

# Enhancing Gut Microbiome focusing on Anti-Inflammatory Foods, Dietary Fiber, and Polyphenols

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**Abstract.** The gut microbiome, a complex ecosystem of diverse microbial species residing in the gastrointestinal tract, plays an integral role in maintaining human health. Often referred to as a “vital organ,” the gut microbiome influences various physiological processes, including nutrient metabolism, immune regulation, and neural communication. Its composition, shaped by genetic, dietary, and environmental factors, is crucial for sustaining overall homeostasis. Balanced gut microbiota supports digestion, synthesizes essential nutrients such as short-chain fatty acids (SCFAs), vitamins, and amino acids, strengthens the intestinal barrier, and communicates with the central nervous system through the gut-brain axis, impacting cognitive and mental health. Conversely, gut dysbiosis—marked by an imbalance in beneficial and harmful bacteria—has been linked to metabolic disorders, autoimmune diseases, inflammatory bowel diseases (IBD), and neurodegenerative conditions. The potential of particular dietary treatments, such as the Mediterranean diet, low-FODMAP diets, and fiber-rich foods, in modifying microbial composition and fostering gut health is highlighted by recent research that highlights the reciprocal relationship between diet and gut microbiota. Furthermore, anti-inflammatory, prebiotics, and polyphenols-rich foods show encouraging therapeutic promise in improving immunological, metabolic, and neurological processes as well as reducing gut dysbiosis. This review looks at the dynamic relationship between gut microbial diversity, dietary patterns, and systemic health to shed light on how specific nutritional strategies may be used as therapeutic and preventative measures to enhance gut health and lower the risk of chronic diseases.

KEYWORDS: Gut Microbiome, Fiber-rich foods, Anti-inflammatory, Prebiotics, Polyphenols.

## 1. INTRODUCTION

Gut microbiome is a collection of diverse bacteria which resides within the gastrointestinal tract [1]. Recently been classified as a “vital organ”, due to its multidirectional and communicational connection or axis within organs through neural, endocrine, humoral, immunological, and metabolic pathways. The gut microbiota is a complex and diverse microbial ecosystem that significantly contributes to various physiological functions, such as nutrient metabolism, immune regulation, and digestion. Although bacteria are found on every surface of the human body, the gastrointestinal system and gut are home to a significant population of them. The gut microbiota is a complex ecological community made up of over a thousand different bacteria species found in the human gut. The gut microbiome is made up of organisms such as *Lactobacillus*, *Saccharomyces cerevisiae*, *Bifidobacterium*, and *Streptococcus* which are involved in production of energy, short-chain fatty acids, floated, vitamins and some other nutritional factors [2].

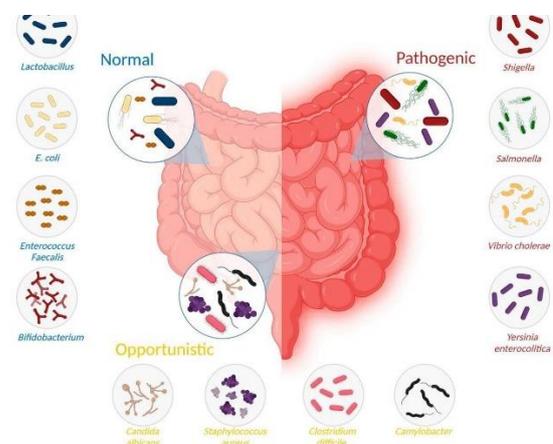


Fig 1.1 Gut Microbiota (*Cancer biology research*)

A well-balanced gut microbiome is essential for maintaining overall health, as disruptions in its composition—referred to as dysbiosis—have been associated with several health conditions, including metabolic disorders, obesity, and inflammatory bowel

disease (IBD). The gut microbiome plays a crucial role in maintaining overall health by influencing various physiological processes including breakdown of nutrients like carbohydrates, proteins and fats that the human body itself cannot digest on its own along with production of essential nutrients, SCFAs (short chain fatty acids), vitamins and amino acids, acts as barrier from harmful toxins and protects against pathogens by interacting with immune system to prevent inflammation, help a regulate appetite, insulin sensitivity and fat storage which help regulate weight. [3]. The gut microbiota regulates the immune system, and autoimmune and inflammatory immune-mediated disorders can be brought on by disruptions in this system. The gut microbiota has promising potential in altering appetite, increasing nutrient harvest, and exerting energy from various food components along the ability to modify the chemical structures of foreign compounds (xenobiotics). While the modification of gut microbiome composition depends mainly on various genetic, nutritional and environmental factors, the composition and function of the gut microbiota can change intestinal permeability, digestion and metabolism as well as immune responses [4]. The relationship between diet and the gut microbiome provides valuable insights into potential therapeutic strategies for improving gut health is shown in Table 1.1.

