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THE GUT-BRAIN AXIS: EXPLORING THE ROLE OF MICROBIOTA IN DEPRESSION AND ANXIETY DISORDER

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Abstract: INTRODUCTION: The intestinal microbiota, comprising trillions of microorganisms primarily bacteria, significantly influences human health and physiology by modulating various biological processes such as nutrient metabolism, immune system regulation, and protection against pathogenic invasion. Dysbiosis, an imbalance in microbiota composition, is associated with a wide range of gastrointestinal disorders, autoimmune diseases, metabolic disorders, and neurological conditions. The microbiota-gut-brain axis represents a bidirectional communication system linking the gut microbiota with the central nervous system, influencing behavior, mood, cognition, and higher-order brain functions. Disruptions in the gut microbiota composition, known as dysbiosis, have been implicated in various neurological and psychiatric disorders, while interventions targeting the gut microbiota have shown promise in ameliorating symptoms of these conditions. **OBJETIVE:** Analyze and describe the main aspects of role of microbiota in depression and anxiety disorder in the last years. **METHODS:** This is a narrative review, in which the main aspects of role of microbiota in depression and anxiety disorder in recent years were analyzed included studies in the MEDLINE – PubMed (National Library of Medicine, National Institutes of Health), COCHRANE, EMBASE and Google Scholar databases. **RESULTS AND DISCUSSION:** The gut microbiota plays a crucial role in modulating neurotransmitter systems such as serotonin, dopamine, gamma-aminobutyric acid (GABA), and glutamate, which are implicated in mood regulation and cognitive function. For instance, gut microbes contribute to serotonin synthesis by metabolizing tryptophan, impacting both local and systemic serotonin levels, thereby affecting mood and mental health. Similarly, emerging evidence suggests that gut microbiota influence dopamine synthesis and metabolism, as well as GABAergic neurotransmission, through various mechanisms. Additionally, gut microbes can modulate glutamate levels, impacting cognition and synaptic plasticity. Dysbiosis of the gut microbiota has been associated with depression and anxiety disorders, characterized by alterations in microbial composition and diversity. Therapeutic interventions targeting the gut microbiota, such as probiotics, prebiotics, and fecal microbiota transplantation, hold promise for alleviating symptoms of mood disorders by restoring microbial balance and modulating neurotransmitter signaling. Understanding the bidirectional communication between the gut microbiota and neurotransmitter systems provides insights into the underlying mechanisms of depression and anxiety disorders and offers novel therapeutic avenues for their treatment and management. **CONCLUSION:** In summary, the gut microbiota exerts significant influence over neurotransmitter systems crucial for regulating mood, anxiety, and cognitive function, with dysbiosis linked to mood disorders like depression and anxiety. Understanding the bidirectional communication via the gut-brain axis unveils therapeutic potentials of interventions targeting the microbiota, including probiotics, prebiotics, and fecal microbiota transplantation, to improve mental well-being. Environmental factors, stress, and dietary habits also shape gut microbiota, further emphasizing the multifaceted nature of the gut-brain axis in mental health. Future research should delve deeper into this complex interplay to develop personalized interventions for individuals with mood and anxiety disorders.

Keywords: Microbiota; Depression; Anxiety; Dysbiosis.

INTRODUCTION

The intestinal microbiota, comprising trillions of microorganisms, primarily bacteria, inhabits the gastrointestinal tract, exerting substantial influence on human health and physiology[1]. This intricate ecosystem plays a pivotal role in various biological processes, including nutrient metabolism, immune system modulation, and protection against pathogenic invasion[2]. The composition and diversity of the intestinal microbiota are influenced by several factors, such as host genetics, diet, age, and environmental exposures[2]. Dysbiosis, an imbalance or perturbation in the microbiota composition, has been associated with a plethora of gastrointestinal disorders, autoimmune diseases, metabolic disorders, and even neurological conditions[1]. Understanding the dynamics of the intestinal microbiota and its intricate interactions with the host holds promise for the development of novel therapeutic strategies aimed at promoting health and preventing disease[1].

