ejpmr, 2025, 12(2), 396-399

SJIF Impact Factor 7.065

EUROPEAN JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH

www.ejpmr.com

Review Article

ISSN 2394-3211

EJPMR

UNDERSTANDING PREBIOTICS: A REVIEW ON THEIR ROLE, BENEFITS, AND APPLICATIONS

Moubani Dutta[1], Piyali Das[2] and Sayan Bhattacharyya*[3]

[1]Assistant Professor, Dept. of Dietetics and Nutrition, NSHM Institute of Health Science, Kolkata.
[2]MSc. Applied Nutrition, AIIH & PH, Kolkata.
[3]Associate Professor, Microbiology, AIIH & PH, Kolkata.

***Corresponding Author: Sayan Bhattacharyya**

Assistant Professor, Dept. of Dietetics and Nutrition, NSHM Institute of Health Science, Kolkata.

Article Received on 21/12/2024 **Article Revised on 10/01/2025** **Article Accepted on 30/01/2025**

ABSTRACT

Prebiotics are moieties present in food which act by various means to increase levels of probiotic bacteria in the human gut. Prebiotic foods include Asparagus, sugar beet, garlic, chicory, onion, Jerusalem artichoke, wheat, honey, banana, barley, tomato, rye, soybean, banana and others. Fructooligosaccharides and galactooligosaccharides are the active components of prebiotics. Prebiotics can lead to many health benefits by enhancing levels of healthy or probiotic bacteria in gut. This review tries to address these issues.

KEYWORDS: prebiotics, fructooligosaccharides, galactooligosaccharides.

INTRODUCTION

The profile of Prebiotics: A specific category of nutrients entitled prebiotics are decomposed by the gut microbiota, which results in good growth of healthy or probiotic bacteria in gut. Recent times have seen an upsurge in pursuit of the ways they relate to generalized human health. They have the capability to sustain the gut bacteria, and the short-chain fatty acids they construct while decomposition are distributed into the bloodstream, which influences not solely the gastrointestinal tracts but also adjacent organs.[1]

A vast majority of microorganisms are present in the large intestine, which are essential for human health. The human colon contains 10^{10}–10^{12} bacterial species per gram.[1]

Formerly prebiotics have been defined as 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.

Prebiotics exist in a plenty of forms. Asparagus, sugar beet, garlic, chicory, onion, Jerusalem artichoke, wheat, honey, banana, barley, tomato, rye, soybean, human and cow's milk, peas, beans, seaweeds, microalgae, and more count among the foodstuffs that organically possess them.[1,2] Most of them are oligosaccharide carbohydrates (OSCs), which are a specific group within the bracket of carbohydrate.[1]

Carbohydrate structure has a considerable influence on gut microbial fermentation and influences the colonic ecology. Dietary fibre structure has a considerable impact on fermentation. The effects of different prebiotics on gut flora vary. Glycanases, either endo-glycanases or exo-glycosidases, may be found inside cells, on cell walls, or released. They are unique to the anomeric structure and position of glycosidic linkages in carbohydrates. A microorganism's enzyme production has a significant impact on the carbohydrate structures that it can breakdown for nutrition and energy.[3]

Prebiotic foods: Chicory, inulin, oats, garlic, fruits, asparagus and banana (neither too unripe nor too ripe) are excellent prebiotics due to their high content of fructooligosaccharides and galactooligosaccharides.

Synbiotics: The prebiotic food (s) and the probiotic bacteria they enhance in the body, together are called synbiotics. There are many symbiotic foods.

Types of Prebiotics

a. **Galacto-Oligosaccharides**: (Alternatively known as TOS or trans-galacto-oligosaccharides): This is a resultant of actose extension, organically sourced from human milk.[1,4]
b. **Fructans**: This subset combines oligofructose and fructo-oligosaccharide or inulin.[1] Asparagus, garlic, leek, onion, Jerusalem artichokes, and chicory roots belong to several plant species that are rich in

fructans and are frequently consumed as vegetables.[5]

c. **Starch and Glucose-Derived Oligosaccharides**: Resistant starch (present in foods like rice), and polydextrose are two classical examples of this group.[1,6,7,8]
d. **Pectin Oligosaccharides**: The polysaccharide's lateral chains are connected to sugars like galactose, arabinose, and xylose or ferulic acid.[6]
e. **Other types**: Non-Carbohydrate Oligosaccharides, includes cocoa-derived flavanols.[1,6,9]

Fig. 1: below shows illustrative image of banana (neither too ripe nor raw), an ideal prebiotic food.

Fig. 1: Banana (neither too ripe nor raw), an ideal prebiotic (image: authors).

