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Fermented foods and mental health: The gut–brain axis in therapeutic nutrition

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Abstract
Mental health disorders, including depression, anxiety, bipolar disorder, and stress-related illnesses, represent a growing global health burden. Emerging evidence suggests that dietary interventions, particularly fermented foods, may influence mental health through modulation of the gut–brain axis. Fermented foods contain diverse microorganisms, bioactive metabolites, vitamins, peptides, and neurotransmitter precursors capable of influencing intestinal microbiota, immune regulation, neurotransmitter synthesis, and neural signaling. This review examines current evidence regarding the role of fermented foods in promoting mental well-being, emphasizing the biological mechanisms underlying gut–brain communication. Major pathways discussed include microbial modulation, vagal nerve signaling, immune regulation, endocrine interactions, neurotransmitter production, and microbial metabolite synthesis. Clinical and experimental evidence indicates that fermented foods such as yogurt, kefir, kimchi, sauerkraut, kombucha, tempeh, miso, and fermented dairy products may alleviate symptoms of depression, anxiety, and psychological stress. However, considerable heterogeneity exists among clinical studies regarding fermented food composition, dosage, microbial strains, and study duration. While fermented foods demonstrate considerable promise as complementary therapeutic agents in nutritional psychiatry, additional large-scale randomized controlled trials are required to establish standardized dietary recommendations.

Keywords: Fermented foods, gut–brain axis, microbiome, probiotics, depression, anxiety, nutritional psychiatry, therapeutic nutrition

Introduction

Mental health disorders account for one of the leading causes of disability worldwide, affecting hundreds of millions of individuals annually. Conventional treatments including pharmacotherapy and psychotherapy remain effective for many patients; however, incomplete response rates, adverse drug effects, and relapse continue to challenge clinicians. Consequently, nutritional psychiatry has emerged as an important interdisciplinary field investigating dietary interventions capable of supporting mental health (Silva *et al*., 2020) [16].

Recent discoveries have identified the gut microbiota as a major regulator of brain function. The gastrointestinal tract contains trillions of microorganisms that interact continuously with the central nervous system through neural, immune, endocrine, and metabolic pathways. This bidirectional communication network is collectively termed the gut–brain axis **(**Mayer *et al*., 2015 [11]**)**.

Fermented foods have been consumed for thousands of years and constitute important components of traditional diets worldwide. Fermentation not only enhances food preservation and nutrient bioavailability but also generates beneficial microorganisms and biologically active compounds capable of influencing host physiology. Increasing evidence suggests that fermented foods may beneficially modify gut microbiota composition, reduce systemic inflammation, improve intestinal barrier integrity, and promote neurotransmitter production, thereby influencing cognitive function and emotional health (Miller and Raison, 2016) [12].

This review synthesizes current evidence regarding fermented foods and mental health, with particular emphasis on mechanistic pathways linking gut microbial modulation to psychiatric outcomes.

The Gut–Brain Axis

The gut–brain axis is a multidirectional communication system that establishes continuous interactions between the gastrointestinal tract and the central nervous system, enabling coordinated regulation of gastrointestinal, neurological, endocrine, and immune functions (Carabotti *et al*., 2015; Cryan *et al*., 2019) [4, 5]. This highly integrated network comprises the central nervous system (CNS), enteric nervous system (ENS), autonomic nervous system (ANS), vagus nerve, immune system, endocrine system, and the gut microbiota, all of which work together to maintain physiological homeostasis (Mayer *et al*., 2015; Cryan *et al*., 2019) [5, 11]. Communication within this axis occurs through multiple interconnected pathways, including neural signaling via the vagus nerve and autonomic nervous system, endocrine regulation through hormones and the hypothalamic–pituitary–adrenal (HPA) axis, immune signaling mediated by cytokines and other inflammatory mediators, and the production of microbial metabolites such as short-chain fatty acids, neurotransmitters, and tryptophan-derived compounds (Dinan & Cryan, 2017; Morais *et al*., 2021) [8, 13]. These chemical messengers continuously influence intestinal function, immune responses, metabolism, mood, cognition, stress adaptation, and behavior, while signals originating in the brain simultaneously regulate gut motility, secretion, permeability, and microbial composition (Cryan *et al*., 2019; Mayer *et al*., 2015) [5, 11]. A healthy gut–brain axis is therefore essential for maintaining both gastrointestinal and psychological well-being. Conversely, disturbances in any component of this communication network, including gut microbial dysbiosis, impaired intestinal barrier function, chronic inflammation, altered neuroendocrine responses, or disrupted neural signaling, can impair gut–brain communication and have been implicated in the pathogenesis of depression, anxiety disorders, autism spectrum disorders, Parkinson's disease, Alzheimer's disease, and other stress-related neurological and psychiatric conditions (Dinan & Cryan, 2017; Cryan *et al*., 2019; Morais *et al*., 2021) [5, 8, 13].

