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Emerging Role of Psychobiotics in Mental Health and Cognitive Function

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Abstract

Mental health disorders are among the leading causes of disability worldwide and represent a major public health concern. While conventional treatments remain essential, increasing evidence suggests that gut may influence brain health by modulating the gut microbiota, which communicates bidirectionally with the central nervous system through the gut–brain axis (GBA). This growing understanding has led to the emergence of psychobiotics as a promising nutritional approach to support mental well-being. The review aims to critically examine explore the relationship between diet, gut microbiota, and the GBA, through the biological mechanisms underlying psychobiotic action and evaluate current clinical evidence. A comprehensive review of recent scientific literature was conducted through online and offline databases. Evidence was synthesized to evaluate the effects of psychobiotics on depression, anxiety, stress management, cognitive performance, mild cognitive impairment, and neurodegenerative diseases, with emphasis on nutrition-based interventions and their proposed mechanisms of action. Current evidence suggests that psychobiotics including probiotics, prebiotics, synbiotics, and related microbiome-targeted interventions may support mental health by promoting a healthy gut microbiota and enhancing gut–brain communication. Proposed mechanisms include neurotransmitter production, vagus nerve signaling, regulation of the hypothalamic–pituitary–adrenal axis, immune modulation, reduction of systemic and neuroinflammation, and the production of short-chain fatty acids. Psychobiotics represent a promising adjunctive nutritional strategy for promoting mental health and cognitive resilience. High-quality clinical trials, standardized psychobiotics formulations, long-term safety evaluations, and personalized microbiome-based approaches are needed before psychobiotics can be routinely incorporated into evidence-based clinical nutrition and public health recommendations.

Keywords: Cognitive function, Gut microbiota, Gut–brain axis, Mental health, Prebiotics, Probiotics, Psychobiotics

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Introduction

Mental health is increasingly recognized as an essential component of overall health and well-being, influencing an individual's ability to cope with daily life, maintain productive relationships, and contribute meaningfully to society.[1] Over the past few decades, mental health disorders have emerged as one of the greatest public health challenges worldwide, affecting individuals across all age groups and socioeconomic backgrounds.[2] According to the World Health Organization, nearly one in seven people worldwide are living with a mental disorder. Among the most prevalent mental health disorders, depression, anxiety, chronic stress, and age-related cognitive decline impose a considerable burden on individuals and families, healthcare systems, and national economies. Beyond their psychological consequences, these conditions are associated with impaired academic and occupational performance, increased risk of chronic diseases, social isolation, and diminished productivity. Depression and anxiety alone are estimated to cost the global economy approximately US$1 trillion annually through reduced productivity and healthcare expenditure.[3] Although antidepressants, anxiolytics, psychotherapy, and behavioral interventions remain the cornerstone of treatment, their effectiveness varies among individuals, and many patients experience delayed therapeutic responses, incomplete symptom relief, adverse effects, or poor long-term adherence.[4] These limitations have prompted increasing interest in complementary lifestyle-based approaches, particularly nutritional interventions, that may enhance conventional therapies while promoting overall health.

Nutrition has emerged as one of the most important lifestyle factors influencing both physical and mental health.[5] Dietary recommendations for mental well-being focused primarily on ensuring adequate intake of essential nutrients such as omega-3 fatty acids, B vitamins, vitamin D, magnesium, zinc, and antioxidants that support normal brain function.[6] Eating a diet rich in fruits, vegetables, whole grains, legumes, nuts, seeds, and fermented foods is reliably linked to better mental health and a lower risk of depression and anxiety.[7] On the other hand, diets high in ultra-processed foods, refined sugars, and saturated fats are linked to higher inflammation, less gut bacterial diversity, and worse mental health.[8]

Emerging paradigms in nutrition and neurology increasingly emphasize the role of the gut microbiota in modulating brain

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function through bidirectional gut-brain axis (GBA). The gut microbiota comprises trillions of microorganisms including bacteria, viruses, fungi, and archaea that inhabit the gastrointestinal tract and perform essential physiological functions.[9] These microorganisms contribute to the digestion of dietary components, synthesis of certain vitamins, maintenance of intestinal barrier integrity, protection against pathogenic microbes, and regulation of immune responses.[10,11] The composition and diversity of the gut microbiota are strongly influenced by diet, lifestyle, age, medication use, and environmental exposures.[12] Fiber-rich foods, whole grains, fruits, vegetables, legumes, fermented foods, and other plant-based dietary components nourish beneficial gut bacteria, whereas diets high in processed foods and low in dietary fiber may disrupt microbial balance, a condition commonly referred to as dysbiosis.[13] Increasing evidence indicates that gut dysbiosis is associated not only with gastrointestinal disorders but also with metabolic, immune, and neuropsychiatric conditions.[14]

