Implications of Prebiotics and Probiotics for Human Health and Wellbeing

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Abstract

The human gut microbiome have a critical role in wellness and ailments affected by dietary components, including prebiotics and probiotics. Prebiotics, the non-digestible carbohydrates act as a substrate for useful bacteria in gut increasing immune and metabolic functions while reducing the tendency of pathogeneses. Key prebiotics involved in Gut microflora modulation are resistant starches, galactooligosaccharides and fructans. Probiotics are the live micro-organisms like Bifidobacterium and Lactobacillus species having potential health benefits like better digestion, improved immunity, and reduced incidence of gastrointestinal ailments. Emerging research is greatly highlighting the medicinal and therapeutic potential of modulation of gut microbiota in prevention of obesity, cancer, cardiovascular diseases etc. Supplements and fermented foods are the chief source of probiotics. However, their efficacy is greatly dependent on viability and specificity. Further research studies need to focus on personalized interventions targeting to optimize probiotic formulations and their safety regulations in clinical study to minimize the chances of hazard to the consumers. Current chapter is intended to explore the possible mechanisms of pre and probiotics in diseases prevention, treatment and functionality of human gut microbiota.

Keywords: Gut microbiota, Non-digestible fiber, Immune and metabolic functions, Pathogenesis, Therapeutic potential

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Introduction

The alimentary canal is composed of many species of microbial organisms, termed the intestinal microbiome. There have been claims that the human colon contains live microorganisms ranging from 10^{10} to 10^{12} per gram (Collins & Reid, 2016). The inhabitant microbial group in the gastrointestinal tract is essential for the well-being of humans. A significant number of microbial organisms, which are mainly anaerobic, inhabit the colon (Louis et al., 2016). The intestinal microbiome, which plays a significant role within the host under normal and diseased conditions. Various conditions support the establishment of the gut flora of humans throughout early childhood. Dietary habits are recognized as a major contributor to developing the intestinal microbiome throughout life. Gut flora supports immunological and metabolic processes and defends in contrast to pathogenic microorganisms. The change in gut microbiota (dysbiosis) is connected to the progression of various inflammation-related conditions and infectious diseases (Mohammed, 2019).

Prebiotics consists of indigestible fiber that travels along the upper alimentary canal without being digested and promotes advantageous bacteria in the colon by functioning as a substrate (Hutkins et al., 2016). Prebiotics and probiotics and their health benefits for human health and well-being have gained significant importance in the current era worldwide. Research on the gut microbiome has grown significantly over the last ten years, and probiotics and prebiotics have gained popularity as ways to alter the gut flora (Obayomi et al., 2024). Evidence supporting the prebiotic benefits of various substances (such as oligomers of mannose, glucose, xylose, pectin, starches, human milk, and polyphenols) is growing. At the same time, glucans and fructans are well-established prebiotics (Bevilacqua et al., 2024). This chapter will keenly focus on the interplay of pre and pro biotics in health and wellbeing. Keeping in view the unique attributes of prebiotics and probiotics, contemporary chapter has following objectives:

1. To explore the mechanisms behind the influence of prebiotics and probiotics on the composition as well the functionality of human gut microbiota
2. To discuss the therapeutic potential of prebiotics and probiotics in management of GIT and systemic diseases

2. Human Gut Microbiota and Prebiotics

The bacteria serve multiple purposes, comprising the transformation of macronutrients from the diet into metabolic products, which may affect host health positively or negatively. Prebiotics consist of indigestible fiber that travels along the upper alimentary canal without being digested and promotes advantageous bacteria in the colon by functioning as a substrate. In 1995, Marcel Roberfroid initially recognized and also termed them as Prebiotics (Hutkins et al., 2016). Prebiotics, similar to probiotics, are considered functional food factors that bridge the gap between food and pharmaceuticals. In March 2007, a more precise statement was proposed by Roberfroid in the *Journal of Nutrition* declaring: "The prebiotics are fermentable substances which enable particular modifications in the composition and activity in the gut microbiota which provides beneficial effects on quality of life and wellness" (Roberfroid et al., 2007).

