






REVIEW

The role of the intestine as a target with a therapeutic role in people with neurodegenerative diseases

El rol del intestino como diana con papel terapéutico en personas con enfermedades neurodegenerativas

María Paz Valdivieso Castro¹  , Julio Cesar Ojeda Sánchez¹  , Jorge Eduardo Ochoa Aucay¹  

¹ Universidad Católica de Cuenca, Cuenca, Ecuador.

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ABSTRACT

There is a bidirectional exchange known as the gut-brain axis with several connections including the vagus nerve, the immune system, metabolites, and bacterial products. During dysbiosis, there is an alteration of the blood-brain barrier permeability and neuroinflammation. The objective of this review was to describe the role of the gut microbiota and its therapeutic role in neurodegenerative diseases. The gut microbiota-brain axis includes a set of microorganisms including common bacteria (*Lactobacillus* and *S. aureus*), fungi, and viruses that play an important role in gut function, such as barrier protection and preventing the passage of bacteria or pathogens from outside the gut, as well as metabolizing carbohydrates and producing vitamins K, B12, and B7. However, when the gut microbiota is altered due to stress, diet, or other factors, communication through ascending pathways can lead to alterations in the immune, endocrine, and nervous responses.

Keywords: Gut; Microbiota; Therapeutics; Neurodegenerative Disease.

RESUMEN

Existe un intercambio de papeles conocido como red bidireccional entre el cerebro e intestino con varias conexiones que incluyen el nervio vago, el sistema inmune, metabolitos y productos bacterianos, durante la disbiosis, se produce alteración de la permeabilidad de la barrera hematoencefálica y neuroinflamación. Esta revisión tuvo como objetivo describir el rol de la microbiota intestinal y su papel terapéutico en enfermedades neurodegenerativas. El eje microbiota-intestino-cerebro incluye como tal un conjunto de microorganismos entre ellos bacterias (*Lactobacillus* y *S. Aureus*) de los más comunes, hongos y virus por demás que cumplen un papel importante cuando hablamos del intestino, entre sus funciones está proteger al intestino como efecto barrera y no permitir el paso de bacterias o en si patógenos externos al intestino, también de metabolizar carbohidratos y la producción de vitamina K, B12, B7, sin embargo cuando está microbiota se ve alterada debido al estrés, la dieta o algún otro factor la comunicación mediante vías ascendentes provoca alteraciones en la respuesta inmunitaria, la endocrina y la nerviosa.

Palabras clave: Intestino; Microbiota; Terapéutica; Enfermedad Neurodegenerativa.

INTRODUCTION

There is a well-known exchange of roles known as the bidirectional gut-brain axis, with several connections including the vagus nerve, the immune system, metabolites, and bacterial products. During dysbiosis, there is alteration of the blood-brain barrier permeability and neuroinflammation.⁽¹¹⁾ The gut microbiota hosts a trillion

microorganisms, including anaerobic and aerobic bacteria such as *Escherichia coli* and *Lactobacillus*, among the most common,⁽²⁾ as well as fungi and viruses that allow for the recovery of metabolic energy, nutrients, and host defense against invasion by external microorganisms.⁽³⁾

The “microbiota-gut-brain axis” is a bidirectional communication system regulated by the nervous, immune, and endocrine systems, in which microorganisms play a complex role. Through the enteric nervous system, the secretions of the digestive tract, movements, blood flow, and mucosa are controlled, influencing the intestinal flora. This system is connected to the central nervous system via the vagus nerve through bidirectional neurochemical signals.⁽⁴⁾ The gut flora generates acetic, propionic, and butyric acid that control and regulate the intestinal microbiota through immunity and bodily fluids, allowing for a dynamic balance of the same.⁽⁵⁾

Neurodegenerative diseases are composed of a heterogeneous group of symptoms with a common denominator: the involvement of the central nervous system through progressive neuronal loss and dysfunction, starting in specific areas and progressing over time. The most common are Alzheimer’s and Parkinson’s diseases.⁽⁶⁾ Analysis of 157 epidemiological studies worldwide between 1980 and 2009 determined that the prevalence of dementia is between 5-8 % in individuals over 60 years old, with an increase according to age and predominance in women.⁽⁷⁾ As for Alzheimer’s disease, another meta-analysis that included eight European studies showed a predominance in females (7,1:3,3) and an increase with age up to 22,5 % in individuals over 85 years old (8).⁽⁸⁾

