



THE ROLE OF DIETARY FIBER IN PROMOTING GUT HEALTH AND PREVENTING GASTROINTESTINAL DISEASES: A COMPREHENSIVE REVIEW

Bareera Sana^{1*}, Nouman Mushtaq², Zainab Hira³, Aimen Ramzi⁴, Fatima Abid⁵, Areeba Sanaullah⁶, Bibi Nusrat Batool⁷, Saleha Hameed⁸

^{1*}Student, University Institute of Diet & Nutritional Sciences, The University of Lahore, Pakistan
(bareerasana@gmail.com)

²Student, University Institute of Diet & Nutritional Sciences, The University of Lahore, Pakistan
(noumanmushtaqfsd@gmail.com)

³Program Assistant, United Nations World Food Programme (Zaynabhira@yahoo.com)

⁴Visiting Faculty, Riphah International University, Gujranwala Campus
(stunning.9211@gmail.com)

⁵Assistant Professor, University Institute of Diet & Nutritional Sciences, The University of Lahore, Pakistan (Fatima.abid@dnsc.uol.edu.pk)

⁶Visiting Faculty, Arid University Barani Institute of Sciences, Burewala, Pakistan
(areebasanaullah793@gmail.com)

⁷Student, University Institute of Diet & Nutritional Sciences, The University of Lahore, Pakistan
(nusrat.xaidi@gmail.com)

⁸Assistant Professor, School of Human Nutrition & Dietetics, Minhaj University Lahore, Pakistan
(hameed.saleha@yahoo.com)

***Corresponding Author:** Bareera Sana

***E-mail:** (bareerasana@gmail.com)

Abstract:

Dietary fibre has a significant influence on gut microbiota and human health. Fibre significantly impacts both gut microbial ecology and host physiology. The article highlights the protective effects of fibre against heart disease, obesity, diabetes, and cancer. It emphasizes fibre's ability to lower LDL cholesterol, blood pressure, and BMI while also promoting feelings of satiety and maintaining intestinal health. SCFAs, produced through fibre fermentation, are identified as pivotal in regulating energy balance and supporting immune function. Furthermore, SCFAs are noted for their role in enhancing the secretion of insulin and maintaining glucose mechanism from the gut-brain axis, particularly in individuals with obesity and diabetes. In short, the review highlights the critical connection between dietary fibre, the composition of gut microbiota, and human health.

Introduction:

Dietary fibre refers to edible carbohydrate polymers containing three or more monomeric units. The enzymes in small intestines do not easily digest these compounds, thus avoiding hydrolysis and absorption. Structurally, dietary fibres include complex carbohydrates, un easily digested starches, resistant oligosaccharides, and lignin. Lignin, a non-carbohydrate polymer found alongside the cellulose in plant cell walls, is also included in this classification. From a sourcing perspective, dietary fibres can be categorized into three subgroups: (i) carbohydrate compounds naturally found in plant-

based foods, (ii) carbohydrate polymers derived from foods that are raw through different processes, known to offer physiological benefits (e.g., indigestible oligosaccharides, inulin, psyllium); and (iii) artificial carbohydrate demonstrating physiological benefits (Jha Sk et al., 2017)ⁱ.

Dietary fibres comprise different kinds of organic materials with different compositions and bonds. They have a complex and varied structure. Dietary fibres are grouped based on solubility, viscosity, and fermentability characteristics. Solubility is one way to classify them, with two main types: insoluble and soluble fibres. Insoluble fibres, which do not dissolve in water, typically have a robust and rigid structure. They form tight bonds between sugar molecules, making them resistant to being broken down by enzymes in your body. Cellulose is the most common type of insoluble fibre found in plants, and it is made of a type of sugar called beta-glucose. It is a vital part of plant cell walls, often mixed with other fibres like hemicellulose, pectin, and lignin (Dreher ML, 2017)ⁱⁱ.