The normal intestinal microbiota encompasses a diverse array of microorganisms, primarily bacteria, which coexist in a symbiotic relationship within the human gastrointestinal tract[1]. Among the predominant bacterial phyla residing in the gut are Firmicutes, Bacteroidetes, Actinobacteria, Proteobacteria, and Verrucomicrobia[3]. Within these phyla, numerous genera and species contribute to the complexity of the intestinal microbial community[3]. Some of the prominent bacterial genera commonly found in the healthy gut include Bacteroides, Prevotella, Faecalibacterium, Ruminococcus, Bifidobacterium, and Lactobacillus[2]. These microorganisms play crucial roles in maintaining gut homeostasis, including fermentation of dietary fibers, synthesis of vitamins, and modulation of immune responses[3]. Additionally, certain commensal bacteria such as Akkermansia muciniphila have garnered significant attention for their potential health-promoting effects, particularly in metabolic regulation and gut barrier integrity[1].

Dysbiosis is a term utilized to describe an imbalance or perturbation in the composition, diversity, or function of the microbial communities residing in a particular ecological niche, such as the gastrointestinal tract[4]. It represents a disruption in the symbiotic relationship between the host and its indigenous microbiota, often characterized by alterations in the relative abundance of beneficial and pathogenic microorganisms[4,5]. Dysbiosis can manifest as qualitative or quantitative changes in the gut microbiota, leading to a state of microbial dysregulation that may contribute to the pathogenesis of various diseases[5]. These disturbances in microbial equilibrium can arise from a multitude of factors, including antibiotic usage, dietary changes, chronic stress, infections, and inflammatory conditions[4,5]. Dysbiosis has been implicated in the etiology and progression of numerous gastrointestinal disorders, such as inflammatory bowel disease (IBD), irritable bowel syndrome (IBS), and colorectal cancer, as well as extra-intestinal conditions like obesity, metabolic syndrome, and neurological disorders[4].

Depression and anxiety are two distinct but often comorbid mental health disorders that significantly impair an individual's emotional well-being and daily functioning[6]. Depression, clinically referred to as major depressive disorder (MDD), is characterized by persistent feelings of sadness, hopelessness, and a loss of interest or pleasure in previously enjoyed activities[7]. Individuals with depression may experience disturbances in sleep and appetite, fatigue, difficulty concentrating, and recurrent thoughts of death or suicide[7]. Anxiety disorders encompass a spectrum of conditions marked

by excessive worry, fear, and apprehension, often accompanied by physical symptoms such as muscle tension, restlessness, palpitations, and shortness of breath. Generalized anxiety disorder (GAD), panic disorder, social anxiety disorder, and phobias are among the most common forms of anxiety disorders[6]. Both depression and anxiety can have profound detrimental effects on social relationships, occupational functioning, and overall quality of life, highlighting the importance of timely diagnosis and appropriate intervention to alleviate symptoms and prevent long-term complications[6,7].

The microbiota-gut-brain axis (MGBA) represents a bidirectional communication system linking the gut microbiota with the central nervous system (CNS) and the enteric nervous system (ENS), facilitating cross-talk between the gut and the brain[8]. This intricate network relies on a variety of signaling pathways, including neural, hormonal, immune, and metabolic mechanisms, which collectively modulate physiological processes and influence behavior, mood, cognition, and even higher-order brain functions[9]. Microbial metabolites, such as short-chain fatty acids (SCFAs), neurotransmitters (e.g., serotonin, dopamine), and immune mediators, serve as key messengers in the MGBA, exerting profound effects on neurotransmission, neuroinflammation, and neuroplasticity[9]. Disruptions in the gut microbiota composition, known as dysbiosis, have been implicated in the pathogenesis of various neurological and psychiatric disorders, including depression, anxiety, autism spectrum disorders, and neurodegenerative diseases[8]. Conversely, interventions targeting the gut microbiota through probiotics, prebiotics, dietary modifications, or fecal microbiota transplantation (FMT) have shown promise in ameliorating symptoms of these conditions, underscoring the therapeutic potential of modulating the MGBA to promote brain health[8,9].

OBJETIVE

Analyze and describe the main aspects of role of microbiota in depression and anxiety disorder in the last years.

SECONDARY OBJECTIVES

1. Investigate the relationship between gut microbiota composition and the onset or exacerbation of depression and anxiety disorders.
2. Analyze the mechanisms through which gut microbiota communicate with the brain and how these interactions influence mood regulation.
3. Explore the potential therapeutic interventions targeting the gut-brain axis for the treatment or management of depression and anxiety disorders.
4. Examine the impact of diet and lifestyle factors on gut microbiota diversity and its implications for mental health outcomes.