The data revealed by the EURODEM study showed an incidence rate of 1,3/1000 individuals per year, with a higher risk in the age group between 65-69 years old and 24/1000 individuals per year for those over 90 years old. The NEDICES (Neurological Disorders in Central Spain) study in Spain showed an incidence of 1,4/1000 individuals per year for those 65 years old and above.⁽⁷⁾

The composition of the microbiome is not static; it must adapt to its environment and the functions it performs. When there is an imbalance, the development of neurodegenerative diseases is facilitated. Therefore, if we come to understand the intestinal microbiota and its role from a neuroimmunoendocrinological perspective, along with epigenetic factors such as diet, age, and antibiotic use, we can build the foundation for future research and potential cures for these types of diseases.⁽¹⁰⁾

By describing the role of the intestine as a therapeutic plan in people with neurodegenerative diseases in relation to the function that the microbiota plays with the brain through the mechanism that interferes with the intestine in diseases such as Alzheimer’s and Parkinson’s disease.

METHODS

A bibliographic review was carried out based on a systematic search. The systematic search was conducted with the help of open-access scientific databases such as Hindawi, Pubmed, using the PRISMA methodology. A search was performed using bibliographic descriptors such as DECS and MESH, connectors such as “and, or, not” with keywords such as: Intestine-microbiota-therapeutic-Neurodegenerative to improve the search.

The search was limited to the period from 2012 to January 2023. The data were processed using a synthesis table of results that includes titles, authors, year, place, population, and conclusions.

Primary and secondary articles were included, while clinical case presentations, letters to the editor, and degree theses were excluded. The final number of included articles was 17 (Figure 1).

RESULTS AND DISCUSSION

A large part of the current literature supports the theory that describes the intestinal microbiome as a key adapter of the “microbiota-gut-brain axis,” influencing decisively the understanding of intestinal pathophysiology and its manifestations in brain functions.^(9,11) The intestinal microflora hosts a set of abundant and diverse microorganisms with a great impact on intestinal homeostasis and immunity.⁽⁷⁾

Table 1 shows the main results and conclusions of the studies included in the review.

Most of the microorganisms that predominate and regulate host physiology are part of the normal digestive tract, which is known as commensal microflora. Their functions include nutrition and metabolism, as the enteric flora fulfills its function by metabolizing undigested food substrates, endogenous mucus, and cellular detritus (cellular waste).⁽¹²⁾ In the cecum and right colon, the fermentation of non-digestible carbohydrates by the host takes place, which functions as an important source of energy necessary for bacterial proliferation and the production of SCFA that the host can absorb (known as energy recovery). There is also absorption of ions such as calcium, magnesium, and iron in the cecum. In addition, the production of vitamins K, B12, B7 (biotin), B5 (pantothenic acid), and folic acid.⁽¹³⁾

Among the protective functions, there is the barrier effect due to the defensive function, while a balance between resident bacteria confers firmness to the set of microbial population. Trophic functions include cell proliferation and differentiation of epithelial cells.⁽¹⁴⁾