Furthermore, as stated in the 2007 reanalysis of prebiotics, Roberfroid claimed that merely two specific prebiotics completely satisfied the statement: inulin and T-GOS (trans-galacto-oligosaccharide). However, different types of fibers such as xylo-oligosaccharides (XOS) Larch-derived arabinogalactan, beta-glucans, dietary-resistant starch and pectin fiber also meet the statement about prebiotics outlined by Roberfroid in 1995.

2.2. Types of Prebiotics

There are many types of prebiotics. Many of them are categorized into groups of carbohydrates and carbohydrate oligosaccharides.

2.2.1. Fructans

This type includes inulin and fructo-oligosaccharide. The molecular structure is a linear fructose chain linked by β (2→1) bonds. Typically, the terminal position contains glucose units connected by β (2→1) bonds. The polymer chain length of inulin is to the extent of 60, whereas the polymer chain length of fructo-oligosaccharide is below 10 (Louis et al., 2016). Fructans promote other beneficial species of bacteria, in one way or another. In the past, certain research indicates that fructans can promote lactic acid bacteria specifically (Hutkins et al., 2016).

2.2.2. Galactooligosaccharides

The galactooligosaccharides are categorized into 2 subsets: (i) the galactooligosaccharides containing excess galactose at C_3, C_4, or C_6, and (ii) the galactooligosaccharides derived from lactose with the help of enzyme facilitated trans-glycosylation. This reaction commonly leads to a mixture of tri- to pentasaccharides with galactose linked with β (1→6), β (1→3), and β (1→4) bonds is the outcome of this reaction (Macfarlane et al., 2008). Galacto-oligosaccharides can support *Lactobacilli* and *Bifidobacteria*. *Bifidobacteria* highlighted high integration with GOS in infants. GOS stimulates *Enterobacteria*, *Bacteroidetes*, and *Firmicutes*, but less significant than *Bifidobacteria* (Louis et al., 2016).

2.2.3. Starch and Glucose-derived Oligosaccharides

A type of starch that is present in the upper digestive tract is called resistant starch. Resistant starch produced elevated butyrate levels to stimulate well-being. Research evidenced that resistant starch can also be deteriorated by *Bifidobacterium adolescentis* and *Ruminococcus bromii*, also mildly affected by *Bacteroides thetaiotaomicron* and *Eubacterium rectale*. Conversely, *R. bromii* is crucial for the degradation of resistant starch (RS), in bacterial-fecal cultures (Ze et al., 2012).

2.2.4. Other Oligosaccharides

Pectin can give rise to certain oligosaccharides. It is known as pectic oligosaccharide. They originate from the prolongation of rhamnose or galacturonic acid. Methyl esterification can substitute the carboxyl groups, and the structure is subject to acetylation at C_2 or C_3. Different forms of sugars or ferulic acid are connected with side groups (Yoo et al., 2012). Their formation substantially relies on the pectic oligosaccharide sources (Gullón et al., 2013).

2.2.5. Non-carbohydrate Oligosaccharides

However, carbohydrates tend to satisfy the requirements of the prebiotics definition, certain substances are not categorized as carbohydrates, yet, they are regarded as prebiotics, like flavanols derived from cocoa. In vitro and in vivo investigation indicates that lactic acid-producing bacteria are stimulated by flavanols (Tzounis et al., 2011).

2.3. Action Mechanism of Prebiotics

It is assumed that prebiotics make their way to the gut and are specifically used. Microbial growth can stimulate fecal bulking and bowel habits. Microbial pathogens and mineral absorption are affected by metabolites involving acidic organic compounds that reduce the pH of the intestines. Metabolites can also affect the integrity of the epithelial layer and the regulation of hormone levels. Bacteria responding to intake of prebiotics can impact the microbiome setup by producing microbe-targeting compounds and competitive processes, potentially decreasing pathogenic infections and microorganisms comprising lipopolysaccharides (Yamashiro, 2022).