METHODS

This is a narrative review, in which the main aspects of role of microbiota in depression and anxiety disorder in recent years were analyzed. The beginning of the study was carried out with theoretical training using the following databases: PubMed, sciELO and Medline, using as descriptors: "gut microbiota" AND "dysbiosis" AND "depression" AND "anxiety disorder" in the last 10 years. As it is a narrative review, this study does not have any risks. Only studies in English and Portuguese were selected

Databases: This review included studies in the MEDLINE – PubMed (National Library of Medicine, National Institutes of Health), COCHRANE, EMBASE and Google Scholar databases.

RESULTS AND DISCUSSION

Gut microbiota play a crucial role in modulating the serotonergic system, primarily through the metabolism of tryptophan, an essential amino acid precursor to serotonin biosynthesis[10]. Tryptophan is converted to serotonin primarily in the gut by the enzyme tryptophan hydroxylase 1 (TPH1), with approximately 90% of the body's serotonin being synthesized in the gastrointestinal tract[11]. The gut microbiota contribute to this process by metabolizing tryptophan through various pathways, including the production of indole derivatives such as indole-3-acetic acid and indole-3-propionic acid[12]. These microbial metabolites can modulate the expression and activity of TPH1, impacting serotonin levels locally in the gut and potentially influencing systemic serotonin levels, which in turn have implications for mood regulation and mental health[11]. Additionally, gut microbiota-derived metabolites can also influence the expression of serotonin receptors and serotonin transporter proteins in the gut epithelium and the brain, further implicating the gut-brain axis in the regulation of mood and emotional states[10,12].

Emerging evidence suggests a bidirectional communication between gut microbiota and the dopaminergic system, highlighting the intricate interplay between the gastrointestinal tract and brain function[13]. Gut microbes can influence dopamine synthesis and metabolism through several mechanisms. For instance, certain bacteria possess the enzymatic machinery necessary for the production of dopamine from precursor molecules such as tyrosine, while others regulate the expression of enzymes involved in dopamine degradation[14]. Additionally, gut microbiota-derived metabolites, including short-chain fatty acids and bile acids, can impact dopaminergic neurotransmission indirectly by modulating the activity of dopaminergic neurons or influencing the expression of dopamine receptors in the brain and gastrointestinal tract[15]. These findings underscore the potential role of gut microbiota in modulating dopamine signaling pathways, thereby implicating the gut-brain axis in the regulation of mood, motivation, and cognitive function[14].

Recent research has shed light on the intricate relationship between gut microbiota and the γ-aminobutyric acid (GABA) system, a major inhibitory neurotransmitter system in the central nervous system[16]. Gut microbes have been found to produce and regulate GABA levels through various mechanisms[16]. Certain bacterial species possess the enzymatic machinery necessary for GABA synthesis from precursor molecules such as glutamate, while others modulate the expression of enzymes involved in GABA metabolism[17]. Moreover, gut microbiota-derived metabolites, including short-chain fatty acids and bioactive peptides, can influence GABAergic neurotransmission by binding to GABA receptors or altering the expression of GABA receptor subunits in the brain and gastrointestinal tract[13]. These findings highlight the potential for gut microbiota to modulate GABAergic signaling pathways, implicating the gut-brain axis in the regulation of mood, anxiety, and cognitive function[17].

Recent studies have elucidated the intricate relationship between gut microbiota and the regulation of glutamatergic neurotransmission, a crucial excitatory system in the central nervous system[13]. Gut microbes have been found to influence glutamate levels through various mechanisms[16]. Certain bacterial species possess the enzymatic machinery necessary for glutamate synthesis from precursor molecules such as glutamine, while others regulate the expression of enzymes involved in glutamate metabolism[18]. Moreover, gut microbiota-derived metabolites,

including short-chain fatty acids and amino acid derivatives, can impact glutamatergic neurotransmission by modulating the activity of glutamate receptors or altering the expression of glutamate receptor subunits in the brain and gastrointestinal tract[18]. These findings underscore the potential for gut microbiota to modulate glutamatergic signaling pathways, implicating the gut-brain axis in the regulation of cognition, learning, and synaptic plasticity[18].

