



# A Systematic Review of the Comparison of Ante-Mortem and Post-Mortem Radiological Data for Identification

**GUT PROBIOTICS UNLOCKING THE SECRETS TO OPTIMAL HEALTH**  
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## **Abstract:**

Probiotics, live microorganisms that confer health benefits, have been increasingly recognized as a crucial component of optimal health. The gut microbiota plays a vital role in maintaining immune homeostasis, regulating inflammation, and influencing various physiological processes. This review explores the multifaceted benefits of probiotics, prebiotics, symbiotics, and postbiotics in promoting gut health and preventing diseases. Probiotics have been shown to enhance the gut microbiota, inhibit harmful bacteria, and stimulate the production of short-chain fatty acids, which regulate energy metabolism and modulate the immune response. The mechanisms of action of probiotics include strengthening the epithelial barrier, regulating inflammation, and producing bioactive compounds. Specific probiotic strains, such as Lactobacillus and Bifidobacterium, have been found to be effective in preventing and treating various diseases, including cancer, inflammatory bowel disease (IBD), obesity, and mental health disorders. The review highlights the importance of probiotics in cancer prevention and treatment, where they have been shown to inhibit cancer cell proliferation, induce apoptosis, and stimulate an immune response against tumors. In IBD, probiotics have been found to reduce inflammation, promote gut health, and modulate inflammatory pathways. Additionally, probiotics have been shown to play a crucial role in obesity management by regulating energy metabolism, improving insulin sensitivity, and reducing inflammation. Overall, this review provides a comprehensive overview of the benefits of probiotics, prebiotics, symbiotics, and postbiotics in promoting gut health and preventing diseases. The evidence suggests that probiotics are a promising therapeutic strategy for various diseases, and further research is needed to fully elucidate their mechanisms of action and potential health benefits.

**Keywords:** Probiotics, Postbiotics, Symbiotics, Prebiotics, IBD, Obesity, Cancer, Mental Health, Immunity

## **1. Introduction**

The term "probiotic" was first used in 1965, by Lilly and Stillwell, to describe substances secreted by one organism which stimulate the growth of another. The word "Probiotic," derived from Greek meaning "for life," which was introduced by Lilley and Stillwell. It refers to non-pathogenic microbes that offer benefits to their hosts. An expert panel commissioned By FAO (Food and Agriculture Organization) and WHO (World Health Organization) describes probiotics as "live microbes that provide a health benefit to the host when taken in sufficient quantities."<sup>[1]</sup> They help to enhance the microbial balance in the gastrointestinal tract. Probiotics work by strengthening the epithelial barrier, encouraging beneficial microbes to adhere to the intestinal lining while inhibiting the attachment of harmful pathogens. They also help to regulate the immune system and produce biochemicals that can inhibit the growth of pathogenic microorganisms.<sup>[2]</sup>

Prebiotics are indigestible components of food that promote health by encouraging the growth of beneficial microbes in the gastrointestinal tract (GIT). They primarily help stimulate the activity and proliferation of good bacteria in the GIT, particularly in the colon. Unlike other food components, prebiotics are resistant to the hydrolyzing enzymes and acids found in the GIT, but they can be fermented by helpful bacteria.<sup>[3]</sup> Lactobacillus

rhamnosus GG (LGG) is the earliest probiotic that has garnered significant clinical interest. The *Lactobacillus* strain historically employed in dairy fermentation was ineffective at colonizing the gut. Consequently, in 1985, *Lactobacillus rhamnosus* strain GG was identified by creating a set of ideal characteristics for probiotics.<sup>[1]</sup>

Some of the commonly used probiotic microorganisms include *Lactobacillus rhamnosus*, *Lactobacillus reuteri*, various bifidobacteria, select strains of *Lactobacillus casei*, the *Lactobacillus acidophilus* group, *Bacillus coagulans*, *Escherichia coli* strain Nissle 1917, certain enterococci like *Enterococcus faecium* SF68, and the yeast *Saccharomyces boulardii*. The majority of these probiotics, especially the bacterial spore formers from the *Bacillus* genus, are frequently incorporated into foods, particularly fermented dairy products, either individually or in combinations. Ongoing research efforts are continually leading to the discovery of new genera and strains of probiotics.<sup>[4]</sup> Some of the new trends in probiotics includes the prebiotics, symbiotics and postbiotics.

**Prebiotics:** Prebiotics are primarily non-digestible fibers that positively influence the host's health by selectively promoting the growth and activity of certain microorganisms in the colon, particularly lactobacilli and bifidobacteria. An effective prebiotic should meet three criteria: 1) It must withstand the effects of stomach acids, bile salts, and other digestive enzymes in the intestine. 2) It should not be absorbed in the upper gastrointestinal tract. 3) It must be easily fermentable by beneficial gut microflora.