The intestinal epithelium and gut flora are essential elements that have an antagonistic effect in contrast to microbial infiltration in the gastrointestinal tract, restricting pathogenic organisms like *Salmonella* spp, *E. coli*, *Campylobacter*, and other bacterial pathogens (Gibson & Wang, 1994). Here are five potential functions that involve: acidic by-products of metabolism(acids) which reduce the colonic pH under the pathogenic bacteria levels, competitive impact because of the limited number of sites for colonization, antagonism via inhibitory peptides, competitive interaction for inadequate nutrients, and improvement of the immunological system (Gibson et al., 2005).

SCFAs, produced by prebiotic dietary-fiber fermentation, may also help with enhancing gut defense mechanisms (Suzuki et al., 2008). Oligo-fructan is indicated to stimulate specific microbiota change (*Bifidobacterium* spp), increasing innate production of glucagon-like peptide-2, consequently enhancing gut defense mechanisms also offering stronger junctions and lower inflammation (Cani et al., 2009). Natural killer cells, B cells, T_{REG} cells and effector T cells are all impacted by prebiotics and the metabolic products that are synthesized as a result of fermentation. In particular, butyrate has been indicated to influence T cells, dendritic cells and macrophages (Frei et al., 2015).

2.4. Sources of Prebiotics

Prebiotics have a significant effect on the health of individuals. Prebiotics occur naturally in various dietary products, including wheat, barley, rye, soybean, tomato, asparagus, garlic, peas, beans, onion, Jerusalem artichoke, honey, sugar beet, banana, cow's and human's milk, and chicory. They are produced on industrial scales as a result of their subtle concentration in foods. Few of them are derived from starch, sucrose, and lactose as crude materials (Yamashiro, 2022). Mostly prebiotics are categorized as galacto-oligosaccharides and fructo-oligosaccharides on a commercial scale.

3. Probiotics

The term Probiotics became more commonly used in the post-1980. The emergence of the notion is commonly linked with Élie Metchnikoff, who proposed that Bulgarian farmers who consume yogurt, had longer lifespans due to this practice. In 1907, he offered that "the dependability of the gut microorganisms upon the food enables it to integrate approaches to alter the gut flora in our bodies also exchange the pathogenic microorganisms by beneficial microorganisms". In 2001, the World Health Organization proposed a definition of probiotics "viable microbes that, when taken in enough quantities, impart a benefit upon host health". Probiotics efficacy of administration is contingent upon the organism being alive (Sanders et al., 2019).

3.2. Identification of Probiotics

Probiotics are recognized by their specific strain, which comprises the species, the subspecies (if applicable) the genus, and an alphanumeric strain designation (Table 1). The seven core genera of microorganisms commonly incorporated in probiotic preparations are *Bacillus, Escherichia, Streptococcus, Bifidobacterium, Enterococcus, Streptococcus, Saccharomyces* and *Lactobacillus* (NIH, 2023).

Table 1: Nomenclature for sample commercial strains of probiotics

Genus	Species	Subspecies	Strain designation	Strain nickname	Reference
Bifidobacterium	*longum*	longum	35624	Bifantis	(Guarner et al., 2024)
Lactobacillus	*rhamnosus*	none	GG	LGG	
Bifidobacterium	*animalis*	lactis	DN-173 010	Bifidus regularis	

3.3. Mechanism of Action of Probiotics

The alimentary canal is inhabited by various microbes, containing bacterial organisms, archae-bacteria, pathogens, fungi, and protozoans. Human health can be affected by the activity of these microbes (collectively recognized as the gut microbiome) (Zmora et al., 2018). Probiotics also impose health impacts by strain-specific, species-specific, and nonspecific mechanisms (Hill et al., 2014). Strain-specific mechanisms are exceptional and are utilized by a limited number of strains of a particular species, involving cytokine activity, immune system regulation, and impact upon the endocrinological and neural pathways. Species-specific mechanisms involve the vitamin biosynthesis process, intestinal permeability regulation, metabolic processing of bile salts, enzyme action, and antitoxin activity. The nonspecific mechanisms differ significantly among strains, species, or even genera of commonly used probiotic supplements. These mechanisms involve restriction of the development of infectious agents in the alimentary canal, formation of metabolic products, and decrease in intestinal lumen pH in the large intestine.