Fermented Foods

Fermented foods are produced through the controlled metabolic activity of beneficial microorganisms that convert carbohydrates into organic acids, alcohols, carbon dioxide, and other bioactive metabolites, thereby enhancing food preservation, safety, flavor, digestibility, and nutritional value (Roy and Tewari, 2024; Marco *et al*., 2021; Tamang *et al*., 2020) [10, 14, 17]. The fermentation process is primarily carried out by lactic acid bacteria, yeasts, and certain molds and spore-forming bacteria, which transform raw food substrates into products with improved functional and health-promoting properties. Common beneficial microorganisms involved in food fermentation include species of *Lactobacillus*, *Lactococcus*, *Bifidobacterium*, *Leuconostoc*, *Saccharomyces*, and *Bacillus*. These microorganisms produce a variety of bioactive compounds, including probiotics, short-chain fatty acids, organic acids, bioactive peptides, exopolysaccharides, vitamins, antioxidants, and neurotransmitter precursors that contribute to gut health and immune regulation (Marco *et al*., 2021) [10]. In addition to extending shelf life and improving sensory characteristics, fermented foods promote the growth of beneficial gut microbiota, suppress pathogenic microorganisms, strengthen intestinal barrier function, and modulate inflammatory and metabolic pathways. Through these mechanisms, regular consumption of fermented foods has been associated with improved gastrointestinal health, enhanced immune function, and potential benefits for mental health via modulation of the gut–brain axis (Dimidi *et al*., 2019; Tamang *et al*., 2020) [7, 17].

Table: 1 Common fermented food (Marco *et al*., 2021; Dinan & Cryan, 2017) [8, 10].

Food	Dominant Microorganisms	Potential Mental Health Benefits
Yogurt	*Lactobacillus, Bifidobacterium*	Mood improvement
Kefir	Lactic acid bacteria + yeast	Anxiety reduction
Kimchi	*Lactobacillus plantarum*	Anti-inflammatory
Sauerkraut	Lactobacillus *spp*.	Gut microbiome diversity
Miso	*Aspergillus oryzae*	Antioxidant effects
Tempeh	*Rhizopus oligosporus*	Vitamin B synthesis
Kombucha	Acetic acid bacteria	Antioxidant activity

Fermentation increases

- B vitamins
- Vitamin K
- Short-chain fatty acid precursors
- Bioactive peptides
- Polyphenol bioavailability
- Gamma-aminobutyric acid (GABA)

Mechanisms Linking Fermented Foods to Mental Health

1. Modulation of Gut Microbiota

Fermented foods enrich beneficial microbial populations while suppressing pathogenic bacteria. Increased microbial diversity is associated with improved emotional resilience and reduced depressive symptoms.

Beneficial bacteria produce metabolites that influence host metabolism, immune function, and neurotransmission.

2. Production of Short-Chain Fatty Acids

The production of short-chain fatty acids (SCFAs) is one of the most important mechanisms through which fermented foods and the gut microbiota influence the gut–brain axis and mental health. During fermentation, beneficial microorganisms metabolize dietary fibres and other non-digestible carbohydrates to produce the major SCFAs—butyrate, acetate, and propionate—which exert diverse physiological and neuroprotective effects (Dalile *et al*., 2019; Silva *et al*., 2020) [6, 16]. These metabolites serve as key signaling molecules that strengthen intestinal barrier function by enhancing the expression of tight-junction proteins, thereby reducing intestinal permeability and preventing the translocation of inflammatory endotoxins into systemic circulation. SCFAs also possess potent anti-inflammatory properties by suppressing the production of pro-inflammatory cytokines while promoting the differentiation of regulatory T cells and maintaining immune homeostasis (Dalile *et al*., 2019) [6]. Within the central nervous system, SCFAs regulate the maturation and activation of microglial cells, the resident immune cells of the brain, thereby limiting neuroinflammation and supporting neuronal survival. Furthermore, they influence neuroplasticity by promoting the expression of neurotrophic factors, including brain-derived neurotrophic factor (BDNF), which is essential for learning, memory, and synaptic remodeling (Silva *et al*., 2020) [16]. Among the SCFAs, butyrate has received particular attention because it functions as a histone deacetylase (HDAC) inhibitor, leading to epigenetic modifications that regulate the expression of genes involved in neuronal differentiation, synaptic plasticity, oxidative stress resistance, and neuroprotection. Through these combined actions, SCFAs contribute to maintaining gut integrity, regulating immune and inflammatory responses, and supporting healthy brain function, highlighting their central role in the therapeutic potential of fermented foods for improving mental health through the gut–brain axis.