Gut microbiota and its importance:

Refers to a vast range of tiny microorganisms living in the human GIT. Predominantly comprised of prokaryotic species, many unicellular organisms lack specialized organelles and the microbiota also includes fungi, parasites, archaea, and viruses. The gut microbiome refers to microbial species' combined genetic and functional traits in our digestive system. The human body contains almost as many bacterial cells as human cells. Bacteria are classified into different groups based on their evolutionary relationships, with organisms in the same group having more similar genetic sequences (Yamashiro Y et al., 2018)ⁱⁱⁱ.

Types of dietary fibre

Dietary fibres encompass a variety of plant-derived compounds such as polysaccharides, lignin, and oligosaccharides, including resistant starch and inulin, which resist digestion by the digestive enzymes of humans. These resistant or partially digested fibres undergo fermentation by the intestinal flora in the small intestine or colonic region. Solubility is a basis for classifying dietary fibres into soluble and insoluble types. Soluble dietary fibres found abundantly in fruits and vegetables (e.g., pectin, inulin) play a significant role. In contrast, insoluble fibres, prevalent in wheat bran, oats, and barley (e.g., cellulose, hemicellulose), contribute to bulking effects.

Dissolvable fibres, particularly viscous or fermentable fibres like β -glucans and pectin, exert crucial roles in regulating glucose homeostasis regulated by insulin, especially in individuals with diabetes. These fibres undergo fermentation in the rectum, with their byproducts conferring beneficial effects. Coarse fibres, such as wheat bran, primarily provide the bulking effects and undergo partial fermentation in the intestine.

Regular intake of soluble fibres like guar gum and hydroxypropyl methylcellulose has been associated with reduced serum LDL cholesterol levels, thus helping in atherosclerosis and heart disease prevention. Psyllium husk, a key component of fiber-supplemented products, shows highlighted effects in reducing blood pressure, cholesterol levels, sugar levels in blood, and the risk of heart diseases. Additionally, soluble fibres like guar gum contribute to reducing gastrointestinal problems, thereby helping prevent ulcers of the duodenum (SP et al., 2020)^{iv}.

Gut microbiota and its function

The foundation of the human gut microbiota commences in the early stages of life, and it plays a pivotal role in the host organism and its normal functioning. This diverse microbial community synthesizes various products of metabolism that can impact human health through interactions with the host. By inhabiting and replicating on surfaces of the intestines, the gut flora creates a stable system that inhibits pathogenic microorganisms from invading the system. The microbiota's metabolic activities involve breaking dietary elements into bioactive components. Nondigestible fibres such as cellulose, hemicelluloses, and lignin are metabolized into volatile fatty acids like acetic, propionic, and other acids, primarily by bacteria and other anaerobic microorganisms of the gut.

Moreover, the gut microbiota contributes to the formation of essential vital nutrients such as biotin, thiamine, cobalamin, riboflavin, niacin, and other nutrients, along with vitamins B and K. Additionally, certain neurochemicals synthesized by the gut microbiota, like gamma-aminobutyric acid (GABA), can affect both the CNS and the peripheral enteric framework. Carbohydrates, branched-chain amino acids, amines, and conjugated polyunsaturated fatty acids are among the other compounds generated by the gut microbiota's enzymatic activities.

The gut microbiota's protective role involves occupying surfaces of the intestines and providing stability within the system, thus preventing pathogenic microorganisms from invading. Furthermore, the microbiota's metabolic capabilities, such as the fermentation of nondigestible compounds into SCFAs, strengthen the mucosal barrier, provide a significant energy source for intestinal walls, and exhibit anti-inflammatory and anti-carcinogenic properties.

The gut microbiota's impact extends beyond gastrointestinal health, influencing bone growth and development. SCFAs produced by the microbiota enhance calcium absorption, thus contributing to bone mineralization. Additionally, certain strains of gut bacteria regulate processes of bone metabolism. The gut-brain axis serves as a two-directional communication pathway between gut microbes and the cerebrum, coordinating gut functions and connecting emotional centres of the intellect with functions of the peripheral intestines. SCFAs produced by the intestinal flora influence the ethics of the blood-brain barrier, while compounds like lipoproteins and lipopolysaccharides affect the autoimmune function and neuronal activation, subsequently altering mood and behaviour (Rowland et al. 2018)^v.

