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# Feeding the Mind: The Role of Fermented Foods and Probiotics in Anxiety Treatment

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## Abstract

**Introduction:** Anxiety disorders represent the most common mental health disorders globally which makes their treatment a major clinical problem. Recent research has increasingly focused on the gut-brain axis, because scientists have discovered that gut microbiota functions as a key controller of mental health. Scientists investigate fermented foods as dietary interventions because they contain probiotics and bioactive molecules to potentially adjust the gut-brain axis for anxiety symptom reduction.

**Methods:** This review combines results from PubMed and Google Scholar databases through searches of "probiotics," "gut microbiota," "anxiety disorders," "fermented food" and "gut-brain axis" to evaluate existing evidence.

**Findings:** Research shows that the gut microbiota influences anxiety through multiple pathways, including direct modulation of microbial composition, production of neuroactive compounds like gamma-aminobutyric acid (GABA), and regulation of systemic inflammation. Research conducted in both laboratory and human subjects demonstrates that consuming fermented foods together with particular probiotic strains can positively impact these mechanisms. However, clinical evidence shows inconsistent results because some studies demonstrate substantial anxiety symptom reduction in clinical populations yet other investigations reveal minimal or no effects while bacterial strain and dosage and host factors play a significant role.

**Conclusion:** The gut microbiota is a promising therapeutic target for anxiety disorders. Specific probiotics and fermented foods added to the diet could become important supplementary treatments. Nevertheless, large-scale, well-controlled clinical trials are necessary to establish

optimal strains, dosages, and treatment protocols to translate these findings into reliable clinical strategies.

**KEYWORDS:** probiotics, anxiety disorders, mental health, gut microbiota, gut-brain axis, fermented food

## Anxiety disorder

Generalized anxiety disorder (GAD) is a significant mental health condition that tends to become chronic without treatment while causing major disability. GAD affects up to 6% of people over their lifetime. Despite its impact, GAD remains overlooked and underdiagnosed. Its presentation is further complicated by additional challenges because it commonly exists with psychiatric disorders such as major depressive disorder and panic disorder and substance or alcohol abuse which make treatment more difficult (Maron and Nutt 2017). Patients with GAD often experience excessive anxiety about everyday situations. This anxiety is persistent, intrusive, and can significantly impact their well-being and ability to function, affecting various aspects of life such as work and health. Patients experience irritability and difficulty concentrating or a “blank mind”. Additionally, GAD is frequently accompanied by physical symptoms including sleep disturbances, getting tired easily, muscle tension, digestive issues, and chronic headaches (DeMartini et al., 2019). For individuals with mild to moderate anxiety symptoms, strong evidence from randomized trials supports psychotherapeutic techniques including cognitive behavioral therapy (CBT) as a first-line treatment. CBT focuses on how thoughts affect feelings and behaviors. The therapy consists of two fundamental elements which include thought pattern modification (cognitive) and changing behaviors (behavioral). A key cognitive technique, cognitive restructuring, helps identify and confront their negative thoughts by replacing them with constructive thinking. The behavioral component includes social skills training along with relaxation techniques and exposure therapy. Exposure techniques are particularly effective in reducing avoidance behaviors, because these behaviors create a cycle of anxiety. One widely used method is systematic desensitization, which exposes patients to anxiety-inducing stimuli in a gradual and controlled manner to decrease fear responses throughout time (Kaczkurkin et al., 2015). Medication is available for all type of anxiety disorders and can significantly improve quality of life while reducing disability. Antidepressants such as selective serotonin reuptake inhibitors (SSRIs) and the serotonin-norepinephrine reuptake inhibitors (SNRIs) are recommended as first-line pharmacological treatment for most anxiety disorders due to their proven effectiveness in randomized controlled trials, overall safety, and low risk of misuse. Since anxiety disorders often coexist with

depression, antidepressants provide the advantage of treating both conditions simultaneously (Craske and Stein, 2016). The primary treatment goal for GAD is achieving remission, meaning the complete elimination of anxiety symptoms and bringing the individual back to their pre-illness state of functioning and life quality (Reinhold and Rickels, 2015). However, given that a lot of patients experience only partial response or struggle with side effects, there is a clear need for novel adjunctive therapies.