According to FAO/WHO, prebiotics are non-living food components that offer health benefits to the host by influencing the microbiota. They consist of various carbohydrate substances that are not well understood in terms of their sources, fermentation characteristics, and the amounts needed to achieve health benefits.<sup>[4]</sup>

**Symbiotic :** Symbiotics consist of live microorganisms that, when taken in sufficient amounts, can enhance the health of the host. They are created by combining one or more probiotics with one or more prebiotics. Prebiotics work in conjunction with probiotics, thereby amplifying their individual benefits. This combination helps ensure that probiotic bacteria survive in food and in the acidic environment of the stomach, allowing them to take effect in the large intestine, where their impacts can be either additive or synergistic. A symbiotic product positively impacts the host by enhancing the survival and establishment of live microbial dietary supplements in the gastrointestinal tract, selectively promoting the growth and/or activation of specific health-enhancing bacteria. Since the term "synbiotics" implies a synergistic effect, it should only be used for products where the prebiotic components specifically benefit the probiotic organisms.<sup>[5]</sup>

**Postbiotics:** Postbiotics are beneficial bioactive compounds generated during fermentation. They exist in a delicate balance within our bodies, and an overload of metabolites from any source can disrupt various physiological functions. As a novel strategy, postbiotics can be utilized to enhance immune tolerance and manage food allergies, especially in infants and young children.

Postbiotics are compounds produced by microorganisms through various activities, including enzyme production, carbohydrate fermentation, and vitamin and peptide synthesis. These bioactive substances can also originate from bacterial structures. To identify and measure postbiotics in complex biological systems, metabolomics is a highly effective approach.<sup>[6]</sup>

## 2. Classification of probiotics

The classification of probiotics is multifaceted and follows specific criteria. Probiotic products can be divided into single strain and multi strain categories. Single strain probiotics are further categorized by the genus to which they belong. The scientific name of probiotics consists of two parts: the genus (in italics) and the species (also in italics). In some cases, the strain name is added following the species.<sup>[7]</sup>

### Popular Genera of Probiotics

The most frequently consumed probiotics belong to two primary genera, which are also the most researched:

**Bifidobacteria:** This group of bacteria is often included in various foods and supplements. They are believed to strengthen the immune system and suppress the growth of harmful bacteria in the gut and also aid in the breakdown of lactose into usable nutrients.

**Lactobacillus:** This genus produces lactase, an enzyme essential for breaking down lactose (milk sugar), and generates lactic acid. Lactic acid helps regulate harmful bacterial growth, serves as energy for muscles, and enhances the body's mineral absorption.

### Common Probiotic Species

Probiotic species are specific genetic subtypes within these genera, each having unique effects on the body. You'll see these species names alongside the genus on food and supplement labels.<sup>[8]</sup>

Table 1: common species used as probiotics.

Sr. No	Probiotic bacterial genera.	Species involved.	Reference
1	<i>Lactobacillus</i>	<i>L. plantarum</i> , <i>L. paracasei</i> , <i>L. acidophilus</i> , <i>L. casei</i> , <i>L. rhamnosus</i> , <i>L. crispatus</i> , <i>L. gasseri</i> , <i>L. reuteri</i> , <i>L. bulgaricus</i>	[9]
2	<i>Bifidobacterium</i>	<i>B. longum</i> , <i>B. catenulatum</i> , <i>B. breve</i> , <i>B. animalis</i> , <i>B. bifidum</i> , <i>B. infantis</i>	[9]
3	<i>Enterococcus</i>	<i>E. faecium</i>	[9]
4	<i>Bacillus</i>	<i>B. laterosporus</i> , <i>B.coagulans</i> , <i>B. subtilis</i> ,	[10]
5	<i>Streptococcus</i>	<i>S. sanguis</i> , <i>S. oralis</i> , <i>S. mitis</i> , <i>S. thermophilus</i> , <i>S. salivarius</i>	[10]
6	<i>Bacteroides</i>	<i>B. uniformis</i>	[10]
7	<i>Propionibacterium</i>	<i>P. jensenii</i> , <i>P. freudenreichii</i>	[10]
6	<i>Bacteroides</i>	<i>B. uniformis</i>	[10]
8	<i>Saccharomyces</i>	<i>S. boulardii</i>	[11]
9	<i>Pediococcus</i>	<i>P. acidilactici</i> , <i>P.pentosaceus</i>	[11]
10	<i>Akkermansia</i>	<i>A.Muciniphila</i>	[11]

Here are six well-known probiotic species are as follows

**B. animalis:** Found in Dannon's Activia yogurt, it aids digestion, combats foodborne bacteria, and is believed to enhance immunity.

**B. breve:** Residing in the digestive system and vagina, it helps fight off infection-causing bacteria and yeast while fermenting sugars to assist nutrient absorption and breaking down plant fibers for better digestion.

**B. lactis:** Originating from raw milk, it is an ingredient in Nestle's probiotic infant formula, Good Start Natural Cultures, and serves as a starter culture for buttermilk, cottage cheese, and other cheeses.

