



EFFECT OF MICROBIOME-GUT-BRAIN AXIS ON BEHAVIOUR AND IS A PLANT-BASED DIET BETTER THAN AN OMNIVOROUS DIET?

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Abstract

The microbiome-gut-brain axis plays a crucial role as a communication network linking the gut microbiota with the central nervous system, thereby influencing mood, cognitive functions, and behavior. An imbalance in the gut microbiota, known as dysbiosis, has been linked to disorders such as anxiety and depression. This review delves into the impact of this axis on human behavior and evaluates whether plant-based diets, which are high in fiber, offer greater benefits than omnivorous diets in terms of modulating the gut microbiome.

Plant-based diets are associated with promoting a diverse and beneficial gut microbiota. These diets aid in the production of short-chain fatty acids and neurotransmitters like serotonin, which are crucial for mental health and cognitive functions. In contrast, while omnivorous diets provide a variety of nutrients, they may lead to different microbial compositions that could result in less favorable health outcomes. This review critically examines current research to determine if plant-based diets offer superior benefits for enhancing mental and behavioral health by modulating the gut microbiome.

Evidence indicates that both dietary patterns can positively influence the gut microbiome. However, plant-based diets might provide more significant benefits in fostering a healthy microbiome and enhancing mood and cognitive health. This underscores the importance of dietary choices in maintaining mental well-being and cognitive functions.

Introduction

Recent studies have highlighted the importance of the microbiome-gut-brain axis, a complex, bidirectional communication network connecting the gut microbiota with the central nervous system through three main mechanisms: the endocrine system, the immune system, and the central nervous system (CNS). This axis has been shown to significantly influence mood, cognition, and behavior (Cryan & Dinan, 2012; Clarke et al., 2014). Disorders such as anxiety, depression, and autism spectrum disorders have been linked to dysbiosis, showing the potential for targeting the microbiome for therapeutic interventions (Quigley, 2018; Bauerl et al., 2018).

Diet is a critical factor in modulating the composition and functionality of the gut microbiome. The types of nutrients consumed have a direct impact on the diversity and activity of microbial populations (Tremaroli & Bäckhed, 2012). Among the various dietary patterns, plant-based diets have gained attention due to their potential to foster a healthy microbiome, largely attributed to their high fiber content, which serves as a key substrate for beneficial bacteria (Wu et al., 2011; David et al., 2014). In contrast, omnivorous diets, which include animal products, tend to promote a different microbial composition that could be linked to less favorable health outcomes (Graf et al., 2015; Smith & Spector, 2014). This review rigorously analyzes current research to determine if plant-based diets provide superior benefits in modulating the microbiome in ways that positively influence human behavior.

The Microbiome-Gut-Brain Axis

The microbiome-gut-brain axis is a complex and dynamic system that includes the gut microbiota, the intestinal barrier, and the host's immune, endocrine, and nervous systems (Cryan & Dinan, 2012). This axis is vital for maintaining gastrointestinal health and influencing various physiological processes throughout the body. The gut microbiota is composed of trillions of

microorganisms, such as bacteria, viruses, fungi, and protozoa, which reside in the gastrointestinal tract. These microbes engage in a symbiotic relationship with the host, performing essential functions like digesting dietary fibers, synthesizing vitamins, and protecting against pathogens (Turnbaugh et al., 2007) (David et al., 2014).

The microbiome-gut axis operates through a multifaceted array of mechanisms that intricately link gut microbiota to the host's overall health. Firstly, the gut microbiota, comprising a diverse community of microorganisms, interacts extensively with the host's immune system, promoting immune tolerance and defending against harmful pathogens. This interaction is crucial for the regulation of immune responses and the maintenance of gut-associated lymphoid tissue (GALT), which plays a vital role in the host's immune function (Quigley, 2018). The gut microbiota also influences the endocrine system of the gut, particularly through enteroendocrine cells (EECs), which release over 20 different types of signaling molecules in response to chemical and mechanical stimuli. These molecules, such as glucagon-like peptide-1 (GLP-1) and peptide YY, can enter the systemic circulation and reach the central nervous system (CNS), influencing ingestive behavior and energy metabolism (Quigley, 2018). Notably, microbial metabolites, including bile acids and short-chain fatty acids (SCFAs) like butyrate, propionate, and acetate, play a significant role in these interactions (Cryan & Dinan, 2012).