Consequently, the effects of probiotics could be distinct to particular species and strains of probiotics, clinical and research studies are needed to be specific to the type and strains (Zmora et al., 2018). Additionally, various study types of probiotics can lead to misleading conclusions concerning their effectiveness and defensiveness.

3.4. Sources of Probiotics

3.4.1. Food

The microbial growth and metabolic functions of a wide range of living microorganisms produce fermented foods. Multiple foods in this category are abundant sources of active and possibly friendly bacteria. Fermented food products, especially yeast-fermented bread and most commonly available pickles, are processed when they are fermented and do not include viable cultures in their consumable form. Most of the commercially available yogurts, a different type of fermented products, include beneficial microbes, especially *L. bulgaricus* and *S. thermophilus*.

The viable microbes used to produce various fermented food products, such as curd, usually endure successfully in the product throughout its storage life. However, it is common for them to not endure transit via the stomach and may not resist deterioration in the small intestine caused by enzymes involved in hydrolysis and bile acids, limiting their ability to arrive at the lower gastrointestinal tract. However, authentic healthy bacterial cultures found within curd or other additional foods withstand intestinal transit. Fermentation-based foods which comprised of active cultures though do not usually compose of authentic probiotic microbes involve sauerkraut, kombucha, cheese varieties, kimchi, unpasteurized apple cider vinegar, pickles, and miso produced by apple sugar fermentation (Kessler, 2020).

3.4.2. Dietary Supplements

The probiotics can also be provided as nutraceuticals comprising a diverse range of types and amounts. The combined cultures of microbes instead of monocultures are present in these products. The impacts of various manufactured goods comprising probiotics are still not investigated in scientific investigations, and it remains complicated for individuals unfamiliar with studies regarding probiotics to figure out what kind of products are supported by research. However, certain institutes have thoroughly evaluated the existing research and formulated guidelines about particular probiotics—involving appropriate dosage, products, also composition—to adopt for the prevention and treatment of multiple medical issues (Szajewska et al., 2014).

The colony forming units (CFU) are used to measure probiotics, which represent the number of active units. Product labels possibly show the amount as, for instance, CFUs of 1 billion having 1×10^9 or CFUs of 10 billion having 1×10^{10}. Usually, 1 to 10 billion CFU per dose is present in probiotic products, though certain products comprise as many as CFUs of 50 billion or above (Szajewska et al., 2014).

3.4.3. Health Benefits of Probiotics

There is emerging evidence for claims of beneficial outcomes associated with probiotics, comprising improving gastrointestinal well-being, boosting immunological defense, drop in serum lipid levels, also inhibition of cancer development (Table 2). The effect of probiotics on individual well-being has been investigated across a broad range of factors, along with a wide range of research dedicated to digestive disorders, allergic conditions, infections of the respiratory tract, endocrine disorders, circulatory function, mental health conditions, bone density, autism, gynecological health issues, overweight, fatty liver (NAFLD) and liver dysfunction encephalopathy, atopic dermatitis and thermal burns (Kechagia et al., 2013).