**B. longum:** Found in the gastrointestinal tract, it helps digest carbohydrates and acts as an antioxidant.

**L. acidophilus:** Located in the small intestine and vagina, it aids digestion and may assist in combating vaginal bacteria. It is commonly found in yogurt and fermented soy products, like miso.

**L. reuteri:** This species inhabits the intestine and mouth. Research has indicated it reduces oral bacteria linked to tooth decay and is thought to support digestive health.<sup>[8]</sup>

#### 4. Food Sources:

Fermented foods contain additional microbial cultures. For instance, yogurt is produced by introducing live microorganisms (like *Lactobacillus* or *Streptococcus*) into milk. However, the probiotic benefits of these microorganisms depend on their types and quantities. Certain fermented foods, such as sourdough bread and many pickles, undergo further processing after fermentation, which eliminates the microorganisms. Dead microorganisms do not offer the same benefits as living ones and are not classified as probiotics. Additionally, some fermented foods have microorganisms that haven't been researched, leaving their potential probiotic advantages uncertain. Examples of these foods include apple cider vinegar, cheese, kimchi, kombucha, miso, and sauerkraut. Similarly, some unfermented products like specific cereals, juices, milks, nutrition bars, smoothies, and infant formulas also contain added microorganisms. The probiotic benefits of these items depend on the types and quantities of microorganisms they include.<sup>[12]</sup>

**Kefir:** is a fermented milk beverage characterized by its tangy taste and low alcohol content. Unlike some other fermented products, it stands out due to its starter culture, known as kefir grains, which provide a rich diversity of microorganisms. Kefir comes in both dairy and non-dairy options. Most studies exploring the health benefits of kefir focus on the dairy version, leaving the benefits of non-dairy kefir less understood.

**Yogurt:** is commonly available in grocery stores and not only contains probiotics but is also rich in nutrients such as calcium, phosphorus, potassium, vitamin A, vitamin B2, and vitamin B12, making it a very nutritious choice. Consuming yogurt has been linked to a reduced risk of osteoporosis, diabetes, and heart disease, as well as improved gut health.

**Buttermilk:** is a type of fermented dairy product whose name reflects its history; it was originally the liquid left over after churning cream into butter. Nowadays, store-bought buttermilk is produced by adding lactic acid to milk. Research has shown that buttermilk may offer health benefits, including a lower risk of breast cancer and possibly colon cancer.

**Tempeh :** is primarily made from soybeans but can also be prepared using various legumes such as corn, red beans, green beans, and black beans. It is regarded as a functional food due to its high levels of protein, vitamins, antioxidants, probiotics, and calcium. Eating tempeh has been linked to various health advantages, including enhanced athletic performance.

**Miso:** is a salty, savory paste derived from soybeans, widely used in Japanese cuisine, particularly in dishes like miso soup. It undergoes a two-step fermentation process involving mold followed by bacteria and yeast. Miso has been researched for its potential anticancer, antimicrobial, and antiobesity effects.<sup>[13]</sup>

**Paneer:**, or cottage cheese, is one of the best probiotic-rich foods. It is made by curdling milk with an acidic substance like lemon juice. Rich in proteins and probiotics, paneer is the perfect example of a natural probiotic food.

## Dietary Supplements

Probiotics can be found in various dietary supplements, including capsules, powders, and liquids, featuring numerous strains and dosages. These products typically contain a blend of live microorganisms instead of individual strains. Many commercially available probiotic products have not undergone research evaluation, making it challenging for individuals unfamiliar with the field to identify evidence-backed options. Nevertheless, certain organizations have conducted systematic reviews of the existing data and provide guidelines on specific probiotics—covering suitable products, dosages, and formulations—for the prevention or treatment of various health issues.<sup>[14]</sup>

Probiotics are quantified in colony-forming units (CFU), signifying the count of live cells. Product labels may indicate quantities such as  $1 \times 10^9$  for 1 billion CFU or  $1 \times 10^{10}$  for 10 billion CFU. Most probiotic supplements offer between 1 to 10 billion CFU per dose, while some can have up to 50 billion CFU or more. However, a higher CFU count does not necessarily enhance the health benefits of the product. Current labeling guidelines require manufacturers to indicate only the total weight of microorganisms on the Supplement Facts labels of probiotic products. This weight can include both live and dead microorganisms, which does not reflect the number of viable cells. Manufacturers may choose to voluntarily provide CFU counts in addition to the total microorganism weight on their labels. Since probiotics must be alive to provide health advantages and may lose viability over their shelf life, consumers should seek products that specify the CFU count at the end of the shelf life rather than at the time of production. Probiotics come in a variety of forms, such as liquids, powders, and capsules. Your lifestyle and personal preferences will determine which form is ideal for you.<sup>[15]</sup>