The relationship between the gut microbiota and mental health is mediated through the GBA, a complex bidirectional communication network that links the gastrointestinal tract with the central nervous system (CNS).[15]

Figure 1 illustrates the bidirectional communication between the gut microbiota and the brain through neural, endocrine, immune, and microbial metabolic pathways. It demonstrates how a healthy diet promotes beneficial gut microorganisms that support neurotransmitter production, immune homeostasis, and brain function, whereas gut dysbiosis may contribute to inflammation, mood disorders, and cognitive impairment. This conceptual framework highlights the therapeutic potential of psychobiotics in promoting mental well-being through modulation of the GBA.

Building on growing evidence linking the gut microbiota to brain health, psychobiotics have emerged as an important area within nutritional psychiatry.[16] Originally defined as probiotic microorganisms capable of improving mental health, the concept now includes probiotics, prebiotics, synbiotics, and other microbiome-targeted interventions that promote psychological well-being by modulating the gut microbiota.[17] Psychobiotics represent a safe, accessible, and nutrition-based approach that may complement conventional treatments for depression, anxiety, stress, and cognitive decline.[18] Recent randomized controlled trials and systematic reviews suggest that selected psychobiotic strains may improve mood, reduce stress, enhance cognitive function, and promote emotional resilience (Figure 2).[19]

By integrating current evidence with a nutrition-focused perspective, this review seeks to highlight the potential of dietary strategies and microbiome-targeted interventions as complementary approaches for promoting mental well-being and cognitive health.

Aim and Scope of the Review

The primary aim of the review is to critically examine the emerging role of psychobiotics in mental health and cognitive function by integrating current evidence on the interactions among diet, gut microbiota, and the GBA. Specifically, the review discusses the composition and functions of the gut microbiota, the influence of dietary habits on microbial diversity, and the mechanisms through which psychobiotics may affect brain health, including neurotransmitter production, vagus nerve signaling, immune modulation, regulation of inflammation, and the production of short-chain fatty acids (SCFAs). In addition, it evaluates recent clinical evidence on the effectiveness of psychobiotics in depression, anxiety, stress management, cognitive function, and neurodegenerative diseases, while critically examining the strengths and limitations of current research.

The scope of the review extends beyond mechanistic insights to emphasize practical nutritional approaches for maintaining a healthy gut microbiota. It highlights the role of healthy dietary patterns, fermented foods, probiotics, prebiotics, and other gut-supportive dietary components as potential strategies for promoting mental well-being. The review also discusses the implications of psychobiotics for clinical nutrition, dietetic practice, and public health and identifies key research gaps and future priorities, including personalized nutrition and microbiome-based interventions.

By synthesizing recent evidence from a nutrition-focused perspective, this review aims to provide a comprehensive and balanced understanding of the potential of psychobiotics as complementary dietary interventions for mental health. It is intended to serve as a valuable resource for researchers, clinicians, dietitians, nutritionists, and public health professionals, while contributing to the growing body of literature by bridging advances in microbiome science with practical nutritional applications for improving psychological well-being and cognitive health.

Factors Affecting Gut Microbiota Composition and Diversity

The composition and diversity of the gut microbiota is continuously shaped by a complex interplay of dietary, environmental, physiological, and lifestyle factors throughout life.[20] Diets rich in dietary fiber, whole grains, fruits, vegetables, legumes, nuts, and fermented foods provide fermentable substrates that promote the growth of beneficial bacteria such as *Bifidobacterium*, *Lactobacillus*, and other SCFA-producing microbes.[21] The fermentation of dietary fibers by these microorganisms generates SCFAs, including acetate, propionate, and butyrate, which maintain intestinal barrier integrity, regulate immune responses, suppress inflammation, and influence gut–brain communication.[22] In contrast, Western-style dietary patterns characterized by high intakes of ultra-processed foods, refined sugars, saturated fats, and low fiber reduce microbial diversity, promote gut dysbiosis, and increase the abundance of pro-inflammatory microorganisms, thereby contributing to metabolic disorders, impaired immune function, and neuropsychiatric diseases.[23]

Antibiotic exposure is another major factor capable of profoundly altering the gut microbiota. Although antibiotics are indispensable for treating bacterial infections, their broad-spectrum activity often eliminates beneficial commensal bacteria alongside pathogenic microorganisms, leading to reduced microbial diversity and disruption of microbial metabolic functions.[24] Repeated or prolonged antibiotic use may delay microbiota recovery, alter the production of microbial metabolites such as SCFAs and bile acids, increase susceptibility to opportunistic pathogens, and impair immune homeostasis.[25] Emerging evidence also suggests that antibiotic-induced dysbiosis may influence metabolic health and potentially affect gut–brain signaling through alterations in microbial metabolite production and inflammatory pathways.[24,21]