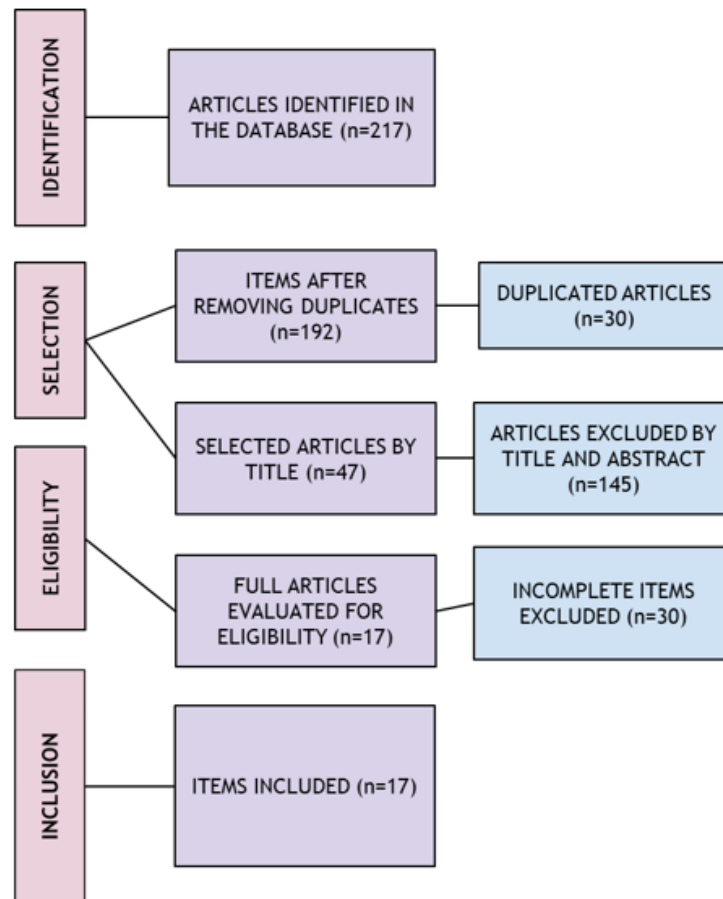


Figure 1. PRISMA Flowchart

Table 1. Main results and conclusions of the included studies

Author, location	Year	Results
Quigley EMM. ⁽²³⁾ , United States	2017	Animal models that have been used for study have responded to studies with an altered gut microbiota in various central nervous system disorders including PD AND AD. However, studies in humans are scarce.
Cryan JF et al. ⁽¹⁹⁾ , Sweden	2019	The brain and the microbiota will communicate with each other through several pathways, including the immune system, tryptophan metabolism, SNE and vagus nerve, among them involving microbial metabolisms (SCFA, branched-chain amino acids and peptidoglycans).
Socala K et al. ⁽²⁰⁾ , Poland	2021	The role of the gut microbiota in the bidirectional communication between the brain and the gut suggests that gut microorganisms can lead to neural development, neurotransmission and thus affect behavior and thus pathogenesis, neurological and neuropsychiatric disorders.
Tonini et al. ⁽²⁴⁾ , Brazil	2020	Bidirectional communication between the gut and brain is known to occur via the vagus nerve, enteric nervous system (ENS), hypothalamic-pituitary-adrenal (HPA) axis, neurotransmitters and immune pathways. Nine of the 10 studies analyzed demonstrated the efficacy of probiotics in reducing depressive symptoms. The most commonly used probiotics in the studies were Lactobacillus, Bifidobacterium and Lactococcus lactis W19, which helped reduce inflammation exponentially.
Rutsch et al. ⁽¹⁾ , Germany	2020	The microbiota comes into contact with the immune system at mucosal sites, giving way to immune tolerance to commensal microbes and balancing mucosal integrity at the same time. In addition, distal organs between them are affected and mainly the brain, in particular, undergoes dramatic changes in early stages of life.
Fung TC ⁽²⁾ , United States	2020	Inflammatory bowel disorders are associated with neurophysiological and behavioral symptoms. However, many CNS disorders are accompanied by intestinal complications. These observations suggest that intestinal and nervous system physiology are functionally related.
Kim & Shin ⁽³⁾ , South Korea	2018	Neuroscience research studies suggest that gut microorganisms are critical to the development and maturation of brain systems related to a stress-derived response.