The microbiota facilitates the fermentation of indigestible carbohydrates into SCFAs. These SCFAs not only serve as vital energy sources for colonocytes but also reinforce the integrity of the intestinal barrier, reducing permeability and exerting anti-inflammatory effects (Quigley, 2018). SCFAs such as acetate and butyrate modulate the secretion of GLP-1 via receptors like free fatty acid receptor 2 (FFAR2) and G-protein-coupled receptor 43 (GPR43) on enteroendocrine cells. This interaction is critical for maintaining glucose homeostasis and regulating appetite (Cryan & Dinan, 2012).

Furthermore, the size and composition of the bile acid pool are heavily influenced by the gut microbiota through their metabolism of dietary fats. Bile acids, which activate the farnesoid X receptor (FXR) in the ileum, lead to the production of fibroblast growth factor 19 (FGF19). FGF19 can enter the systemic circulation and influence brain functions, such as energy and glucose metabolism, by acting on the hypothalamus (Cryan & Dinan, 2012).

SCFAs and other microbial metabolites produced in the gut can enter the bloodstream and influence distant organs, including the brain. These metabolites can modulate neuroinflammation and neurochemical balance by altering blood-brain barrier permeability and interacting with neural pathways. They are known to stimulate enteroendocrine cells in the distal ileum to secrete hormones that induce satiety and behavioral changes, highlighting the significant impact of gut microbiota on both local and systemic physiological functions (Cryan & Dinan, 2012). These complex interactions underscore the potential of the microbiome as a target for therapeutic intervention, not only for gastrointestinal health but also for neuropsychiatric conditions like anxiety, depression, and autism spectrum disorders (Quigley, 2018).

Beyond local effects, the microbiome-gut axis exerts significant influence over the central nervous system through the gut-brain axis, a complex bidirectional communication network involving neural, hormonal, and immune pathways. This system includes critical interactions via the vagus nerve, a primary conduit for neural signals between the gut and the brain, facilitating real-time communication and coordination of functions. Variations in gut microbiota composition can profoundly impact mood, behavior, and cognitive processes, as the microbiota influences the synthesis and availability of neurotransmitters such as serotonin, which is predominantly produced in the gut and plays a crucial role in mental health (Cryan & Dinan, 2012). Moreover, the gut microbiota affects the metabolism of tryptophan, a precursor to serotonin, further highlighting the intricate connections between gut health and psychological well-being.

Overall, the microbiome-gut axis is a cornerstone of human health, orchestrating a range of physiological functions and contributing to the pathogenesis of various diseases when dysregulated. Comprehensive understanding of this axis is essential for the development of therapeutic strategies aimed at modulating the gut microbiota, thus offering potential for significant improvements in health outcomes (Quigley, 2018).

Effect of microbiome diversity on mood

One of the most compelling areas of research is the connection between gut microbiome diversity and mood regulation. The gut-brain axis, a bidirectional communication network, facilitates interactions between the gut microbiota and the central nervous system. Diverse microbiomes produce a wide array of metabolites, including short-chain fatty acids (SCFAs), neurotransmitters, and neuroactive compounds that influence brain function and mood. For instance, SCFAs such as butyrate have anti-inflammatory properties and enhance the integrity of the blood-brain barrier, potentially reducing neuroinflammation linked to mood disorders (Quigley, 2018).