The gut microbiota also undergoes significant changes across the human lifespan. Early-life microbial colonization is influenced by factors such as mode of delivery, breastfeeding, complementary

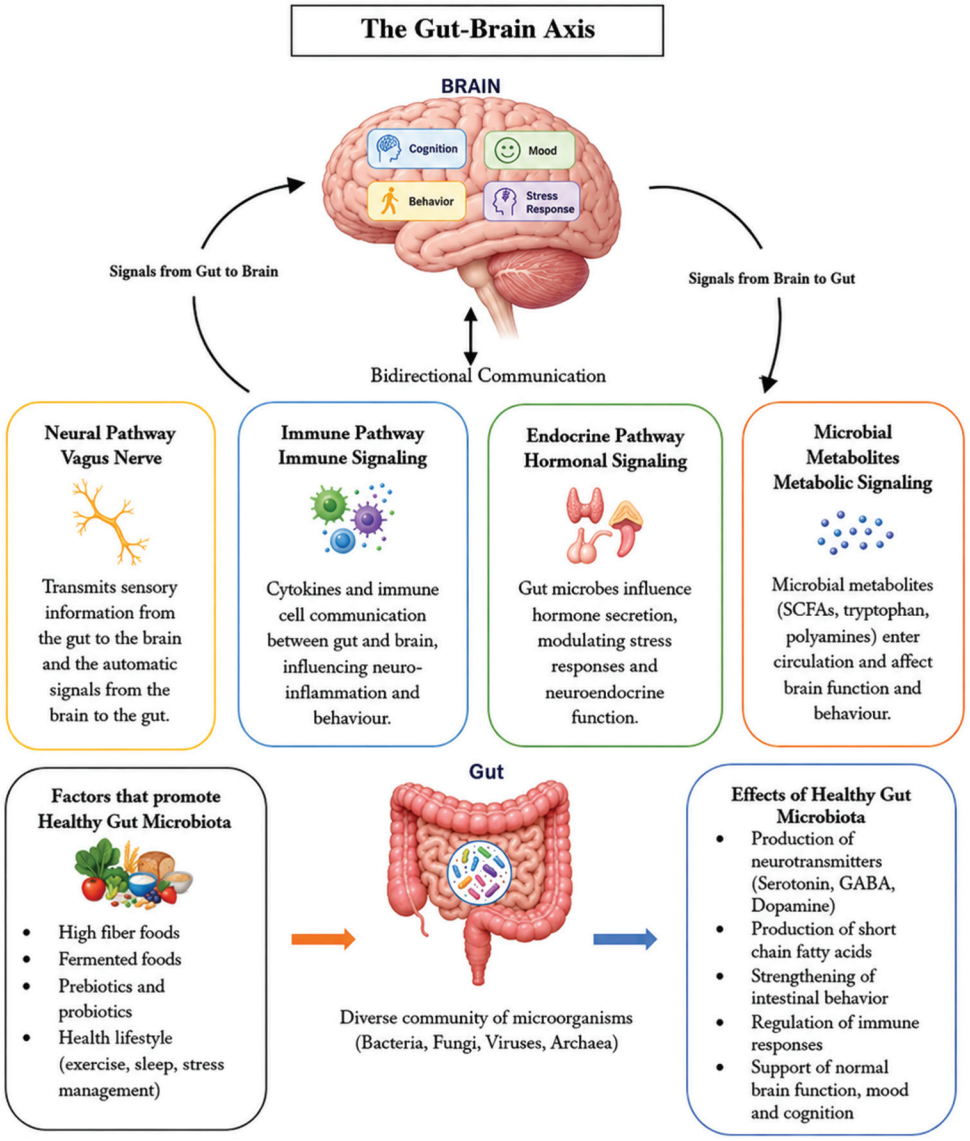


Figure 1: Bidirectional communication between the gut microbiota and the central nervous system

feeding, and antibiotic exposure, which collectively shape immune maturation and metabolic development.[26] During adulthood, the microbiota generally remains relatively stable; however, aging is often associated with reduced microbial diversity, loss of beneficial bacteria, and increased abundance of opportunistic microorganisms.[27] These age-related alterations may contribute to immunosenescence, chronic low-grade inflammation, frailty, cognitive decline, and increased susceptibility to chronic diseases, emphasizing the importance of maintaining a diverse and resilient gut microbiota throughout life.[28]