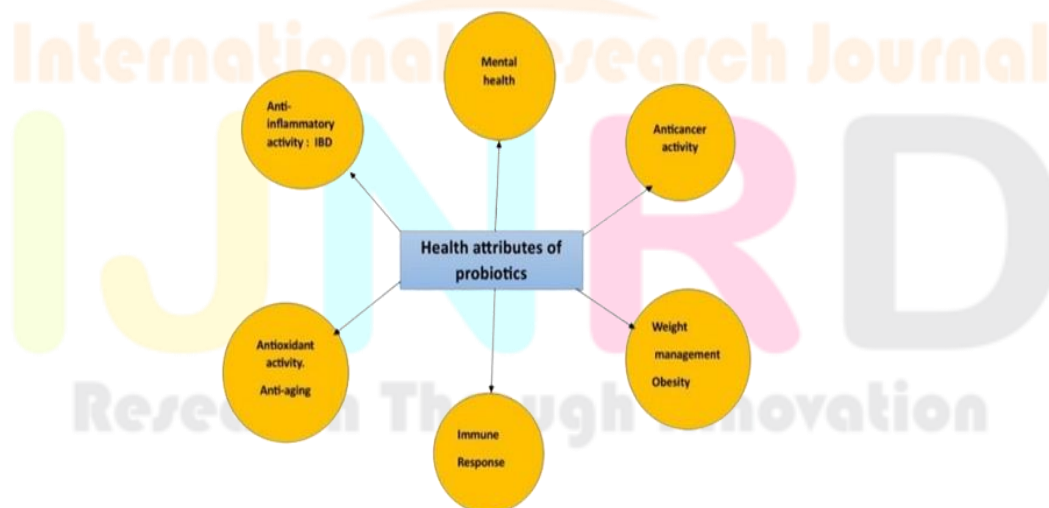


fig 1. health attributes of probiotics

## 5. Health attributes of probiotics

### 5.1 Cancer treatment

Cancer is a deadly disease with significant clinical importance and remains one of the leading causes of morbidity and mortality. Major cancer types that contribute to high death rates include colorectal, prostate, lung, stomach, liver, and breast cancers. The disease arises from inadequate DNA repair mechanisms or mutations during DNA replication, with key risk factors including environmental exposure, lifestyle choices, and genetic predispositions. Some of these risk factors include infectious agents, toxic substances, and UV radiation. Characterized by

unchecked cell proliferation, cancer is typically diagnosed at advanced stages and originates from a single cell, spreading throughout the body.

Probiotics play a crucial role in the prevention and treatment of various cancer types, as highlighted in several studies. While many reviews have focused on the effects of live bacteria in relation to colorectal cancer (CRC), the current review is the first to sufficiently explore the importance of both bacterial and fungal probiotics across different types of cancer. It discusses cancer prevention and alternative treatment strategies, examining the potential roles of probiotics in these areas. Lastly, the review aims to provide a foundational understanding of alternative methods and mechanisms for cancer prevention and treatment.<sup>[16]</sup>

Probiotics play a significant role in cancer prevention by influencing the complex ecosystem of the gut microbiota. They affect the network of inflammatory mediators, promote the production of antimicrobial agents that can target cancer cells, stimulate an immune response against tumors, and aid in the creation of antioxidant molecules that protect cells from harmful damage.<sup>[17]</sup>

Numerous in vitro studies have indicated that probiotics offer positive effects on the regulation of cancer cell proliferation and apoptosis. For instance, it has been shown that the *Lactobacillus rhamnosus* GG strain inhibits growth and promotes apoptosis in mouse colon cancer HGC-27 as well as human colon cancer Caco-2, DLD-1, and HT-29 cells.

In preclinical studies, possible antitumor agents comprise probiotics and their byproducts, including butyrate and pyridoxine. Short-chain fatty acids (SCFAs) serve as an energy source for colon cells, help sustain the acidic environment of the intestine, prevent the excessive production of secondary bile acids, and encourage acidosis and apoptosis in cancer cells.<sup>[18]</sup>

## 5.2 IBD

Crohn's disease (CD) and ulcerative colitis (UC) are among the most chronic inflammatory diseases of the GIT and are collectively called IBD. Crohn's disease can impact any section of the gastrointestinal tract, including the mucosa, submucosa, and serosa, with inflammation potentially extending throughout the entire tract. In comparison, ulcerative colitis primarily affects the large intestine, particularly the mucosa and submucosa of the colon. Research has shown that an imbalance in the gut microbiota plays an important pathophysiological role in the positive regulation of IBD.<sup>[11]</sup>

Probiotics have shown significant promise in managing Inflammatory Bowel Disease (IBD). Clinical evidence supports their use in reducing inflammation and promoting gut health. Certain probiotics, such as *Saccharomyces boulardii*, have strong anti-inflammatory effects, making them potential maintenance treatments for IBD patients. Additionally, engineered probiotics like ECN-pE(C/E)2 have demonstrated therapeutic potential in enhancing protective tight junction proteins, reducing inflammation, and boosting anti-inflammatory cytokines.<sup>[19]</sup>