Certain gut bacteria can synthesize neurotransmitters like serotonin, dopamine, and gamma-aminobutyric acid (GABA), which are critical for mood regulation. Approximately 90% of the body's serotonin is produced in the gut, with microbial diversity influencing the availability of its precursor, tryptophan (Clarke et al., 2014). Reduced microbial diversity is associated with decreased production of these neuroactive compounds, potentially leading to imbalances in neurotransmitter levels and contributing to depression and anxiety (Cryan & Dinan, 2012).

Microbiome diversity is crucial for maintaining cognitive functions, including memory, learning, and executive function. A rich and diverse gut microbiome supports cognitive health by modulating neuroinflammation and promoting the production of neurotrophic factors like brain-derived neurotrophic factor (BDNF), which is essential for neurogenesis and synaptic plasticity (Quigley, 2018). Animal studies have shown that microbiome alterations can affect cognitive performance, with germ-free mice exhibiting deficits in spatial memory and anxiety-like behaviors, underscoring the importance of a diverse microbiome for cognitive resilience (Cryan & Dinan, 2012).

In humans, dysbiosis—a condition characterized by reduced microbial diversity—has been linked to cognitive decline and neurodegenerative diseases. For example, patients with Alzheimer's disease have been found to have less diverse gut microbiota compared to healthy individuals, suggesting a potential link between microbiome diversity and cognitive health (Bauerl et al., 2018). The gut microbiome can influence cognitive function through its effects on the hypothalamic-pituitary-adrenal (HPA) axis, which regulates stress responses and is implicated in cognitive impairment and mood disorders.

Impact on social behaviour

Microbiome diversity significantly impacts social behavior, an area of growing interest in both human and animal studies. Social behavior is influenced by various factors, including neurodevelopmental processes and the modulation of social cognition, both of which can be affected by the gut microbiome. For instance, studies in animal models have demonstrated that microbiome diversity is crucial for normal social behavior, with germ-free animals exhibiting reduced social interaction and increased anxiety-like behaviors (Cryan & Dinan, 2012).

In humans, alterations in the gut microbiome have been associated with behavioral conditions such as autism spectrum disorder (ASD), which is characterized by social deficits and repetitive behaviors. Children with ASD often show less microbial diversity and a higher prevalence of potentially pathogenic bacteria in their gut microbiota compared to neurotypical children, suggesting that microbiome diversity may play a role in the development and modulation of social behaviors (Bauerl et al., 2018). This relationship is possibly mediated through the regulation of gut-derived neurotransmitters and the modulation of the immune system.

The mechanisms through which microbiome diversity influences human behavior are complex and multifaceted. Key pathways include the production of microbial metabolites that can cross the gut barrier and interact with the central nervous system, modulation of immune responses that affect brain inflammation, and direct signaling through the vagus nerve (Clarke et al., 2014). Additionally, the gut microbiome can impact the expression of genes involved in neurodevelopment and neuroplasticity, further highlighting its role in shaping behavior (Quigley, 2018).

Overall, a diverse gut microbiome appears to be integral to maintaining mental health and behavioral stability. The reduction in microbiome diversity due to factors such as poor diet, antibiotic use, and environmental stressors can have profound effects on mood, cognition, and social behaviors, underscoring the importance of maintaining a healthy and diverse microbial community in the gut for overall well-being.

Effect of microbiome composition on mood

The composition of the gut microbiome, which refers to the specific makeup of microbial species and their relative abundances, has a profound influence on human behavior. This impact is mediated through intricate biochemical interactions and neurophysiological pathways that link the gut environment with brain function and behavior. Research has increasingly highlighted how variations in microbiome composition are associated with changes in mood, cognitive processes, and social behavior, underscoring the complex role of gut microbiota in shaping human behavioral responses.

Microbiome composition plays a critical role in the modulation of mood, with imbalances in microbial communities often linked to mood disorders such as depression and anxiety. A balanced gut microbiome is necessary for the production of key neurotransmitters like serotonin and dopamine, which are crucial for mood regulation (Cryan & Dinan, 2012). Dysbiosis, or the disruption of normal microbiome composition, can lead to a decrease in beneficial bacteria that produce these neurotransmitters, resulting in lower levels of these mood-regulating chemicals. For instance, a reduction in the abundance of Bifidobacteria and Lactobacilli, both of which are known to produce gamma-aminobutyric acid (GABA), can lead to increased anxiety and depressive symptoms (Quigley, 2018).

