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Potential Impact of Probiotics on Human Health and Prospects in Clinical Application

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Abstract:
This article discusses the detailed effects of probiotics and the potential uses in curing diseases. Research shows that certain living organisms can bring about the following benefits for man; they help maintain the ratio of the good bacteria in the intestines, improve the immune system, reduce allergic reactions, aid intestinal movement and digestion. On the other hand, probiotics may also help to modulate emotions, cognition, and stress by influencing the communication between the gut-brain axis and neurotransmitter. Furthermore, the identified probiotic metabolites, the short-chain fatty acids, are involved in metabolic processes within the intestine and other organs. Probiotics also have some anti-cancer, anti-disease and anti-inflammatory effects, and can suppress pathogens and inflammation by affecting immune cells. This article also discusses the link between probiotics in the intestinal and nervous system diseases and chronic diseases and their roles in future medical science and clinical practice. Most of the current research work is done on probiotics is done in vitro and animal studies and future clinical study has to be undertaken to ascertain their mechanisms and effectiveness in human beings.

Keywords: Probiotics, intestinal microbiota, immune system, gut-brain axis, metabolic mechanism.

1. Introduction

Probiotics are microorganisms that generally live in the human body. They can change the composition of the host flora, which is beneficial to the human body. They can maintain nutrient absorption and intestinal health by regulating the host mucosa and immune function of the system or by regulating the balance of the intestinal flora. The most important probiotics in the human body are lactobacillus Lactobacillus, yeast, bifidobacterium, Lactobacillus casei and clostridium butyricum. For example, lactic acid bacteria is a relatively common probiotic, which is mainly found in some yogurt drinks. It can ferment and decompose some fat to synthesize vitamin B to provide nutrients for the human body. Lactic acid bacteria can also help the gastrointestinal digestion to maintain

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the normal operation of the intestine, so this probiotic can help people relieve constipation. And yeast is generally in bread and steamed bread, the glucose in yeast can provide people with rich energy, reduce people's damage in antibiotics, so this probiotic can promote people's metabolic ability.

The microorganisms in the human body are mainly divided into lactobacillus acidophilus, Lactobacillus rhamnosus, Lactobacillus casei, Lactobacillus paracei, Lactobacillus plantarum, Lactobacillus Grigeri, Lactobacillus reuteri, Lactobacillus bulgariae, Lactobacillus Johni and so on. Bifidobacterium: mainly includes bifidobacterium bifidum, bifidobacterium longum, bifidobacterium brevis, bifidobacterium juvenilis, bifidobacterium infantile, etc.

Probiotics can mainly balance intestinal flora, improve constipation and diarrhea, enhance the immunity of the digestive system, relieve symptoms of allergic diseases, etc. In addition, they can also regulate lipid metabolism, colon cell proliferation, etc. In this paper, the human microbe will be studied. Through this study, we can learn about the impact of probiotics on the human body, the correlation between the microbes in the human gut and human health, and the application of probiotics and the probiotics in the nervous system.

2. The Role of Probiotics in the Human Body

Intestinal flora refers to the long-term interdependence of bacteria in the human intestine with the human body. There are many kinds of intestinal flora, and there are 500 to 1000 kinds of intestinal flora confirmed by current studies. Biologically, it can be divided into three categories, mainly including probiotics such as bifidobacterium and Lactobacillus acidophilus, harmful bacteria such as staphylococcus and pseudomonas aeruginosa, and opportunistic pathogens such as enterococcus and Escherichia coli. Probiotics can promote food digestion and intestinal peristalsis, inhibit some pathogenic bacteria, and harmful bacteria if a large number of growth will cause a variety of harmful diseases to the body, neutral bacteria are bacteria with dual roles, they are good for health under normal circumstances, once the proliferation is out of control, it will cause many physical problems. The intestinal flora is generally in a state of balance, and the flora are interdependent and mutually restricted.

2.1 Regulation and Effect of Probiotics on Intestinal Flora

Probiotics can promote intestinal motility, and when probiotics multiply in the gut, they can produce lactic acid and other short-chain fatty acids, which helps promote the acid-base balance of the intestinal environment, thus helping the gastrointestinal tract to digest better and promoting bowel movement. Probiotics can also maintain the balance of intestinal flora. Probiotics can grow harmful microorganisms in the intestine, thus maintaining the balance of different intestinal flora and protecting the intestine from damage. Probiotics can also boost immunity by increasing gut immunoglobulin secretion and boosting immunity.