Table 2: Therapeutic effects of probiotics

Sr. no.	Condition	Probiotics	Potential benefits	References
1.	Kidney/Urinary stones	*Oxalobacter formigenes*	Helps in modification and degradation of urinary stones	(Siener et al., 2013)
2.	Atopic Diseases	*Lactobacillus fermentum, L. rhamnosus Lactis, Lactobacillus GG*	Atopic eczema and Atopic dermatitis reduction was observed dependent on specific probiotic Strains, administration time, exposure duration and dose.	(Yesilova et al., 2012)
3.	Colic	*S. thermophilus, L. casei, B. breve, L. acidophilus, L. rhamnosus, B.infantis*	Reduced colic incidence in breastfeeding infants and children	(Kianifar et al., 2014)
4.	Constipation	*Bifidobacterium species, Lactobacillus species*	They can help in alteration and restoration of disturbed community in GIT. Moreover they can improve and manage gut transit time, stool consistency and frequency	(Sadeghzadeh et al., 2014)
5.	Irritable bowel syndrome	*L. acidophilus, L. casei, L. plantarum, S cerevisiae, B.lactis,*	Alleviated and managed IBS symptoms	(Ortiz et al., 2014)

4. Probiotics Health Benefits Related to Intestinal Diseases

4.1. Antibiotic-associated Diarrhea

Normal gut flora is usually inhibited by common adverse effects of antibiotic treatment, such as moderate or severe diarrhea episodes, lifting the excessive growth of contingent or disease-causing strains. Cure with *Streptococcus* species, Lactobacillus species, Saccharomyces species, *Bacillus* species, *Lactococcus* species, *Bifidobacterium* species, or *Leuconostoc cremoris*, independently or collectively were proven to have a defensive impact in hindering diarrhea associated with antibiotics (Fontana et al., 2013).

4.2. Rotavirus Diarrhea

Acute infantile diarrhea is caused by rotavirus across the globe and is a major contributor to the infant death rate. Medical research studies have demonstrated that probiotics like *Bifidobacterium animalis* Bb12*, Lactobacillus casei Shirota*, *Lactobacillus reuteri, Lactobacillus rhamnosus* GG may reduce the period of acute rotavirus diarrhea with the definitive proof indicating the efficiency of *B. animalis* Bb12 and *L. rhamnosus* GG (Kechagia et al., 2013).

4.3. Travelers' Diarrhea

Diarrhea is prevalent in people traveling to hotter regions and underdeveloped nations by 50%. About this, a systematic review indicated a defensive impact by a combination of *Bifidobacterium bifidum* and *Lactobacillus acidophilus* with *Saccharomyces boulardii* (Guarino et al., 2009).

4.4. Irritable Bowel Syndrome

A chronic condition, exhibiting an effect on 3-25% of individuals for whom there is no impactful cure available. Therefore, treatment is intended to minimize the symptoms (Fontana et al., 2013). Findings from a study indicate an escalation in patients with significant improvement in symptoms of irritable bowel syndrome after getting a probiotic mixture of *Streptococcus thermophilus LA104, Lactococcus lactis LA103, Lactobacillus acidophilus LA102, Bifidobacterium longum LA101* (Drouault-Holowacz et al., 2008). Another study indicated that the administration of bacterial lysate of *Escherichia coli* and *Enterococcus faecalis* considered to be efficient in mitigating irritable bowel syndrome symptoms (Enck et al., 2008).

4.5. Inflammatory Bowel Disease

It consists of various gut-related conditions. Crohn's disease and ulcerative colitis are the two main types; that are caused by long-term inflammatory conditions of the mucosa. In patients with Crohn's disease, the non-pathogenic strain of *E. coli* Nissle 1917 is efficient in prohibiting recurrence, and *S. boulardii* is effective in reducing the Crohn's disease symptoms also alleviating the risk of a recurrence (Maurya et al., 2014).

4.6. Lactose Intolerance

Inadequate lactase production also known as milk tolerance results from genetic variation where there is a deficiency of lactase (beta-galactoside) which inhibits one's ability to make the glucose and galactose sugars from lactose molecule. For such individuals, intake of lactose-containing products like milk leads to the onset of diarrhea, offensive rumbling of the stomach, pain in the tummy, and gas problems. Some outcome was achieved thanks to the application of thermophilic *Streptococcus* and lactic acid-producing bacterium whose effect is partly due to increased lactose-hydrolyzing enzyme (beta-galactosidase) activity (Kechagia et al., 2013).