Studies have shown that specific changes in microbiome composition, such as an increase in pathogenic bacteria like Clostridium or a decrease in beneficial bacteria like Faecalibacterium, are associated with heightened inflammatory responses and altered neuroendocrine functions, both of which are implicated in the pathogenesis of mood disorders. Elevated levels of pro-inflammatory cytokines, which can be triggered by dysbiotic microbiota, have been linked to depressive symptoms through their impact on brain inflammation and neurotransmitter metabolism (Clarke et al., 2014).

The gut microbiome composition is also crucial for cognitive functions, including memory, learning, and decision-making. Variations in the types of gut bacteria and their metabolic products can influence cognitive processes by affecting the brain's structural and functional integrity. Certain bacterial genera, such as Bacteroides and Prevotella, are known to produce metabolites that can cross the blood-brain barrier and impact cognitive function (Cryan & Dinan, 2012). These metabolites can modulate the expression of genes involved in neurogenesis and synaptic plasticity, which are essential for learning and memory.

Research has demonstrated that a balanced composition of gut microbiota supports cognitive health by modulating the gut-brain axis. For instance, a study by Clarke et al. (2014) found that the presence of certain bacteria, such as those from the genus Bifidobacterium, is associated with improved cognitive performance and a reduction in age-related cognitive decline. Conversely, the presence of potentially harmful bacteria such as Enterobacteriaceae has been linked to impaired cognitive function and an increased risk of neurodegenerative diseases like Alzheimer's disease, highlighting the critical role of microbial composition in maintaining cognitive health (Quigley, 2018).

The composition of the gut microbiome is intricately linked to social behavior, with specific bacterial species influencing social interactions and related behaviors. Animal studies have shown that changes in gut microbiome composition can lead to significant alterations in social behavior. For example, mice treated with antibiotics, which disrupt normal microbiome composition, exhibit reduced social interaction and increased anxiety-like behaviors (Cryan & Dinan, 2012). These changes are thought to be mediated by alterations in gut-derived metabolites that influence brain function and behavior.

In humans, variations in microbiome composition have been associated with behavioral conditions characterized by social deficits, such as autism spectrum disorder (ASD). Children with ASD often show differences in gut microbiome composition compared to neurotypical children, with a higher prevalence of potentially pathogenic bacteria and lower levels of beneficial species like Bifidobacterium and Lactobacillus (Quigley, 2018). These compositional changes are believed to influence the gut-brain axis and contribute to the social and behavioral challenges associated with ASD. Additionally, specific microbial metabolites, such as those produced by Lactobacillus and Bifidobacterium, are known to modulate social behavior by affecting the production of neurotransmitters and neuropeptides that regulate social cognition (Clarke et al., 2014).

The mechanisms by which microbiome composition influences human behavior are multifaceted and involve both direct and indirect pathways. Key mechanisms include the production of neuroactive metabolites that can cross the gut barrier and enter the bloodstream, thereby influencing brain function; the modulation of immune responses that affect brain inflammation and neurotransmission; and direct signaling through the vagus nerve, which connects the gut to the brain (Cryan & Dinan, 2012).

These pathways underscore the integral role of gut microbiota composition in shaping behavioral outcomes and highlight the potential for targeting the microbiome to manage behavioral and neurological disorders.

Effect of Plant-Based Diet on Microbiome Diversity

The human gut microbiome, a complex ecosystem of microorganisms, plays a crucial role in health and disease. A plant-based diet, characterized by high fiber, polyphenols, and plant-derived nutrients, significantly influences the composition and diversity of the gut microbiota. This dietary pattern promotes the growth of beneficial microbes and enhances microbial diversity, which are associated with numerous health benefits, including improved digestion, immune function, and metabolic health. Recent research has shed light on the mechanisms through which a plant-based diet modulates the gut microbiome, emphasizing its potential for disease prevention and health promotion.

