Prebiotics and Gut Microbiota: Role in Maintaining Normal Human Physiology

Sadia Bibi[1], Zainab Nisa[2], Anza Ahmed[3], Muhammad Tuaseen[4], Muhammad Ibrahim[5], Abdul Wahid[6], Ayesha Shahzadi[6], Hassan Nawaz[6], Muhammad Rabi Raza[6] and Aisha Sethi*[,2]

[1]Department of Clinical and Experimental Medicine, University of Modena and Reggio Emilia (Unimore), Italy
[2]Department of Pharmacy, Faculty of Pharmaceutical Sciences, Government College University Faisalabad, Punjab, Pakistan
[3]Department of Pharmacy Practice, Bahauddin Zakariya University, Multan, Pakistan
[4]Department of Eastern Medicine, Faculty of Life Sciences, Government College University Faisalabad. 38000, Punjab, Pakistan
[5]Faisalabad Medical University, Punjab, Pakistan
[6]Sahara Medical College, 51600, Narowal, Punjab, Pakistan
*Corresponding author: ayeshasethi786@gmail.com

Abstract

An important factor in both health and illness is the human gut microbiota, a complex ecosystem found in the gastrointestinal tract. Prebiotics, which are indigestible food elements, have become a crucial modulator of this intricate microbial community. They work by selectively promoting the growth and/or activity of helpful microbes, which benefits the host. This review article examines the development of the prebiotic concept, lists the different kinds of prebiotics, such as fructans, galacto-oligosaccharides, xylo-oligosaccharides, chito-oligosaccharides, lactulose, resistant starch, and polyphenols, and explains how they affect the composition of the gut microbiota. We explore the processes by which prebiotics work, paying special attention to the synthesis of short-chain fatty acids and the alteration of the gut microbiota to produce a composition that is beneficial to health. This review attempts to improve understanding of prebiotics' involvement in health and disease by combining existing knowledge and pointing out areas for further study, highlighting their significance in preserving a healthy gut microbiome and general well-being.

Keywords: Prebiotics, Gut Microbiota, Probiotics, Human Physiology, Immune system.

Cite this Article as: Bibi S, Nisa Z, Ahmed A, Tuaseen M, Ibrahim M, Wahid A, Shahzadi A, Nawaz H, Raza MR and Sethi A, 2025. Prebiotics and gut microbiota: Role in maintaining normal human physiology. In: Şahin T, Ameer K, Abid M and Tahir S (eds), Nutritional Foundations of Holistic Health: From Supplements to Feed Strategies. Unique Scientific Publishers, Faisalabad, Pakistan, pp: 199-205. https://doi.org/10.47278/book.HH/2025.386

A Publication of Unique Scientific Publishers

Chapter No: 25-028

Received: 15-Jan-2025
Revised: 02-Apr-2025
Accepted: 03-May-2025

Introduction

The human gut microbial communities, a diverse and dynamic population of trillions of bacteria, is critical for maintaining human health. The makeup and activity of this microbial population have a major impact on a variety of physiological functions. Diet, lifestyle, and environmental factors all have a significant effect on the gut flora, with prebiotics emerging as important modulators. This chapter investigates the significance of prebiotics and gut bacteria in maintaining normal human physiology, including their effects on digestion, immunological function, metabolism, and overall well-being (Plamada & Vodnar, 2021).

1. Prebiotics

Definition and Characteristics

Prebiotics are indigestible food constituents that enhance the host's health by specifically promoting the development and/or activity of advantageous gut microorganisms. Unlike probiotics, prebiotics are typically dietary fibers or oligosaccharides that pass through the superior digestive region undigested and reach the colon unharmed (Megur et al., 2022).

Common Sources of Prebiotics

Prebiotics are naturally present in many plant-based foods, as shown in Figure 1 (Gibbons et al., 2022). The most commonly recognized prebiotics include:

- **Inulin and Fructo oligosaccharides (FOS):** Found in chicory root, garlic, onions, leeks, asparagus, and bananas.
- **Galacto oligosaccharides (GOS):** Present in legumes, beans, and certain dairy products.
- **Resistant Starch:** Found in whole grains, seeds, legumes, and cooked and cooled starchy foods like potatoes and rice.
- **Beta-Glucans:** Found in oats and barley.
- **Pectins:** Present in fruits such as apples, citrus fruits, and strawberries

Mechanisms of Action

Prebiotics that are regularly included in the food encourage the growth and function of particular species or genera of bacteria, modifying the GM and having a persuasive bifidogenic impact. The goblet cells play an important part in the formation of secretion, which protects the mucous membrane and forms a layer in the colon that reduces inflammation produced by bacterial interactions with intestinal epithelial cells. The modified GM agitates prebiotics to produce SCFAs (acetate, propionate, and butyrate), which can provide health advantages. Prebiotic supplementation can suppress and limit the growth of pathogenic bacteria by producing antimicrobial agents and lowering the pH levels of the intestine, which can have a good impact on health. Prebiotics are mostly metabolized by the gut microbiome. This fermentation process generates short-chain fatty acids (SCFAs) and other chemicals that have important functions in gut health and general physiology (Figure 2) (Subhash et al., 2024).