3. Neurotransmitter Production

Many probiotic microorganisms synthesize neurotransmitters including:

Neurotransmitter	Producing Microorganisms
GABA	Lactobacillus spp.
Serotonin precursor	Enterococcus spp.
Dopamine	Bacillus spp.
Acetylcholine	Lactobacillus spp.

Approximately 90% of serotonin is synthesized within the gastrointestinal tract, emphasizing the importance of gut health in mood regulation.

4. Vagus Nerve Signaling

The vagus nerve serves as the principal neural pathway linking the gastrointestinal tract and the brain, providing rapid bidirectional communication within the gut–brain axis. As the tenth cranial nerve, it transmits sensory information from the gut to the central nervous system while simultaneously regulating gastrointestinal motility, secretion, immune function, and intestinal permeability (Breit *et al*., 2018; Cryan *et al*., 2019) [3, 5]. Beneficial microorganisms and their metabolites, including short-chain fatty acids, gamma-aminobutyric acid (GABA), and other neuroactive compounds, stimulate vagal afferent fibres either directly or indirectly through enteroendocrine cells, initiating neural signals that influence mood, cognition, stress responses, and emotional behavior. Activation of vagal signaling also modulates inflammatory pathways by suppressing the release of pro-inflammatory cytokines through the cholinergic anti-inflammatory reflex, thereby reducing systemic and neuroinflammation (Breit *et al*., 2018) [3]. Experimental animal studies have provided compelling evidence for the importance of this pathway, demonstrating that the anxiolytic and antidepressant-like effects of several probiotic strains, particularly *Lactobacillus rhamnosus*, are abolished following vagotomy, indicating that an intact vagus nerve is essential for microbiota-mediated behavioral and neurochemical changes (Bravo *et al*., 2011) [2]. These findings highlight the vagus nerve as a critical mediator of gut microbiota–brain communication and suggest that fermented foods rich in probiotic microorganisms may exert beneficial effects on mental health by enhancing vagal signaling, improving stress resilience, and promoting emotional and cognitive well-being.

5. Immune Regulation

Immune regulation represents a fundamental mechanism through which fermented foods influence the gut–brain axis and promote mental health. Chronic low-grade inflammation has been increasingly recognized as a major contributor to the pathophysiology of depression, anxiety, and other neuropsychiatric disorders by disrupting neurotransmitter metabolism, impairing neuroplasticity, and promoting neuroinflammation (Dinan & Cryan, 2017; Miller & Raison, 2016) [8, 12]. Gut microbial dysbiosis and increased intestinal permeability facilitate the translocation of bacterial endotoxins, particularly lipopolysaccharides (LPS), into systemic circulation, triggering the activation of immune cells and the release of pro-inflammatory cytokines. Fermented foods rich in probiotic microorganisms help restore immune homeostasis by enhancing gut microbial diversity, strengthening the intestinal barrier, and modulating both innate and adaptive immune responses. Clinical and experimental studies have shown that regular consumption of fermented foods and probiotic strains can reduce circulating inflammatory biomarkers, including interleukin-6 (IL-6), tumor necrosis factor-alpha (TNF-α), and C-reactive protein (CRP), while promoting the production of anti-inflammatory cytokines such as interleukin-10 (IL-10) (Marco *et al*., 2021; Westfall *et al*., 2017) [10, 18]. This reduction in systemic inflammation limits activation of microglial cells within the central nervous system, decreases oxidative stress, and protects neurons from inflammatory damage. Furthermore, improved immune regulation enhances the availability and metabolism of neurotransmitters such as serotonin and dopamine by reducing inflammation-induced activation of the kynurenine pathway, thereby supporting normal synaptic function, neuroplasticity, mood regulation, and cognitive performance. Collectively, these findings suggest that fermented foods may serve as an effective nutritional strategy for mitigating chronic inflammation and promoting psychological well-being through immune modulation and improved gut–brain axis communication.