Almaguer Mederos et al. ⁽²¹⁾ , Cuba	2018	The PMH revealed certain previously unknown relationships between humans and their microbiota and hints at the influence of the microbiome on various biological events and processes involved in human health and disease.
Richarte et al. ⁽¹⁰⁾ , Spain	2018	Colonization of bacteria in the gastrointestinal tract depends on several factors, including delivery and method of postpartum feeding.
Garre. ⁽⁷⁾ , Spain	2019	Modification of the permeability of the intestine, since an increase in its permeability between cells of the intestinal epithelium allows bacterial products, cytokines and chemokines to cross into the circulation and the blood-brain barrier, contributing to systemic inflammation, as well as the alteration of BBB and, therefore, neuroinflammation.
Șchiopu et al. ⁽¹¹⁾ , Romania	2022	Through the sympathetic and parasympathetic pathway there is a bidirectional regulation and influence on cognition, emotion and behavior in addition to the functionality of the gastrointestinal system with its roles as digestion, absorption and enteric immune system.
Guillot. ⁽²⁷⁾ , Ecuador	2018	Symbiotics are a combination of probiotics and prebiotics. They have a characteristic modulatory effect on the intestinal microbiota. They have been shown to increase the survival rate of probiotics in the upper GI tract. Breast milk is a notable symbiont because it contains lactic acid bacteria and bifidobacteria (lactic acid bacteria). Modulation of the intestinal microbiota currently appears to be a novel therapeutic strategy.
Suganya et al. ⁽¹²⁾ , South Korea	2020	Studies have shown that the gut microbiota influences central nervous system and nervous system development, function and disorders through the interaction and activation of pattern recognition receptors, such as Toll-like receptors 2 and 4 (TLR2) and TLR4. Intestinal dysbiosis and the associated loss of intestinal barrier integrity and intestinal permeability allow for increased translocation of intestinal bacterial-derived metabolites and microbial-associated molecular patterns into mesenteric lymphoid tissue, leading to the progression and development of various nervous system diseases.
Wang et al. ⁽¹³⁾ , China	2019	It has been shown that a restoration of dysbiosis of the microbiome induced by various factors by administration of probiotics or FMT of commensal gut bacteria allows the restoration of adaptive immunity functions that are suppressed in humans and mice.
Andreo-Martínez et al. ⁽²⁹⁾ , Spain	2019	Dysbiosis of the microbiome or a problem in the intestinal flora can induce inflammation in the gut that will be associated with obesity, DM2 and Alzheimer's disease.
Garre Olmo. ⁽⁸⁾ , Taiwan	2018	Dementia is a rare syndromic disease, where it is subdivided into several types and differs in etiology, presentation, clinical course and associated disorders.
Gomez-Eguilaz et al. ⁽⁹⁾ , Taiwan	2019	The microbiota-gut-brain axis is targeted as a possible pathogenic foundation of high-impact neurological diseases such as AD, PD or multiple sclerosis.
Takiishi et al. ⁽¹⁴⁾ , Brazil	2017	The gastrointestinal tract is considered the largest immune organ in the body and plays a central role in the regulation of immune homeostasis. Contrary to previous assumptions, the intestinal epithelial barrier is not a static physical barrier, but interacts strongly with the intestinal microbiome and immune system cells.
Pavón Fuentes et al. ⁽¹⁶⁾ , Cuba	2019	Activated T cells can cause neuronal damage through cell-cell contacts. The α -synuclein may play a role in the observed microglial activation and increased expression of MHC-II molecules in the SNpc.
Chen et al. ⁽⁸⁾ , Taiwan	2022	The genetic inheritance of Parkinson's disease with respect to immune responses, and poor mitochondrial function will lead to vulnerable neurons that are sensitive to environmental factors and, with it, neuronal degeneration.
Mulak et al. ⁽¹⁷⁾ , France	2017	PD will be characterized by α -synucleinopathy affecting all structures of the brain-gut axis, including the CNS, ANS and ENS.

The Autonomic Nervous System (ANS) allows for the homeostasis of the gastrointestinal tract through the neuroendocrine axis and therefore obtains a response from the intestine such as its permeability, movement, mucosa, and immune responses of the intestine, which are part of the efferent pathway. Local signals such as anxiety, dysbiosis, and pain, i.e., an external factor, will be modulated and transmitted to the central nervous system as afferent pathways through the sympathetic and parasympathetic systems, resulting in responses in connected brain areas.⁽¹⁵⁾

The main communication pathway that exists between these systems is the vagus nerve, which acts by transporting signals from the microbiota and alteration stimuli, as well as directing responses from the brain with direct activation of vagal ganglia after intestinal inoculation, as demonstrated in model mice, and its connectivity with anxiety with inflammatory responses. These afferent pathways transmit information through a fiber density from the duodenum to the transverse colon. The ANS is connected to the Enteric Nervous System (ENS), which activates the vagal-vagal reflexes that regulate motility, the balance of the microflora, and mucosal function.