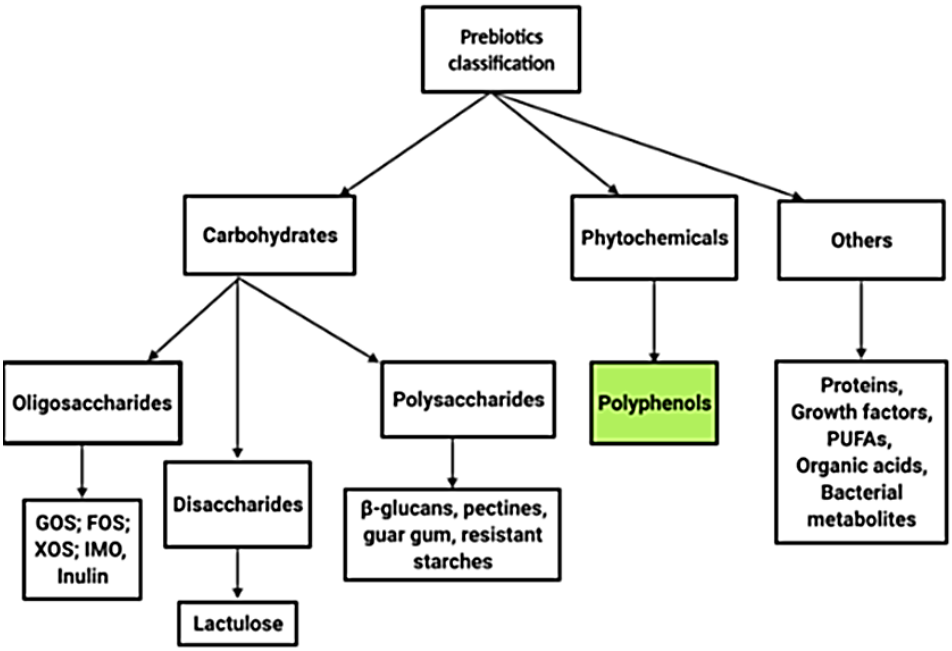

Fig. 1: Showing Prebiotic Classification

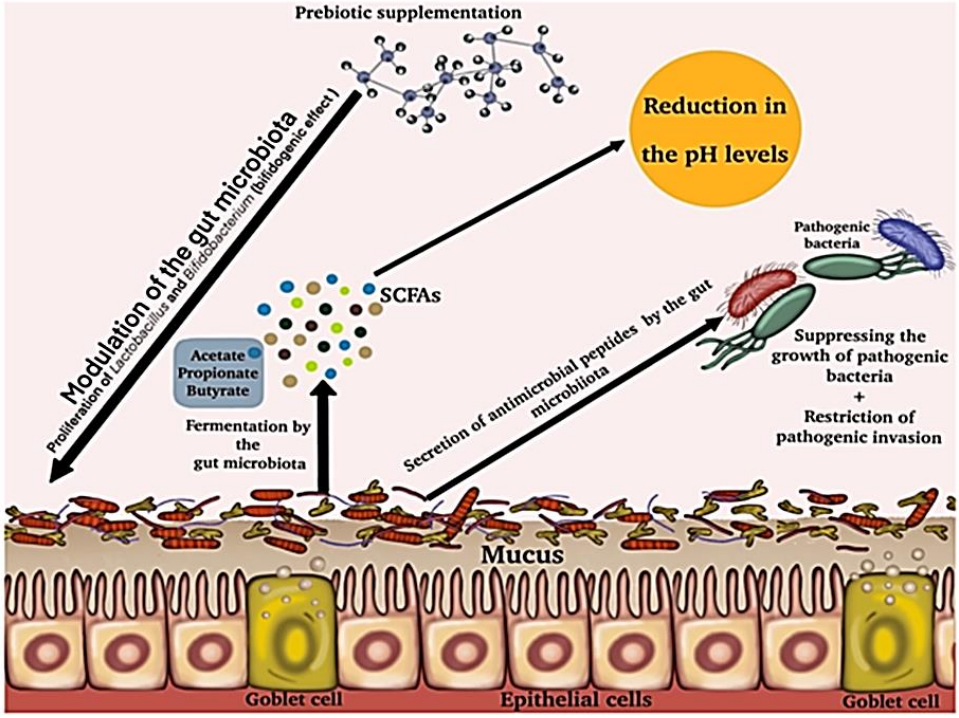

Fig. 2: Showing Mechanisms of Action

2. Beneficial Effects of Prebiotics on CVDs (Cardiovascular disease)

The host is protected against CVD by consuming prebiotics. The majority of these examined the positive benefits of inulin or inulin-