**Table 1.1. Gut Microbiome Genera and their Functions**

Genera	Function of Gut Microbiome
<i>Bifidobacterium</i>	Ferments carbohydrates to produce lactic acid and acetic acid
<i>Clostridium</i>	Metabolic activity within the gut
<i>Bacteroides</i>	Aids in digestion and nutrients absorption
<i>Eubacterium</i>	Metabolic processes
<i>Roseburia</i>	Fermentation of dietary fibre
<i>Faecalibacterium</i>	Anti-inflammatory properties
<i>Ruminococcus</i>	Degradation of complex carbohydrates
<i>Akkermansia</i>	Degrading bacterium
<i>Escherichia</i>	Vitamin K synthesis
<i>Enterococcus</i>	Act as opportunistic pathogens
<i>Streptococcus</i>	Acts as probiotics, Lactic acid fermentation
<i>Klebsiella</i>	Fermentation of lactose

## 2. INTERRELATIONSHIP OF GUT MICROBIOTA AND HUMAN HEALTH

The composition of the gut microbiota varies among individuals and is influenced by factors such as genetics, diet, age, and environmental exposures. It is initially populated with *Enterococcus* and *Klebsiella*, and then followed by *Clostridium*, *Bifidobacterium*, and *Bacteroides*. Gut microbiota dysbiosis in the first week of life can weaken the immune system and increase the risk of serious intestinal diseases like NEC (necrotizing enterocolitis) [5]. The predominant bacterial phyla in the human gut include *Firmicutes*, *Bacteroidetes*, *Actinobacteria*, and *Proteobacteria*. A balanced gut microbiota, known as eubiosis, promotes homeostasis, whereas an imbalance, referred to as dysbiosis, which harmful bacteria exceed helpful ones in the gut microbiota disrupts immune function, thereby heightening vulnerability to infections and contributing to the development of autoimmune disorders such as type 1 diabetes, rheumatoid arthritis, and multiple sclerosis, obesity, inflammatory bowel disease (IBD), and metabolic syndrome. The gut microbiome contributes to development and shaping of the host immune system. It is via the gut-associated lymphoid tissues composed of Peyer's patches and affecting the synthesis of anti-inflammatory cytokines, gut microbes affect the immune system. A well-balanced gut microbiota supports immune homeostasis by regulating immune responses and reducing the risk of chronic inflammation and autoimmune diseases.

Homeostatic microbiome maintains intestinal integrity by regulating occluding junction proteins and preventing harmful bacteria from entering the bloodstream. Microbial metabolic processes, such as the metabolism of carbohydrates, amino acids, and nucleotides, stayed constant across time despite changes in the human gut microbiome [6]. It has become apparent that dysbiosis of the gut microbiota is hampered by dysfunctional microbiota, which leads to several complex diseases, so including cirrhosis of the liver, alcoholic liver disease (ALD), cardiovascular diseases (CVDs), hepatocellular carcinoma, inflammatory bowel diseases (IBDs), anxiety etc., are often due to inflammation [7]. Short-chain fatty acids like butyrate, which are vital for kidney protection, are produced less frequently in CKD patients due to an overabundance of pathogenic bacteria like *Proteobacteria* and a decrease in helpful taxa like *Bifidobacterium* and *Faecali bacterium*. Increased intestinal permeability brought on by this imbalance makes it possible for uremic toxins such p-cresyl sulfate and indoxyl sulfate to reach the bloodstream and exacerbate renal injury [8].

In addition to being a significant carbon flow from the meal that is broken down by the gut microbiota and

plays crucial regulatory functions in local, intermediate, and peripheral metabolisms, SCFAs are vital fuels for intestinal epithelial cells (IECs). SCFAs primarily work by improving the function of the intestinal barrier, suppressing the inflammatory response, encouraging apoptosis, boosting GPCR expression, altering histone acetylation, and controlling immunity.