2.2 Immunoregulation

Human health is significantly influenced by microbes, particularly the gut microbiome. They significantly impact the immune system's equilibrium and functionality. Probiotics have garnered significant interest as advantageous microorganisms because of their capacity to enhance gut health and modulate immune responses. Probiotics come in a variety of forms, such as lactic acid bacteria, bifidobacterium, and others. They impact the host's immune system and general well-being via various routes.

Research has demonstrated that probiotics control the immune system in addition to improving the host's defenses against infections. Stop the harm that comes from an overreactive immune response. Probiotics help in the treatment and prevention of infections, allergy disorders, and other immune-related conditions because of this effect. Probiotics specifically have the ability to improve the intestinal microecological environment, encourage the growth of good bacteria, and prevent the colonization of harmful bacteria, all of which can improve the function of the intestinal barrier. Probiotics can also influence both particular and non-specific immune responses through their ability to interact with intestinal immune cells and control cytokine production.

2.3 Mechanism of Action of Probiotics

Probiotics have a variety of effects that can strengthen the host's non-specific immune response. Natural killer (NK) cells, for instance, have been demonstrated to be greatly activated by Lactobacillus casei, and dendritic and NK cells can be efficiently stimulated by Lactococcus lactis subsp. cremoris. These cells are crucial for both antiviral and anti-tumor immunity. Probiotic cell wall constituents, such lipoteichoic acid, activate macrophage toll-like receptors (TLRs) and trigger the release of pro-inflammatory cytokines like TNF-α and IL-10. These cytokines are important for controlling immunological and inflammatory responses. Among them, the anti-inflammatory cytokine IL-10 can prevent the synthesis of other pro-inflammatory proteins, helping to keep the immune system in balance.

In terms of specific immune regulation, Probiotics have the ability to modulate the immune response by controlling cytokine production. For example, bifidobacterium is able to stimulate dendritic cells to produce IL-10,

thereby inhibiting Th2 cell activity and enhancing Th1 immune response. Lactobacillus rhamnosus R389 was able to reduce serum IL-6 levels and increase IL-10 levels in mice, demonstrating the potential of probiotics in the regulation of inflammatory responses. Furthermore, Lactobacillus plantarum strain YU stimulates the Th1 immune response and successfully wards off viral infection, while Lactobacillus paracasei controls the balance between Th1 and Th2 by directly affecting Th1 cells. These mechanisms demonstrate that probiotics can not only enhance immune response, but also effectively regulate allergic reactions, reduce IgE levels, and have anti-allergic ability.
The immunomodulatory role of probiotics is related to their interaction with immune cells in the Peyer‘s patches of the gut, where TLRs induce an immune response by activating NF-κB and MAPK signaling pathways. Some probiotics activate innate immunity by binding to the TLRs of Pyle‘s node, while others induce the production of cytokines such as IL-12 by directly stimulating macrophages and dendritic cells within Pyle‘s node, thereby activating the Th1 immune response. Probiotics can also influence the immune response by regulating the composition of the gut microbiota, so that gut health is kept stable. Healthy intestinal microecology can inhibit the growth of pathogens, enhance intestinal barrier function, and prevent the invasion of pathogens and toxins. Thus, probiotics have the potential to enhance the variety and stability of gut flora, support immune system homeostasis, and lower the risk of long-term inflammation.[1]