containing prebiotics on a range of CVDs in both human and animal models, such as coronary artery disease, chronic kidney disease, atherosclerosis, hypercholesterolemia, and congenital heart disease or diabetes associated with congenital heart disease. Inulin supplementation (or co-supplementation with inulin and other components) enhanced anti-oxidative parameters and gut microbiota dysbiosis while lowering cholesterol levels, including total and LDL cholesterol, CRP, and many inflammatory cytokines. However, contrary to earlier findings that inulin supplementation effectively reduces inflammation and plasma lipid levels, one study found that inulin exacerbated the accelerated development of atherosclerosis in hypercholesterolemia individuals, which is caused by elevated plasma cholesterol (Wu & Chiou, 2021).

Other prebiotics or prebiotic compounds have also been shown to positively affect CVD in addition to inulin. In female rats with simulated heart failure, intestinal dysbiosis and endotoxemia were found to be resolved by administering a prebiotic complex derived from fermented wheat bran. In participants with mild hypercholesterolemia and a low risk of coronary artery disease, the positive effects of soluble fiber (Minolest) supplementation on the lipid profile were identified. In a rat ischemia-reperfusion model, larch arabinogalactan, an active ingredient in pectin, was found to reduce cardiac damage by blocking apoptotic mechanisms. Furthermore, by improving antioxidant capabilities and lipid profiles by encouraging the establishment of probiotic species in intestinal flora, chitosan oligosaccharides (COS) show protective effects in Coronary Heart Diseases (Abdel-Latif et al., 2022).

Prebiotics may alleviate CVD symptoms through several pathways related to inflammation, antioxidant capacity, and the restoration of the dysbiotic gut microbiota. However, the observed adverse effects of prebiotics on CVD call for caution while using inulin in people (Fiocchi et al., 2022).

3. The Gut Microbiota

Structure and Diversity

The gut microbiota is multifaceted and assorted, consisting of bacteria, archaea, viruses, and fungi. Bacteria are the most abundant, with *Firmicutes, Bacteroidetes, Actinobacteria*, and *Proteobacteria* being the dominating phyla. Genetics, diet, age, and external variables all affect an individual's gut microbiota composition (Figure 3) (Liu et al., 2021).

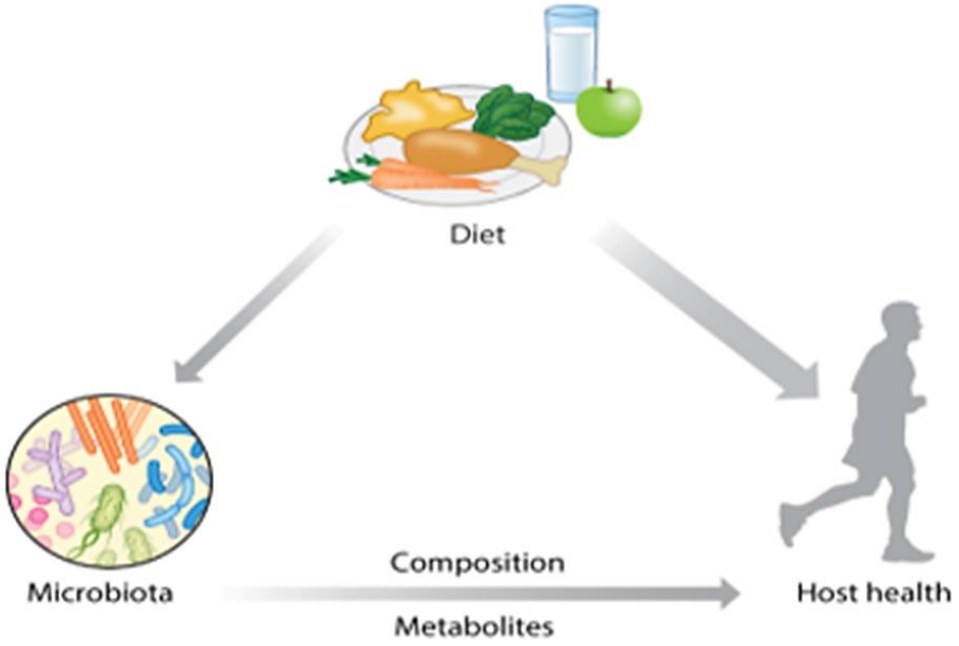

Fig. 3: showing gut microbiota relate with host health and microbiota

Functions of the Gut Microbiota

The gut microbiota executes several critical functions crucial to human health (Thursby & Juge, 2017).