The gut microbiome plays a crucial role in IBD, with any microbial imbalance potentially weakening the gut barrier and triggering inflammation. IBD patients often experience dysbiosis, characterized by an increase in harmful microbes and a decrease in beneficial ones. Probiotics have been shown to produce antimicrobial substances that activate receptors linked to IBD, and specific strains like *Lactobacillus* species have demonstrated anti-inflammatory effects.<sup>[20]</sup>

Recent studies have highlighted the importance of modulating inflammatory pathways in IBD management. The Total Gut Restoration (TGR) approach, which combines five probiotic strains, has been shown to modulate IL-6 and TNF- $\alpha$  pathways, minimizing inflammatory responses. Furthermore, probiotic supplements containing strains like *Lactobacillus*, *S. boulardii*, and VSL#3 have been found to lower pro-inflammatory activities in gastrointestinal epithelial cells, helping manage inflammatory responses.<sup>[21]</sup>

## 5.3 Obesity:

Obesity is generally characterized by an excessive amount of body fat. In adults, a Body Mass Index (BMI) of 30 or above is typically used as the standard indicator of obesity. This condition heightens the likelihood of developing severe health issues. Treatment options involve modifying dietary habits, increasing physical activity, and accessing mental health resources.<sup>[22]</sup>

Due to immoderate meals consumption and absorption and decreased electricity expenditure, weight problems have end up an endemic medical condition. Numerous current investigations have validated that human intestinal micro-organism make a contribution substantially to the improvement of weight problems, the usage of green electricity manufacturing and vitamins absorption. Additionally, it's miles nonetheless recounted that the duodenal microbiota in overweight people is extra numerous than in lean people. Obesity has been connected to the increase of a few intestines' microbial taxa, consisting of *Escherichia coli*, *Staphylococcus aureus*, and different regular bacterial species, along with bifidobacterium.<sup>[23]</sup> Probiotics were determined to persuade the manipulate of weight problems thru numerous mechanisms of movement which includes regulating the capabilities of endogenous microbiota. Studies have additionally determined that probiotics compete with pathogens, enhance intestinal barrier feature and improve the herbal immune responses.<sup>[24]</sup>

Mechanism of action of probiotics in the gastrointestinal system: Probiotics enhance the diversity of gut microbiota, inhibit the growth of harmful bacteria, stimulate the production of short-chain fatty acids (SCFAs) in the intestines, regulate appetite, influence glucose and lipid metabolism, and improve the integrity of the intestinal

barrier. The role of gut microbiota in obesity development: Reduced expression of AMPK leads to a decrease in  $\beta$ -oxidation in the liver and muscles. The inhibition of ANGPTL4 raises lipoprotein lipase activity, resulting in triglyceride accumulation in adipose tissue. Decreased levels of GLP-1 hinder the body's response to insulin, while lower PYY levels trigger increased hunger. There is an upsurge in hepatic lipogenesis through the activation of acetyl CoA carboxylase and fatty acid synthase. Inflammatory processes in adipose tissue are instigated by lipopolysaccharides (LPS). Additionally, stimulation of GPR 41/43 receptors enhances lipolysis in adipose tissue, and CB1 receptors are activated.<sup>[25]</sup>

#### 5.4 Anti-aging

Aging might be a prime social trouble international withinside the coming decades .During the growing old technique, the frame tissues and organs of the older human beings go through purposeful decline or deterioration, accordingly growing their susceptibility to age-associated illnesses and shortening their wholesome lifestyles span, which has added substantial economic strain to nations international in phrases of pension, scientific expenses, and fitness care . Therefore, exploring the organic nature of growing old, trying to find secure and powerful intervention techniques to undoubtedly modify fitness status, and prolonging the wholesome lifespan of the growing old populace are crucial for decreasing the worldwide pension burden and selling wholesome growing old.<sup>[26]</sup>

Probiotics may be implemented to modulate the age-associated intestine microbiota imbalance and to introduce lines with precise health-selling effects. The foremost claimed advantages of probiotics in aged humans are prevention of diarrheal diseases, safety towards pathogens, enhancement of the intestinal barrier function, development of gastrointestinal motility and inflammatory intestinal disorders, immunomodulatory effects.<sup>[27]</sup> Numerous studies have highlighted the significance of probiotics and fermented plant products rich in probiotics in relation to the aging process. Lactic acid bacteria, a well-known probiotic strain, is noted for its recognized health benefits. Research indicates that probiotics can help balance age-related disruptions in the human gut microbiome and promote specific beneficial strains. They influence immune system genes and regulate gene expression and cell differentiation, leading to anti-aging effects. The anti-aging benefits of probiotic combinations may stem from their ability to balance intestinal microbiota and suppress inflammation induced by the TLR4/NF $\kappa$ B pathway.<sup>[28]</sup>