2.4 2Neurological/Psychological Health

2.4.1 The brain-gut axis (BGA)

The BGA refers to the two-way communication system between the brain and the gut. This system can regulate the body‘s digestion and absorption but also affect the body‘s emotions and behavior, so it has an important position. The BGA affects the heart in four ways are neurologic, endocrine, humoral/metabolic, and immune.
Neural pathways include the activity of neurotransmitters in the vagus nerve, enteric nervous system and gastrointestinal tract. The vagus nerve is the 10th cranial nerve, the longest and most widely distributed of the cranial nerves. As the main transmission pathway, the vagus nerve carries signals from the gut directly to the brain. The vagus nerve guides all unconscious body actions, such as stabilizing the heart rate and making sure the digestive tract works properly. It also influences mood and stress responses. Studies have shown that vagus nerve stimulation can improve symptoms of depression and anxiety.
The role of the endocrine pathway is to monitor and manage growth and metabolism. Microbes in the gut are capable of synthesizing a variety of hormones, such as motilin and insulin. Their component glands communicate by secreting hormones into the blood circulation, thus sending signals throughout the body. They affect brain function by producing and regulating hormones and neurotransmitters (e.g., serotonin, adrenaline).
Humoral and Metabolic Pathways are Bacterial metabolites, which are the decisive humoral factors. Its main role is to affect the nutrition of intestinal cells, and it has two remarkable characteristics: one is hormone-like activity, and the other is immune regulation, which operates by stimulating sympathetic nerve branches of the nervous system to interact with nerve cells.
The immune pathway is that the gut microbiota influences the state of the central nervous system by regulating the immune system of the gut and the local inflammatory response. The microbiota can alter the inflammatory state of the nervous system by affecting the intestinal barrier function and regulating the release of inflammatory factors. For example, an imbalance of the microbiome may lead to a breakdown of gut barrier function, which in turn leads to a systemic inflammatory response that affects brain health.
Involvement in disease occurrence and development: The imbalance of the BGA can lead to a variety of physical diseases, such as irritable bowel syndrome, inflammatory bowel disease, and neurodegenerative diseases.

2.4.2 Neurotransmitters

Neurotransmitters play a key role in the maintenance and regulation of nervous system functions. They transmit nerve impulses, regulate neuronal excitation and inhibition, and control emotions, movements, and cognitive functions. Neurotransmitters can be divided into many types. Cholinergic neurotransmitters mainly include acetylcholine, which has certain pharmacological effects and can affect the functions of the cardiovascular system, gastrointestinal tract, and urinary tract. For example, acetylcholine regulates cardiovascular function by activating the parasympathetic nervous system to regulate heart rate and dilate blood vessels, and promotes intestinal peristalsis in the gastrointestinal tract and regulates bladder contraction in the urinary system. Amine neurotransmitters are represented by dopamine and adrenaline. They mainly act as central neurotransmitters and can cause vasoconstriction by stimulating vascular receptors and dilate coronary arteries. Dopamine is closely related to reward, motivation, and motor control. The intestinal microbiota affects the synthesis and metabolism of dopamine by regulating metabolic enzymes such as aromatic amino acid decarboxylase and neurotransmitter precursors, thereby affecting emotions, motivation, and behavior. For example, changes in intestinal microorganisms may affect the expression of dopamine transporters, thereby changing dopamine levels and leading to depression or anxiety. Amino acid neurotransmitters have important

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neurotransmission functions, among which γ-aminobutyric acid (GABA) is the main inhibitory neurotransmitter that regulates nerve excitability. Some probiotics can help relieve anxiety symptoms by enhancing the synthesis of GABA. Peptide neurotransmitters such as neuropeptides exist in nerve tissues. Abnormalities in their synthesis and release can hinder normal information transmission and lead to epileptic seizures. Purine neurotransmitters include adenosine and adenosine triphosphate, which have the function of protecting neurons and promoting the growth and regeneration of nerve axons. Gaseous neurotransmitters such as nitric oxide and carbon monoxide can play a beneficial regulatory role under certain conditions. In addition, lipid neurotransmitters include prostaglandins and neuroactive steroids, which have certain enhancing and interfering effects on the central nervous system. Different types and functions of neurotransmitters are crucial in maintaining normal nervous system function, including regulating nerve excitability, emotions, motor control and cognitive function. Different neurotransmitters play their own unique roles in these processes.

2.4.3 Neuroinflammation

Neuroinflammation is a core feature of many nervous system diseases, and the mechanisms by which the gut microbiota influences neuroinflammation include: Inflammatory factors are gut microbes that play an important role in the neuroinflammation process by regulating the release of inflammatory factors in the body, such as cytokines (such as tumor necrosis factor α, interleukin-6) and chemokines. An imbalance of the microbiota may lead to excessive release of inflammatory factors, which can aggravate neuroinflammation. The immune system is the microbiome that influences the degree of neuroinflammation by regulating the function of immune cells, such as T cells, B cells, and macrophages. For example, the gut microbiome may influence the differentiation and activation of T cells, which in turn regulate the degree of neuroinflammation.

Neuroinflammation can lead to neurodegenerative diseases, and imbalances in the gut microbiota can lead to an increase in neuroinflammation, which can worsen the symptoms of neurodegenerative diseases. Microbiota imbalance may contribute to the progression of neurodegeneration by increasing systemic and local inflammatory responses. For example, the gut microbiota of people with Alzheimer‘s often shows imbalances and changes in inflammatory markers, which can worsen the condition.