A plant-based diet is rich in dietary fibers, which serve as prebiotics—non-digestible food components that stimulate the growth and activity of beneficial gut bacteria. These fibers are fermented by gut microbiota to produce short-chain fatty acids (SCFAs) like butyrate, acetate, and propionate, which support gut health and systemic immunity (David et al., 2014). The increase in dietary fiber intake associated with plant-based diets enhances microbial diversity, a key indicator of a healthy gut microbiome. Higher microbial diversity is linked to greater resilience against pathogenic colonization and a lower risk of gastrointestinal and systemic diseases (Tremaroli & Bäckhed, 2012).

Studies comparing the gut microbiota of individuals on plant-based diets to those on animal-based diets consistently find that plant-based diets promote a more diverse microbiota. For instance, a study by Wu et al. (2011) demonstrated that individuals consuming a diet rich in fruits, vegetables, legumes, and whole grains had higher levels of beneficial bacteria such as *Bifidobacterium* and *Lactobacillus*, and a more diverse microbial community overall compared to those on a typical Western diet high in animal fats and proteins. This increased diversity is thought to confer greater metabolic flexibility and a robust immune system, capable of efficiently responding to dietary and environmental changes (Tremaroli & Bäckhed, 2012).

Effect of Plant-Based Diet on Microbiome Composition

A plant-based diet leads to significant shifts in the composition of the gut microbiome. One of the primary effects is an increase in the abundance of bacteria that can ferment dietary fibers into beneficial metabolites. Key bacterial genera that thrive on a plant-based diet include *Bacteroides*, *Prevotella*, and *Ruminococcus*, which are known for their ability to degrade complex carbohydrates and produce SCFAs. These metabolites not only serve as energy sources for colonocytes but also play crucial roles in maintaining the intestinal barrier, modulating immune responses, and reducing inflammation (David et al., 2014).

The increase in beneficial bacteria is often accompanied by a decrease in pathogenic and pro-inflammatory bacteria. For instance, a higher intake of plant-based foods has been linked to reduced levels of opportunistic pathogens such as *Clostridium difficile* and *Enterobacteriaceae*, which are associated with gastrointestinal disorders and systemic inflammation (Wu et al., 2011). The suppression of these harmful bacteria by beneficial microbes results from competitive exclusion, where beneficial bacteria outcompete pathogens for nutrients and attachment sites in the gut lining, enhancing gut health and reducing disease risk (Tremaroli & Bäckhed, 2012).

Polyphenols, abundant in plant-based diets, further contribute to the modulation of gut microbiota composition. These bioactive compounds have antimicrobial properties that can selectively inhibit the growth of pathogenic bacteria while promoting the proliferation of beneficial microbes. Polyphenols such as flavonoids, tannins, and phenolic acids are metabolized by gut bacteria into bioactive metabolites that enhance microbial diversity and support the growth of beneficial species like *Bifidobacterium* and *Lactobacillus* (Tremaroli & Bäckhed, 2012).

Moreover, plant-based diets are rich in a variety of vitamins, minerals, and phytochemicals that provide essential nutrients for microbial growth and metabolic activity. These nutrients support the proliferation of a wide range of beneficial bacteria, contributing to a more balanced and diverse microbiome. For example, the consumption of leafy greens, nuts, and seeds provides a range of nutrients that not only nourish the host but also create a favorable environment for the growth of health-promoting microbes (Wu et al., 2011).

The mechanisms by which a plant-based diet influences microbiome composition and diversity are complex and multifaceted. Key mechanisms include the provision of substrates for microbial fermentation, the promotion of microbial metabolites that benefit the host, and the suppression of pathogenic bacteria through competitive interactions and antimicrobial effects of plant compounds (David et al., 2014). The increased production of SCFAs, resulting from the fermentation of dietary fibers, plays a central role in enhancing gut health by reducing inflammation, improving barrier function, and supporting the growth of beneficial bacteria (Tremaroli & Bäckhed, 2012).