- **Nutrient Metabolism:** The microbiota aids digest complex sugar molecules, proteins, and lipids that human enzymes are unable to break down, resulting in the creation of SCFAs and other metabolites.
- **Vitamin Synthesis:** Gut bacteria produce vital vitamins, including vitamin K and B vitamins.
- **Immune System Modulation:** The microbiota helps in the development and regulation of the immunity, teaching it to differentiate between harmful pathogens and benign antigens.
- **Gut Barrier Maintenance:** The microbiota maintains the integrity of the gut barrier by making mucus and tight junction proteins.
- **Protection against Pathogens:** A balanced microbiota can constrain the growth of pathogenic organisms by occupying ecological niches and producing antimicrobial compounds (Thursby & Juge, 2017).

4. Interaction Between Prebiotics and Gut Microbiota

Fermentation and Production of Short-Chain Fatty Acids (SCFAs)

Prebiotics enter the colon intact and are fermented by the gut microbiota, resulting in the generation of SCFAs such as acetate, propionate,

and butyrate (Gomaa, 2020). These serve multiple important functions:

- **Energy Source:** SCFAs, especially butyrate, provide a significant energy source for colonocytes (cells covering the colon).
- **Regulation of Gut Motility:** SCFAs stimulate the delivery of gut hormones that standardize intestinal motility.
- **Anti-inflammatory Effects:** SCFAs have anti-inflammatory properties, modulating immune responses and promoting the production of regulatory T cells.

Modulation of Gut Microbiota Composition

Prebiotics preferentially promote the progression of beneficial bacteria such as *Bifidobacteria* and *Lactobacillus*. These bacteria help maintain a well gut environment by generating SCFAs and suppressing pathogenic germs (Afzaal et al., 2022).

Enhancement of Gut Barrier Function

SCFAs increase the making of mucus and tight junction proteins, firming the intestinal barrier and lowering the risk of inflammation and infection (Fan & Pedersen, 2021).

5. Gut Microbiota linked with brain Communications

It is known that a variety of signals from immunological, neurological, and endocrine pathways mediate the connection between the stomach, the microbiota, and the brain. The enteric nervous system (ENS), a special neurological system found only in the gut, is permanently and directly connected to the brain via nerves. Due to the direct harmful entry of located microbes that cause intestinal inflammation and rupture and directly affect the ENS, it is possible that microbiota interacts indirectly with this nervous system by transferring them from the lumen of the gut to the surface of the lamina propria via the microfold cells or dendritic cells. They can also interact with specific receptors, such as G-protein coupled receptors (GPCRs) and Toll-like receptors (Ansari et al., 2023).

6. Physiological Benefits of Prebiotics and Gut Microbiota

Enhanced Immune Function

The gut microbiota plays a crucial role in developing and regulating the immune system. By modulating the gut microbiota, prebiotics enhance immune function through:

- **Promotion of Regulatory T Cells:** SCFAs promote the differentiation and function of regulatory T cells, maintaining immune tolerance (Duan et al., 2021).
- **Decreased Chronic Inflammation:** Prebiotics aid in reducing chronic inflammation by stimulating the production of beneficial bacteria and anti-inflammatory short-chain fatty acids (SCFA).
- **Strengthened Immune Responses:** Prebiotics make the gut more resistant to infections by enhancing the production of antimicrobial peptides and strengthening the gut barrier (Lu et al., 2022).

Improved Digestive Health

Prebiotics contribute to digestive health by:

- **Reducing Constipation:** By encouraging the growth of bacteria that manufacture SCFAs, prebiotics soften and amplify the volume of stools (Qiu et al., 2022).
- **Managing Irritable Bowel Syndrome (IBS):** Prebiotics can lessen bloating, pain in the abdomen, and irregular stool movements, among other IBS symptoms (Chen & Wang, 2022).

Metabolic Health and Energy Balance

The gut microbiota influences energy metabolism and body weight (Zhu et al., 2024).