Prevalence of gut-related diseases and conditions:

The prevalence of gut-related diseases varies depending on geographic location, demographics, lifestyle, and genetic predisposition. However, several gut-related diseases are commonly observed worldwide:

IBS in the three countries was slightly higher than the worldwide occurrence. However, it was significantly lower in China compared to Japan and South Korea. Among age groups, individuals in their 40s had the highest prevalence of IBS, while those in their 60s had the lowest. Men showed a higher prevalence of IBS with diarrhea. More research is necessary to understand the factors contributing to this regional variation (Takeoka et al., 2023)^{vi}.

GERD is a chronic condition categorized by the reflux of stomach components into the esophagus, leading to indications such as heartburn, vomiting, and chest pain. It affects approximately 10-20% of the population in Western countries.^{vii} Diverticular disease is diverticula, a small pouch that develops in the colon wall. When these pouches become inflamed or infected, they lead to diverticulitis. The prevalence of diverticular disease increases with age, affecting up to 50% of individuals over the age of 60 in Western countries.^{viii} Celiac disease is an autoimmune disorder initiated by gluten intake, wheat, barley, and rye protein. It damages the small intestine and inefficient absorption of nutrients. The prevalence of celiac disease varies widely across different populations, with estimates ranging from 0.5 to 1% globally (Thongpiya et al., 2023)^{ix}.

Table 1.1:

Metabolic Products	Description
Short-chain fatty acids (SCFAs)	Bacteria and other anaerobic gut microorganisms from indigestible carbohydrates synthesize acetic acid and other similar compounds.
Essential vitamins	Gut microbiota synthesizes biotin, thiamine, cobalamin, riboflavin, niacin, pantothenic acid, and vitamins B and K.
Neurochemicals	Gamma-aminobutyric acid (GABA) is synthesized by gut microbiota and affects the central nervous and peripheral enteric systems.
Other compounds	Carbohydrates, branched-chain amino acids, amines, phenols, indoles, phenylacetic acid, bile acids, cholesterol, and conjugated fatty acids are generated by gut microbiota's enzymatic activities.

Protective Role	Description
Occupying intestinal surfaces	Gut microbiota creates stability within the system, preventing the invasion of pathogenic microorganisms.
Strengthening the mucosal barrier	Fermentation of nondigestible compounds into SCFAs strengthens the mucosal barrier, provides intestinal epithelial cells energy, and exhibits anti-inflammatory and chemo-preventive properties.
Impact on Bone Health	Description
Enhanced calcium absorption	Volatile fatty acids produced by gut microbiota enhance calcium absorption, contributing to bone mineralization.
Regulation of bone remodeling	Certain strains of gut bacteria regulate osteoclast-osteoblast-mediated bone remodelling processes.
Gut-Brain Axis	Description
Influence on blood-brain barrier	Volatile fatty acids produced by gut flora influence the ethics of the blood-brain barrier.
Effect on mood and behaviour	Lipoproteins and lipopolysaccharides affect the autoimmune function and neuronal activation, subsequently altering mood and behaviour.

Mechanisms of Action of Dietary Fiber in the Gut:

Fermentation:

- Dietary fibres, particularly those resistant to digestion by human enzymes, reach the colon intact.
- Gut microbiota ferments these indigestible fibres, breaking them down into smaller molecules.
- This fermentation process produces volatile fatty acids, including acetate, propionate, and others, which serve as energy sources for colonocytes and have numerous beneficial effects on gut health.

Modulation of Gut Microbiota Composition:

- Dietary fibres promote the growth and function of essential gut bacteria, such as Bifidobacteria and Lactobacilli, while inhibiting the progress of potentially harmful bacteria.
- The fermentation of dietary fibres by gut microbiota produces metabolites that create an environment conducive to the growth of beneficial bacteria, thereby modulating the overall composition of the gut microbiota.

Maintenance of Gut Barrier Function:

- Short-chain fatty acids (SCFAs) produced during fibre fermentation support the integrity of the intestinal barrier by stimulating mucin production. Mucin serves as a protective lining along the intestinal epithelium.
- Short-chain fatty acids (SCFAs) also stimulate the production of tight junction proteins, which control the permeability of the intestinal epithelium and prevent the entry of harmful substances into the bloodstream.