## The Gut-Brain Axis and the Role of Fermented Foods

The gut-brain axis (GBA) is the two-way communication network between the central and the enteric nervous system located in the digestive tract. This system involves multiple systems, including neural, hormonal, and immunological signaling pathways, which the gut microbiota regulates through its regulatory function. The main function of the gut-brain axis is to integrate responses between the gut and brain. It also regulates physiological processes like digestion and immune response and maintains homeostasis. Furthermore GBA has an impact on mood, cognition, and mental health (Carabotti et al., 2015, Cryan and Dinan, 2012). The gut microbiota is a diverse microbial community of bacteria, archaea, fungi, and viruses that reside in the human intestines. It is primarily composed of five bacterial phyla: Firmicutes, Bacteroidetes, Actinobacteria, Proteobacteria, and Verrucomicrobia. These microorganisms are essential for digestion, preserving epithelial integrity, synthesizing essential vitamins, and interacting with the immune system (Fehily et al., 2021, Heintz-Buschart and Wilmes, 2018). The composition of the gut microbiome is unique to each individual and shaped by factors like dietary habits, geographic location, medications, birth mode, diet, age, and stress (Cresci and Bawden, 2015). A compositional and functional imbalance of microbiota, known as dysbiosis, is associated with various health issues, including mood disorders (DAS and Nair, 2019). For instance, individuals with GAD have shown significantly reduced abundance of five specific genera: Faecalibacterium, Eubacterium rectale, Lachnospira, Butyricicoccus, and Sutterella, which produce short-chain fatty acids (SCFAs) which are essential to maintain gut barrier integrity and support the immune function. A decrease in SCFAs amounts may contribute to dysregulated immune responses and disturbances in brain function. This highlights the potential importance of these microbial genera in maintaining mental health (Peirce and Alviña, 2019).

The microbiota's extensive impact has led researchers to focus on diet as a method to modify its composition. The main dietary approach for microbiota modification involves eating fermented foods that result from intentional microbial fermentation processes (Chilton et al., 2015). The fermentation process conducted by lactic acid bacteria (LAB) and yeasts converts raw materials into products that gain longer shelf life and improved safety features and nutritional content (Marco et al.,2017). These foods contribute to health through a combination of three key components. Probiotics are live microbes which, when consumed in adequate amounts, have a beneficial effect on the host's health (Sanders, 2003). Prebiotics function as nondigestible food ingredients that encourage the growth and activity of beneficial intestinal bacteria (Stanton et al., 2005). The fermentation process of microorganisms also generates bioactive compounds known as biogenics (or postbiotics) which include vitamins and peptides and the neurotransmitter gamma-aminobutyric acid (GABA) that demonstrates neuroactive properties (Stanton et al., 2005; Sahab et al.,2020). The list of fermented foods includes yogurt, kefir, sauerkraut, kimchi and kombucha. The consumption of these foods presents a promising method to affect the gut-brain axis through multiple mechanisms (Marco et al., 2017; Mitsuoka, 2014).

## Mechanisms: How the Gut Microbiota Influences Anxiety

To determine whether fermented foods may impact mental health, it is important to analyze the mechanisms by which this is possible. Research points to three primary pathways: restoring microbial balance, modulating neuroactive compounds, and reducing inflammation.

### 1. Restoring Microbial Balance to Counter Dysbiosis

Research shows that anxiety disorders may develop from gut microbiota dysbiosis which is a state of an imbalance of microbial populations. However, this presents a causality dilemma, as anxiety itself can alter GI function and thus the microbiota (Halverson and Alagiakrishnan 2020). Research conducted with animals demonstrates that subclinical infections can lead to behaviors that resemble anxiety (Lyte et al., 1998) and transiently altering the gut microbiota with antimicrobials result in increased exploratory behavior without causing inflammation (Bercik et al., 2011). Research conducted on a large population revealed that individuals who had intestinal infections before showed 1.34 times higher odds of developing anxiety disorders (Bruch 2016). Furthermore, GAD patients demonstrate reduced microbial diversity through decreased SCFA-producing bacteria and increased Escherichia-Shigella populations which are considered pathogenic (Jiang et al., 2018). The established relationship between gut microbiota and anxiety disorders makes microbial balance restoration an important therapeutic goal and fermented foods together with probiotics demonstrate potential benefits in this therapeutic field. Research on animals demonstrates that fermented barley and soybean consumption leads to increased Lactobacilli populations and reduced inflammation levels (Woo et al., 2016). The consumption of fermented milk containing Bifidobacterium animalis by IBS patients resulted in elevated SCFA production and decreased Bilophila wadsworthia pathobiont levels (Veiga et al., 2014). Research also indicates that high consumption of fermented foods leads to increased microbial diversity and decreased inflammatory markers in the body (Wastyk et al., 2021). Even popular fermented beverages like kombucha have shown modest but promising ability to enrich SCFA-producing taxa (Ecklu-Mensah et al., 2024). Also, the American Gut Project conducted a large-scale analysis which demonstrated that people who regularly eat fermented foods develop a consistently different gut microbiota composition and have higher levels of health-related metabolites compared to non-consumers (Taylor et al., 2020).