4.7. Allergy

The efficiency of different numbers of strains in the healing and shielding of allergies among newborns has been tested on a limited scale (Kechagia et al., 2013). In an analysis of breastfeeding babies' discomfort from atopic dermatitis, it was indicated that the use of *B. lactis* and *Lactobacillus* GG is effective in decreasing the severity of pro eczema. In addition, *L. rhamnosus* GG was effective in preventing the development of atopic eczema in high-risk infants (Isolauri et al., 2000). However, in controlling reactive airway disease (asthma) probiotics have not proved to be very useful (Kechagia et al., 2013).

4.8. Reduction in Serum Cholesterol

An in vivo experiment examining the cholesterol-reducing capability of *Lactobacillus casei subsp. case* in rats found that lipid levels in the blood plasma were reduced by 2 to 11% in groups fed fermented milk, and by 15 to 25% in groups that consumed dehydrated cultures, contrasted to the group given fat-free milk (Mishra et al., 2015). A variety of methods have been suggested to describe the reducing capability impacts of *Lactobacillus* strains, including the integration of cholesterol by cellular growth, the association of cholesterol to the bacterial coating, its integration into the cell membrane, the disassociation of biliary acids via bile salt-de-conjugating enzyme, and the simultaneous precipitation of cholesterol with disassociation of biliary acids. However, the accurate procedure remains uncertain and is still debated (Anandharaj et al., 2014).

4.9. Prevention of Dental caries Formation

The primary microbial organism responsible for dental caries is *Streptococcus mutans*. The utilization of probiotics, such as *L. rhamnosus* GG, has been shown to hinder the oral microbiome colonization of cavity-inducing microbes, thus reducing the chance of tooth decay in pediatrics (Goel et al., 2014).

4.10. Urinary Tract Infections

Urinary tract infections (UTIs) are widespread among women and often occur again. The main etiological agents include *Proteus spp.*, *Klebsiella spp., E.coli,* and *Staphylococcus spp.,* which are primarily urinary tract pathogens from the intestines. A diminishment of vaginal *Lactobacilli* has been associated with a higher likelihood of UTIs, suggesting that replenishing these bacteria could be favorable (Fontana et al., 2013). Studies have shown that increased vaginal microbial load with *Lactobacillus crispatus* probiotics is associated with a significant reduction in recurrent UTIs (Stapleton et al., 2011).

4.11. Prevention of Osteoporosis

Some animal studies, along with a specific human study, have shown favorable effects of probiotics on osteo-metabolism and osseous density. Females consuming *Lactobacillus* fermented milk experienced a reduction in parathyroid hormone (PTH) levels, enhance in serum calcium, and a reduction in bone resorption. Additionally, participants who consumed *L. helveticus* fermented milk had higher levels of phosphate, total calcium, and urinary calcium, ionized serum calcium compared to the control group (Parvaneh et al., 2014).

4.12. Anticancer Effects

Various animal studies have shown that dietary supplementation with specific strains of lactic acid-producing bacteria (probiotics) could prohibit the formation, development, and metastatic spread of transplantable tumors and tumors induced by chemicals. Research in human participants has also showed that probiotic treatment may decrease the colon cancer risk by inhibiting the conversion of carcinogen precursors to oncogenic agents, binding/deactivating mutagenic agents, producing mutagen-blocking agents, inhibiting the growth of cancer-promoting bacteria, decreasing the mutagen absorption from the gastrointestinal tract improving immune system activity, have cell growth inhibiting effect via modulation of apoptosis and cellular differentiation, fermentation of indigestible food which helps produce short-chain fatty acids (SCFA) and suppression of tyrosine kinase-associated signaling pathways (Uccello et al., 2012). An inverse correlation between the consumption of probiotic dairy products, comprising *Lactobacillus* and *Bifidobacterium* species, and the occurrence of colorectal and breast cancer has also been described in epidemiology-based and population-based retrospective studies.