### **3.EXPLORING POTENTIAL PATHWAYS BETWEEN NUTRIENTS AND GUT MICROBIOME**

#### **3.1. Anti-inflammatory foods:**

The inclusion of anti-inflammatory superfoods in the diet is linked to improved gut health. Berries, for example, are abundant in fiber, vitamins, and antioxidants, which help reduce inflammation. Foods abundant in omega-3 fatty acids—such as salmon, flaxseeds, and chia seeds—have been associated with benefits to brain function, cardiovascular health, and the gut microbiome. These nutrients are essential for maintaining cell membrane integrity, modulating inflammatory responses, and supporting neuronal communication. Additionally, omega-3s have been shown to influence the composition of the gut microbiota, promoting a balanced microbial environment. Green tea is renowned for its antioxidant properties, primarily due to its high catechin content, especially epigallocatechin-3-gallate (EGCG). Epidemiological studies have also suggested that green tea consumption may lower the risk of developing certain cancers, such as colorectal cancer. [9]. Dark leafy greens are rich in essential vitamins and phytochemicals, while beans and legumes provide lean protein, fiber, and vital nutrients like potassium and folate [10]. Omega 3 fatty acids, which are mostly present in fatty fish, flaxseed, and chia seeds, increase the numbers of good bacteria like *Bifidobacterium* and *Lactobacillus*, having anti-inflammatory qualities can have a positive impact on the gut microbiota's makeup. Including these fatty acids in the diet has been linked to higher levels of good bacteria and better anti-inflammatory molecule synthesis [11].

#### **3.2. Dietary fiber:**

Dietary fiber, present in plant-based meals, serves as a prebiotic, which means it nourishes good bacteria in the gut. Dietary fiber is classified as soluble and insoluble fiber each serving unique functions in gut health. Unlike other nutrients, fiber is not digested by

human enzymes; instead, it serves as fuel for gut bacteria, supporting microbial diversity and overall digestive function. Prebiotics are indigestible food ingredients that support the growth of probiotics, or beneficial bacteria, in the gut. They are fermentable in the large intestine, neither digested nor absorbed by the small intestine's enzymes, it aids in the large intestine's laxation and may improve the absorption of minerals. Foods such as garlic, onions, and whole grains etc. are classified as prebiotics. The gut microbiota in the colon ferments dietary fiber, which is found in fruits, vegetables, legumes, and whole grains, producing short-chain fatty acids (SCFAs) like butyrate. Because it has anti-inflammatory and intestinal barrier-strengthening qualities, butyrate is crucial for gut health. Increased microbial diversity and a lower risk of inflammatory illnesses have been linked to diets high in fiber. Antioxidants and dietary fiber found in cruciferous vegetables, like kale and broccoli, support intestinal health. These vegetables' high fiber content promotes a healthy gut microbiota and aids with digestion, leading to improvement of gastrointestinal health. Right proportion of probiotics and prebiotics (symbiotic) are required to support and maintain positive gut microflora [12]. Citrus fruits, apples, and berries contain pectin, a form of fiber that improves gut microbiota by encouraging the growth of probiotic bacteria like *Lactobacillus* and *Bifidobacteria* [13]. Both probiotics and prebiotics have been associated with enhanced gut barrier integrity and modulation of immune responses, leading to reduced inflammation. [14]. Probiotics are live microorganisms that help the host regain microbial balance and improve health when taken in sufficient quantities. (WGO) Fermented foods such as kefir, kimchi, and yogurt are common sources. Acute diarrhea, Crohn's disease, cardiovascular and urogenital infections, cancer, lactose intolerance, cystic fibrosis, UTI, dental caries, and oral illnesses are among the benefits that probiotic strains are safe and effective in offering consumers. Additionally, it is thought to help treat periodontal disease, reduce tooth decay, and lessen bad breath. Diets high in fiber improve metabolic health, boost microbial diversity, and lower the incidence of diseases like inflammatory bowel disease, type 2 diabetes, and obesity that are linked to dysbiosis. Additionally, they have been connected to better cardiovascular health, lower cholesterol, and increased insulin sensitivity. Fiber-mediated SCFA synthesis may enhance mood, reduce anxiety, and promote cognitive function, and the gut-brain axis links gut health to mental health. Whole grains, legumes, nuts, seeds, fruits, and vegetables are all excellent sources of dietary fiber, which helps to preserve microbial equilibrium and stave against dysbiosis.