### 2. Modulation of Neuroactive Compounds

The GaBAergic system is a crucial element of a nervous system involved in anxiety and it has been shown in both animal and human studies. This is why most traditional anti-anxiety drugs like benzodiazepines target this system (Murrough et al., 2015, Altamura et al. 2013). For example, anxious behaviour in rats is associated with reduced GABAergic action (Kalueff and Nutt 2007). There is growing evidence that dieterry GABA can positively influence brain function through the gut-brain axis. In mice, dietary GABA activated vagal nerves to influence feeding behaviour (Nakamura et al., 2022) and human studies suggest that oral GABA intake may reduce stress and induce relaxation, as supplementing with GABA caused increased alpha brain waves, indicative of relaxation, and decreased beta brain waves, that are associated with active thinking and problem solving (Hepsomali et al., 2020, Yoto et al., 2012).

The gut microbiota, particularly strains found in fermented foods, can directly influence the levels of neuroactive compounds in the human body. Specific microbial taxa are known to synthesize different types of molecules like GABA, serotonin and dopamine. Species commonly found in fermented foods, Lactobacillus and Bifidobacterium, are producers of

GABA (Galland 2014). There is a growing interest among researchers in various techniques that enrich food witch GABA through microbial fermentation using stains like Lactiplantibacillus plantarum (Iorizzo 2023, Tamés et al., 2023, Park and Oh 2007, Li et al., 2010). Although evidence that dietary GABA can directly influence anxiety in humans remains limited, the ability of microbes in fermented foods to produce these compounds within the gut present a promising mechanism of influencing brain function that hopefully will be widely studied in the future.

**3. Alleviating Inflammation**

Inflammation plays a key role in pathogenesis of anxiety disorders. Elevated inflammatory signals, such as cytokines and C-reactive protein, have been observed in GAD, PTSD and panic disorder (Yang et al., 2016). This may be caused by a disrupted stress response system, where increased sympathetic activity amplifies the release of pro-inflammatory cytokines (Michopoulos et al., 2017). For example, this mechanism is observed in metabolic syndrome, where chronic inflammation significantly increases the risk of developing anxiety (Cen et al., 2024). Animal models also support this hypothesis, by showing that chronic gut inflammation can lead to anxiety-like behaviours, probably by altering levels of brain-derived neurotrophic factor (BDNF) in the hippocampus or by causing neuroinflammation in the amygdala (Bercik et al., 2010, Zheng et al., 2021). Consumption of fermented foods may offer a new interesting approach to mitigate this inflammation. A recent review highlighted that fermented food can lower inflammatory conditions, for example rheumatoid arthritis and osteoarthritis, by modulating immune pathways and improving microbial balance in the gut (Paul et al., 2023). Consumption of fermented dairy products have been associated with reduced systemic inflammation markers like C-reactive protein (CRP) (Zhang et al., 2023). In vitro, probiotic strains from Limosilactobacillus fermentum from pickles, have been shown to significantly reduce pro-inflammatory cytokines like TNF-**α** and IL-6 (Hao et al., 2024). Similarly, extracts from lacto-fermented cucumbers and sourdough-fermented wheat have demonstrated promising anti-inflammatory effects by lowering the levels of inflammatory mediators (Kao and Lin 2023, Gabriele et al., 2023). These findings suggest that fermented foods can serve as a valuable dietary strategy for managing chronic inflammation associated with anxiety.

**Clinical Evidence: A Review of Human Studies**

While there are many mechanisms that can explain the possible positive impact of fermented foods on anxiety, clinical evidence in humans is complex and still emerging. The following studies highlight both the promise and the challenges in this field.

The study of Tianyue Fan et al. used Mendelian randomization analysis to determine the relationship between the composition of a gut microbiota, anxiety and depressive disorders. It found out that Clostridium innocuum was positively correlated with anxiety disorders. This finding suggests that specific microbes may be targets for diagnosis and potentially therapy (Fan et al., 2024).

Meta- analyses of studies which link consumption of probiotic supplements with symptoms of mental illness have found small but promising effects in reducing symptoms of depression and anxiety. The strongest effects were observed in clinical psychiatric populations, which suggest that direct supplementing with beneficial bacteria can be an useful adjunctive treatment (Liu et al., 2019, Navarro-Tapia et al., 2021).

