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Natural Psychobiotic Foods and Their Role in Gut–Brain Axis Modulation

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ABSTRACT

The bidirectional communication between the gut and brain, termed the gut–brain axis, has emerged as a critical determinant of mental health and neurological function. Growing evidence highlights the role of gut microbiota in modulating neurochemical signaling, stress response, mood regulation, and cognitive performance. Psychobiotics, a class of probiotics and prebiotics that beneficially influence brain function, have gained increasing attention. In particular, natural psychobiotic foods—such as fermented dairy products, kimchi, sauerkraut, kefir, tempeh, kombucha, whole grains, legumes, and polyphenol-rich fruits and vegetables—offer sustainable and non-pharmacological approaches to enhance mental well-being. These foods contain live beneficial microbes, prebiotic fibers, or bioactive compounds that modulate gut microbiota composition, promote the production of short-chain fatty acids, and regulate neurotransmitter pathways, including serotonin, dopamine, and γ-aminobutyric acid. Moreover, dietary psychobiotics influence systemic inflammation and hypothalamic–pituitary–adrenal (HPA) axis activity, thereby mitigating anxiety, depression, and cognitive decline. Despite compelling preclinical and clinical evidence, challenges remain in standardizing dietary intake, establishing dose–response relationships, and understanding individual variability in gut microbiome responses. This review aims to provide a comprehensive overview of natural psychobiotic foods, their microbial and biochemical mechanisms, and their potential applications in preventive and therapeutic strategies for mental health. Emphasis is placed on recent advances in gut microbiome research, food-based interventions, and translational opportunities to integrate natural psychobiotics into daily nutrition. Ultimately, harnessing natural psychobiotic foods represents a promising frontier in personalized nutrition and sustainable mental healthcare.

KEYWORDS: Psychobiotics, Gut–brain axis, Microbiota, Fibres, Probiotics, Prebiotics.

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INTRODUCTION

The last few years have seen the emergence of the bidirectional communication system between the gastrointestinal tract as well as the central nervous system, known as the gut-brain axis (GBA), as one of the most crucial determinants of human health. This axis of GBA also incorporates the communication of the gut and the brain with neural, immune, endocrine, and metabolic systems, creating a continuous cross-talk with gut microbes.[1,2] The disruption of this balanced cross-talk has been associated with a range of disorders as gastrointestinal disorders, such as irritable bowel syndrome (IBS), and other psychiatric and neurodegenerative disorders, like depression, anxiety, autism spectrum disorder, and even Parkinson's disease.[3] This and other factors have raised concern and led to research on the microbiota, and the recognition of the microbiota as an active participant in this system has led to the research and development of a new type of intervention called psychobiotics, which is essentially microbial-based strategies aimed at mental health.[4,5]

The term psychobiotics, describing live microorganisms that have positive effects on mental health when consumed in appropriate amounts, was first used in 2013.[6] This definition has evolved with time to include, not just probiotics, live beneficial bacteria, but also include prebiotics, which are substrates that stimulate the growth of beneficial bacteria, and postbiotics which are inactivated microbes or microbial metabolites and synbiotics which are blends of probiotics and prebiotics.[7,8] All these are neuroactive. These

agents influence the GBA through diverse mechanisms such as modulation of neurotransmitter synthesis, regulation of the HPA stress axis, strengthening of intestinal barrier integrity, the production of short-chain fatty acids (SCFAs), and immune and inflammation regulation.[9,10]

The neurochemical basis is also related to the action of psychobiotics. Some gut microbes have been shown to manufacture or modulate the synthesis of crucial transmitters like serotonin, dopamine, and gamma-aminobutyric acid (GABA).[11] Serotonin, which plays an important role in regulating mood, is produced by the gut in almost 90% of its proportion.[12] Microbes also produce short-chain fatty acids (SCFAs) like butyrate, propionate, and acetate, which are signaling molecules important for the maintenance of the blood-brain barrier, neurogenesis, and reducing inflammation.[13] In addition, the alteration of tryptophan metabolism by certain microbes tilts the equilibrium away from neurotoxic byproducts, which also favors mental health.
The neurochemical basis of psychobiotic action is especially noteworthy. Gut microbes synthesize or influence precursors of key neurotransmitters such as serotonin, dopamine, and gamma-aminobutyric acid (GABA).[14] For example, nearly 90% of serotonin, a neurotransmitter central to mood regulation, is produced in the gut. Microbial fermentation also generates SCFAs such as butyrate, propionate, and acetate, which serve as signaling molecules supporting blood–brain barrier integrity, neurogenesis, and anti-inflammatory activity.[15] Moreover, microbial modulation of tryptophan metabolism shifts the balance away from neurotoxic metabolites, further supporting mental well-being.[16]