- **Maintaining Blood Sugar Levels:** One of the metabolic benefits that prebiotics can offer is the ability to maintain healthy blood glucose levels, since SCFAs also increase insulin sensitivity.
- **Reducing Body Fat:** Prebiotics can help reduce body fat by increasing energy expenditure and fat oxidation.
- **Altering the Lipids:** Prebiotics are able to alter the lipids by lowering the intestinal absorption of cholesterol and heightening its elimination.

Mental Health and the Gut-Brain Axis

The gut-brain axis is a complex communication network between the gut and the brain (Järbrink-Sehgal & Andreasson, 2020). The consequences of Prebiotics on mental health can be summarized through the following points:

- **The word goodbye to anxiety and despair**: Prebiotics could help lessen the symptoms of anxiety and depression by giving a boost to the growth of good bacteria that produce neurotransmitters.
- **Cognitive performance enhancement:** Prebiotics, on the other hand, are likely to improve cognitive performance through reducing neuro-inflammation and stimulating SCFAs, which are neuroprotective.

7. Prebiotics in Clinical Practice

Therapeutic Potential

Prebiotics' potential for treatment is being investigated in several clinical contexts (Sanchez-Fuentes, Rivera-Caravaca, Lopez-Galvez, Marin, & Roldan, 2022):

- **Gastrointestinal Issues:** Prebiotics have shown promise in managing constipation, inflammatory bowel disease (IBD), and IBS.
- **Metabolic Disorders:** Prebiotics are being researched for their potential use in healing overweightness and dyslipidemia.

Mental Health: The effect of prebiotics on mental health via the interaction between the gut and the brain is an emerging topic of research, with possible consequences for treating diseases including anxiety and depression (Alqaydi et al., 2024)

Prebiotic Supplements

Prebiotic supplements are available for people who do not obtain enough prebiotics from their diet. Gut health could be promoted by these supplements especially in those whose has medical conditions (Kim et al., 2022).

Dietary Recommendations

Gut health can be improved by adding prebiotic-rich food to your diet, including some recommendations (Freijy et al., 2023).

- **Eating a Variety of Fruits and Vegetables:** Foods like garlic, onions, leeks, asparagus, and bananas are rich in prebiotics.
- **Consuming Whole Grains and Legumes:** Whole grains and legumes provide resistant starch and other prebiotic fibers.
- **Including Fermented Foods:** While primarily known for their probiotic content, some fermented foods also contain prebiotics.

8. Impact of Prebiotics on Autism Spectrum Disorder

ASD is typified by repetitive and constrained patterns of interests and activities, changes in sensory processing linked to neurobehavioral and neurodevelopment problems, and challenges with social communication and engagement. According to the findings of continuing research, it is becoming more and more common worldwide, which is cause for alarm. According to prevalence statistics released ten years ago, males are almost four times more likely than females to have the condition, with a rate of 100/10,000 morbidity. Because the condition is so complicated, it is recognized to have multiple etiological bases, such as genetic anomalies, neurochemical dysfunctions, and alterations in the anatomy of the brain. The illness mechanism is thought to be influenced by the altered routes of numerous neurotransmitters, such as oxytocin, serotonin, dopamine, and N-acetyl aspartate (Mörkl, et al., 2020).

There are some indications that genetic modification may have an impact on the pathogenicity of autism. Patients' behavioral issues are exacerbated by the high comorbidity of GIT symptoms, which include diarrhea, constipation, and abdominal pain. The population and function of GM are linked to the pathogenesis of ASD through gut-brain connections. It has been shown that the gut bacterial makeup of individuals with ASD differs from that of healthy controls. However, the patient's unique lifestyle, including their food and bowel habits, may be the cause of the changed microbiota. The concept of the therapeutic benefits of altering GM on ASD was created in light of the data (Tabrizi et al., 2019).

Germ-free mice, which cause autism characteristics like repetitive behavior and reduced communication and movement, were given GM from people with ASD during a study. Additionally, treating bacterial metabolites such as 5-aminovaleric acid, which is diminished in individuals with ASD, might enhance repetitive and social behavior as well as the prefrontal cortex, which is linked to social cognition. Probiotics and prebiotics have garnered particular interest among the many treatment options to alter the gut-brain axis in ASD (Ojeda et al.,2021). Numerous investigations have been carried out to evaluate the impact of probiotics and prebiotics on ASD. GI health and symptoms associated with ASD were the primary objectives. A variety of Bifidobacterium and Lactobacillus strains, including *L. acidophilus, L. plantarum*, and *L. paracasei,* had been given (Ansari et al., 2020).