Several lifestyle factors, including physical activity, sleep, psychological stress, and daily habits, further influence gut microbial composition and function.[29] Regular physical activity has consistently been associated with greater microbial diversity and enrichment of beneficial SCFA-producing bacteria, thereby improving intestinal barrier function, reducing systemic inflammation, and supporting metabolic and cognitive health.[30] Conversely, sedentary behavior may negatively affect microbial diversity and metabolic homeostasis.[31] Adequate sleep is increasingly recognized as an important regulator of the gut microbiota, whereas chronic sleep deprivation and circadian rhythm disruption can alter microbial composition, increase intestinal permeability, and promote inflammatory responses that may adversely affect both gut and brain health.[32] Similarly, chronic psychological stress activates the hypothalamic–pituitary–adrenal (HPA) axis, elevating cortisol secretion, which alters intestinal motility, mucus production, gut permeability, and microbial composition.[33] These stress-induced changes can disrupt gut–brain communication and have been associated with anxiety, depression, and impaired cognitive function.[34]

Thus, the gut microbiota reflects the cumulative effects of diet, medication use, aging, physical activity, sleep quality, stress, and broader lifestyle habits. These factors collectively determine microbial diversity, metabolic activity, and resilience, thereby influencing not only gastrointestinal function but also immune regulation, systemic metabolism, and brain health through the GBA. Understanding how modifiable lifestyle factors shape the gut microbiota provides important opportunities for developing

dietary and behavioral interventions aimed at preserving microbial homeostasis and promoting both physical and mental well-being.

Foods That Promote A Healthy Gut Microbiota

Diet is one of the most important modifiable determinants of the composition and functional activity of the gut microbiota. In addition to supplying essential nutrients, specific dietary components can selectively stimulate the growth and metabolic activity of beneficial microorganisms, thereby influencing microbial diversity, the production of health-promoting metabolites, and influencing a wide range of host physiological processes. Increasing evidence indicates that regular consumption of foods rich in probiotics, prebiotics, dietary fiber, and polyphenols supports the establishment of a healthy gut microbial ecosystem. These dietary components help maintain intestinal barrier integrity, regulate immune and inflammatory pathways, and promote the production of beneficial microbial metabolites, particularly SCFA. Diet-induced microbial changes have also been associated with improved communication along the GBA. However, the magnitude of these effects varies depending on the type of food consumed, its bioactive components, and the specific microbial populations that are selectively influenced. Table 1 summarizes key food groups that have been reported to beneficially modulate the gut microbiota, highlighting their major effects on microbial composition, underlying mechanisms and potential implications for gut and brain health.

Dietary Factors that Negatively Influence the Gut Microbiota

While several dietary components contribute to maintain a healthy and diverse gut microbiota, certain dietary patterns have the opposite effect by disrupting microbial homeostasis. Diets rich in ultra-processed foods, refined sugars, saturated fats, and inadequate dietary fiber have consistently been linked to reduced microbial diversity, a decline in beneficial bacterial, and an increase in pro-inflammatory microorganisms. These microbial alterations can impair the production of beneficial metabolites, weaken intestinal barrier function, and trigger chronic low-grade inflammation. As a result, disrupted gut microbial homeostasis may impair bidirectional communication between the gut and the brain, thereby contributing to metabolic dysfunction as well as an increased risk of mood disorders, cognitive decline, and other neurological conditions. Given the increasing evidence linking dietary quality with gut microbial composition and GBA function, identifying dietary factors that adversely affect the gut microbiota is essential for developing effective nutritional strategies to support gastrointestinal and mental health. Table 2 summarizes the major dietary factors associated with unfavorable changes in the gut microbiota, their underlying mechanisms, and their potential implications for gut and brain health.

Collectively, current evidence indicates that diet is the most important modifiable determinant of gut microbiota composition. Diets emphasizing minimally processed, fiber-rich, plant-based, and fermented foods promote microbial diversity, enhance SCFA production, strengthen intestinal barrier function, and reduce inflammation, thereby supporting both gut and brain health. In contrast, dietary patterns characterized by excessive intake of ultra-processed foods, refined sugars, saturated fats, and inadequate dietary fiber disrupt microbial homeostasis, promote dysbiosis, and may contribute to chronic metabolic, inflammatory, and neuropsychiatric disorders through alterations in the GBA.

