it is an inhabitant of the gut and the substances it produces reduce or prevent the growth of many bacteria including Gram positive and Gram negative bacteria (Pszozola, 2002). The use of special delivery systems that will enable them implant and colonize the gut of the host should be developed. Already a company, Bio Gaia AB, Stockholm, Sweden has developed a special delivery system for *L. reuteri* in a product called LifeTop which has been exhibited in USA (Pszozola, 2002).

It is also necessary that the concept of synbiotics be properly further investigated as some workers (Orrhage *et al.*, 2000) have demonstrated that administration of probiotics and prebiotics after antibiotic therapy helped reestablish the beneficial bacteria. Probiotic and prebiotic formulas are proving very popular and are advertised at various places (Collier, 2004) and this is because evidence that they promote good health is strong (Gibson, 2003).

Oligosaccharides are known to cause flatulence and distension in some individuals that consume them (Ruiz-Terans and Owens, 1999). Thus the use of these oligosaccharides as prebiotics can also result in the discomfort of the consumers. However, researches have not been conducted to determine the best levels of administration of the prebiotics to bring to the barest minimum the problem of flatulence and distension while still maintaining the prebiotic effects attributable to them. Such studies will try to produce an internationally acceptable dosage of the prebiotics for maintaining the good health and general wellbeing of the consumers.

Another important aspect that needs consideration is the possibility of these probiotics acquiring virulence from pathogens in the gut. This needs to be investigated and prevented so that these probiotics will remain the health promoting bacteria they are meant to be.

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