The patients were also given hydrolyzed guar gum and malto-dextrin as prebiotics. Following the conclusion of the intervention, some RCTs revealed no discernible difference in the severity of behavioral issues and symptoms between the probiotic and placebo groups. Bias distorted the effect in other studies where the placebo and control groups differed significantly (Zhang et al., 2019). Therefore, it can be said that probiotics have not yet been shown to have an impact on symptoms of ASD. Nonetheless, research on the effects of prebiotics and symbiotic indicates that the medication is helpful in improving a number of symptoms associated with ASD. For example, GOS with a prebiotic supplement (Bimuno®) can decrease antisocial behavior, while prebiotic oligosaccharides and *B. longum subsp. infantis* UCD272 together had a beneficial effect on patients' lethargy (Irwin et al., 2020).

Four trials revealed no improvements following probiotic use, according to the findings of a comprehensive evaluation of the RCTs. Two of the trials showed a significant decrease in GIT symptoms, which were known to be linked to behavioral signs of ASD. The studies' primary conclusion was that the prebiotic group improved GIT symptoms such as diarrhea, constipation, and odorous stools compared to the control group. It should be mentioned that the prebiotic and symbiotic trials have longer treatment durations than the probiotic research, which could account for the results seen in the prebiotic studies (Naomi et al., 2021).

Additionally, these studies include a number of comparisons and results, including sub-group analysis, which raises the possibility of a statistically significant difference. Therefore, some of the noteworthy outcomes might just be the consequence of chance rather than the actual effects of the substances that were supplied. We are currently unable to confirm that prebiotics can help people with ASD (Tan et al., 2021).

Prebiotics' impact on Mineral Absorption

Osteoporosis and its increasing prevalence are serious worldwide issues. In order to help establish proper bone-building in teenagers and the elderly, prebiotic intake primarily aims to increase the rate and uptake of calcium in the human body. The body's main calcium absorption location is the distal intestine, and an increase in prebiotic fermentation by gut bacteria, along with a number of other chemicals, directly affects the rate of absorption (Manzoor et al.2022).

The Immune System's Defenses and Prebiotics

The quantity of cells in the human GIT is important because it starts signaling cascades, which in turn trigger immunologic reactions. The

prebiotic itself, B cells, natural killer cells, Treg cells, effector T cells, and the molecules created by prebiotic fermentation can all be impacted. Although it's unclear how exactly they impact the immune system (Pavlidou et al. 2022).

Emerging Research: Prebiotics

Scientists are looking into how prebiotics affect mental health. A small study with 40 people explored the impact of eating lots of prebiotics on feelings of depression and anxiety. The results showed that taking prebiotics might help mental health through the gut. People who ate prebiotics saw clear improvements in their mood and how well their brain worked. Prebiotics have emerged as a potentially effective treatment option for a number of gastrointestinal-related illnesses. Prebiotics can help prevent a number of illnesses, including COVID-19, congenital heart disease, diarrhea, inflammatory bowel disease, high blood pressure, genitourinary tract infections, colon cancer, allergy disorders, mineral absorption, eczema, and immune system defense.

Challenges and Future Directions

Variability in Individual Responses

Gut microbial composition, genetics and life style patterns may be varied in response to prebiotic in individuals. Intake prebiotics according to need with opinion of scientists (Cunningham et al., 2021).

Mechanistic Understanding

Researchers find the mechanisms of actions of prebiotics and make it better with respect to treatment for people. We also need to understand processes of prebiotic.

Probiotics Integration

The Mixing of probiotics and prebiotics are tern as symbiotic. The boost activity and survival of good bacteria by adding prebiotics into probiotics for good health (Spacova et al., 2020).

Regulatory and Safety Considerations

We have to ensure that prebiotics are safe for customers and have no harmful effects after consuming them. Different laws and testing declared the prebiotic or probiotic useful for mankind and easy to consume (Vandeputte, 2020).

Conclusion

Prebiotics are now safe and effective choices for a range of treatment approaches. They provide important functional qualities that may help us satisfy most of our needs for medicinal and nutritional supplements. In clinical trials, these bacteria have shown encouraging outcomes for a number of illnesses and ailments, such as food allergies, diarrhea, and IBS. The proper mix of both ingredients in a single product can have a greater effect than either probiotics or prebiotics alone since prebiotics give probiotic microorganisms energy and nourishment. Prebiotics and other nutritional supplements are becoming more and more popular as people's health concerns grow. As a result of the aforementioned factors, the prebiotic market is expanding and numerous novel prebiotics are being found. More health advantages than those discovered thus far are anticipated as a result of these discoveries. However, more thorough research is required to ascertain the impact on human health, including carefully planned major organ clinical trials. However, if taken correctly and with adequate information, prebiotics should have a positive impact on enhancing human health**.**

References

Abdel-Latif, H. M., Yilmaz, E., Dawood, M. A., Ringo, E., Ahmadifar, E., & Yilmaz, S. (2022). Shrimp vibriosis and possible control measures using probiotics, postbiotics, prebiotics, and synbiotics: A review. *Aquaculture, 551*, 737951.