5. Prebiotics Health Benefits Related to Diseases

Prebiotics have a positive impact on gut-associated lymphoid tissues (Table 3) (GALT). Therapeutic nutritional preparations like inulin, fructo-oligosaccharides (FOS), manno-oligosaccharides, and arabinogalactans promote optimal gut function by supporting the proliferation of probiotic bacteria and inhibiting the proliferation of infectious agents. Consuming benefits can regulate immune indicators in GALT, peripheral lymphatic tissues, and peripheral blood flow (Bodera, 2008). The neonatal necrotizing enterocolitis (NEC) is a significant cause of illness and death in preterm infants. Probiotics and prebiotics help regulate the gut microbiota, promoting the proliferation of probiotics. Human testing and animal experiments indicate that beneficial agents reduce the occurrence of NEC (Stenger et al., 2011).

The prebiotic fiber fructo-oligosaccharides (FOS) are more frequently added to food products and baby formulas because of their bowel-regulating effects. Their intake increases stool volume and the rate of bowel movements, helping to reduce constipation, a common issue linked to inadequate fiber intake in the contemporary world and among neonatal infants (Sabater-Molina et al., 2009). There is substantial trial evidence supporting the idea that prebiotic mixtures can significantly improve infant formulas.

The intake of enriched arabinoxylan oligosaccharides diets has been shown to decrease the incidence of pre-cancerous lesions in the rat colon exposed to the cancer-causing agent dimethylhydrazine. This suggested that AXOS may have chemo-preventive potential against colon carcinogenesis, warranting further investigation of health benefit potential human applications (Femia et al., 2010). Cellobiose 2-epimerase enzyme from *R. albus* efficiently transforms milk sugar (lactose) into epilactose. Dietary enrichment with epilactose increases content in the cecum lowers its pH level, enhances the populations of *Bifidobacteria* and *Lactobacilli*, and suppresses *Bacteroides* or *Clostridia* in Wistar Spontaneously Transformed rats. The epilactose as a prebiotic also inhibits the transformation of endogenous bile acids into byproduct bile acids, which are colon cancer-enhancing agents (Watanabe et al., 2008).

The short-chain fatty acids (SCFAs) derived from the fermenting process of galacto-oligosaccharides (GOS) are acknowledged to activate programmed cell death. It has been demonstrated that propionate has an inflammation-lowering effect on colorectal cancer cells (Nurmi et al., 2005). Evidence suggests that butyrate inhibits the NF-κB transcription factor expression in HT-29 cell lines, while studies reveal that acetate promotes antibody synthesis in peripheral blood and natural killer cell function in oncology patients (Macfarlane et al., 2008).

Table 3: Therapeutic effects of prebiotics

Sr. No.	Condition	Prebiotics	Potential benefits	References
1.	Constipation	Fructooligosaccharides(FOS)	Help regulate bowel movements	(McRae, 2020)
2.	Insulin sensitivity	Type 2 Resistant starch (RS2)	Regulate glucose metabolism	(Kim et al., 2020)
3.	Chronic inflammation	Type 3 Resistant Starch (RS3)	Lower inflammation in the body	(Plongbunjong et al., 2017)
4.	Infections and allergies	Beta-glucans	Strengthen the immune system	(Xin et al., 2022)
5.	Digestive Issues	Inulin	Improve digestion and metabolism	(Yang et al., 2013)
6.	Hypercholesterolemia	Pectin	Normalize cholesterol level	(Bang et al., 2018)