The intestinal tissue, which is a dense mucosal layer, plays an important role in being protective and a center of coordination between the intestinal lumen and the internal environment. The enteric immune system distinguishes autoantigens and eliminates possible threats from foreign microorganisms. It also has mechanisms that could accept and provoke inflammatory responses.

Parkinson's disease (PD) is a neurodegenerative disorder characterized by neuroinflammation and loss of dopaminergic neurons.⁽¹⁶⁾ It has been discovered that specific cells in the intestinal epithelium (enteroendocrine cells) contain properties similar to neurons, including the expression of alpha-synuclein, since this protein being misfolded allows the formation of Lewy bodies characteristic of this pathology and its anomalous accumulation, which leads us to think about the progression of the disease.⁽¹⁷⁾ Due to its contact with the intestinal lumen and its sympathetic connection, enteric neurons create a neural circuit that goes between the gastrointestinal tract and the ENS.⁽⁸⁾

Pathogenic microbial flora produces toxic amino acids (isoleucine, phenylalanine) that stimulate toxic lymphocytes such as T helper lymphocytes (Th1) and extracellular growth bacteria (Th17) in peripheral blood. These cells cross the blood-brain barrier (BBB) producing a neuroinflammatory reaction in the brain. They activate microglial cells to produce neuroinflammation and activate the production of amyloid and phospho-tau, all of which are considered to be Alzheimer's neurodegeneration inducers.^(13,18)

A systematic review concluded that both the brain and the microbiota are interconnected through pathways involving the immune system, tryptophan metabolism, the enteric nervous system, and the vagus nerve, which is the most essential pathway for the mechanism of this axis, involving microbial metabolites such as SCFA, branched-chain amino acids, and peptidoglycans.

Stress and inflammation play key roles in the pathophysiology of diseases in which the microflora can be involved. Stress is involved in depression, psychiatric disorders such as schizophrenia and autism spectrum disorder, migraine, and epilepsy. However, it is important to note that inflammation is the trigger and therefore important in the aforementioned disorders, adding Parkinson's disease and Alzheimer's disease.

Rutsch et al.⁽¹⁾ and Almaguer Mederos et al.⁽²¹⁾ suggest that the contact of the intestinal microflora with the immune system at mucosal sites promotes immune tolerance to commensal microbes, balancing host mucosal integrity at the same time. Lotti-Mesa et al.⁽²²⁾ mention that when one of these pathways is altered, the most affected organs are the distal organs, primarily the brain, especially since it undergoes dramatic changes in early life stages, where the emergence of the intestinal microbiota is also influenced.

In recent years, it has become evident that microorganisms can also produce neuroactive molecules that are directly attributed to the communication between the intestine and the brain. The neurotransmitters involved are acetylcholine, GABA, and serotonin, which are preceded by bacteria corresponding to lactobacillus, bifidobacterium, Enterococcus, and Streptococcus species, which directly and indirectly influence the physiology of brain cells. Rutsch adds that 90 % of serotonin required for mood, sleep, behavior, and various functions within the central nervous system and the gastrointestinal tract is produced in the intestine.

Contrary to the results of previous studies, Quigley⁽²³⁾ determined that in animal models such as mice with altered intestinal microbiota, they are associated with central nervous system disorders such as Parkinson's and Alzheimer's disease, however, studies in humans are scarce and lack relevance.

Fung et al.⁽²⁾ state that inflammatory bowel disease, being a chronic inflammatory infection that affects the digestive tract and has a multifactorial etiology, is one of the multiple diseases directly associated with the microbiota, and its causal role of the microflora in inflammatory bowel disease has been the most recognized. Intestinal microbes are drivers of intestinal inflammation in a pathological way, thanks to the breakdown of physical and immune mechanisms that maintain the separation between intestinal microbes and the host's immune system, and the relationship this has with neurodegenerative diseases.