Afzaal, M., Saeed, F., Shah, Y. A., Hussain, M., Rabail, R., Socol, C. T., &Rusu, A. V. (2022). Human gut microbiota in health and disease: Unveiling the relationship. *Frontiers in Microbiology, 13*, 999001.

Alqaydi, T. K., Bedir, A. S., Abu-Elsaoud, A. M., El-Tarabily, K. A., & Al Raish, S. M. (2024). An assessment of the knowledge, attitude, and practice of probiotics and prebiotics among the population of the United Arab Emirates. *Foods, 13*(14), 2219.

Ansari, F., Neshat, M., Pourjafar, H., Jafari, S. M., Samakkhah, S. A., & Mirzakhani, E. (2023). The role of probiotics and prebiotics in modulating of the gut-brain axis. *Frontiers in Nutrition, 10*, 1173660.

Ansari, F., Pourjafar, H., Tabrizi, A., & Homayouni, A. (2020). The effects of probiotics and prebiotics on mental disorders: a review on depression, anxiety, Alzheimer, and autism spectrum disorders. *Current Pharmaceutical Biotechnology, 21*(7), 555-565.

Chen, L., & Wang, J. (2022). Gut microbiota and inflammatory bowel disease. *WIREs Mechanisms of Disease, 14*(2), e1540.

Cunningham, M., Azcarate-Peril, M. A., Barnard, A., Benoit, V., Grimaldi, R., Guyonnet, D., Obis, D. (2021). Shaping the future of probiotics and prebiotics. *Trends in Microbiology, 29*(8), 667-685.

Duan, M., Wang, Y., Zhang, Q., Zou, R., Guo, M., & Zheng, H. (2021). Characteristics of gut microbiota in people with obesity. *Plos One, 16*(8), e0255446.

Fan, Y., & Pedersen, O. (2021). Gut microbiota in human metabolic health and disease. *Nature Reviews Microbiology, 19*(1), 55-71.

Fiocchi, A., Cabana, M. D., & Mennini, M. (2022). Current use of probiotics and prebiotics in allergy. *The Journal of Allergy and Clinical Immunology: In Practice, 10*(9), 2219-2242.

Freijy, T. M., Cribb, L., Oliver, G., Metri, N.-J., Opie, R. S., Jacka, F. N., &Sarris, J. (2023). Effects of a high-prebiotic diet versus probiotic supplements versus synbiotics on adult mental health: The “Gut Feelings” randomized controlled trial. *Frontiers in Neuroscience, 16*,