GBA

The GBA is a complex bidirectional communication network that links the gastrointestinal tract with the CNS.[57] It integrates neural, endocrine, immune, and metabolic signaling pathways, allowing continuous exchange of information between the gut and the brain. It is referred to communication between the brain and the gastrointestinal tract through the autonomic nervous system and enteric nervous system.[58]

Recent advances in microbiome research have expanded the concept of the GBA to the gut–brain–microbiome axis, recognizing the gut microbiota as an integral component of this bidirectional communication system. Increasing evidence indicates that the gut microbiota plays an important role in brain development, emotional regulation, cognition, and behavior.[59]

The GBA also plays a vital role in maintaining normal gastrointestinal and neurological function through continuous bidirectional communication between the gut and the brain (Table 3).[60] This interaction helps regulate essential physiological processes, including digestion, intestinal barrier integrity, immune function, appetite, and the body's response to stress. In turn, signals from the brain influence gut physiology by modulating intestinal motility, digestive secretions, blood flow, and the composition of the gut microbiota through autonomic and neuroendocrine pathways.[33] When this communication becomes disrupted, it can impair gut homeostasis and contribute to the development of both gastrointestinal and neurological disorders. Increasing evidence has linked dysfunction of the GBA with conditions such as anxiety, depression, autism spectrum disorder, Alzheimer's disease, and Parkinson's disease, highlighting its important role in maintaining both gut and brain health.[61]

Communication between the Gut and the Brain

Communication between the gut and the brain occurs through several interconnected signaling pathways. The GBA has emerged as a key regulator of mental health, as it integrates microbial, neural, immune, and endocrine signals that influence emotional well-being and cognitive function.[58] A healthy and diverse gut microbiota helps maintain this communication by supporting the production of neuroactive compounds, preserving the integrity of the intestinal and blood–brain barriers, regulating immune function, and promoting appropriate responses to stress.[67] Conversely, an imbalance in the gut microbiota, known as dysbiosis, disrupts these processes, leading to increased intestinal permeability, chronic inflammation, altered neurotransmitter activity, and dysregulation of the HPA axis.[68]

Growing evidence indicates that changes in the composition and function of the gut microbiota can influence brain health through the production of microbial metabolites, modulation of immune and inflammatory responses, and signaling through the vagus nerve.[69] Microbiota-targeted strategies, including dietary modification, probiotics, prebiotics, psychobiotics, and fecal microbiota transplantation act as potential approaches to support mental health and cognitive function.[70]

Table 1: Foods that support beneficial gut microbiota and their potential effects on gut and human health

Food	*Major microbial changes*	*Key mechanisms*	*Gut and mental health benefits*	*References*
Fermented foods				
Yogurt	↑ *Lactobacillus*, ↑ *Bifidobacterium*	Live cultures, lactic acid, bioactive peptides	Improves microbial diversity, intestinal barrier integrity, immune regulation; may support mood through the gut–brain axis	[35,36]
Kefir	↑ SCFA-producing bacteria, ↑ microbial diversity	Probiotic bacteria and yeasts, kefiran, organic acids	Enhances gut barrier, reduces inflammation; may improve mood and cognition	[37]
Buttermilk	↑ Lactic acid bacteria	Lactic acid bacteria, milk phospholipids, bioactive peptides	Improves digestion, microbial balance, and gut health	[36]
Kimchi	↑ *Lactiplantibacillus*, ↑ SCFA-producing bacteria	Probiotics, dietary fiber, polyphenols, organic acids	Enhances gut barrier, reduces inflammation; supports gut–brain communication	[36,38]
Sauerkraut	↑ Probiotic bacteria, ↑ microbial diversity	Lactic acid bacteria, vitamin C, phenolics	Supports gastrointestinal health and intestinal barrier integrity	[39]
Miso	Supports beneficial gut microbiota	Fermented soybean peptides, isoflavones, probiotics	Antioxidant and anti-inflammatory effects; supports metabolic and gut health	[40]
Tempeh	↑ Beneficial bacteria, ↑ microbial diversity	Fermented proteins, isoflavones, fiber, probiotics	Improves intestinal health, protein digestibility, and reduces inflammation	[37]
Prebiotic foods				
Garlic	↑ *Bifidobacterium*, ↑ *Lactobacillus*	Inulin, FOS, organosulfur compounds	Enhances SCFA production, reduces inflammation, strengthens epithelial barrier	[41]
Onion	↑ Beneficial bacteria, ↑ SCFA production	Inulin, FOS, quercetin, polyphenols	Improves gut barrier integrity and reduces intestinal inflammation	[42]
Banana	↑ *Bifidobacterium*, ↑ butyrate producers	Resistant starch, pectin, FOS, fiber	Improves bowel function, intestinal health, and SCFA production	[34]
Oats	↑ SCFA-producing bacteria	β-glucan, resistant starch, soluble fiber	Improves microbial diversity, metabolic health, and reduces gut inflammation	[43]
Asparagus	↑ Beneficial gut bacteria	Inulin, fructans, dietary fiber	Enhances SCFA production and immune regulation	[44]
Chicory root	↑ *Bifidobacterium*	Inulin, oligofructose	Improves microbial diversity and gut barrier function	[45]
High-fiber foods				
Fruits	↑ SCFA-producing bacteria, ↑ microbial diversity	Dietary fiber, pectin, vitamins, polyphenols	Improves gut barrier, reduces inflammation, supports gut–brain communication	[46]
Vegetables	↑ Beneficial bacteria, ↑ microbial diversity	Soluble and insoluble fiber, resistant starch, phytochemicals	Enhances SCFA production and reduces inflammation	[47]
Whole grains	↑ Butyrate-producing bacteria	Arabinoxylans, β-glucan, resistant starch	Improves microbial diversity, metabolic health, and gut integrity	[34]
Millets	↑ Beneficial bacteria, ↑ SCFA-producing bacteria	Dietary fiber, resistant starch, phenolics, minerals	Supports intestinal, metabolic, and potentially mental health through the gut microbiota	[48]
Legumes	↑ *Bifidobacterium*, ↑ butyrate producers	Resistant starch, soluble fiber, oligosaccharides, plant protein	Improves gut barrier integrity and reduces chronic inflammation	[49]
Polyphenol-rich foods				
Berries	↑ *Akkermansia*, ↑ *Bifidobacterium*	Anthocyanins, flavonoids, phenolic acids	Reduces oxidative stress, improves gut barrier, and supports brain health	[50]
Cocoa	↑ Beneficial bacteria, ↑ SCFA producers	Flavanols, catechins, polyphenols	Reduces inflammatory cytokines and supports gut–brain signaling	[51]
Green tea	↑ Beneficial bacteria, ↓ Pathogenic bacteria	Catechins (EGCG), polyphenols	Antioxidant, anti-inflammatory, and neuroprotective effects	[52]
Extra-virgin olive oil	Supports beneficial microbial communities	Hydroxytyrosol, oleuropein, MUFAs, polyphenols	Improves gut barrier, reduces inflammation, and supports cardiometabolic and brain health	[50]