#### 5.5 Mental Health

Depression and tension are the maximum ordinary intellectual fitness issues amongst adults, with 5% of adults tormented by melancholy globally. These issues are a number of the main reasons of incapacity across the world. Depression is an intellectual contamination characterized via way of means of a constantly low mood. Typical signs consist of anhedonia, apathy, depressed mood, and psychomotor slowing. If left untreated, melancholy may have adverse outcomes on severa components of an individual's lifestyles and interpersonal relationships. Depression is a multifactorial intellectual contamination as a consequence of mind chemical abnormalities, genetics, psychosocial stressors, trauma, clinical conditions, and positive medications . Anxiety issues also are one of the maximum not unusual place intellectual fitness issues, affecting 19.1% of America populace of adults elderly 18 years or older . Anxiety is defined as a kingdom of extreme fear. When it turns into immoderate and interferes with day by day functioning, it turns into a disorder.

While dealt with with prebiotics and probiotics, people with tension or despair can enhance their temper and reduce the severity in their symptoms. This is finished with the aid of using a couple of mechanisms, however in large part via attenuating the inflammatory reaction and growing serotonin availability. The outcomes of those research propose that prebiotics and probiotics can also additionally have a position to play withinside the remedy of those intellectual illnesses.<sup>[29]</sup>

Probiotics may be taken into consideration an accessory remedy to control metabolic and psychiatric diseases. Predominantly, Lactobacillus and Bifidobacterium lines are documented as amazing probiotics, which assist to hold the bidirectional interactions among the intestine and mind. The intake of probiotics and probiotics containing fermented ingredients may want to enhance the intestine microbiota. The food plan influences intestine microbiota, and a balanced food plan may want to hold the integrity of intestine–mind verbal exchange via way of means of facilitating the manufacturing of neurotrophic elements and different neuropeptides. However, the useful consequences of probiotics and food plan would possibly rely upon numerous elements, consisting of strain, dosage, duration, age, host physiology, etc. This evaluation summarizes the significance and involvement of probiotics and food plan in neuroprotection and dealing with consultant neurological disorders, accidents and temper states.<sup>[30]</sup>

Research on probiotics' impact on anxiety and depression is gaining momentum, as they offer a promising, side-effect-free, and personalized treatment approach. Human clinical trials have consistently shown that probiotics and prebiotics have a positive effect on mental health. Studies have found that specific probiotic combinations, such as *L. helveticus* and *B. longum*, can reduce stress and anxiety in healthy individuals, while prebiotic supplements have improved mood and reduced anxiety in patients with irritable bowel syndrome (IBS). Additionally, consuming probiotic-rich foods and drinks has been shown to boost mood and overall well-being in healthy individuals.<sup>[31]</sup>

## 5.6 Immune response

Probiotic microorganisms have been shown to enhance the body's natural defense mechanisms, boosting the immune system's response to pathogens. In addition to promoting a healthy gut microbiome, probiotics have been found to enhance humoral immune responses, strengthening the gut's immunologic barrier. They also stimulate non-specific host resistance to microbial pathogens, aiding in immune elimination. Furthermore, probiotics modulate the host's immune responses to potentially hazardous antigens, reducing the risk of allergic reactions. Overall, probiotics play a crucial role in supporting the body's immune system, promoting a healthy balance between immune activation and tolerance.<sup>[32]</sup>

Probiotics play a function in host innate and adaptive immune responses with the aid of using modulating immune cells inclusive of dendritic cells (DCs), macrophages, and B and T lymphocytes. Interactions among host intestinal cells and probiotics especially arise on the floor of the intestinal barrier, along with the intestinal epithelium and the underlying lamina propria. Intestinal microbiota is separated from the intestinal epithelium with the aid of using a mucus layer secreted with the aid of using goblet cells. Consumed probiotic micro organism adhere to intestinal epithelial cells and set off them with the aid of using sample reputation receptors (PRRs). Cytokines inspired with the aid of using probiotic micro organism cause the activation of T regulatory (Treg) cells, which preserve immune homeostasis withinside the intestinal mucosa. Tregs are powerful suppressors of the immune reaction and play a key function in proscribing immune reaction.<sup>[33]</sup>

The renovation of Intestinal immune and metabolic homeostasis in mammals is strongly stricken by the interactions among the mucosa and the intestinal microbiota<sup>1</sup>. The advantageous outcomes of prebiotics and probiotics on human fitness have often been attributed to their oblique and direct immunomodulating capacity, despite the fact that different mechanisms of motion have additionally been proposed, which includes modulation of cell metabolism, epithelial barrier features or proliferation. Nevertheless, human research the use of prebiotic and probiotic interventions to set off immune-fitness benefits — which include the suppression of allergic and autoimmune sickness or the stimulation of immune defense — have generated contradictory outcomes. These contradictory outcomes may also in component be because of variations in observe design, however they may be additionally because of our lack of knowledge of the specificity and mechanisms via way of means of which those prebiotics and probiotics, introduced in both dietary supplements or foods, elicit their outcomes. For example, it stays in large part unknown to what quantity prebiotic compounds may also without delay have an effect on immune signaling pathways, or whether or not they act completely thru their modulation of the endogenous intestinal microbiota. Probiotics may also elicit Immunomodulatory consequences thru direct interactions with the intestinal epithelium, specifically withinside the small intestine, that's much less densely populated with the aid of using the commensal microbiota. By contrast, probiotic immunomodulatory consequences withinside the densely populated colon is much more likely to arise through modulation of the endogenous microbiota.<sup>[34]</sup>