Other studies on fermented food consumption have yielded more nuanced results. One study of 710 young adults found that higher consumption of fermented foods was associated with fewer social anxiety symptoms, particularly for individuals with a high genetic risk of neuroticism. This points to a potential low-risk intervention for those predisposed to anxiety (Hilimire et al., 2015).

Intervention trials have shown mixed but promising outcomes. In an eight-week trial, GAD patients receiving a probiotic supplement (containing *Bifidobacterium* and *Lactobacillus* strains) alongside the antidepressant sertraline showed a greater decrease in anxiety symptoms compared to those taking sertraline and a placebo. However, while the Hamilton Rating Scale for Anxiety showed significant improvement, scores on the Beck Anxiety Inventory did not differ remarkably between groups (Eskandarzadeh et al., 2021). Another study found that anxious students who took a probiotic (*L. plantarum* JYLP-326) for three weeks reported reduced anxiety, depression, and insomnia, with corresponding shifts in their gut microbiota and fecal metabolites (Zhu et al., 2023).

However, not all studies show clear benefits. A 2023 study on a psychobiotic diet (rich in prebiotic and fermented foods) found a reduction in perceived stress, but the difference between the intervention and control groups was not statistically significant. Interestingly, higher adherence to the diet correlated with greater stress reduction, and changes in gut microbiota composition (termed microbial volatility) were linked to this effect (Berding et al., 2023). A particularly complex finding came from a study of medical students, where higher intake of fermented foods was unexpectedly associated with more anxiety symptoms in healthy individuals, but with fewer depressive and anxiety symptoms in students with pre-existing psychiatric conditions (Karbownik et al., 2022). This suggests the effects may be highly dependent on an individual's baseline mental and physiological state.

**Discussion**

Multiple studies demonstrate through evidence that fermented foods and probiotics have biological validity as treatments for anxiety through gut-brain axis interactions. The evidence from microbial modulation research, neuroactive compound production and anti-inflammatory effects has created a strong basis. However, The diverse results from human trials demand a better understanding of the underlying causes.

First, strain and dose specificity are critical. Different probiotic strains show unique effects because the term "probiotic" refers to multiple bacterial strains instead of being a single individual. A particular bacterial strain specializes in GABA synthesis but another strain demonstrates better ability to produce anti-inflammatory short-chain fatty acids. Similarly, different studies have used different dosages for therapeutic effects which have not resulted in standardization. This lack of unification makes it difficult to make a direct comparison between trials.

Second, it is hard to compare the intervention type between probiotic supplements and whole fermented foods. A supplement contains a concentrated dose of specific, pre-selected microbes. In contrast, a fermented food contains a diverse community of microorganisms that exist within the complex structures of food. This formula also contains prebiotics that nourish the microbes and biogenics (postbiotics) that are the direct products of fermentation. The synergistic effects of these combined components may produce outcomes that differ significantly from those of an isolated probiotic strain.

Third, the baseline state of the host appears to be a crucial determinant of the efficacy of probiotics. In a healthy individual with a balanced gut microbiota, the introduction of new microbes may have minimal effect or could even be disruptive. Conversely, in an individual with a pre-existing dysbiosis or a clinical anxiety disorder, the same intervention may have a corrective, therapeutic effect. The conflicting results from study (Karbownik et al., 2022). suggest that the impact may vary depending on the baseline state of gut microbiota of a patient. This highlights the need for personalized therapeutic strategy rather than a universal recommendation.

Finally, current research is limited by several factors, including small sample sizes, short intervention durations, and a lack of standardization in dietary protocols and the fermented products used. Future studies must address these limitations. There is a need for large-scale, randomized controlled trials that can follow participants for multiple years to assess changes. These trials should analyze gut microbiome and metabolome changes together with host inflammatory markers while also using validated clinical anxiety scales.

## Conclusion

The gut microbiota represents a valid and promising therapeutic approach for developing new treatments to manage anxiety disorders. The evidence shows that dietary approaches to modify the gut microbiota through fermented foods and particular probiotic supplements can benefit neurobiological mechanisms of anxiety. The current clinical evidence does not support the establishment of definitive treatment guidelines despite promising preliminary findings. The effectiveness of microbiota-based interventions depends on particular microbial strains together with dosage levels and intervention formats and the host's current physiological state. These interventions should be used as additional therapeutic tools together with CBT and pharmacotherapy instead of being considered standalone treatments. Future research needs to conduct well-designed clinical trials to determine optimal treatment protocols for specific patient groups in order to achieve the complete therapeutic benefits of the gut-brain axis.

## Disclosure

## Supplementary Materials

Not applicable.

## Author's contribution

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