6. Hypothalamic–Pituitary–Adrenal Axis Regulation

The hypothalamic–pituitary–adrenal (HPA) axis is the body's primary neuroendocrine system responsible for coordinating physiological responses to psychological and physical stress. Under conditions of chronic stress, persistent activation of the HPA axis leads to excessive secretion of cortisol, which disrupts gut microbial homeostasis, increases intestinal permeability, impairs immune regulation, and contributes to the development of anxiety, depression, and other stress-related disorders (Dinan & Cryan, 2017; Cryan *et al*., 2019) [5, 8]. Growing evidence suggests that fermented foods may help normalize HPA axis activity through their beneficial effects on the gut microbiota and the gut–brain axis. Probiotic microorganisms present in fermented foods improve microbial diversity, strengthen the intestinal barrier by enhancing tight-junction integrity, and reduce intestinal permeability, thereby limiting the translocation of bacterial endotoxins such as lipopolysaccharides (LPS) into systemic circulation. These changes suppress the production of pro-inflammatory cytokines, including interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α), which are known to stimulate HPA axis activation and cortisol release (Foster *et al*., 2017) [9]. In addition, fermentation-derived metabolites such as short-chain fatty acids (SCFAs) and gamma-aminobutyric acid (GABA) modulate vagus nerve signaling and neuroendocrine communication, further contributing to stress regulation and emotional stability. Clinical and experimental studies indicate that regular consumption of probiotic-rich fermented foods may reduce circulating cortisol concentrations, improve resilience to psychological stress, enhance adaptive stress responses, and alleviate symptoms of anxiety and depression. Through the combined modulation of gut microbial composition, intestinal barrier function, immune responses, and neuroendocrine signaling, fermented foods represent a promising nutritional approach for maintaining HPA axis homeostasis and supporting mental health.

7. Improved Intestinal Barrier Function

The intestinal epithelium serves as a critical physical and immunological barrier that prevents the translocation of pathogenic microorganisms, bacterial endotoxins, and other harmful substances from the gut lumen into systemic circulation while permitting the selective absorption of nutrients. The integrity of this barrier is maintained by specialized tight-junction proteins, including occludin, claudins, and zonula occludens (ZO) proteins, which regulate paracellular permeability and preserve intestinal homeostasis (Bischoff *et al*., 2014) [1]. Disruption of these tight junctions results in increased intestinal permeability, commonly referred to as a "leaky gut," allowing bacterial endotoxins such as lipopolysaccharides (LPS) to enter the bloodstream and trigger systemic inflammation. Elevated inflammatory responses can subsequently activate microglial cells, impair neurotransmitter metabolism, disrupt blood–brain barrier function, and contribute to the pathogenesis of depression, anxiety, and other psychiatric disorders through the gut–brain axis (Cryan *et al*., 2019; Kelly *et al*., 2015) [5, 11]. Fermented foods rich in probiotic microorganisms enhance intestinal barrier integrity by increasing the expression of tight-junction proteins, stimulating mucus secretion, promoting epithelial cell regeneration, and increasing the production of short-chain fatty acids (SCFAs), particularly butyrate, which serves as the primary energy source for colonocytes and reinforces epithelial function. These actions reduce intestinal permeability, prevent the translocation of bacterial endotoxins, and suppress excessive immune activation, thereby lowering circulating inflammatory cytokines and oxidative stress. By preserving intestinal barrier function and limiting systemic inflammation, fermented foods support healthy gut–brain communication, improve neuronal function, and may reduce the risk of inflammation-associated psychiatric and neurodegenerative disorders.

Clinical Evidence

Depression

Multiple randomized controlled trials suggest probiotic-rich fermented dairy products improve depressive symptoms.
Meta-analyses indicate modest but statistically significant improvements, particularly in patients with mild to moderate depression.

Anxiety

Kefir and fermented milk products have demonstrated reductions in anxiety scores among healthy adults and clinical populations.

Possible mechanisms include

- reduced inflammation
- increased GABA production
- vagal stimulation

Stress

University student populations consuming fermented dairy products exhibit lower perceived stress and improved sleep quality during examination periods.