## Reference

1. Gupta V, Garg R. Probiotics. *Indian J Med Microbiol.* 2009 Jul-Sep;27(3):202-9. Doi: 10.4103/0255-0857.53201. PMID: 19584499.
2. Latif A, Shehzad A, Niazi S, Zahid A, Ashraf W, Iqbal MW, Rehman A, Riaz T, Aadil RM, Khan IM, Özogul F, Rocha JM, Esatbeyoglu T and Korma SA (2023) Probiotics: mechanism of Action, health benefits and their application in Food industries. *Front. Microbiol.* 14:1216674. Doi: 10.3389/fmicb.2023.1216674
3. Sarita B, Samadhan D, Hassan MZ and Kovaleva EG (2025) A comprehensive review of probiotics and human health-current prospective and applications. *Front. Microbiol.* 15:1487641. doi: 10.3389/fmicb.2024.1487641.
4. Pandey KR, Naik SR, Vakil BV. Probiotics, prebiotics and synbiotics- a review. *J Food Sci Technol.* 2015 Dec;52(12):7577-87. Doi: 10.1007/s13197-015-1921-1. Epub 2015 Jul 22. PMID: 26604335; PMCID: PMC4648921.
5. Flesch, A. G., Poziomyck, A. K., & Damin, D. C. (2014). The therapeutic use of symbiotics. *Arquivos brasileiros de cirurgia digestiva : ABCD = Brazilian archives of digestive surgery*, 27(3), 206–209. <https://doi.org/10.1590/s0102-67202014000300012>.
6. N. Rafique ,S. Y. Jan ,A. H. Dar ,K. K. Dash,A. Sarkar ,R. Shams ,V.K. Pandey ,S.A. Khan,Q. Akeemu Amin,S. Z. Hussain “ Promising bioactivities of postbiotics: A comprehensive review” *JAFR* Dec 2023 vol 14 <https://doi.org/10.1016/j.jafr.2023.100708>.
7. <https://probiotic.creative-enzymes.com/classification-of-probiotics.html>.
8. Saurabh Sethi, M.D., MPH “What Are the Most Common Types of Probiotics?” Updated on January 27, 2022 <https://www.healthline.com/health/types-of-probiotics>.
9. Kechagia M, Basoulis D, Konstantopoulou S, Dimitriadi D, Gyftopoulou K, Skarmoutsou N, Fakiri EM. Health benefits of probiotics: a review. *ISRN Nutr.* 2013 Jan 2;2013:481651. Doi: 10.5402/2013/481651. PMID: 24959545; PMCID: PMC4045285.
10. Dixit Y, Wagle A, Vakil B. Patents in the field of probiotics, prebiotics, synbiotics: a review. *J Food Microbiol Saf Hygiene* 2016;1:1e13.