Mechanisms of Action: To enable digestion, metabolism, and the biosynthesis of vital components, the digestive tract, the body's second brain, must communicate with hut microbial flora. Probiotics and prebiotics are beneficial for individual wellness and nutrition. Prebiotics are elements that probiotics may absorb and metabolize for assistance in their metabolism and reproduction, but the host cells cannot afford to digest them.[10]

Table 1: Summary of the mechanism of Prebiotics Source: Researchers' compilation.[11]

Level	Process	Consequences
Metabolic consequences	Short-chain fatty acid synthesis, fat utilization, and ion influx	Increased Calcium, Iron, Magnesium availability in the body
Immunity development	Optimizing the immunity of the host	IgA generation, cytokine regulation

How exactly prebiotics lead to increase in probiotic bacteria: Probiotic bacteria release various enzymes like hydrolases and glycosidases which break down prebiotics and thereby the healthy bacteria derive nutrition from the prebiotic foods. *Bacteroides cellulosilyticus* initiates carbohydrate degradation through a surface endo-glycoside hydrolases, and releases oligosaccharides that are further metabolised by other members of the gut microbial flora.

Health Benefits of Prebiotics: Prebiotics lead to good growth of live healthy bacteria like *Lactobacillus* and *Bifidobacterium* spp. that, when present in adequate amounts, provide many biological benefits that extend basic nutrition. It can be detected in various foods, drug products, and nutritional supplements. Prebiotics indirectly raise immune system functionality, gut integrity, decrease intestinal infections, inhibit allergic reactions, and promote digestion and waste disposal, via probiotic bacteria.[11]

Enhancement of healthy Colon Transport duration: Constipation is a prevalent medical illness which impact on many people, particularly the older people, expectant and lactating mother and those who are dieting to lose weight and those who have affected their daily schedules. Prebiotics can enhance stool volume and regularity by rising microbial volume, reducing transport time, minimizing colonic fluid resorption, and improving stool regularity. An amalgamation of inulin-type fructans and galactooligosaccharides has been found to boost stool regularity in babies, enhances stool regularity and hydrated stool formation in constipated elder men, and decrease severe constipation in expectant mother.[11,12,11,13,14,15,16]

Formation of Short-Chain Fatty Acid: Prebiotics serve as energy sources for the probiotic gut bacteria, which in turn, produce short-chain fatty acids necessary for gut tissue formation and metabolism. In the colon, acetate is the most common short-chain fatty acid, following propionate and butyrate. Acetate is synthesized by the muscles, heart, and brain, while propionate inhibits the

liver's glucose output and cholesterol output. Butyrate affects colonocyte differentiation, improvement, expression of gene, and transcriptional proteins. It enhances the synthesis of glutathione S-transferase and catalase, thereby boosts detoxification and protection against antioxidant while suppressing the advancement of cell cycle as well as reducing DNA repair pathways in cancer cells.[11,17,18,19,20,21,22,23]

Reduction of cancer development in the colon: Colorectal cancer, considered to be the third most prevalent cancer, is a multi-step illness that is composed of genetic defects, adenomatous tumors, and advanced and metastatic cancer. Cancer causing compound delivered into the intestinal tract by food or generated by gut bacteria trigger to the early stages of cancer. Butyrate, a prebiotic fermentation product, has been demonstrated to assist hinder the growth of colorectal cancer. Prebiotics have been shown in culture and in animal experiments to boost colon cell detoxification, minimize the toxic metabolite formation in the gut as well as provide protection against colonic tumour growth. Bacterial growth enhances biomass and stool quantity, declining intestinal transit time and lowering exposure to possibly cancer-causing toxins. Prebiotics like inulin-type fructans, galactooligosaccharides, and xylooligosaccharides have been demonstrated to decrease chemically generated colon cancer and precancerous colon lesions. Synbiotics produce a more powerful protective impact. Dietary inulin and oligofructose supplementation also decrease the chance of chemically generated breast cancer, delays progression of tumour, prevent the metastatic cancer, and upgrades cancer curative performance.[11,24,25,26,27,28,29,30,31,32]

Reduction of antimicrobial resistance: The administration of prebiotic bacteria would cause increase in probiotic bacteria in gut, and therefore would indirectly mitigate the chances of occurrence of foodborne infections. Consequenly, the presence of antimicrobial-resistant foodborne bacteria would also decrease. Here it is important to clarify that dietary fibre is not synonymous with prebiotics. Dietary fibre are complex polysaccharides while prebiotics are mostly oligosaccharides and resistant starches.