3. Application Status of Probiotics

Probiotics, prebiotics, and Biostime have all been defined in various ways; however, the most basic explanation is that they are a class of microorganisms that live in the gut and feed the host internally.[2] Probiotics, which include microorganisms obtained from the natural environment such Lactobacillus, Lactococcus, or bifidobacterium, are typically taken as preparations of live cultures.[3] Because of their many beneficial qualities, probiotics are well known for being important health promoters. The primary focus of study in recent years has been on examining the viability and culture conditions of probiotic strains throughout processing and storage. Sensitivity to low pH; Adhesion to isolated cells or cell cultures; Interactions with other bacteria; Gastric fluid, bile, pancreatic and intestinal fluid, and intestinal or respiratory mucus.

According to recent studies, in the absence of living organisms, bacterial metabolites may affect the operation of the barrier and the signaling system. Known as postbiotics, these bacterial products are also known as inactive bacterial products or metabolic metabolites of probiotics that are still active within the host. Bacteriotin, organic acids, ethanol, diacetyl, acetaldehyde, and hydrogen peroxide are examples of bacterial metabolic byproducts that are generally included in postbiotics. However, it has also been discovered that some heat-inactivated probiotics can retain significant bacterial structures that may have biological activity in the host [4]. According to studies, these metabolites can be employed as an alternative to antibiotics because they have broad inhibitory effects on harmful microbes [5]. Since epigenomes are inactive bacterial products or metabolic byproducts of probiotics, they are non-toxic, non-pathogenic, and resistant to the hydrolysis of mammalian enzymes. By activating α2β1 integrin collagen receptors, epigenons can sometimes promote angiogenesis in epithelial cells both in vitro and in vivo, as well as improve barrier function against species such Saccharomyces burra [6]. Numerous other probiotic species, including Bacteroides fragilis, Lactobacillus, Escherichia coli, Coprofecalis prai, Bifidobacterium brevis, Bifidobacterium lactis, and Bifidobacterium infantilum, have been shown to have similar characteristics.

Nutrients called prebiotics have the power to change the gut microbiome. It can specifically promote the growth or activity of advantageous bacterial species in the stomach, despite being difficult to digest.[7]. Several well-known prebiotics include oligosaccharides that contain galactose and xylose, insulin produced from sucrose, and fructooligosaccharides (FOS) for bifidobacteria characteristics.[8] The main energy source of the epithelial cells in the colon is the fermentation of carbohydrates, and these requirements are easily met due to the fermentation of prebiotics by the gut microbiota (such as bifidobacterium). Apart from bifidobacteria, various other gut microorganisms are also crucial for the fermentation of these nondigestible oligosaccharides. Naturally occurring prebiotics are found in foods including fruits, vegetables, and grains that we eat. our regular existence. Prebiotics have several benefits in addition to being an energy source. health advantages, including lessening the frequency and length of diarrhea, inflammation and additional signs of intestinal illness, as well as taking a serving as a barrier to stop colon cancer. Prebiotics have additionally been connected to higher Mineral absorption and bioavailability decreased a few cardiovascular risk factors. illness, and encouraged eating less and losing weight.

Combining probiotic and prebiotic products, Biostime raises the likelihood of live microbial dietary supplements surviving and implanting in the gut [9]. Synergies are more successfully produced in living systems when probiotics and prebiotics cooperate. Prebiotics and probiotics work together symbiotically to promote health, according to mounting scientific data. The functional foods from Biostime are good for treating and preventing diseases, as well as intestinal health. Currently, the development of novel foods that promote health and the selection of novel cultures that show improved gut occupancy and prebiotic processing capabilities are the main areas of research in this field.

4. Clinical Significance of Probiotics and Its Potential Applications

Probiotics contain numerous unique qualities, including anti-pathogenicity, anti-diabetic, anti-obesity, anti-inflammatory, anti-cancer, anti-allergic, and angiogenic activities, as well as effects on the brain and central nervous system, that make them highly promising for use in clinical settings.