Overall, adopting a plant-based diet leads to beneficial changes in the gut microbiome, characterized by increased microbial diversity and a shift towards a composition dominated by health-promoting bacteria. These changes are associated with improved metabolic health, enhanced immune function, and a reduced risk of chronic diseases, highlighting the importance of dietary choices in modulating the gut microbiome and promoting overall health (Wu et al., 2011).

Individuals on plant-based diets often report lower levels of stress and anxiety, potentially due to the diet's impact on the gut microbiota and subsequent neurotransmitter production. Enhanced microbial diversity and increased production of short-chain fatty acids (SCFAs) may lead to better regulation of the hypothalamic-pituitary-adrenal (HPA) axis, which is involved in stress response and mood regulation. This indicates that plant-based diets can contribute to emotional well-being and resilience against stress-related disorders (Quigley, 2018).

Effect of Omnivore Diet on Microbiome Diversity

The omnivore diet, characterized by the inclusion of both plant-based and animal-based foods, significantly impacts the composition and diversity of the human gut microbiome. This diet pattern provides a diverse array of nutrients, including proteins, fats, carbohydrates, and various bioactive compounds, which collectively shape the gut microbial ecosystem. The

microbiome's response to an omnivore diet is complex, reflecting the influence of both the variety of food sources and the balance between animal and plant-derived nutrients. Recent research has provided insights into how an omnivore diet influences gut microbiota, highlighting its effects on microbial diversity and the relative abundance of specific bacterial taxa.

The omnivore diet tends to support moderate levels of gut microbial diversity compared to purely plant-based or animal-based diets. Diversity is influenced by the range of food types consumed and the balance between fiber-rich plant foods and protein- and fat-rich animal products. Studies have shown that omnivore diets generally promote greater microbial diversity than diets limited to animal-based foods alone but may offer less diversity than high-fiber, plant-based diets (Wu et al., 2011).

The inclusion of various plant foods provides dietary fibers, which are fermented by gut bacteria to produce short-chain fatty acids (SCFAs) like butyrate, acetate, and propionate. These SCFAs support a healthy and diverse microbiota by providing energy to gut epithelial cells and promoting anti-inflammatory effects. On the other hand, animal-based foods contribute proteins and fats that differentially affect microbial populations, often promoting bacteria involved in protein and fat metabolism such as *Bacteroides* and *Alistipes* (David et al., 2014). These bacteria can metabolize proteins into amino acids and fatty acids, which can further be utilized by other microbes or absorbed by the host.

Research indicates that the balance between plant and animal foods in an omnivore diet plays a crucial role in shaping the microbiome's composition and diversity. A study by David et al. (2014) demonstrated that omnivores consuming higher amounts of fiber-rich plant foods tend to have a more diverse microbiota compared to those with diets heavily skewed towards animal products. This diversity is associated with a healthier gut environment, capable of resisting pathogenic colonization and supporting overall metabolic health.

Effect of Omnivore Diet on Microbiome Composition

An omnivore diet influences gut microbiome composition by supporting a balance between bacteria that thrive on plant-derived fibers and those that metabolize proteins and fats from animal sources. Key bacterial groups that are commonly enriched in omnivores include *Bacteroides*, Firmicutes, and Proteobacteria. *Bacteroides* species, which are adept at breaking down complex carbohydrates and proteins, are typically more abundant in omnivores due to their flexible metabolic capabilities that allow them to utilize a wide range of dietary substrates (Wu et al., 2011).