FOS: Fructooligosaccharides, SCFA: Short-chain fatty acids

Table 2: Dietary factors associated with adverse alterations in the gut microbiota composition and their implications for gut and human health

Dietary factor	*Major microbial changes*	*Key mechanisms*	*Gut and mental health implications*	*References*
Ultra-processed foods	↓ Microbial diversity, ↓ *Bifidobacterium*, ↑ pro-inflammatory bacteria (Enterobacteriaceae)	High refined carbohydrates, food additives, and low fiber reduce SCFA production, impair gut barrier function, and promote endotoxemia.	Promotes gut dysbiosis, chronic inflammation, metabolic disorders, and GBA dysfunction; associated with depression, anxiety, and cognitive decline.	[23,53]
High sugar intake	↓ *Bifidobacterium*, ↓ butyrate-producing bacteria, ↑ opportunistic bacteria	Excess sugars reduce SCFA production, disrupt the mucus barrier, and increase intestinal permeability.	Contributes to dysbiosis, systemic inflammation, impaired gut–brain signaling, and poorer mood and cognitive function.	[54]
High saturated fat intake	↓ *Roseburia*, ↓ *Faecalibacterium*, ↑ bile-tolerant bacteria (*Bilophila*, *Alistipes*)	Alters bile acid metabolism, increases LPS production, and activates inflammatory pathways.	Promotes intestinal inflammation, metabolic dysfunction, neuroinflammation, and impaired cognitive and emotional health.	[34,55]
Low-fiber diets	↓ *Bifidobacterium*, ↓ *Lactobacillus*, ↓ butyrate-producing bacteria, ↓ microbial diversity	Reduces fermentable substrates, SCFA production, and intestinal barrier integrity.	Increases gut permeability and inflammation, impairing gut–brain communication and increasing disease risk.	[34,56]