The stress response provides another angle on the psychobiotic-GBA interplay. Chronic stress and depression are often marked by the classic sign of HPA axis dysregulation: overproduction of cortisol. It appears psychobiotics are capable of mitigating HPA axis hyperactivity with a corresponding decrease in cortisol levels and an enhancement of stress resilience.[17,18] Moreover, psychobiotics mitigate neuroinflammation—critical in the development of psychiatric and neurodegenerative illness—by improving gut barrier function, lowering systemic endotoxemia, and indirectly reducing neuroinflammation.

Role of Microbiota in Mental Health

Mental disorders like anxiety, depression, stress-related afflictions and neurodegenerative diseases are increasing worldwide and have become a serious challenge for health care providers. Historically, the brain was thought to be an isolated organ and relatively walled off from external influences; however, recent research has emphasised the close relationship that exists between the gut and the brain, known as the gut–brain axis.[19,20] The gut microbiota, a complex ecosystem of microorganisms that inhibit the gastrointestinal tract, factors significantly in this communication. There is now compelling evidence supporting the role of the gut microbiota in shaping brain function and mental health and it does so through a range of physiological, neurochemical and immunological pathways. Elucidating this complex interplay is crucial for the search for new therapeutic strategies in psychiatric and neurological diseases.[21,22]

The human gut contains up to several trillion microorganisms, including bacteria, archaea, fungi, and viruses. The major bacterial divisions are Firmicutes, Bacteroidetes, Actinobacteria and Proteobacteria. These residents are not mere passive inhabitants, they make enormous digestion, nutrient absorption, metabolism, and immune system maturation contributions. Crucially, the gut microbiota is now appreciated to be neuroactive, generating and modifying neurotransmitters, neuropeptides, and other signaling molecules that reach the central nervous system (CNS), by direct or indirect means.[23,24]

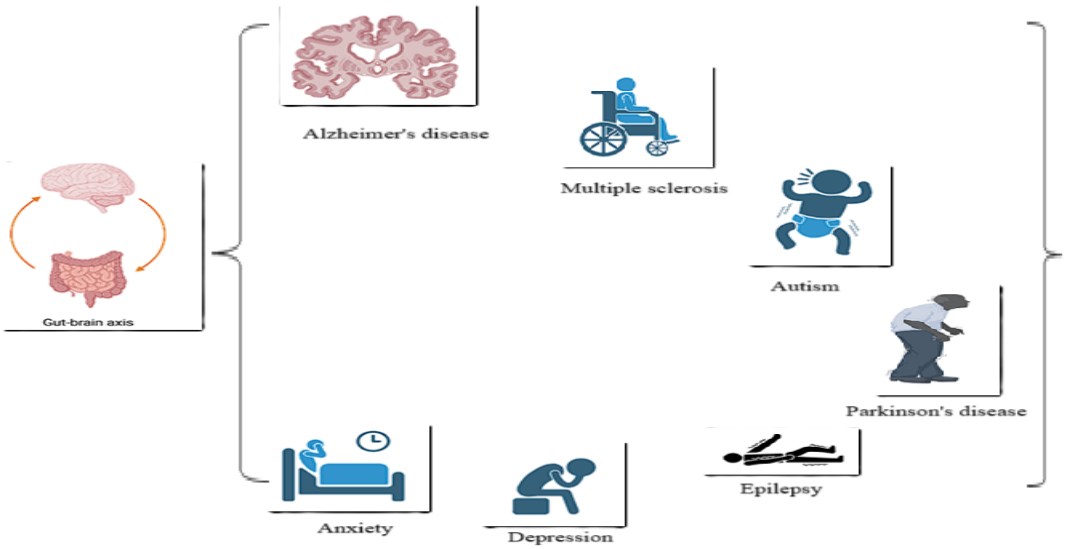

Fig 1. Gut–Brain Axis and Its Association with Neurological and Psychiatric Disorders