The presence of animal-based foods in an omnivore diet supports the growth of bacteria that metabolize animal fats and proteins. For instance, *Bilophila wadsworthia*, a bacterium associated with bile acid metabolism, is often more prevalent in omnivores due to the higher intake of animal fats that stimulate bile acid production (David et al., 2014). This bacterium and similar ones can impact gut health by influencing bile acid metabolism, which plays a role in lipid digestion and absorption.

The metabolite profile of the gut microbiome in omnivores is influenced by the consumption of both plant and animal foods, leading to a complex mixture of fermentation products. The fermentation of plant fibers results in the production of short-chain fatty acids (SCFAs), which have beneficial effects on gut health, including anti-inflammatory properties and enhanced gut barrier function. These metabolites also play roles in signaling to the host's metabolism and immune system, contributing to overall health (Wu et al., 2011).

Animal-based foods in an omnivore diet contribute to the production of metabolites such as branched-chain amino acids (BCAAs) and trimethylamine-N-oxide (TMAO). BCAAs are derived from the metabolism of dietary proteins and play crucial roles in muscle synthesis and metabolic regulation. However, elevated levels of TMAO, a metabolite produced by the gut microbiota from dietary choline and carnitine found in red meat, have been linked to an increased risk of cardiovascular disease (David et al., 2014). Thus, while an omnivore diet provides a wide range of nutrients, the balance of these nutrients can influence health outcomes, highlighting the importance of dietary moderation and balance.

The effects of an omnivore diet on the gut microbiome are mediated through several mechanisms. The diet provides substrates for microbial fermentation, influences the production of bioactive metabolites, and affects the gut environment's pH and redox potential. These factors collectively shape the composition and diversity of the microbiome. Additionally, the intake of various nutrients modulates immune responses and gut barrier function, further influencing the microbial ecosystem (Graf et al., 2015).

Overall, an omnivore diet promotes a gut microbiome that is adapted to a diverse nutrient environment, supporting a variety of microbial taxa that contribute to health and disease prevention. However, the specific balance of plant and animal foods is crucial in determining the overall impact on gut microbiota, emphasizing the need for a well-rounded diet to maintain optimal microbial diversity and composition (Wu et al., 2011).

Influence of Omnivore Diets on Behavior and Brain Function

Omnivore diets, which include both plant-based and animal-based foods, provide a diverse range of nutrients that influence gut microbiota composition and, consequently, brain function. The balance between plant and animal foods in an omnivore diet plays a crucial role in shaping gut microbial diversity. While this diet promotes greater microbial diversity than purely animal-based diets, it may offer less microbial diversity compared to plant-based diets high in fiber (Wu et al., 2011).

Animal-based foods in omnivore diets significantly impact the gut microbiome by promoting the growth of bacteria that metabolize proteins and fats, which in turn influence neurotransmitter synthesis. Proteins from animal sources are rich in amino acids such as tryptophan and tyrosine, which are precursors for key neurotransmitters like serotonin and dopamine, respectively. Tryptophan from animal proteins is converted by gut bacteria into metabolites that serve as precursors for serotonin synthesis, a neurotransmitter crucial for regulating mood, anxiety, and overall emotional well-being. A diet rich in animal proteins can enhance the availability of tryptophan, thereby boosting serotonin production in the gut (Cryan & Dinan, 2012). Similarly, tyrosine, another amino acid found in animal products, is metabolized by gut bacteria into catecholamines, including dopamine, which plays a significant role in motivation, reward, and cognitive functions (Quigley, 2018). This dietary intake supports neurotransmitter synthesis, which is essential for mental health and cognitive performance.

Research demonstrates that dietary intake of specific amino acids directly influences the gut microbiome's capacity to produce serotonin and dopamine, highlighting the role of diet in neurotransmitter regulation (Yano et al., 2015). For instance, gut-derived serotonin, which accounts for about 95% of the body's total serotonin levels, is heavily influenced by dietary intake of tryptophan from animal sources (Yano et al., 2015). Increased dietary protein intake has been shown to alter gut microbiota composition towards more protein-metabolizing bacteria, thereby affecting neurotransmitter production (David et al., 2014). However, an imbalance between beneficial and potentially harmful bacteria in the gut microbiome can disrupt neurotransmitter levels and brain function. Excessive protein intake from animal sources may promote the growth of pathogenic bacteria such as *Clostridium* and *Bacteroides*, which can produce neurotoxic metabolites that negatively impact brain health, potentially contributing to conditions such as anxiety and depression (David et al., 2014).