### 3.3. Polyphenols:

Polyphenols majorly found in plant-based diets regulates the immune system. Having an anti-inflammatory, and antioxidant properties. Polyphenols significantly impact the human health, microbial composition, and metabolism. Their promise as dietary therapies for chronic diseases are highlighted by their ability to lower inflammation, enhance metabolic function, and improve neurological health. However, interactions with the gut flora and food processing have a significant impact on their biological activity and absorption. These interactions can change the structures of polyphenols, which can change their capability to promote health. Thus, it is essential to create food processing techniques that maximize the bioactivity and bioavailability of polyphenols while maintaining their integrity [15]. Having antibacterial properties against *Salmonella spp.*, *Escherichia coli*, and *Clostridium difficile*, which may lower the risk of gastrointestinal illnesses [65]. Consuming polyphenols on a regular basis improves microbial diversity, which is linked to improved immunological and metabolic health. By lowering oxidative stress and modifying cytokine production, polyphenols control inflammatory pathways. Research indicates that polyphenols can increase anti-inflammatory cytokines while lowering proinflammatory indicators such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF- $\alpha$ ). By influencing gut microbes linked to the synthesis of serotonin and dopamine, polyphenols may alleviate the symptoms of depression and anxiety [8].

The relationship between human health and gut microbiota is intricate and ever-changing, impacted by several variables like nutrition, environmental exposure, and genetics. Numerous physiological processes, including digestion, metabolism, immunological control, and brain function, depend on gut bacteria. Numerous illnesses, including metabolic disorders, inflammatory diseases, and neurodegenerative disorders, have been connected to dysbiosis, or disturbance of the gut microbiome. The composition of the gut microbiota is largely determined by diet, with components such as fiber, polyphenols, and foods that reduce inflammation having a considerable impact on the variety and function of microorganisms. Reduced gut inflammation and enhanced microbial diversity have been linked to anti-inflammatory diets, particularly those high in omega-3 fatty acids, antioxidants, and bioactive substances. Omega-3 fatty acids aid in the maintenance of good bacteria like *Lactobacillus* and *Bifidobacterium*, which improve immunological

responses and maintain a healthy gut environment. Short-chain fatty acids (SCFAs), like butyrate, are produced when gut microbes ferment dietary fiber, especially prebiotics, which are vital nutrients for good gut bacteria. These SCFAs are necessary for preserving the integrity of the gut barrier and lowering inflammation. Improved metabolic health and a lower risk of chronic inflammatory disorders have been associated with higher fiber intake. Additionally, probiotics help to improve gut barrier function, preserve microbial balance, and regulate the immune system [14].

Plant-based diets contain polyphenols, which selectively promote good bacteria while suppressing bad ones, increasing the diversity of gut microbes. Polyphenols also affect metabolic pathways, lower oxidative stress, and affect immunological responses. According to [8] these substances have also been connected to the gut-brain axis, which may have consequences for mental health issues like anxiety and depression. Although there is mounting evidence that diet affects gut microbiota, individual differences in microbiome composition, eating patterns, and genetic predispositions make it difficult to pinpoint exact processes. As a result, developing conventional dietary recommendations for gut health is still challenging, and additional clinical research is required to comprehend the long-term impacts of dietary treatments on gut microbiota and human health. With everything taken into account, human health depends on preserving a balanced gut microbiota, and dietary changes offer a promising way to enhance the composition of gut microbes.

## 4. CONCLUSION

The gut microbiota's makeup, diversity, and metabolic activity are all significantly influenced by diet. Dietary patterns like the Mediterranean diet, low-FODMAP, and Western diet have a great influence on gut microbiota. Mediterranean diet, which includes a moderate number of fish, fruits and vegetables, whole grains etc. increases the synthesis of healthy metabolites like short-chain fatty acids (SCFAs), which maintain the integrity of the gut barrier and lower inflammation. While the low-FODMAP diet is successful in treating gastrointestinal symptoms in disorders such as IBS, its restrictive nature may temporarily deplete beneficial bacteria populations, necessitating careful reintroduction of fermentable substrates. On the other hand, gut dysbiosis, decreased microbial diversity, and an increase in pro-inflammatory microorganisms are strongly linked to the Western diet, which is marked by a high intake of processed foods, sweets, and saturated fats. These

factors contribute to chronic metabolic and inflammatory illnesses like obesity and type 2 DM. Diet is a flexible and easily accessible way to affect the makeup and function of the gut microbiota. Even while there is currently data supporting the advantages of specific dietary patterns, future research must focus on refining these tactics through personalized nutrition, evidence-based methods that optimize microbial diversity and resilience to improve human health outcomes more broadly. Prebiotics and probiotics combined, or symbiotic, offer a helpful way to control gut flora and improve overall health outcomes. It has been observed that polyphenols, another dietary component with important interactions with the gut flora, have antioxidant and anti-inflammatory properties.

Future studies should concentrate on individualized nutrition strategies that take into account each person's unique microbiome profile in order to provide dietary interventions that are specifically designed to prevent disease and promote health.

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