Effect of Psychobiotics vs. Pathogenic Gut Microbiota

The gut microbiota is a dynamic population of billions of microorganisms that live in the human gut. This ecosystem is essential for immunological control, digestion, and metabolism, but more significantly, it interacts with the brain via the gut–brain axis.[25] In this context, two different kinds of bacteria have conflicting effects on mental and physical health: pathogenic gut microbiota, which upset gut balance and impair mental health, and psychobiotics, which are good microbes that promote brain function and emotional well-being.[26]

Psychobiotics: The Protectors

Psychobiotics are probiotics (good bacteria) and prebiotics (dietary fibers that fuel them) that have positive impacts on mental health through their action on the gut–brain axis.[27] Bifidobacterium and Lactobacillus are important microorganisms that are frequently present in fermented foods and probiotic supplements.[28]

The most important effect of psychobiotics is their ability to restore gut balance. By boosting the number of beneficial bacteria, they help stop the overabundance of dangerous species.[29] By doing this, they establish a steady environment in the stomach that promotes good metabolism and nutrient absorption.

Neuroactive substances, including serotonin, dopamine, and gamma-aminobutyric acid (GABA) are also produced by psychobiotics. These neurotransmitters have a direct impact on stress reactions, emotion, and cognition.[30] For instance, the gut produces over 90% of the body's serotonin, and psychobiotics help regulate its levels, enhancing mental stability and reducing the symptoms of anxiety and depression.

Another important function of psychobiotics is their role in reducing inflammation. They promote the release of anti-inflammatory cytokines and strengthen the gut barrier, preventing toxins and pathogens from leaking into the bloodstream.[31] This reduces systemic inflammation and protects the brain from harmful immune signals that can trigger neuroinflammation.

Through these combined actions, psychobiotics support stress regulation by calming the hypothalamic–pituitary–adrenal (HPA) axis and lowering cortisol levels. This helps improve resilience to stress, enhances memory and learning, and may even protect against neurodegenerative disorders such as Alzheimer's disease.[32]

Pathogenic Gut Microbiota: The Disruptors

Pathogenic microorganisms, on the other hand, are dangerous germs that upset the delicate equilibrium of the gut microbiota. Salmonella, Escherichia coli (toxic strains), and Clostridium difficile are a few examples.[33] When these species predominate, they lead to gut dysbiosis, which lowers the quantity of helpful bacteria and damages the microbiome's general health. Toxic chemicals like lipopolysaccharides (LPS), which harm the gut lining, are frequently produced by pathogens.[34] Leaky gut syndrome may result in this condition, where harmful substances enter the bloodstream and trigger extensive inflammation. Neuroinflammation, which is closely linked to depression, anxiety, and cognitive loss, is facilitated by these inflammatory signals' easy access to the brain.[35]

Furthermore, by interfering with the synthesis of serotonin, dopamine, and GABA, pathogenic bacteria upset the equilibrium of neurotransmitters. They could exacerbate mood swings, stress, and mental exhaustion rather than promoting serenity and emotional equilibrium.[36]

Additionally, pathogenic microbiota overactivates the HPA axis, which causes an overabundance of cortisol to be released. Weakened immunity, poor emotional regulation, and cognitive impairment are all associated with chronically elevated cortisol levels. This leads to a cycle of stress, inflammation, and neurodegeneration over time.