Regulation of Immune Function:

- Dietary fibres and their fermentation products interact with immune system cells in the gut-associated lymphoid tissue (GALT), influencing immune function.
- SCFAs produced during fibre fermentation have immunomodulatory effects. They promote. They promote anti-inflammatory responses and reduce the risk of immune system diseases such as inflammatory bowel disease (IBD).

Regulation of Metabolism:

- SCFAs produced from fibre fermentation are vital in initiating glucose and lipid metabolism.
- Short-chain fatty acids (SCFAs), especially butyrate, have been demonstrated to enhance insulin sensitivity, decrease inflammation, and reduce blood lipid levels, promoting metabolic health (Bhatia et al., 2023)^x.

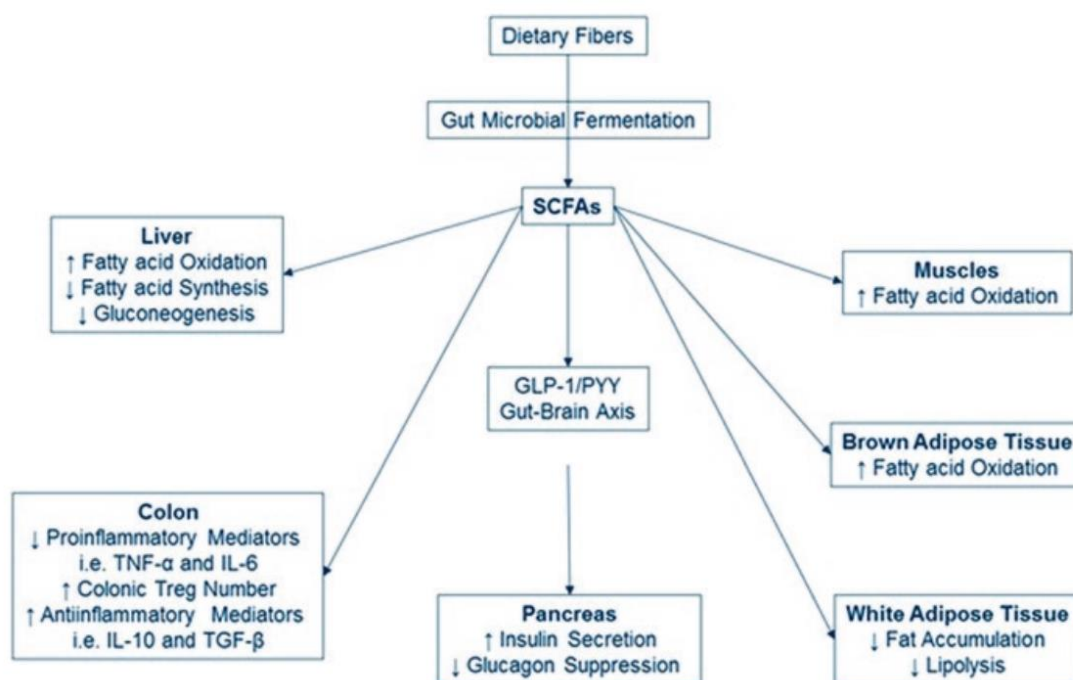


Figure 1.1: Mechanism of action of dietary fiber. Diagram illustrating the metabolic effects of short-chain fatty acids (SCFAs) produced through gut microbial fermentation of dietary fibres. SCFAs influence various organs and metabolic pathways:

2. Liver: Volatile fatty acids (SCFAs) increase fatty acid oxidation, decrease their synthesis, and stop gluconeogenesis.
3. Colon: SCFAs reduce proinflammatory mediators like $\text{TNF-}\alpha$ and IL-6, increase the number of rectum regulatory T cells (Treg), and promote anti-inflammatory mediators such as IL-10 and $\text{TGF-}\beta$.
4. Pancreas: SCFAs enhance the secretion of insulin and suppress glucagon release.
5. GLP-1/PYY Gut-Brain Axis: SCFAs influence this axis, regulating appetite and energy expenditure.
6. Muscles: SCFAs increase fatty acid oxidation in muscles.
7. Brown Adipose Tissue: SCFAs enhance fatty acid oxidation in brown adipose tissue.
8. White Adipose Tissue: SCFAs reduce fat accumulation and promote lipolysis in white adipose tissue.