The role of prebiotics in managing Obesity and Diabetes: Obesity has been closely linked to gut microbiota (GM) composition, particularly an increased Firmicutes/Bacteroidetes ratio, which is commonly observed in obese individuals. Firmicutes are more efficient at extracting energy from food, leading to higher calorie absorption and weight gain. However, prebiotics play a crucial role in modulating this ratio by promoting the growth of beneficial Bacteroidetes while reducing Firmicutes abundance, thereby supporting weight loss. Additionally, prebiotics enhance the presence of beneficial bacteria such as *Bifidobacterium* and *Faecalibacterium*, which are associated with reduced fat mass and lower systemic inflammation. Studies have shown that supplementation with prebiotics like inulin leads to increased proportions of these bacteria, which in turn improve gut integrity and metabolic functions. By restoring gut microbial balance, prebiotics help regulate food intake, appetite, and lipid metabolism, making them a valuable dietary intervention for obesity management.

Beyond obesity, prebiotics also play a significant part in managing type 2 diabetes mellitus (T2DM) by influencing glucose metabolism. The consumption of prebiotics leads to the production of short-chain fatty acids (SCFAs), which improve insulin sensitivity, lower blood glucose levels, and stimulate glucagon-like peptide-1 (GLP-1) secretion. Certain prebiotics, such as fructooligosaccharides (FOS) and inulin-type fructans (ITF), have been found to reduce fasting blood glucose and enhance gut microbial diversity. Additionally, compounds like chitooligosaccharides (COS) have demonstrated significant benefits in managing hyperglycemia, hyperlipidemia, and inflammation, further supporting their role in diabetes management. By reducing gut permeability, bacterial translocation, and lipopolysaccharide (LPS)-induced inflammation, prebiotics help mitigate many adverse effects of metabolic diseases.

CONCLUSION

Prebiotics are dietary elements which act by myriad mechanisms to exert various helpful functions like increase in count of probiotic bacteria. They consist mainly of various fructooligosaccharides and galactooligosaccharides. They have other effects like antihyperlipidemic and anticancer effects, other than its noted effect on probiotic bacteria. More research awaits the field of prebiotics to find novel applications like reducing the burden of antimicrobial resistance caused by microbes causing foodborne infections.

REFERENCES

1. Davani-Davari D, Negahdaripour M, Karimzadeh I, Seifan M, Mohkam M, Masoumi S, et al. Prebiotics: Definition, Types, Sources, Mechanisms, and Clinical Applications. Foods, 2019 Mar 9; 8(3): 92.
2. Preparation and Processing of Religious and Cultural Foods [Internet]. Elsevier Shop. 2018 [cited 2025 Jan 27]. Available from: https://shop.elsevier.com/books/preparation-and-processing-of-religious-and-cultural-foods/ali/978-0-08-101892-7.
3. Blatchford P, Ansell J, de C, Fahey G, Whelan K. Prebiotic mechanisms, functions and applications - A review. International Journal of Probiotics and Prebiotics, 2013 Oct 1; 8(4): 109–32.
4. Niittynen L, Kajander K, Korpela R. Galacto-oligosaccharides and bowel function. Scandinavian Journal of Food and Nutrition, 2007 Jun; 51(2): 62-6.
5. Franco-Robles E, López MG. Implication of Fructans in Health: Immunomodulatory and