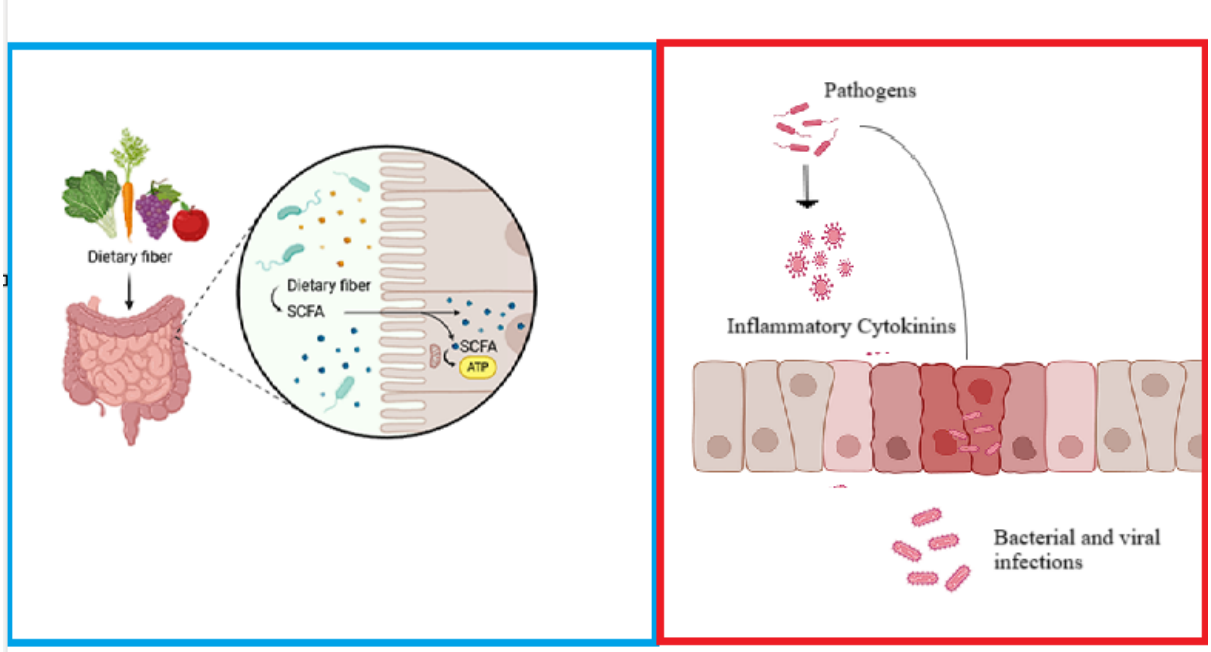

Fig 2. Impact of Dietary Fiber and Pathogens on Gut Microbiota and Intestinal Health

Table 1: Natural Sources of Psychobiotics

Source	Example	Major Psychobiotic Compounds	Mechanism of Action	Reference
Fermented Dairy Foods	Yogurt, Kefir, Curd	*Lactobacillus rhamnosus, Lactobacillus helveticus, Lactobacillus casei*	Produce γ-aminobutyric acid (GABA); regulate HPA axis; reduce anxiety and depression symptons	37,38
Fermented vegetables	Kimchi, Sauerkraut, pickled vegetables	*Lactiplantibacillus plantarum, Leuconostoc mesenteroides*	Enhance gut microbial growth, modulate serotonin synthesis,	39,40
Fermented soy products	Natto, Tempeh, Tofu, Miso	*Bacillus subtilis, Lactobacillus plantarum*	Increase dopamine and serotonin precursors, also support gut-brain signaling	41,42
Non-Dairy Fermented Beverages	Fermented fruit juices, Kombucha	*Saccharomyces cerevisiae, Acetobacter*	Provide organic acid, improve mood via microbiota modulation	43,44
Probiotic-rich foods	Yogurt, drinks, milk, fortified foods	*Bifidobacterium bifidum, Lactobacillus acidophilus*	Maintain intestinal barrier; suppress neuroinflammation	45, 46
Fruits and vegetables	Apple, Banana, Onion, Garlic, chicory root	*Pectin, fructoligosaccharide, inulin*	act as prebiotics to promote the development of psychobiotic strains.	47, 48
Traditional Indian Fermented Foods	Curd, Pickle, Dhokla, Rice	*Lactic acid, Lactobacillus fermentum,*	Indigenous psychobiotic sources promoting gut-brain wellness	49,50
Fermented Cereals and Pulses	Fermented millet, rice, soybean, black gram	*Lactobacillus spp., Bacillus spp.*	Create short-chain fatty acids (SCFAs) and bioactive peptides that have neuroactive properties.	51,52
Cheese and other fermented Milk products	Aged cheese, curd, cheese	*Lactobacillus casei, Propionibacterium freudenreichii*	Generate folate and GABA to improve mood regulation	53
Cereal and legume-based fermented food	Dosa batter, Idli, Injera	*Lactobacillus mesenteroides, Pediococcus pentosaceus*	Boost neurotransmitter balance and enhance gut health and cognitive resilience	54,55
Plant-Based beverages	Fermented tea (Kombucha), rice beer	*Acetobacter xylinum, Zygosaccharomyces bailii*	Modulate oxidative stress and emotional stability	56,57