SCFA: Short-chain fatty acids, GBA: Gut–brain axis, LPS: Lipopolysaccharides

Table 3: Major components of the gut-brain axis and their functions

Component	*Description*	*Major functions*	*Role in gut–brain communication*	*References*
CNS	The CNS comprises the brain and spinal cord and serves as the primary control center of the gut–brain axis.	• Integrates gut-derived sensory signals • Regulates appetite, stress responses, emotions, and cognition • Controls autonomic nervous system activity	Receives information from the gut through neural, hormonal, and immune pathways and sends regulatory signals that influence gastrointestinal motility, secretion, permeability, and immune function	[59,61]
ENS	The ENS is an extensive network of approximately 500 million neurons located within the gastrointestinal tract and is often referred to as the "second brain."	• Regulates intestinal motility and secretion • Controls gastrointestinal blood flow • Coordinates local reflexes and immune responses	Acts as the local communication network of the gut by transmitting sensory information to the CNS while responding to signals from the brain and gut microbiota.	[62]
Gut microbiota	The gut microbiota consists of trillions of microorganisms, including bacteria, viruses, fungi, and archaea, that inhabit the gastrointestinal tract.	• Digests dietary components • Synthesizes vitamins and bioactive compounds • Produces short-chain fatty acids (SCFAs) • Maintains intestinal barrier integrity and immune homeostasis	Produces microbial metabolites and neuroactive molecules that communicate with the brain through neural, immune, endocrine, and metabolic pathways, thereby influencing mood, cognition, and behavior.	[59,63]
Vagus nerve	The vagus nerve is the principal neural connection between the gut and the brain.	• Transmits sensory signals from the gut to the brain • Regulates gastrointestinal motility and secretion • Maintains autonomic homeostasis	Serves as the major neural communication pathway by rapidly transmitting information regarding microbial activity, nutrient availability, inflammation, and gut physiology between the gut and brain.	[64,65]
Immune system	The intestinal immune system continuously interacts with gut microbes to maintain immune tolerance toward beneficial microorganisms while protecting the host against pathogens.	• Maintains immune homeostasis • Produces cytokines and inflammatory mediators • Protects against pathogenic microorganisms	Immune mediators such as cytokines influence brain function through circulation and neural pathways. Dysregulated immune activation contributes to neuroinflammation and mental health disorders, including anxiety and depression'	[66]
Endocrine system	The endocrine component primarily involves the hypothalamic–pituitary–adrenal (HPA) axis and enteroendocrine cells of the gastrointestinal tract.	• Regulates stress responses through cortisol release • Secretes gastrointestinal hormones (e.g., GLP-1, PYY, CCK) • Influences appetite and metabolism	Facilitates hormonal communication between the gut and brain. Stress hormones alter gut physiology and microbial composition, whereas gut microbes influence hormone secretion and serotonin synthesis, thereby affecting mood and behavior.	[57]

CNS: Central nervous system, ENS: Enteric nervous system, SCFA: Short-chain fatty acids, HPA, hypothalamic–pituitary–adrenal, GLP-1: Glucagon-like peptide-1, PYY: Peptide YY, CCK: Cholecystokinin

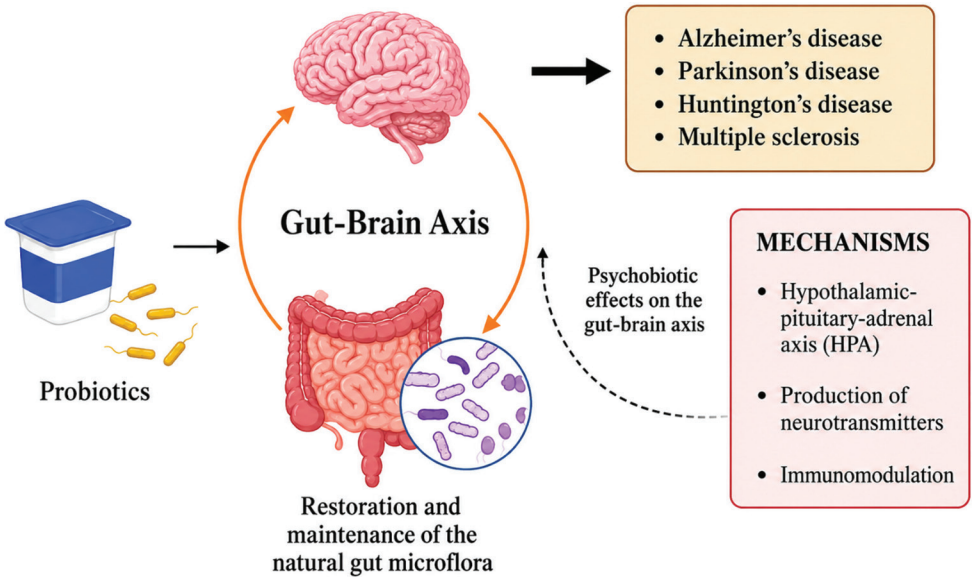


Figure 2: Psychobiotic modulation of the gut–brain axis and its mechanisms of action.

Psychobiotics and its Mechanism

Psychobiotics refer to probiotics, prebiotics, synbiotics, or other microbiota-targeted interventions that improve mental health by modulating the composition and activity of the gut microbiota and influencing bidirectional signaling along the GBA.[71] They exert their effects through neural, immune, endocrine, and metabolic pathways, thereby affecting mood, cognition, stress response, and overall brain function.[72] Psychobiotics influence brain function by modulating the composition and activity of the gut microbiota, producing neuroactive substances, regulating immune responses, and affecting communication between the gut and the brain.[73] These work in the following pathways:

- Neural pathway: They communicate with the brain through the vagus nerve and the enteric nervous system
- Neurotransmitter production: Certain strains produce or stimulate the production of neurotransmitters such as gamma-aminobutyric acid, serotonin, and dopamine, which regulate mood and cognition
- Immune modulation: They reduce systemic and neuroinflammation by regulating inflammatory cytokines
- Endocrine regulation: They influence the HPA axis, helping to regulate cortisol levels and the body's response to stress
- Metabolic effects: They produce SCFAs and other metabolites that support intestinal barrier integrity and brain function.