Cognitive Function

Emerging evidence indicates fermented foods may improve:

- attention
- executive function
- working memory

These effects appear mediated through reduced neuroinflammation and enhanced neuroplasticity.

6. Experimental Evidence

Animal studies consistently demonstrate beneficial effects.
Observed findings include:

- reduced depressive behavior
- improved memory
- increased hippocampal BDNF
- reduced neuroinflammation
- increased microbial diversity

Although translation to humans remains ongoing, these mechanistic studies provide biological plausibility.

Nutritional Components Contributing to Mental Health

Fermented foods contain several bioactive compounds beyond live microorganisms.

Bioactive Components

Fermentation enhances the nutritional and functional properties of foods by generating a diverse range of bioactive compounds that contribute to gut health, immune function, and neurological well-being. These compounds include probiotics, prebiotics, postbiotics, gamma-aminobutyric acid (GABA), B vitamins, vitamin K_2 (menaquinone), bioactive peptides, polyphenols, exopolysaccharides, and organic acids, all of which play important roles in maintaining gut microbial balance and modulating the gut–brain axis (Marco *et al*., 2021; Tamang *et al*., 2020) [10, 17]. Probiotic microorganisms, such as *Lactobacillus* and *Bifidobacterium* species, promote intestinal microbial diversity, inhibit pathogenic bacteria, and strengthen the intestinal barrier. Prebiotics serve as fermentable substrates that selectively stimulate the growth and activity of beneficial gut microbes, while postbiotics—non-viable microbial cells, cell components, and microbial metabolites—exert immunomodulatory, anti-inflammatory, and antioxidant effects without requiring live microorganisms. Certain lactic acid bacteria synthesize GABA, an inhibitory neurotransmitter that supports stress reduction, emotional stability, and improved sleep quality. Fermentation also increases the bioavailability of B-complex vitamins and vitamin K_2, which are essential for energy metabolism, neurotransmitter synthesis, neuronal function, and cognitive health. In addition, microbial proteolysis during fermentation generates bioactive peptides with antioxidant, antihypertensive, antimicrobial, and neuroprotective properties, whereas exopolysaccharides enhance probiotic survival, reinforce intestinal barrier integrity, and regulate immune responses. The fermentation process further improves the release and bioavailability of polyphenols, enhancing their antioxidant and anti-inflammatory activities, while organic acids such as lactic acid and acetic acid inhibit pathogenic microorganisms and maintain a favorable intestinal environment. Collectively, these fermentation-derived bioactive components contribute to neuroprotection, antioxidant defense, immune regulation, intestinal barrier maintenance, and healthy gut–brain communication, supporting the therapeutic potential of fermented foods in the prevention and management of mental health disorders.

Conclusion

Fermented foods represent an emerging area of interest in nutritional psychiatry due to their capacity to modulate the gut–brain axis through multiple interconnected mechanisms. Current evidence indicates that fermentation-derived microorganisms and bioactive metabolites influence microbial diversity, neurotransmitter synthesis, immune regulation, intestinal barrier integrity, endocrine signaling, and neural communication. These mechanisms collectively contribute to improvements in mood, stress resilience, cognitive function, and overall psychological well-being.

Although substantial mechanistic and preclinical evidence supports the therapeutic potential of fermented foods, clinical findings remain heterogeneous because of differences in study design, microbial composition, dosage, and intervention duration. Consequently, fermented foods should presently be considered complementary rather than primary therapeutic interventions for mental disorders. Continued interdisciplinary research integrating microbiology, neuroscience, nutrition, psychiatry, and systems biology will be essential for translating microbiome science into evidence-based dietary recommendations for mental health.