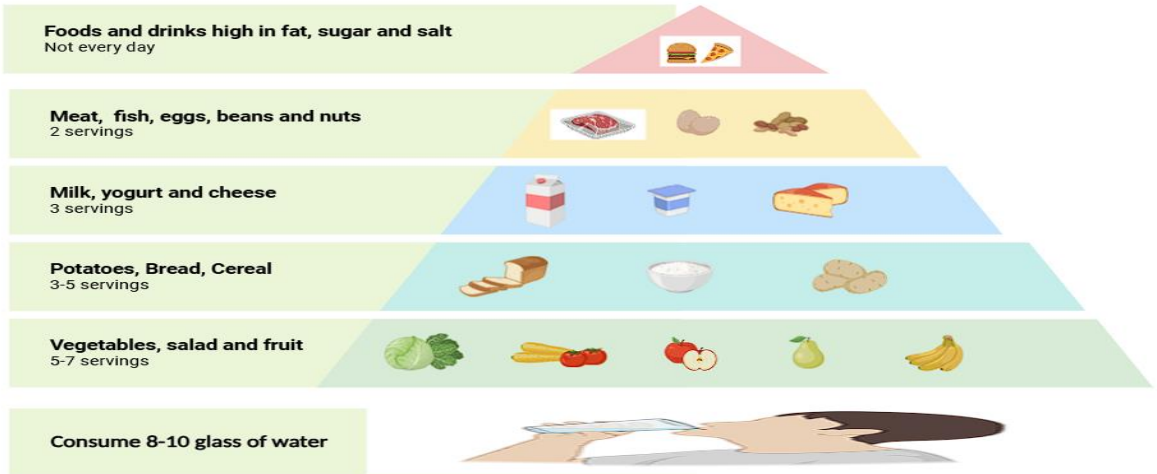

Fig 3. The Food Pyramid: Dietary Guidelines Emphasizing Balanced Nutrition for Gut and Brain Health

Mechanism of Action of Psychobiotics and Their Modulation through Natural Sources

Psychobiotics are helpful microorganisms, primarily Lactobacillus and Bifidobacterium species, that improve mental health via the microbiota–gut–brain axis (MGBA), a two-way communication network that connects the gut microbiota to the central nervous system. Psychobiotics affect the brain through a variety of interrelated mechanisms that include immunological, metabolic, endocrine, and neurological pathways. The vagus nerve, which carries messages from the gut to the brain, is one of the main channels of communication. By generating metabolites including short-chain fatty acids (SCFAs), gamma-aminobutyric acid (GABA), and serotonin, which affect brain areas related to emotion and cognition, psychobiotics can alter vagal activity. It is known that some strains, such as Lactobacillus rhamnosus and Bifidobacterium longum, generate the neurotransmitters GABA and serotonin, which are essential for lowering anxiety, depression, and stress-related behaviour.[58,59]

Another important regulation involves the hypothalamic-pituitary-adrenal (HPA) axis, which regulates the body's reaction to stress, is another crucial process. Long-term stress causes this axis to become overactive, which raises cortisol levels.[60] By lowering cortisol secretion, psychobiotics aid in the restoration of equilibrium and enhance mood stability and stress resilience. Additionally, psychobiotics alter the immune system by raising anti-inflammatory mediators like IL-10 and decreasing pro-inflammatory cytokines like TNF-α and IL-6. Neuroinflammation, which is frequently linked to depression and neurodegenerative diseases, is prevented by this decrease in systemic inflammation.[61] Furthermore, by fortifying tight junctions and inhibiting the translocation of dangerous endotoxins (such lipopolysaccharides), which can cause inflammation and impair brain function, psychobiotics improve the integrity of the intestinal barrier.

Psychobiotics derived from natural sources are essential for sustaining and amplifying these effects. Live probiotic strains that colonise the gut and preserve microbial equilibrium are abundant in fermented foods like yoghurt, kefir, kimchi, miso, and sauerkraut. Foods high in prebiotics, such as bananas, garlic, onions, asparagus, and oats, offer indigestible fibres that act as substrates for probiotic development, encouraging the synthesis of SCFAs and other neuroactive chemicals.[62,63] These natural sources work to produce synbiotics, which are a combination of probiotics that replenish beneficial microorganisms and prebiotics that nourish them.