A novel element reported by Tonini et al.⁽²⁴⁾ indicates that the bidirectional communication between the gut and the brain occurs thanks to the action of the vagus nerve, the enteric nervous system, the hypothalamic-pituitary-adrenal axis, neurotransmitters, and the immune system. Nine out of ten studies analyzed demonstrate the great efficacy of probiotics in reducing depressive symptoms and inflammation, with lactobacillus, bifidobacterium, and lactococcus lactis W19 being among the most commonly used.

Kim et al.⁽³⁾ suggest that gut microorganisms are fundamentally important for the development and maturation of brain systems that are related to a stress-derived response.

Among its mechanisms, Richarte et al.⁽¹⁰⁾ point out the modification of gut permeability, as an increase in permeability allows bacterial products, cytokines, and chemokines to cross into circulation and the blood-brain barrier, contributing to systemic inflammation, as well as alteration of the blood-brain barrier and hence, neuroinflammation.

Noradrenaline, dopamine, and serotonin with precursors such as phenylalanine, which in excess can increase oxidative stress and alter metabolism, tyrosine, and tryptophan, structurally analogous to those of the host's nervous system, are derived from the microbiota and allow for absorption through the intestinal epithelium. They also allow entry into circulation and passage through the barrier.

Based on ROMA IV criteria, Şchiopu et al.⁽¹¹⁾ attribute the mechanism by which the gut microbiome is related to the brain to the vagus nerve, as well as neuronal, immune, metabolic, and hormonal reactions. It includes 3 centers of the axis, the autonomic nervous system that maintains the gastrointestinal tract's homeostasis of endocrine, behavioral, and motor signals, allowing it to monitor the information received from the central nervous system and the neuroendocrine axis ensuring the intestinal response in terms of permeability, motility, and mucosal status. It was also demonstrated that tryptophan, catecholamines, and serotonin interact with this system and influence the pathways that induce cognitive changes.

According to their reviews of studies among the mechanisms of neuro-immunity, a deficiency of lymphocytes results in cognitive and anxiety disorders that can be treated with probiotics of lactobacillus species, as affirmed by Suganya et al.⁽¹²⁾ They also mention that the gut microbiota intervenes in the process, function, and disorders of the central nervous system and enteric nervous system through interaction and activation of pattern recognition receptors, such as Toll-like receptors two and four (TLR2, TLR4), and when there is a reversal of roles, i.e., intestinal dysbiosis and with it the loss associated with the integrity of the gut barrier, its permeability will allow greater translocation of metabolites from intestinal bacteria and patterns related to microbes in mesenteric lymphoid tissues, corresponding to various neurological diseases such as Parkinson's and Alzheimer's disease.

Regarding adaptive immunity, Wang et al.⁽²⁵⁾ and Caputi et al.⁽²⁶⁾ argue that not only Toll-like receptors but also Th17 cells, which are essential in defending against pathogens, particularly in cases of bacterial and fungal infections. They are also important for the production of specific high-affinity bacterial immunoglobulin A. Similarly, Tfh (intestinal T follicular cells) stimulate the production of high-affinity cells.

As a novelty, Guillot⁽²⁷⁾ concludes that symbiotics are a combination of probiotics and prebiotics that are characterized by their modulatory effect on the intestinal microflora. These are necessary and therefore indicated to help improve the survival of probiotic microorganisms during transit through the upper digestive tract, and in this way, achieve better implantation in the colon and stimulate the process of probiotic colonization and growth. Specifically, their specific substrate is necessary to initiate the intestinal fermentation process, which is why breast milk is a highly important symbiotic that contains lactobacillus and bifidobacteria, which are lactic acid bacteria.

Adak et al.⁽²⁸⁾ found that managing the gut microbiota is seen as a new therapy strategy through diet, probiotics, prebiotics, and other routes, allowing for the treatment of gastrointestinal disorders and consequent neurodegenerative diseases.

Similarly, Chen et al.⁽⁸⁾ demonstrated that the ingestion of 2-fucosyllactose as an oligosaccharide through breast milk has an action on the hippocampus that improves memory patterns, learning ability, and markers of cerebral synaptic plasticity related to the microbiota-gut-brain axis and the vagus nerve.