Antioxidant Mechanisms. The Scientific World Journal, 2015; 2015: 1–15.
6. Bamigbade GB, Subhash AJ, Kamal-Eldin A, Nyström L, Ayyash M. An Updated Review on Prebiotics: Insights on Potentials of Food Seeds Waste as Source of Potential Prebiotics. Molecules, 2022 Sep 13; 27(18): 5947.
7. Johnson CR, Thavarajah D, Combs GF, Thavarajah P. Lentil (Lens culinaris L.): A prebiotic-rich whole food legume. Food Research International, 2013 Apr; 51(1): 107-13.
8. Fuentes-Zaragoza E, Sánchez-Zapata E, Sendra E, Sayas E, Navarro C, Fernández-López J, et al. Resistant starch as prebiotic: A review. Starch Stärke, 2011 Jul; 63(7): 406-15.
9. Sorrenti V, Ali S, Mancin L, Davinelli S, Paoli A, Scapagnini G. Cocoa Polyphenols and Gut Microbiota Interplay: Bioavailability, Prebiotic Effect, and Impact on Human Health. Nutrients, 2020 Jun 27; 12(7): 1908.
10. You S, Ma Y, Yan B, Pei W, Wu Q, Ding C, et al. The promotion mechanism of prebiotics for probiotics: A review. Frontiers in Nutrition, 2022 Oct 5; 9.
11. Sharma S, Agarwal N, Verma P. Miraculous Health Benefits of Prebiotics, 2012 Jan 1; 3(6): 1000–9.
12. Kaur N, Gupta AK. Applications of inulin and oligofructose in health and nutrition. J Bio sci., 2002 Dec; 27(7): 703-14.
13. Moro G, Minoli I, Mosca M, Fanaro S, Jelinek J, Stahl B, et al. Dosage-Related Bifidogenic Effects of Galacto- and Fructooligosaccharides in Formula-Fed Term Infants. Journal of Pediatric Gastroenterology and Nutrition, 2002 Mar; 34(3): 291-5.
14. Chen H, Lu Y, Lin J, Ko L. Effects of Isomalto-Oligosaccharides on Bowel Functions and Indicators of Nutritional Status in Constipated Elderly Men. Journal of the American College of Nutrition, 2001 Feb; 20(1): 44-9.
15. TATEYAMA I, HASHII K, JOHNO I, IINO T, HIRAI K, SUWA Y, et al. Effect of Xylooligosaccharide Intake on Severe Constipation in Pregnant Women. Journal of Nutritional Science and Vitaminology, J Nutr Sci Vitaminol, 2005; 51(6): 445-8.
16. Schumann C. Medical, nutritional and technological properties of lactulose. An update. European Journal of Nutrition, 2002 Oct 1; 41(0): 1.
17. Belenguer A, Duncan SH, Calder AG, Holtrop G, Louis P, Lobley GE, et al. Two Routes of Metabolic Cross-Feeding between*Bifidobacterium adolescentis*and Butyrate-Producing Anaerobes from the Human Gut. Appl Environ Microbiol., 2006 May; 72(5): 3593-9.
18. Flint HJ, Duncan SH, Scott KP, Louis P. Interactions and competition within the microbial community of the human colon: links between diet and health. Environmental Microbiology, 2007 May; 9(5): 1101-11.
19. Topping DL, Clifton PM. Short-Chain Fatty Acids and Human Colonic Function: Roles of Resistant Starch and Nonstarch Polysaccharides. Physiological Reviews, 2001 Jul 1; 81(3): 1031-64.
20. Säemann MD, Böhmig GA, Zlabinger GJ. Short-chain fatty acids: bacterial mediators of a balanced host-microbial relationship in the human gut. Wiener klinische Wochenschrift, 2002 Autumn, 2002; 114(8-9): 289–300.
21. Kodde IF, Van Der Stok J, Smolenski RT and De Jong JW: Metabolic and genetic regulation of cardiac energy substrate preference. Comp Biochem Physiol A Mol Integr Physiol, 2007; 146: 26-39.
22. Sauer J, Richter KK and Pool-Zobel BL: Physiological concentrations of butyrate favorably modulate genes of oxidative and metabolic stress in primary human colon cells. J Nutr Biochem., 2007; 18: 736-45.
23. Munshi A, Kurland JF, Nishikawa T, Tanaka T, Hobbs ML, Tucker SL, et al. Histone Deacetylase Inhibitors Radiosensitize Human Melanoma Cells by Suppressing DNA Repair Activity. Clinical Cancer Research, 2005 Jul 1; 11(13): 4912
24. Davani-Davari D, Negahdaripour M, Karimzadeh I, Seifan M, Mohkam M, Masoumi S, et al. Prebiotics: Definition, Types, Sources, Mechanisms, and Clinical Applications. Foods, 2019 Mar 9; 8(3): 92.
25. Candela M, Guidotti M, Fabbri A, Brigidi P, Franceschi C, Fiorentini C. Human intestinal microbiota: cross-talk with the host and its potential role in colorectal cancer. Critical Reviews in Microbiology, 2011 Feb; 37(1): 1-14.
26. Louis P, Flint HJ. Diversity, metabolism and microbial ecology of butyrate-producing bacteria from the human large intestine. FEMS Microbiology Letters, 2009 May; 294(1): 1-8.
27. Davis CD, Milner JA. Gastrointestinal microflora, food components and colon cancer prevention. The Journal of Nutritional Biochemistry, 2009 Oct; 20(10): 743-52.
28. Wijnands M. Effect of dietary galacto-oligosaccharides on azoxymethane-induced aberrant crypt foci and colorectal cancer in Fischer 344 rats. Carcinogenesis, 2001 Jan 1; 22(1): 127-32.
29. Pool-Zobel BL: Inulin-type fructans and reduction in colon cancer risk: review of experimental and human data. Br J Nutr., 2005; 93(Suppl 1): S73-S90.
30. Hsu CK, Liao JW, Chung YC, Hsieh CP and Chan YC: Xylooligosaccharides and fructooligosaccharides affect the intestinal microbiota and precancerous colonic lesion development in rats. J Nutr., 2004; 134: 1523-8.
31. Verghese M, Rao DR, Chawan CB, Williams LL and Shackelford L: Dietary inulin suppresses azoxymethane-induced aberrant cryp foci and colon tumors at the promotion stage in young Fisher 344 rats. J Nutr., 2002; 132: 2809-13.
32. Taper HS and Roberfroid MB: Possible adjuvant cancer therapy by two prebiotics--inulin or oligofructose. In Vivo, 2005; 19: 201-4.