Implications for Nutrition Practice and Public Health

The growing body of evidence demonstrates strong relationship between the gut microbiota and brain function which has significant implications for nutrition practice, clinical care, and public health.[8] Although psychobiotics are not yet recognized as a standalone treatment for mental health disorders, they offer considerable potential as a complementary nutritional approach alongside established medical and psychological therapies. As research in this field continues to evolve, dietitians, nutrition professionals, healthcare providers, researchers, and policymakers all have an important role in translating scientific findings into evidence-based dietary strategies that promote both gut health and psychological well-being.[74]

Role of Dietitians and Nutrition Professionals

Dietitians and nutrition professionals are positioned to bridge the gap between nutrition science and mental healthcare by integrating evidence-based dietary interventions into routine practice.[75] While traditional nutrition counseling has focused on correcting nutritional deficiencies and promoting healthy eating patterns, advances in microbiome research have expanded this role to include dietary strategies that modulate the gut microbiota and potentially support psychological well-being.[76] Nutrition professionals assess dietary patterns that influence microbial diversity, identify factors associated with poor gut health, and develop individualized recommendations that increase the intake of dietary fiber, fermented foods, prebiotic-rich foods, and polyphenol-rich plant foods while limiting highly processed foods to promote a healthier gut microbiota.[77] In clinical practice, dietitians work collaboratively with psychiatrists, psychologists, gastroenterologists, and primary care physicians to provide multidisciplinary care for individuals with depression, anxiety, stress-related disorders, and gastrointestinal conditions with psychological manifestations.[78,79] Through patient education on appropriate food choices, probiotic supplementation, and lifestyle modifications can also improve adherence to psychobiotic interventions.

Future Perspectives

Future nutrition research is moving toward precision-based approaches that integrate microbiome science, multi-omics, digital technologies, and artificial intelligence (AI). Precision nutrition aims to tailor dietary interventions according to an individual's genetic profile, metabolic status, microbiome composition, lifestyle, and environmental factors, thereby improving treatment

effectiveness and reducing unnecessary supplementation. Similarly, personalized psychobiotics may involve selecting specific probiotics, prebiotics, synbiotics, or postbiotics based on an individual's microbial profile, disease subtype, medication history, age, dietary habits, and immune status.

Multi-omics and AI will further advance understanding of the GBA by identifying microbial metabolites, biomarkers, and biological pathways involved in neurotransmission, immunity, metabolism, and stress regulation. AI and machine learning can analyze complex datasets to identify microbial signatures associated with mental and neurodegenerative disorders, predict treatment responses, and support the development of personalized dietary and microbiome-based interventions.

Conclusion

The expanding evidence on the GBA has established a complex bidirectional relationship between the gastrointestinal tract, gut microbiota, and CNS, mediated through neural, endocrine, immune, and metabolic pathways. Gut microorganisms influence mood, stress responses, cognition, and psychological well-being, highlighting the importance of a diverse and balanced microbiota for overall health. Diet represents a key modifiable determinant of microbial composition and function. Dietary patterns rich in fiber, whole grains, legumes, fruits, vegetables, fermented foods, and polyphenols support microbial diversity and beneficial metabolite production, whereas diets high in ultra-processed foods, refined sugars, and saturated fats may promote dysbiosis and adverse mental health outcomes.

Psychobiotics – including probiotics, prebiotics, synbiotics, postbiotics, and microbiome-supportive dietary strategies – show promise as complementary approaches in mental healthcare. Their potential benefits involve modulation of vagal signaling, HPA-axis activity, immune responses, inflammation, neurotransmitter pathways, and SCFA production. Evidence from clinical trials and systematic reviews suggests beneficial effects on symptoms of depression, anxiety, stress, and cognitive function, although clinical translation remains limited by heterogeneity in study designs, interventions, and individual microbiomes. Larger, well-designed multicenter trials with standardized protocols and longer follow-up are needed to establish definitive clinical recommendations. Advances in precision nutrition, multi-omics, microbiome sequencing, and AI may ultimately enable personalized psychobiotic interventions, strengthening the integration of microbiome-focused nutrition into evidence-based mental healthcare.

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