A growing body of research has elucidated the intricate relationship between gut microbiota composition and the onset or exacerbation of depression and anxiety disorders[19]. Studies have consistently demonstrated alterations in the gut microbial community structure, diversity, and abundance in individuals with depression and anxiety disorders compared to healthy controls[20]. These alterations often include reductions in beneficial bacteria such as Lactobacillus and Bifidobacterium species and increases in potentially harmful taxa such as Proteobacteria and Firmicutes[20]. Additionally, dysbiosis of the gut microbiota has been associated with increased intestinal permeability, systemic inflammation, and alterations in neurotransmitter signaling pathways, all of which are implicated in the pathophysiology of depression and anxiety[21]. Furthermore, preclinical and clinical studies have shown that manipulation of the gut microbiota through probiotics, prebiotics, or fecal microbiota transplantation can modulate mood-related behaviors and alleviate symptoms of depression and anxiety, highlighting the potential therapeutic implications of targeting the gut microbiota in these disorders[19].

Analyzing the mechanisms through which gut microbiota communicate with the brain and influence mood regulation reveals a complex interplay involving multiple pathways[8]. One such mechanism involves the production of neurotransmitters and neuromodulators by gut microbes, including gamma-aminobutyric acid (GABA), serotonin, dopamine, and short-chain fatty acids (SCFAs), which can directly affect neuronal activity and mood regulation in the brain. Additionally, gut microbiota-derived metabolites such as lipopolysaccharides (LPS) and cytokines can activate the immune system and trigger inflammatory responses, which have been linked to alterations in mood and behavior[13]. Furthermore, the gut-brain axis involves bidirectional communication mediated by the vagus nerve, allowing signals from the gut to reach the brain and vice versa. Moreover, microbial metabolites can influence the integrity of the blood-brain barrier (BBB), affecting the passage of molecules between the gut and brain and thereby modulating neuroinflammation and neurotransmitter availability[13]. Understanding these intricate mechanisms provides insights into how gut microbiota can impact mood regulation and may offer novel therapeutic avenues for treating mood disorders[8].

Exploring potential therapeutic interventions targeting the gut-brain axis for the treatment or management of depression and anxiety disorders presents promising avenues for novel therapeutic strategies[22]. Probiotics, live microorganisms that confer health benefits to the host when administered in adequate amounts, have gained attention for their potential in modulating gut microbiota composition and improving mental health outcomes[23]. Clinical studies have demonstrated that specific strains of probiotics, such as Lactobacillus and Bifidobacterium species, can alleviate symptoms of depression and anxiety, possibly by regulating neurotransmitter levels, reducing inflammation, and restoring gut barrier integrity[24]. Prebiotics, nondigestible dietary fibers that selectively promote the

growth of beneficial gut bacteria, have also shown efficacy in improving mood and reducing anxiety-related behaviors[23]. Furthermore, fecal microbiota transplantation (FMT), the transfer of fecal material from a healthy donor to a recipient, has emerged as a promising therapeutic approach for restoring microbial balance and ameliorating depressive symptoms[24]. These interventions highlight the potential of targeting the gut-brain axis as a novel and effective strategy for the treatment and management of depression and anxiety disorders[22].

Examining the impact of diet and lifestyle factors on gut microbiota diversity reveals significant implications for mental health outcomes[25]. Dietary patterns rich in fiber, fruits, vegetables, and fermented foods have been associated with greater microbial diversity and a healthier gut microbiota composition, which in turn is linked to improved mood regulation and reduced risk of depression and anxiety[26]. Conversely, diets high in processed foods, saturated fats, and sugars are associated with reduced microbial diversity and dysbiosis, which may contribute to inflammation, oxidative stress, and neurobehavioral abnormalities[26]. Furthermore, lifestyle factors such as physical activity, sleep quality, and stress management also influence gut microbiota composition and function, thereby modulating mental health outcomes[26]. Regular exercise, adequate sleep, and stress reduction techniques have been shown to promote a more diverse and resilient gut microbiota, which may confer protective effects against mood disorders[27]. Understanding the intricate interplay between diet, lifestyle, gut microbiota diversity, and mental health outcomes is crucial for developing targeted interventions to promote mental well-being[25].