References

1. Bischoff SC, Barbara G, Buurman W, Ockhuizen T, Schulzke JD, Serino M, *et al*. Intestinal permeability—A new target for disease prevention and therapy. BMC Gastroenterology,2014:14:189. https://doi.org/10.1186/s12876-014-0189-7
2. Bravo JA, Forsythe P, Chew MV, Escaravage E, Savignac HM, Dinan TG, *et al*. Ingestion of Lactobacillus strain regulates emotional behavior and central GABA receptor expression in a mouse via the vagus nerve. Proceedings of the National Academy of Sciences,2011:108(38):16050–16055. https://doi.org/10.1073/pnas.1102999108
3. Breit S, Kupferberg A, Rogler G, Hasler G. Vagus nerve as modulator of the brain–gut axis in psychiatric and inflammatory disorders. Frontiers in Psychiatry,2018:9:44. https://doi.org/10.3389/fpsyt.2018.00044
4. Carabotti M, Scirocco A, Maselli MA, Severi C. The gut–brain axis: Interactions between enteric microbiota, central and enteric nervous systems. Annals of Gastroenterology,2015:28(2):203–209.
5. Cryan JF, O'Riordan KJ, Cowan CSM, Sandhu KV, Bastiaanssen TFS, Boehme M, *et al*. The microbiota–gut–brain axis. Physiological Reviews,2019:99(4):1877–2013. https://doi.org/10.1152/physrev.00018.2018
6. Dalile B, Van Oudenhove L, Vervliet B, Verbeke K. The role of short-chain fatty acids in microbiota–gut–brain communication. Nature Reviews Gastroenterology & Hepatology,2019:16(8):461–478. https://doi.org/10.1038/s41575-019-0157-3
7. Dimidi E, Cox SR, Rossi M, Whelan K. Fermented foods: Definitions and characteristics, impact on the gut microbiota and effects on gastrointestinal health and disease. Nutrients,2019:11(8):1806. https://doi.org/10.3390/nu11081806
8. Dinan TG, Cryan JF. The microbiome–gut–brain axis in health and disease. Gastroenterology Clinics of North America,2017:46(1):77–89. https://doi.org/10.1016/j.gtc.2016.09.007
9. Foster JA, Rinaman L, Cryan JF. Stress and the gut–brain axis: Regulation by the microbiome. Neurobiology of Stress,2017:7:124–136. https://doi.org/10.1016/j.ynstr.2017.03.001
10. Marco ML, Sanders ME, Gänzle M, Arrieta MC, Cotter PD, De Vuyst L, *et al*. The International Scientific Association for Probiotics and Prebiotics (ISAPP) consensus statement on fermented foods. Nature Reviews Gastroenterology & Hepatology,2021:18(3):196–208. https://doi.org/10.1038/s41575-020-00390-5
11. Mayer EA, Knight R, Mazmanian SK, Cryan JF, Tillisch K. Gut microbes and the brain: Paradigm shift in neuroscience. Journal of Neuroscience,2015:35(41):13884–13893. https://doi.org/10.1523/JNEUROSCI.3299-15.2015
12. Miller AH, Raison CL. The role of inflammation in depression: From evolutionary imperative to modern treatment target. Nature Reviews Immunology,2016:16(1):22–34. https://doi.org/10.1038/nri.2015.5
13. Morais LH, Schreiber HL, Mazmanian SK. The gut microbiota–brain axis in behaviour and brain disorders. Nature Reviews Microbiology,2021:19(4):241–255. https://doi.org/10.1038/s41579-020-00460-0
14. Roy P, Tewari S. Indian Traditional Fermented Foods and their Nutrition and Nutraceutical Potential: An Overview. Applied Clinical Nutrition and Food Science: A Holistic Guide towards Robust Health, 2024, 11.
15. Salminen S, Collado MC, Endo A, Hill C, Lebeer S, Quigley EMM, *et al*. The International Scientific Association for Probiotics and Prebiotics (ISAPP) consensus statement on the definition and scope of postbiotics. Nature Reviews Gastroenterology & Hepatology,2021:18(9):649–667. https://doi.org/10.1038/s41575-021-00440-6
16. Silva YP, Bernardi A, Frozza RL. The role of short-chain fatty acids from gut microbiota in gut–brain communication. Frontiers in Endocrinology,2020:11:25. https://doi.org/10.3389/fendo.2020.00025
17. Tamang JP, Cotter PD, Endo A, Han NS, Kort R, Liu SQ, *et al*. Fermented foods in a global age: East meets West. Comprehensive Reviews in Food Science and Food Safety,2020:19(1):184–217. https://doi.org/10.1111/1541-4337.12520
18. Westfall S, Lomis N, Kahouli I, Dia SY, Singh SP, Prakash S. Microbiome, probiotics and neurodegenerative diseases: Deciphering the gut–brain axis. Cellular and Molecular Life Sciences,2017:74(20):3769–3787. https://doi.org/10.1007/s00018-017-2550-9