Through these methods, psychobiotics and their natural dietary sources nourish the brain through the stomach in a safe, natural, and sustainable way. They also help with stress adaption and mental health.

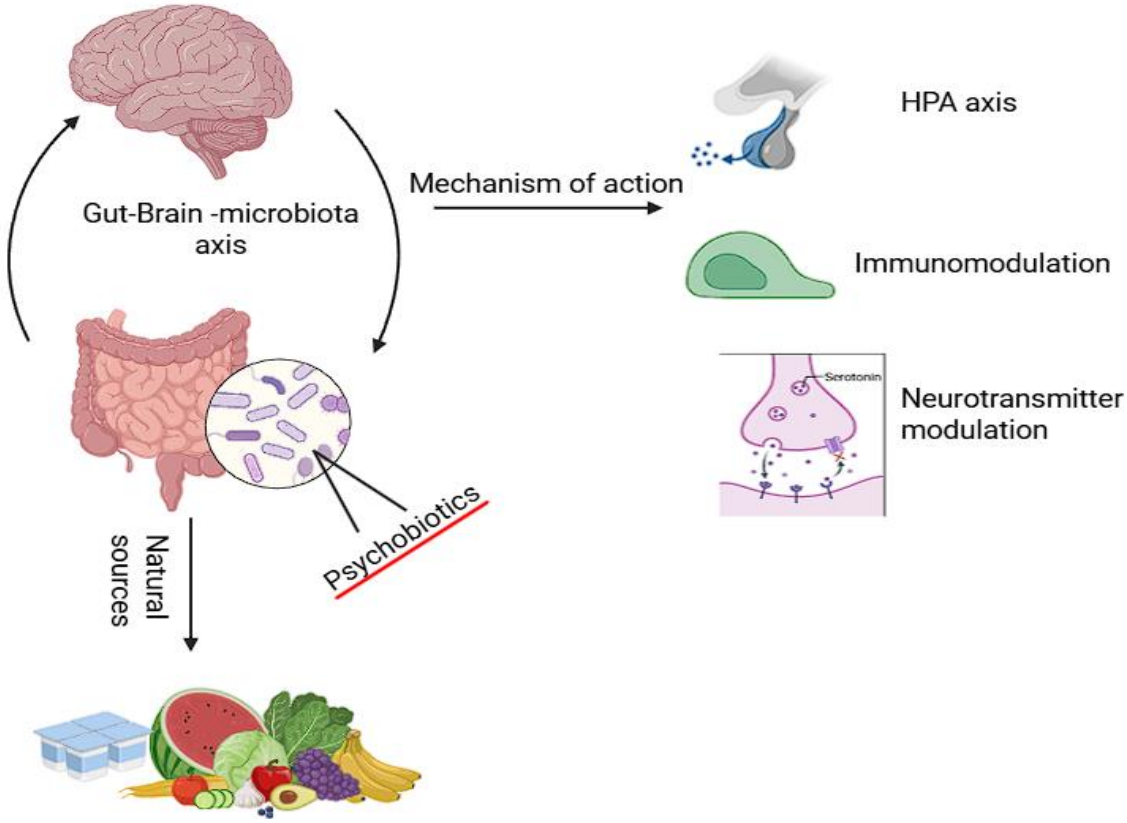

Fig 4. Schematic Representation of Mechanism of Psychobiotic Action and Modulatory Role of Natural Sources in the Gut–Brain Axis.

CONCLUSION

Natural psychobiotic foods represent a promising and sustainable approach to promoting gut health and modulating the gut–brain axis. Fermented foods, prebiotic-rich fruits, vegetables, whole grains, and polyphenol-containing foods provide bioactive compounds and beneficial microbes that enhance microbial diversity, regulate neurotransmitter production, and reduce inflammation. Evidence suggests that these dietary components play a vital role in alleviating anxiety, depression, cognitive decline, and other neuropsychiatric disorders by supporting microbial homeostasis. Unlike synthetic interventions, natural psychobiotic foods are safe, accessible, and culturally accepted, making them ideal candidates for long-term dietary strategies. In

the future, integrating natural psychobiotic foods into personalized nutrition plans could provide a holistic and preventive strategy for maintaining both gut and brain health.

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DATA AVAILABILITY STATEMENT

The data support the findings of this study are available in standard research databases such as PubMed, Science Direct, or Google Scholar.

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

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