Evaluating the role of inflammation and immune system dysregulation in the gut-brain axis sheds light on their contribution to depressive and anxiety-related symptoms[28]. Increasing evidence suggests that chronic low-grade inflammation and immune dysregulation play a crucial role in the pathophysiology of mood disorders, including depression and anxiety[29]. In the context of the gut-brain axis, dysbiosis of the gut microbiota can lead to increased intestinal permeability and translocation of microbial products such as lipopolysaccharides (LPS) into the bloodstream, triggering systemic inflammation[29]. Activation of the immune system, particularly the release of pro-inflammatory cytokines such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α), can disrupt neurotransmitter metabolism, impair neuroplasticity, and alter the function of brain regions involved in mood regulation[30]. Furthermore, immune cells and cytokines can communicate with the central nervous system through neural, endocrine, and humoral pathways, influencing emotional and cognitive processes[30]. Understanding the interplay between inflammation, immune dysregulation, and the gut-brain axis is crucial for elucidating the underlying mechanisms of depression and anxiety and identifying potential therapeutic targets[28].

Investigating the potential of probiotics, prebiotics, and other microbiota-targeted interventions as adjunctive or standalone treatments for depression and anxiety disorders reveals promising therapeutic avenues[31]. Probiotics are live microorganisms that confer health benefits when consumed in adequate amounts and have been shown to modulate the gut microbiota composition and improve mental health outcomes[32]. Clinical studies have demonstrated that specific strains of probiotics, such as Lactobacillus and Bifidobacterium species, can alleviate symptoms of depression and anxiety by regulating neurotransmitter levels, reducing

inflammation, and restoring gut barrier integrity[31]. Prebiotics, on the other hand, are non-digestible dietary fibers that selectively promote the growth of beneficial gut bacteria and have shown efficacy in improving mood and reducing anxiety-related behaviors[25]. Other microbiota-targeted interventions, including fecal microbiota transplantation (FMT) and microbial metabolite supplementation, have also shown promise in modulating gut microbiota composition and ameliorating symptoms of depression and anxiety[31]. These interventions offer novel and potentially effective strategies for the treatment and management of mood disorders, either as adjunctive therapies alongside conventional treatments or as standalone interventions[31].

Assessing the impact of stress and early-life experiences on gut microbiota composition reveals significant implications for long-term mental health outcomes[33]. Stressful events, particularly during critical periods of early development, can disrupt the delicate balance of the gut microbiota and alter its composition, diversity, and function[34]. Early-life stressors such as maternal separation, childhood trauma, or exposure to adverse environments have been shown to induce dysbiosis of the gut microbiota, characterized by decreased microbial diversity and alterations in specific microbial taxa[34]. These changes can persist into adulthood and are associated with an increased risk of developing mood disorders, including depression and anxiety[8]. Moreover, stress-induced alterations in gut microbiota composition can lead to dysregulation of the gut-brain axis, affecting neurotransmitter signaling, immune function, and inflammatory responses, all of which contribute to the pathogenesis of mental health disorders[34]. Understanding the impact of stress and early-life experiences on gut microbiota composition provides insights into the underlying mechanisms linking environmental factors to mental health outcomes and may inform preventive and therapeutic interventions aimed at promoting microbial resilience and mitigating the long-term effects of early-life adversity[33].

Exploring the bidirectional relationship between gut microbiota and neurotransmitter systems implicated in depression and anxiety disorders reveals a complex interplay with significant implications for mental health[35]. The gut microbiota produce and metabolize neurotransmitters such as serotonin, gamma-aminobutyric acid (GABA), dopamine, and glutamate, which play key roles in mood regulation and emotional processing[35]. Dysregulation of these neurotransmitter systems has been implicated in the pathogenesis of depression and anxiety disorders[36]. Conversely, neurotransmitters released by the central nervous system can influence the composition and activity of the gut microbiota through direct and indirect mechanisms[36]. For example, stress-induced alterations in neurotransmitter levels can impact gut permeability, motility, and immune function, leading to dysbiosis of the gut microbiota[36]. Furthermore, the gut microbiota can communicate with the central nervous system through the vagus nerve, microbial metabolites, and immune signaling molecules, influencing neurotransmitter synthesis, release, and signaling in the brain[27]. Understanding the bidirectional relationship between gut microbiota and neurotransmitter systems provides insights into the underlying mechanisms of depression and anxiety disorders and may inform novel therapeutic approaches targeting the gut-brain axis[35].