While omnivore diets do contribute to the production of SCFAs through the fermentation of plant fibers, the overall effect on neuroinflammation and brain function can vary depending on the proportion of plant to animal foods consumed. Higher intake of plant-based components can increase SCFA production, leading to anti-inflammatory effects and improved brain health. Conversely, higher consumption of animal-based foods may reduce SCFA production and increase the risk of neuroinflammation, which can negatively impact mood and cognitive function (David et al., 2014).

The inclusion of both plant and animal foods in omnivore diets can support a balanced gut microbiome, which is beneficial for maintaining cognitive functions such as memory, learning, and decision-making. A diverse and balanced diet ensures the presence of various beneficial bacteria that support overall brain health. Studies indicate that diets rich in a variety of foods, including animal products, support the growth of bacteria like *Bifidobacterium* and *Lactobacillus*, which are associated with improved cognitive function and reduced risk of neurodegenerative diseases (Westfall et al., 2017). Additionally, the presence of SCFAs, produced by fermenting both plant fibers and animal fats, has been linked to enhanced cognitive flexibility and decision-making abilities (Tremaroli & Bäckhed, 2012). These SCFAs support brain health by modulating neuroinflammation and promoting neurogenesis, essential processes for learning and memory (Clarke et al., 2014).

A balanced intake of plant and animal foods can help maintain a diverse gut microbiome, reducing the risk of mood disorders such as depression and anxiety. A balanced diet promotes the growth of bacteria that produce mood-regulating neurotransmitters like serotonin and GABA, thus supporting mental health stability (Wu et al., 2011). However, diets low in fiber and high in animal products may reduce microbial diversity, leading to a dominance of pro-inflammatory bacteria. This imbalance can increase the risk of neuroinflammation, which is linked to mood disorders and cognitive decline (Graf et al., 2015). Maintaining a balanced intake of plant and animal foods is crucial for optimizing gut health and brain function.

Research shows that individuals consuming a balanced diet with both plant and animal foods have a more diverse and resilient microbiome, which is critical for cognitive health and resistance to stress and depression (Wu et al., 2011). Studies highlight that a balanced microbiome supported by an omnivore diet enhances the production of SCFAs, which can cross the blood-brain barrier and positively influence brain function and mood regulation (Smith & Spector, 2014). Diets rich in a variety of nutrients, including proteins and fats from animal sources, can support cognitive functions by providing essential nutrients for brain health and reducing the risk of cognitive impairments (Bauerl et al., 2018).

Conclusion and Future Directions

In conclusion, while both plant-based and omnivore diets have the potential to positively influence gut microbiota and health, the evidence suggests that plant-based diets may offer superior benefits in terms of promoting a healthy gut microbiome and positively impacting mood, cognition, and overall mental health. The high fiber content, abundance of polyphenols, and essential nutrients in plant-based diets support the growth of beneficial bacteria, enhance microbial diversity, and promote the production of neuroactive compounds that improve brain function and behavior. Conversely, an omnivore diet can also support microbial diversity and health, but the balance of plant to animal foods is crucial for maintaining optimal gut health and preventing negative health outcomes. Therefore, adopting a predominantly plant-based diet with moderate inclusion of animal products may provide the best approach for maintaining a healthy microbiome and overall well-being.

Future research should continue to explore the complex interactions between diet, the gut microbiome, and health outcomes to refine dietary recommendations and promote optimal health. By embracing a diet rich in diverse plant-based foods, individuals can support their gut health, enhance mental and cognitive functions, and potentially reduce the risk of chronic diseases.

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