Dietary fibre and diseases:

Inflammatory Bowel Syndrome (Ibs)

Irritable bowel syndrome (IBS) is a condition in which abdominal pain, bloating, and changes in bathroom habits occur. These symptoms can worsen when too much gas in the intestines from food being fermented.

Studies show that in people with IBS, there are more short-chain fatty acids (SCFAs) in their intestines. These SCFAs can make the intestines move faster by releasing a serotonin chemical. Even though IBS is not life-threatening, it can affect how someone feels and their daily life. The gut microbiota living in our intestines also play a role in IBS. People with IBS have different kinds and amounts of these organisms compared to healthy people. This imbalance might contribute to the development and worsening of IBS symptoms. In particular, some types of bacteria increase in people with IBS, while beneficial ones decrease. This imbalance in the gut bacteria might be an essential factor in causing IBS symptoms (Yoosuf S., 2023)^{xi}.

Liver diseases

Fatty liver diseases, like nonalcoholic fatty liver disease (NAFLD), often happen because of overweight, drinking too much alcohol, or having metabolic syndrome. These conditions develop when fat, primarily triglycerides, builds up in liver cells, which can lead to severe problems like liver cirrhosis or cancer.

The exact reasons NAFLD happens are not entirely known, but the gut bacteria in our intestines might play a significant role. Certain studies have indicated that individuals with fatty liver diseases may exhibit decreased levels of specific types of bacteria, such as Firmicutes and Bacteroides while showing higher levels of *E. coli*.

Changes in gut bacteria might contribute to NAFLD in a few ways. For example, having more short-chain fatty acids (SCFAs) and a specific imbalance in bacteria can make the body absorb more energy from food, making more fat in the liver. Also, a problem with gut bacteria can lead to less production of a substance called butyrate, which helps control fat buildup in the liver.

Drinking too much alcohol can also damage the liver by affecting the gut. Alcohol can increase the number of harmful substances like lipopolysaccharide (LPS) in the intestines, which can then get into the liver and cause inflammation. This can happen because alcohol can change the types of bacteria in the gut and make it easier for harmful substances to get through the intestinal walls (Mathers JC et al., 2023)^{xii}.

Obesity

Obesity is characterized by a body mass index (BMI) over 30 kg/m², caused by excess fat tissue accumulation. It is a widespread condition, affecting approximately 2 billion individuals worldwide and leading to various metabolic abnormalities collectively known as metabolic syndrome. These abnormalities include insulin resistance, diabetes, osteoarthritis, hyperlipidemia, liver steatosis, and cancer. Several factors contribute to obesity, including genetic, behavioural, and environmental factors. The gut microbiota also plays a significant role in its development and progression. Microbiota from obese individuals demonstrate an increased capacity for fermenting and harvesting energy from the diet. In obese people, there is often a higher ratio of Firmicutes to Bacteroides/Prevotella, which enhances microbial genes involved in polysaccharide degradation and increases the production of short-chain fatty acids (SCFAs). Consequently, there is increased expression of enzyme-coding genes responsible for carbohydrate metabolism and SCFA production. Obese individuals tend to have an abundance of certain bacteria such as *Porphyromonas*, *Campylobacter*, and others compared to lean individuals. Conversely, lower proportions of beneficial bacteria like *Lactobacillus*, *Bifidobacterium*, and *Faecalibacterium* have been observed in obese individuals (Bennet S et al., 2015)^{xiii}.

Cardiovascular disease

Traditional alarms for heart disease, like being obese and having type 2 diabetes, are well-known. In diets typical in Western countries, foods like choline and carnitine, found in meat and dairy products, can be broken down by gut bacteria into a compound called trimethylamine (TMA), which then turns into trimethylamine-N-oxide (TMAO) in the liver. High levels of TMAO have been linked to clogged arteries. People with clogged arteries have less of certain helpful bacteria in their gut that produce butyrate, a substance that's good for the heart. Instead, they have more genes linked to inflammation, which can make heart disease worse (Allen JM et al., 2018)^{xiv}.