11. Kerry, R. G., Patra, J. K., Gouda, S., Park, Y., Shin, H. S., & Das, G. (2018). Benefaction of probiotics for human health: A review. *Journal of food and drug analysis*, 26(3), 927–939. <https://doi.org/10.1016/j.jfda.2018.01.002>.
12. <https://ods.od.nih.gov/factsheets/Probiotics-HealthProfessional/>
13. <https://www.verywellhealth.com/probiotic-foods-7970825>
14. Szajewska H, Guarino A, Hojsak I, Indrio F, Kolacek S, Shamir R, et al. Use of probiotics for management of acute gastroenteritis: a position paper by the ESPGHAN Working Group for Probiotics and Prebiotics. *J Pediatr Gastroenterol Nutr* 2014;58:531-9.
15. <https://ods.od.nih.gov/factsheets/Probiotics-HealthProfessional/>
16. Legesse Bedada, T., Feto, T. K., Awoke, K. S., Garedew, A. D., Yifat, F. T., & Birri, D. J. (2020). Probiotics for cancer alternative prevention and treatment. *Biomedicine & pharmacotherapy = Biomedecine & pharmacotherapie*, 129, 110409. <https://doi.org/10.1016/j.biopha.2020.110409>
17. Naeem,H, Hassan,H.U, Shahbaz,M ,Imran,M,Memon.A.G,Hasnain,A, "Role of Probiotics against Human Cancers, Inflammatory Diseases, and Other Complex Malignancies"(2024) *Journal of Food Biochemistry*.<https://doi.org/10.1155/2024/6632209>.
18. Lu, K., Dong, S., Wu, X., Jin, R., & Chen, H. (2021). Probiotics in Cancer. *Frontiers in oncology*, 11, 638148. <https://doi.org/10.3389/fonc.2021.638148>.
19. Ledder O. Antibiotics in inflammatory bowel diseases: do we know what we're doing? *Transl Pediatr*. 2019 Jan;8(1):42-55. Doi: 10.21037/tp.2018.11.02. PMID: 30881898; PMCID: PMC6382505.
20. G. P. Venkatesh,G.Kuruvalli,K.Syed, and V. D. Reddy "An Updated Review on Probiotic Production and Applications" *Gastroenterol. Insights* 2024, 15(1), 221-236; <https://doi.org/10.3390/gastroent15010016>
21. Toumi, R.; Samer, A.; Soufli, I.; Rafa, H.; Touil-Boukoffa, C. Role of probiotics and their metabolites in inflammatory bowel diseases (IBDs). *Gastroenterol. Insights* 2021, 12, 56–66. [Google Scholar]
22. <https://my.clevelandclinic.org/health/diseases/11209-weight-control-and-obesity>.
23. Sabiha Gul,Emanuele Durante-Mangoni .Unraveling the Puzzle: Health Benefits of Probiotics—A Comprehensive Review. *J. Clin. Med.* 2024, 13(5), 1436; <https://doi.org/10.3390/jcm13051436>
24. Torres B, Sánchez MC, Virto L, Llama-Palacios A, Ciudad MJ, Collado L. Use of probiotics in preventing and treating excess weight and obesity. A systematic review. *Obes Sci Pract*. 2024 Jun 19;10(3):e759. Doi: 10.1002/osp4.759. PMID: 38903852; PMCID: PMC11187407.
25. Wiciński, M., Gębalski, J., Gołębiewski, J., & Malinowski, B. (2020). Probiotics for the Treatment of Overweight and Obesity in Humans-A Review of Clinical Trials. *Microorganisms*, 8(8), 1148. <https://doi.org/10.3390/microorganisms8081148>
26. Li, Y., Tian, X., Luo, J. et al. Molecular mechanisms of aging and anti-aging strategies. *Cell Commun Signal* 22, 285 (2024). <https://doi.org/10.1186/s12964-024-01663-1>
27. Landete JM, Gaya P, Rodríguez E, Langa S, Peirotn Á, Medina M, Arqués JL. Probiotic Bacteria for Healthier Aging: Immunomodulation and Metabolism of Phytoestrogens. *Biomed Res Int*. 2017;2017:5939818. Doi: 10.1155/2017/5939818. Epub 2017 Oct 1. PMID: 29109959; PMCID: PMC5646295.
28. P.Chaudhary, D. Kathuria,S. Suri ,A. Bahndral, K. Naveen." Probiotics- its functions and influence on the ageing process: A comprehensive review" *FB Apri* 2023 Vol 52<https://doi.org/10.1016/j.fbio.2023.102389>
29. Bistas KG, Tabet JP. The Benefits of Prebiotics and Probiotics on Mental Health. *Cureus*. 2023 Aug 9;15(8):e43217. Doi: 10.7759/cureus.43217. PMID: 37692658; PMCID: PMC10490379.
30. Thangaleela S, Sivamaruthi BS, Kesika P, Chaiyasut C. Role of Probiotics and Diet in the Management of Neurological Diseases and Mood States: A Review. *Microorganisms*. 2022 Nov 15;10(11):2268. Doi: 10.3390/microorganisms10112268. PMID: 36422338; PMCID: PMC9696277
31. E.Merkouris,T.Mavroudi,D.Miliotas,D.Tsptsios, A.Serdari,F.Christidi,T.K.Doskas,C.Mueller, K.Tsamakis,"Probiotics' Effects in the Treatment of Anxiety and Depression: A Comprehensive Review of 2014–2023 Clinical Trials" *Micro*.Vol 12 Feb 2024 <https://doi.org/10.3390/microorganisms12020411>
32. Erika Isolauri, Yelda Sütas,Pasi Kankaanpää, Heikki Arvilommi,Seppo Salminen. Probiotics: effects on immunity.<https://doi.org/10.1093/ajcn/73.2.444s>
33. Mazziotta C, Tognon M, Martini F, Torreggiani E, Rotondo JC. Probiotics Mechanism of Action on Immune Cells and Beneficial Effects on Human Health. *Cells*. 2023 Jan 2;12(1):184. Doi: 10.3390/cells12010184. PMID: 36611977; PMCID: PMC9818925.
34. Klaenhammer, T., Kleerebezem, M., Kopp, M. et al. The impact of probiotics and prebiotics on the immune system. *Nat Rev Immunol* 12, 728–734 (2012). <https://doi.org/10.1038/nri3312>