One of the most beneficial consequences of probiotics is thought to be their antiviral activity, which interferes with or inhibits the makeup of the complex community of gut microbiota. These properties are not present in standard antibiotics. Probiotics and probiotic mixes‘ antiviral properties have been extensively studied. Tejero-Sarinena [10] investigated how probiotics affected the survival of Salmonella enterica, Clostridium typhimurium, and Clostridium difficile in an in vitro setting. By generating short-chain fatty acids (SCFA), such as acetic, propionic, butyric, and lactic acids, probiotics are thought to inhibit pathogens. SCFA supports in preserving the colonic lumen‘s ideal pH, which is necessary for the production of numerous bacterial enzymes as well as the gut‘s metabolism of toxins and carcinogens. Islam [4] also demonstrated how probiotics can create a variety of disease-resistant substances, including peptides, ethanol, organic acids, diacetyl, acetaldehyde, and hydrogen peroxide. Peptides and bacteriocins are the substances that primarily cause target cells‘ membranes to become more porous, which in turn causes membrane potential depolarization leading to cell death.

The WHO Cancer Fact Sheet [10] states that by 2024, there will be 20 million new instances of cancer worldwide and 9.7 million deaths from the disease. Cancer is a horrible illness that affects people everywhere. An estimated one in five people will have cancer at some point in their lives, one in nine men and one in twelve women will pass away from cancer, and 53.5 million people are expected to survive the disease within five years of being diagnosed. Comprehensive cancer research encompassing proteomics, genomics, and molecular pathology has raised public awareness and knowledge of cancer in recent years. Although there have been developments in small molecule hydrogen bond anti-cancer medicines, one of the key obstacles is still tolerance for their burden and side effects. Therefore, natural sources like probiotics with anti-cancer effects have always been in the spotlight. Clinical nutritionists, scientists, and industrialists have taken a keen interest in these, working together to reduce disease and develop an effective medication with few or no side effects [11–13]. Through the production of SCFA (ferulic acid), in vitro studies have demonstrated the great efficiency of probiotic strains fermenting Lactobacillus NCIMB-5221 and -8829 in suppressing colorectal cancer cells and boosting the proliferation of normal epithelial colon cells. Additionally, its capacity has been contrasted with that of other probiotics, including Lactobacillus rhamnosus ATCC 51303 and Lactobacillus acidophilus ATCC 314, both of which have showed tumorigenic activity in the past [14]. Similar to this, it was discovered that two distinct probiotic strains, Lactobacillus acidophilus LA102 and Lactobacillus casei LC232, had notable cytotoxic activity in vitro against the colorectal cancer cell lines Caco-2 and HRT-18 [15]. Probiotics may be able to prevent cancer, however so far only in vitro studies have been conducted on the subject.

The incidence of immune-related allergy illnesses has increased recently, posing a major global economic and social challenge. Thus, it is crucial to comprehend the mechanisms and causes of allergic illnesses in addition to developing novel treatments [16]. The advancement of knowledge regarding the causes and prevention of allergic disorders has been made possible by the positive function that probiotics play in treatment. Certain probiotics, such Lactobacillus plant-based L67, have been shown to produce interleukin-12 and interferon-gamma in their hosts, which may help prevent allergy-related illnesses in vitro [17]. Another study found that in ovalbumin-sensitized mice, Lactobacillus plantarum 06CC2 significantly lowered serum levels of histamine, ovalbumin-specific immunoglobulin E, and overall immunoglobulin E. Lactobacillus plant-based 06CC2 has been shown to dramatically increase the release of interleukin-4 and interferon-gamma in mouse spleen cells, which is what reduces allergy

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symptoms [18].

5. Conclusion

This study systematically expounds on the important role of probiotics in regulating intestinal flora, immune function and neurological health, and explores its potential clinical applications in anti-cancer, anti-disease and allergy prevention. Studies have shown that probiotics can maintain intestinal health by regulating the intestinal environment, inhibiting pathogens and enhancing host immunity. At the same time, the role of probiotics in the nervous system is mainly reflected in the two-way communication with neurotransmitters and neuroinflammation through the BGA, thereby affecting emotions, stress and cognitive functions. In addition, probiotics can also achieve anti-cancer and metabolic regulation functions by producing SCFA and other metabolites. Clinical studies have shown that the interaction between probiotics and specific immune factors such as IL-10, IL-6, IFN-γ, etc. can effectively relieve allergic symptoms and reduce the risk of chronic inflammation. Therefore, as a natural, safe and effective treatment option, probiotics have broad application prospects in disease prevention and health management. However, current research mainly focuses on in vitro experiments and animal models, and larger-scale clinical trials are needed in the future to further verify its efficacy and mechanism in humans to promote the application of probiotics in clinical medicine.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

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