Cancer

Cancer is a significant cause of death worldwide. Certain bacteria, like *Bacteroides fragilis*, *Enterococcus faecalis*, and *Helicobacter hepaticus*, can make cancer more likely by producing harmful compounds that damage DNA. Another bacterium indirectly contributes to cancer by a constant state of inflammation. What we eat also affects our cancer risk, especially for colon cancer. Diets high in animal protein and fats but low in fibre increase the risk, while diets rich in veggies,

fruits, fish, and whole grains lower it. People prone to cancer of the rectum or colon often have more bacteria that make harmful bile acids but fewer that make helpful substances like butyrate. Chronic inflammation is a significant factor in colon cancer risk. Cancer progression does not just depend on specific bacteria but also on how the whole gut microbiota works together. Some studies suggest that the mix of bacteria in the gut could affect how well people respond to specific cancer treatments. Patients who respond well to a type of cancer treatment called anti-PD1 therapy tend to have a more varied mix of gut bacteria compared to those who do not respond as well. This suggests that understanding the gut microbiota could help improve cancer treatments in the future (Estruch R et al., 2018)^{xv}.

Depression

Depression, a mood disorder characterized by immune system dysregulation and deficiencies in tryptophan metabolism, is related to the gut microbiome. Changes in the gut-brain axis associated with depression can lead to inflammation. Alterations in intestine permeability and disrupted barrier ethics allow certain bacteria, such as Enterobacteriaceae, to cross the wall, triggering inflammation. Research conducted by a scientist provided further confirmation that the gut microbiota can play a causal role in the development of depression. The transplantation of fecal microbiota from depressed patients to microbiota-depleted rats altered tryptophan metabolism, leading to anhedonia and anxiety-like behaviour in the recipient animals (Biagi et al., 2017)^{xvi}.

The gut microbiota as a therapeutic agent:

Therapeutic strategies for rebalancing the intestinal ecosystem and treating various diseases can be categorized into three main approaches: (A) probiotics and synbiotics, (B) fecal microbiota transplantation, and (C) phage therapy.

Probiotics and Synbiotics:

Beneficial bacteria (Probiotics) are tiny living organisms considered safe for consumption and can offer health benefits when taken in the right amounts. They can survive in the gut despite harsh conditions like stomach acid and bile. Common probiotics include *Lactobacillus*, *Bifidobacteria*, and yeast such as *Saccharomyces boulardii*. Eating fermented foods like yogurt can boost the levels of these helpful bacteria in the gut. Probiotics come in different forms, like supplements or added to foods such as yogurt, cheese, chocolates, and even non-dairy products. Some companies use special techniques to protect the bacteria and ensure their effectiveness. The benefits of probiotics can vary depending on the type and number of bacteria used (Kelly et al., 2015)^{xvii}.

Probiotic bacteria have several vital roles in the body. They help maintain a healthy balance in the gut by producing volatile fatty acids (SCFAs), making essential vitamins like B and K, and breaking down harmful substances. They also fight off bad bacteria by releasing compounds that inhibit their growth. Additionally, probiotics boost the immune system by activating specific immune cells and strengthening the gut lining. Probiotics help prevent imbalances in the gut caused by things like antibiotics, stress, or chronic illnesses. They can also be used to treat existing imbalances. Research suggests that probiotics might even help prevent and treat diseases like cancer. They can do this by binding to harmful substances, reducing inflammation, and affecting cell growth. Probiotics have shown promise in treating diarrhea, obesity, UTIs, IBS, and type 2 diabetes. In people with type 2 diabetes, probiotics have been found to lower blood sugar levels, reducing the risk of heart disease (Singh et al., 2017)^{xviii}.

Moreover, beneficial bacteria have emerged as a therapeutic alternative for neurological and psychiatric diseases. Supplementation with these bacteria, primarily *Lactobacillus*, *Bifidobacterium*, *Lactococcus*, and *Streptococcus*, has significantly improved psychological symptoms such as depression, stress, and anxiety. Their mode of action may involve reducing proinflammatory cytokines and communicating with the brain through specific nerves, leading to changes in neurotransmitter function (La Fata et al., 2017)^{xix}.