Andreo Martinez et al.⁽²⁹⁾ found that the intestinal microflora is involved in the generation of GABA, neurotrophic factors from the brain, serotonin, and other molecules that are necessary for the proper functioning of the central nervous system. Parkinson's disease is considered a central nervous system disorder that affects the basal ganglia, a term coined from the use of the word "gray nucleus" at the base of the brain. During the course of the disease, more motor symptoms occur than motor nerve system-related ones.

Using positron emission tomography, Pavón Fuentes et al.⁽¹⁶⁾ showed that patients with Parkinson's disease have a significant increase in neuronal inflammation markers in the bridge, basal ganglia, striatum, and frontal and temporal cortex compared to age-matched controls. Alpha-synuclein alterations may be due to genes that code for this protein, mutations on chromosome 4q, or the appearance of an extra copy that is not mutated from the alpha-synuclein gene. This is linked to the intestinal microbiota because the microorganisms present in it directly affect brain function by regulating immune responses, intestinal permeability, and short-chain fatty acids (SCFA) produced by these gut microbes. These acids act as energy for colonocytes covering the colon epithelium and, above all, regulate the intestinal barrier, influencing inflammatory responses.

According to Suganya et al.⁽¹⁸⁾ and Chen et al.⁽⁸⁾, the intestine generates a continuity of products provided by the intestinal microbiota, which exert their influence on the central nervous system, such as short-chain fatty acids, secondary bile acids, or tryptophan metabolites. They act in two ways: by firing ascending signals that activate at the local level or by crossing the intestinal barrier to enter the systemic circulation, even trying to act on the central nervous system after crossing the blood-brain barrier (BBB).

Mulak et al.⁽¹⁷⁾ mention that short-chain fatty acids are microbial metabolites of the gut and are important because they are produced from the fermentation of dietary fibers in the digestive tract. Acetate, butyrate, and propionate are the main fatty acids produced by bacteroidetes and Firmicutes. Afterward, they are immediately absorbed into the portal circulation and transferred to peripheral tissues, including the brain, where they play a crucial role in regulating neurological functions.

Wang et al.⁽³⁰⁾ report that risk factors for Alzheimer's disease include the presentation of phenylalanine and isoleucine, which induce differentiation and proliferation of proinflammatory cells (T helper 1). Meanwhile, Pluta et al.⁽³¹⁾ report that peripheral Th1 immune cells found in the brain, when mixed with microglial activation,

result in neuroinflammation associated with Alzheimer's disease.

Limitations of the study

The main limitation of this review is the fact that studies were mainly found on neurodegenerative diseases such as Alzheimer's disease and Parkinson's disease.

CONCLUSIONS

The gut-brain-microbiota axis includes a set of microorganisms including bacteria (*Lactobacillus* and *S. Aureus*) as the most common, fungi, and viruses that play an important role when it comes to the gut. Among their functions are protecting the gut as a barrier effect and not allowing the passage of bacteria or pathogens external to the intestine, as well as metabolizing carbohydrates and producing vitamin K, B12, B7. However, when the microbiota is altered due to stress, diet (primarily with the consumption of foods containing phenylalanine or isoleucine), or some other factor that damages the gut flora, it communicates with different ascending pathways to transmit information to the immune, endocrine, and nervous systems. Neurotransmitters such as serotonin and GABA detect and respond to inflammation in the case of Alzheimer's disease or an increase in Lewy bodies in Parkinson's disease. Based on these findings, it can be affirmed that if we address gut health and specifically the way we eat (probiotics, prebiotics, symbiotics), the capacity to perform gut functions correctly will be strengthened.

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AUTHORSHIP CONTRIBUTION

Conceptualization: María Paz Valdivieso, Julio Ojeda, Jorge Ochoa.

Research: María Paz Valdivieso, Julio Ojeda, Jorge Ochoa.

Methodology: María Paz Valdivieso, Julio Ojeda, Jorge Ochoa.

Project administration: María Paz Valdivieso, Julio Ojeda, Jorge Ochoa.

Original drafting and editing: María Paz Valdivieso, Julio Ojeda, Jorge Ochoa.

Writing, revising and editing: María Paz Valdivieso, Julio Ojeda, Jorge Ochoa.