1097278.
Gibbons, S. M., Gurry, T., Lampe, J. W., Chakrabarti, A., Dam, V., Everard, A., & Lane, J. (2022). Perspective: leveraging the gut microbiota to predict personalized responses to dietary, prebiotic, and probiotic interventions. *Advances in Nutrition, 13*(5), 1450-1461.
Gomaa, E. Z. (2020). Human gut microbiota/microbiome in health and diseases: a review. *Antonie Van Leeuwenhoek, 113*(12), 2019-2040.
Irwin, C., McCartney, D., Desbrow, B., & Khalesi, S. (2020). Effects of probiotics and paraprobiotics on subjective and objective sleep metrics: a systematic review and meta-analysis. *European Journal of Clinical Nutrition, 74*(11), 1536-1549.
Järbrink-Sehgal, E., & Andreasson, A. (2020). The gut microbiota and mental health in adults. *Current Opinion in Neurobiology, 62*, 102-114.
Kim, C. E., Yoon, L. S., Michels, K. B., Tranfield, W., Jacobs, J. P., & May, F. P. (2022). The impact of prebiotic, probiotic, and synbiotic supplements and yogurt consumption on the risk of colorectal neoplasia among adults: A systematic review. *Nutrients, 14*(22), 4937.
Liu, C., Du, P., Guo, Y., Xie, Y., Yu, H., Yao, W., & Qian, H. (2021). Extraction, characterization of aloe polysaccharides and the in-depth analysis of its prebiotic effects on mice gut microbiota. *Carbohydrate Polymers, 261*, 117874.
Lu, Y., Yuan, X., Wang, M., He, Z., Li, H., Wang, J., & Li, Q. (2022). Gut microbiota influence immunotherapy responses: mechanisms and therapeutic strategies. *Journal of Hematology and Oncology, 15*(1), 47.
Manzoor, S., Wani, S. M., Mir, S. A., & Rizwan, D. (2022). Role of probiotics and prebiotics in mitigation of different diseases. *Nutrition, 96*, 111602.
Megur, A., Daliri, E. B.-M., Baltriukienė, D., & Burokas, A. (2022). Prebiotics as a tool for the prevention and treatment of obesity and diabetes: classification and ability to modulate the gut microbiota. *International Journal of Molecular Sciences, 23*(11), 6097.
Mörkl, S., Butler, M. I., Holl, A., Cryan, J. F., & Dinan, T. G. (2020). Probiotics and the microbiota-gut-brain axis: focus on psychiatry. *Current Nutrition Reports, 9*, 171-182.
Naomi, R., Embong, H., Othman, F., Ghazi, H. F., Maruthey, N., & Bahari, H. (2021). Probiotics for Alzheimer's disease: A systematic review. *Nutrients, 14*(1), 20.
Ojeda, J., Ávila, A., & Vidal, P. M. (2021). Gut microbiota interaction with the central nervous system throughout life. *Journal of Clinical Medicine, 10*(6), 1299.
Pavlidou, E., Fasoulas, A., Mantzorou, M., & Giaginis, C. (2022). Clinical evidence on the potential beneficial effects of probiotics and prebiotics in cardiovascular disease. *International Journal of Molecular Sciences, 23*(24), 15898.
Plamada, D., & Vodnar, D. C. (2021). Polyphenols—Gut microbiota interrelationship: A transition to a new generation of prebiotics. *Nutrients, 14*(1), 137.
Qiu, P., Ishimoto, T., Fu, L., Zhang, J., Zhang, Z., & Liu, Y. (2022). The gut microbiota in inflammatory bowel disease. *Frontiers in Cellular and Infection Microbiology, 12*, 733992.
Sanchez-Fuentes, A., Rivera-Caravaca, J. M., Lopez-Galvez, R., Marin, F., & Roldan, V. (2022). Non-vitamin K antagonist oral anticoagulants and drug-food interactions: implications for clinical practice and potential role of probiotics and prebiotics. *Frontiers in Cardiovascular Medicine, 8*, 787235.
Spacova, I., Dodiya, H. B., Happel, A.U., Strain, C., Vandenheuvel, D., Wang, X., & Reid, G. (2020). Future of probiotics and prebiotics and the implications for early career researchers. *Frontiers in Microbiology, 11*, 1400.
Subhash, A. J., Bamigbade, G. B., Al-Ramadi, B., Kamal-Eldin, A., Gan, R.Y., Ranadheera, C. S., & Ayyash, M. (2024). Characterizing date seed polysaccharides: A comprehensive study on extraction, biological activities, prebiotic potential, gut microbiota modulation, and rheology using microwave-assisted deep eutectic solvent. *Food Chemistry, 444*, 138618.
Tabrizi, A., Khalili, L., Homayouni-Rad, A., Pourjafar, H., Dehghan, P., & Ansari, F. (2019). Prebiotics, as promising functional food to patients with psychological disorders: A review on mood disorders, sleep, and cognition. *NeuroQuantology, 17*(6), 1-9.
Tan, Q., Orsso, C. E., Deehan, E. C., Kung, J. Y., Tun, H. M., Wine, E., & Haqq, A. M. (2021). Probiotics, prebiotics, synbiotics, and fecal microbiota transplantation in the treatment of behavioral symptoms of autism spectrum disorder: A systematic review. *Autism Research, 14*(9), 1820-1836.
Thursby, E., & Juge, N. (2017). Introduction to the human gut microbiota. *Biochemical Journal, 474*(11), 1823-1836.
Vandeputte, D. (2020). Personalized nutrition through the gut microbiota: current insights and future perspectives. *Nutrition Reviews, 78*(3), 66-74.
Wu, H., & Chiou, J. (2021). Potential benefits of probiotics and prebiotics for coronary heart disease and stroke. *Nutrients, 13*(8), 2878.
Zhang, N., Liao, X., Zhang, Y., Li, M., Wang, W., & Zhai, S. (2019). Probiotic supplements for relieving stress in healthy participants: A protocol for systematic review and meta-analysis of randomized controlled trials. *Medicine, 98*(20), e15416.
Zhu, Y., Chen, B., Zhang, X., Akbar, M. T., Wu, T., Zhang, Y., Shen, Q. (2024). Exploration of the Muribaculaceae family in the gut microbiota: Diversity, metabolism, and function. *Nutrients, 16*(16), 2660.