Synbiotics are combinations of pro- and prebiotics, with the prebiotic compounds especially favouring the growth of good organisms. Studies on synbiotics have shown variability, reflecting the diversity of tested probiotic strains and the populations examined. Since gut microbiota composition varies widely among individuals and dysbiosis can occur at different levels and types, careful consideration should be given before choosing synbiotics for patient treatment.

Synbiotics, a combination of probiotics and prebiotics, are being used to treat different illnesses. Inulin, a prebiotic, has effectively treated ulcerative colitis combined with butyrate. This combination has been found to decrease diastolic blood pressure and fasting blood glucose levels, and it can reduce the risk of type 2 diabetes. Synbiotics also hold the potential to lower the risk of colorectal cancer by producing short-chain fatty acids (Kelly JR et al., 2015)^{xx}.

Fecal Microbiota Transplantation (FMT):

Intestinal microbiota transplantation (IMT) involves transferring healthy intestinal microorganisms to patients with intestinal infections to restore their gut microbiota. IMT has shown high effectiveness in restoring the composition and function of the gut microbiota and has been extensively used to treat various diseases, including irritable bowel syndrome, inflammatory bowel disease, obesity, autism, diarrhea, and metabolic syndrome. The exact mechanism of IMT is not fully understood but may involve changes in bacterial composition, modifications in host metabolic profiles, introduction of new species of gut microbiota from healthy donors, and presentation of peptides from the donor that modify host immune responses (Firouzi et al., 2018)^{xxi}.

Despite its benefits, FMT also poses some drawbacks and safety concerns. The microbiota of treated patients has been shown to resemble that of the donor after therapy. However, safety concerns are related to transferring microbial pathogens or undesirable disease traits such as obesity, diabetes, chronic diseases, and metabolic syndromes. To address these concerns, defined preparations of gut microbiota with their therapeutic components, or mixtures of defined species or strains, may be considered as alternatives to traditional FMT (Gianotti et al., 2017)^{xxii}.

Phage Therapy:

Viruses, particularly bacteriophages or phages, are essential to the human virome alongside bacteria. Phages, which comprise about 90% of the virome, play a crucial role in regulating bacterial populations and have the potential for antimicrobial therapy and shaping microbial communities. When administered, phages can multiply rapidly, but this process depends on factors like the concentration of susceptible organisms and the host's immune response. This makes timing and dosage crucial for effective treatment. Although phages have been used in Eastern Europe since the early 20th century, more research is needed to gather essential data for their approval as bactericidal drugs. Further studies are necessary to address these points (Li S et al., 2016)^{xxiii}.

Conclusion:

Our bodies interact with food, and tiny organisms in our gut are essential for our health. Eating foods like fruits, veggies, and whole grains contains dietary fibre, which our bodies cannot fully digest. Instead, this fibre travels to our gut, where helpful bacteria break it down into substances called short-chain fatty acids (SCFAs). These SCFAs do many good things in our bodies, like keeping our immune system strong, helping us control our weight, and even affecting our mood and brain function.

On the other hand, when the balance of these gut bacteria gets messed up, it can lead to various health problems. Conditions like obesity, heart disease, and even depression can be linked to imbalances in our gut bacteria. However, we can do things to help keep our gut bacteria happy and healthy. Eating a balanced diet rich in fibre, taking probiotics or synbiotics (which are supplements that contain good bacteria), and in some cases, even getting a fecal transplant (where healthy gut bacteria are transferred from a donor) can all help regain the balance of bacterial organisms in our guts and improve our health.

Understanding how our bodies and these tiny organisms work together can help us find new ways to treat and prevent diseases, ensuring our health.

Conflict of interest:

The author declares that they have no conflicts of interest.