6. Safety Considerations and Side Effects of Probiotics and Prebiotics

Food and pharmaceutical products without a prescription containing probiotics microorganisms are usually vended widely available lacking proper research for safety. Additionally, there is a lack of data about probiotic harmful effects on specific groups that are healthy (infants, older adults, pregnant), sick (pancreatitis, diabetes mellitus, gut dysfunction, etc.) and weakened immune system (organ transplant, cancer) individuals. Even though probiotics-rich foods are conventionally ingested by humans, their safety evaluation needs the greatest focus as recent varieties from unconventional sources and probiotics with genetic modifications are in various stages of marketing. The formation of probiotics into feed for animals is also consistently increasing and needs special focus as the variety can transfer from animal to human. Extraordinary efforts need to be taken at the global and domestic levels for strict guidelines for probiotic safety and effectiveness, starting from strain selection, production, and labeling to post-launch monitoring of side effects. Producers should also spend more on objective safety and clinical trials rather than gaining additional advantages by emphasizing functional characteristics only. In the end, the benefit-risk ratio of probiotics should be carefully evaluated before their health-related use.

Although there is limited research on the safety of probiotics, they seem to be safe for healthy individuals to consume. They have a prolonged history of extensive and frequent utilization among the public. There's a low probability of harmful side effects for individuals with compromised immune systems. This includes individuals taking immunomodulatory drugs, individuals with life-threatening conditions, and babies who've been born early. A strong immune system will swiftly eliminate the intruder. However, a compromised immune system could cause a severe health condition.

The recommended normal intake of prebiotics is around 20 g/day. Consuming more than this amount may lead to side effects such as abdominal bloating, diarrhea, or gas production. During active diarrhea, prebiotics may have drawbacks as they can worsen the negative effects of simple sugar absorption. Daily intakes exceeding 8 g of inulin and oligo-fructose are considered to have potential side effects.

7. Recommendations and Future Perspectives

The gut flora plays a core role in the evolution of various ailments, and modulating it could offer new, potent interventions. Gut-friendly bacteria and microbiome enhancers both aim to enhance the population of beneficial flora and the creation of their proliferation and energy conversion in the host. This, in turn, can influence various systems, such as the cardiovascular system, urogenital tract, skin, and brain. The field of microbiome research is primed for significant innovations, expanding the range of target microorganisms surpassing the common *Bifidobacterium* spp. and *Lactobacillus* spp. to embrace additional classification and possibly even fungal varieties. These microorganisms could become new probiotic nominees or prospective objectives for gut-health promoter interventions.

There is a need for more precise, accurate, and reproducible measures of microbial composition are necessary for meaningful progress. This will contribute to a broader range of gut health supplements. For instance, beneficial gut metabolites like propionate and butyrate are not produced by *Bifidobacteria* or *Lactobacilli*. This presents a chance to identify microorganisms with biochemical capacities that go over and above those offered by classical probiotic strains.

There is also a need for more well-designed randomized controlled trials (RCTs) are essential to definitively demonstrate that alterations in the gut flora can minimize disease frequency or alleviate disease severity. RCTs are crucial for minimizing biases and enhancing the reliability of results. Due to growing accessibility and the relatively affordable nature of high-throughput sequencing technologies, microbiome analysis is now more attainable, and the disparities in microbiota linked to different disease conditions are becoming increasingly evident. Additionally, the growth of expert-level metabolic profiling and data repositories will be vital for clinical applications. A deeper comprehension of the role of ecology of the enteric system is essential to clarify how this ecosystem impacts overall health. While microbiota and host gene expressing analysis are also crucial, they are costly and labor intensive, requiring significant genomic analysis support. In conclusion, the use of probiotics and prebiotics can significantly enhance human well-being and improve disease management or risk reduction.

Conclusion

Probiotics and prebiotics are crucial in maintenance of human GIT health, impacting immune and metabolic responses, leading to disease prevention. Probiotics are live microbes strengthening gut microflora and prebiotics are the non-digestible carbohydrates responsible for stimulating the growth of beneficial bacteria. This can lead to prevention and treatment of many deleterious ailments. Prebiotic sources (wheat, barley, rye, soybean, beans, onion, Jerusalem artichoke etc.) and probiotic sources (supplements, dairy products) should be incorporated in daily diet to attain maximum benefits. Therapeutic applications will be definitely enhanced by the advancements in microbiome clinical research, leading to effective and target solutions for wellbeing and disease management.

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