Investigating the influence of environmental factors, including pollution and antibiotic exposure, on gut microbiota composition reveals significant implications for mental health disorders[37]. Environmental pollutants, such as heavy metals, pesticides,

and air pollutants, can disrupt the delicate balance of the gut microbiota and promote dysbiosis, characterized by alterations in microbial diversity and abundance[38]. These pollutants can directly affect microbial populations or indirectly through their impact on host physiology, such as oxidative stress, inflammation, and immune dysregulation[39]. Additionally, antibiotic use, while often necessary for treating bacterial infections, can also have profound effects on gut microbiota composition and function[39]. Antibiotics disrupt microbial communities, leading to decreased microbial diversity, overgrowth of opportunistic pathogens, and long-lasting alterations in gut microbiota composition[38]. These environmental insults to the gut microbiota have been linked to an increased risk of mental health disorders, including depression, anxiety, and cognitive dysfunction[39]. Understanding the influence of environmental factors on gut microbiota and its association with mental health disorders is essential for developing preventive strategies and therapeutic interventions aimed at preserving microbial balance and promoting mental well-being[37].

Gut microbiota dysbiosis has been implicated in the pathophysiology of depression, highlighting the intricate relationship between the gut and brain[20]. Several studies have reported alterations in the composition and diversity of gut microbiota in individuals with depression compared to healthy controls[40]. These alterations often include reductions in beneficial bacteria such as Lactobacillus and Bifidobacterium species and increases in potentially pathogenic taxa like Firmicutes and Proteobacteria[20]. Dysbiosis of the gut microbiota can lead to increased intestinal permeability and translocation of microbial products such as lipopolysaccharides (LPS) into the bloodstream, triggering systemic inflammation[40]. Furthermore, gut microbiota dysregulation can influence neurotransmitter signaling pathways, including the serotonin and gamma-aminobutyric acid (GABA) systems, which are crucial for mood regulation[40]. Additionally, microbial metabolites such as short-chain fatty acids (SCFAs) and tryptophan-derived compounds can modulate immune function, neuroinflammation, and neurogenesis, all of which have been implicated in the pathogenesis of depression[26]. Understanding the complex interactions between gut microbiota and depression may pave the way for novel therapeutic strategies targeting the gut-brain axis to alleviate depressive symptoms and improve mental health outcomes[20].

Emerging research has underscored the intricate interplay between gut microbiota and anxiety disorders, revealing potential mechanistic insights and therapeutic avenues[8]. Dysbiosis of the gut microbiota, characterized by alterations in microbial composition and diversity, has been associated with increased susceptibility to anxiety-related behaviors in both preclinical and clinical studies. Specifically, reductions in beneficial bacteria such as Lactobacillus and Bifidobacterium species, along with increases in pathogenic taxa like Firmicutes and Proteobacteria, have been observed in individuals with anxiety disorders[20]. These microbial alterations can lead to disruptions in gut barrier integrity, heightened systemic inflammation, and dysregulated neurotransmitter signaling, all of which contribute to the pathogenesis of anxiety. Moreover, bidirectional communication between the gut microbiota and the central nervous system via the gut-brain axis plays a pivotal role in modulating anxiety-related behaviors[20,37]. Microbial metabolites, such as short-chain fatty acids (SCFAs) and neurotransmitters like serotonin and gamma-aminobutyric acid (GABA), can influence neural circuits involved in

anxiety regulation, highlighting the potential for targeting the gut microbiota as a novel therapeutic approach for anxiety disorders[8, 20, 37].

CONCLUSION

In conclusion, the gut microbiota plays a pivotal role in modulating neurotransmitter systems such as serotonin, dopamine, GABA, and glutamate, which are implicated in the regulation of mood, anxiety, and cognitive function. Dysbiosis of the gut microbiota, characterized by alterations in microbial composition and diversity, has been associated with mood disorders such as depression and anxiety. Understanding the bidirectional communication between the gut microbiota and the brain via the gut-brain axis provides insights into the underlying mechanisms of these disorders and offers novel therapeutic avenues for their treatment and management. Probiotics, prebiotics, fecal microbiota transplantation, and other microbiota-targeted interventions hold promise as adjunctive or standalone therapies for mood disorders, emphasizing the importance of targeting the gut microbiota to promote mental well-being. Moreover, environmental factors, stress, early-life experiences, and dietary and lifestyle habits profoundly influence gut microbiota composition and function, highlighting the multifaceted nature of the gut-brain axis in shaping mental health outcomes. Further research in this field is warranted to elucidate the complex interplay between the gut microbiota and mental health and to develop personalized interventions for individuals with mood and anxiety disorders.

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