REFERENCES:

1. Jha SK, Singh HR, Prakash P. Dietary fibre and human health: an introduction. In Dietary fiber for the prevention of cardiovascular disease 2017 Jan 1 (pp. 1-22). Academic Press.
2. Dreher ML, Dreher ML. Introduction to dietary fiber. Dietary fibre in health and disease. 2018;1-8.
3. Yamashiro Y. Gut microbiota in health and disease. Annals of Nutrition and Metabolism. 2018 Jan 11;71(3-4):242-6.
4. Merenkova SP, Zinina OV, Stuart M, et al. Effects of dietary fibre on human health:2020;20(1):106-13.
5. Rowland I, Gibson G, Heinken A, et al. Gut microbiota functions in the metabolism of nutrients and other food components. European journal of nutrition. 2018 Feb; 57:1-24.
6. Takeoka A, Kimura T, Hara S, et al. Prevalence of irritable bowel syndrome in Japan, China, and South Korea: an international cross-sectional study. Journal of Neuro-gastroenterology and Motility. 2023 Apr 4;29(2):229.
7. Thongpiya J, Charoenngam N, Ponvilawan B, et al. Increased prevalence of gastroesophageal reflux disease among patients with rheumatoid arthritis: a systematic review and meta-analysis. Current Rheumatology Reviews. 2023 Nov 1;19(4):496-503.
8. Bhatia M, Mattoo A. Diverticulosis and diverticulitis: epidemiology, pathophysiology, and current treatment trends. Cureus. 2023 Aug 8;15(8).
9. Yoosuf S, Singh P, Khaitan A, et al. Prevalence of celiac disease in patients with liver diseases: a systematic review and meta-analyses. Official journal of the American College of Gastroenterology| ACG. 2023 May 1;118(5):820-32.
10. Mathers JC. Dietary fibre and health: the story so far. Proceedings of the Nutrition Society. 2023 May;82(2):120-9.
11. Bennet S, Ohman L, Simren M (2015) Gut microbiota as potential orchestrators of irritable bowel syndrome. Gut Liver 9:318–931
12. Betrapally N, Gillevet P, Bajaj J (2016) Changes in the intestinal microbiome and alcoholic and nonalcoholic liver diseases: causes or effects? Gastroenterology 150:1745–1770
13. Allen JM, Mailing LJ, Niemi GM, et al. (2018) Exercise alters gut microbiota composition and function in lean and obese humans. Med Sci Sport Exer 50:747–757
14. Estruch R, Ros E, Salas-Salvado J, et al. (2018) Primary prevention of cardiovascular disease with a Mediterranean diet supplemented with extra-virgin olive oil or nuts. N Engl J Med 378:34–50
15. Biagi E, Rampelli S, Turroni S, Quercia S, Candela M, Brigidi P (2017) The gut microbiota of centenarians: signatures of longevity in the gut microbiota profile. Mech Age Dev 165:180–184
16. Kelly JR, Kennedy PJ, Cryan JF, Dinan TG, Clarke G, Hyland NP (2015b) Breaking down the barriers: the gut microbiome, intestinal permeability and stress-related psychiatric disorders. Front Cell Neurosci 9:392

17. Singh R, Chang H, Yan D, et al. (2017) Influence of diet on the gut microbiome and implications for human health. *J Translate Med* 15–29
18. La Fata G, Weber P, Mohajeri M (2017) Probiotics and the gut immune system: indirect regulation. *Probiotic Antimicrobe Proteins* 10(1):11–21
19. Kelly JR, Kennedy PJ, Cryan JF, et al. (2015b) Breaking down the barriers: the gut microbiome, intestinal permeability and stress-related psychiatric disorders. *Front Cell Neurosci* 9:392–411
20. Firouzi S, Haghighatdoost F (2018) The effects of prebiotic, probiotic, and symbiotic supplementation on blood parameters of renal function: a systematic review and meta-analysis of clinical trials. *Nutrition* 51–52:104–113
21. Gianotti R, Moss A (2017) Fecal microbiota transplantation from *Clostridium difficile* to inflammatory bowel disease. *Gastroenterol Hepatol* 13:209–213
22. Li S, Zhu A, Benes V, et al. (2016) Durable coexistence of donor and recipient strains after fecal microbiota transplantation. *Science* 352(6285):586–589