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PARKINSON'S DISEASE: A MULTITUDE OF BRAIN DISTURBANCES

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ABSTRACT

Parkinson's disease (PD) is the most widespread neurodegenerative disease following Alzheimer's disease (AD). An increased risk of the disease has been observed due to exposure to environmental pollutants and prior traumatic brain damage. PD presents with motor disorders and other disabling symptoms, such as cognitive deterioration, mood changes, depression, muscle stiffness, and tremors, that can predict the arrival of the disease. Symptoms manifest with balance disorders, uncertainty in walking, hunched posture, and slowness in speaking, amongst others. The neurodegeneration that occurs in PD is mediated by dysfunctions that fuel the pathological state. There is neuronal degeneration of the substantia nigra with a reduction in dopamine levels, a lower concentration of neuromelanin, and a reduction of mitochondrial respiratory activity. Various factors are involved in the disease and contribute to abnormal immunological and inflammatory reactions. The immune disorder that occurs involves microglia in the brain and other cells, causing the release of inflammatory cytokines and chemokines, which contributes to the death of dopaminergic neurons and destroys the blood-brain barrier, with infiltration of toxic substances into the brain. Microglia have pattern recognition receptors that bind abnormal proteins that enter the brain to eliminate them. Damage-associated molecular patterns (DAMPs) bind toll-like receptors (TLRs) and activate the NF-kB pathway with the secretion of cytokines such as TNF, IL-1, IL-6, and the chemokine CCL-2, contributing to the pathogenesis of PD.

KEYWORDS: *Parkinson's disease, neurodegeneration, brain, immune, inflammation, dopamine*

INTRODUCTION

Parkinson's disease (PD) affects approximately 1% of people over the age of 65 in industrialized countries (1). The disease was first described by the English physician James Parkinson in 1817 as "shaking palsy" (2). PD is a complex multifactorial and progressive disease that leads to other brain disorders, including immune dysfunction that results in neuroinflammation. In recent decades, much progress has been made regarding the pathogenesis of the disease. However, many points remain unclear, and therefore, further studies are required.

After Alzheimer's disease (AD), PD is the most common neurodegenerative disorder affecting the populations of industrialized countries (3). It is an idiopathic disease with an unknown cause and is not accompanied by other disease

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processes. PD is also a genetic disease; in fact, several mutated genes are involved (4). The pathology occurs due to the loss of cells that produce the neurotransmitter dopamine.

PD presents with the following cardinal symptoms: muscle rigidity of the neck, trunk, and limbs, tremors (also visible from head movement), bradykinesia, speech and swallowing impairment, postural instability, dystonia, shuffling gait, loss of smell, death of neurons, and balance disorders, which are symptoms that can increase in case of psychological difficulties such as anxiety. Non-motor symptoms that appear early at the beginning of the disease could lead to faster diagnosis of PD (5). Moreover, the PD patient may suffer from depression and slowness in verbal expression.

The disorder is characterized by the loss of dopaminergic neurons of the substantia nigra pars compacta, with a lower concentration of melanin, reduction of dopamine, and a long course (6). Dopamine is an important neurotransmitter that allows for communication between nerve cells in the brain. In PD patients, there is a lower activity of alpha-ketoglutarate dehydrogenase, an enzymatic complex belonging to the class of oxidoreductases, participating in the Krebs cycle (7,8). Therefore, there is a reduction in mitochondrial activity and the loss of Lewy body protein inclusions in the PD patient (9).

The causes of the disease are diverse, including environmental and genetic factors, but also brain lesions, infections, brain neurotoxins, and oxidative damage. It appears that individuals who take xanthine derivatives, such as caffeine or theophylline, have a reduced risk of neurodegenerative disease (10). One interesting theory claims that PD is caused by misfolded proteins in the brain, as happens with prions (11). The disease has been seen to worsen in polluted environments and with advanced age (12, 13), two elements that coincide with the dysfunction of the immune system (Table I).

Table I. *Some factors that may contribute to Parkinson's disease (PD) pathology.*

Contributing factors:		
▪ mitochondrial dysfunction	▪ brain lesions, infections	▪ DNA methylation
▪ lower alpha-ketoglutarate dehydrogenase activity	▪ brain neurotoxins	▪ histone modifications
▪ environmental and genetic factors	▪ oxidative damage	▪ altered microRNA expression
▪ sleep disorders		
Risk factors:		
▪ pesticides	▪ alcohol consumption	▪ place of residence
▪ heavy metals	▪ diet	▪ lifestyle
▪ industrial chemicals	▪ vitamin D	▪ professional activity
▪ foods rich in animal fats (saturated or unsaturated)	▪ smoking	

In recent years, many pharmacological therapeutic improvements have been made, although the progressively worsening course of PD makes it difficult to treat. The interactions between an altered immune system, unfavorable environmental factors, and ageing can lead to PD pathology. In this disorder, innate immunological activation can occur through pathogen-associated molecular patterns (PAMPs), and self-originated damage-associated molecular patterns (DAMPs) which can induce "sterile inflammation" through the toll-like receptors (TLR)s (14). Microglia have pattern recognition receptors such as TLR2, TLR4 and TLR6, that bind abnormal proteins that enter the brain to eliminate them.

The alteration of the immune system can involve both T and B cells with the production of autoantibodies. The cerebral lymphatic ducts are rich in B cells, T cells, and antigen-presenting cells, which protect the central nervous system (CNS) from external insults and endogenous changes. Molecules foreign to the body, antibodies, and immune cells can enter through disruption of the blood-brain barrier in neurodegenerative diseases, including PD (15). Experiments on rodent PD models have shown that in systemic inflammation, macrophages migrate into the cerebral tissue and transform into microglial cells, which are more present in the substantia nigra (16).

Immunity in Parkinson's disease

Activation of lymphocytes leads to an increase in CD3+, CD4+, and CD8+ T cells in the substantia nigra, a reaction that causes neuronal damage. Activated immune cells can produce low levels of inflammatory mediators such as the cytokines IL-1β, IL-6, TNF (the receptor of this cytokine is more expressed in T cell patients), and other mediators that contribute to disease. These cytokines are released by activated microglial cells that occupy the substantia nigra and other brain areas involved in PD. Nitrogen monoxide, also called nitric oxide (NO), is an endogenous mediator of vascular processes involved in PD (17).

Activation of the innate immune system driven by microglia causes neuroinflammation, contributing to the death of neurons. The NLRP3 inflammasome signal in microglia is a complex that includes several proteins involved in the inflammatory process in PD. Microglia are similar to monocytes, and in PD, they have CD14 receptors activated, which causes them to increase in number and contribute to the inflammatory state (18). Elevated microbial infections with lipopolysaccharide-producing Gram-negative bacteria, which cause elevated type II interferon (IFN-γ) levels, can also lead to PD. CCL2 chemokines are activated in the disease and contribute to the recruitment of inflammatory monocytes. In addition, both CCL2 and CXCL8 chemokines are elevated in PD and contribute to the recruitment of the lymphocytic and neutrophil lineages, respectively (19). Therefore, dysfunctions of innate immune molecules may be contributing factors to PD.

In the brain of PD patients, in addition to circulating monocytes, activated CD3+, CD4+, CD8+, and Treg lymphocytes can also be found in the substantia nigra and contribute to the pathogenesis of the disease (20). This concept demonstrates that adaptive immunity also participates in brain damage.

In PD, there is a lower number of circulating CD4+ cells than in healthy subjects, while CD45RO+ memory cells are increased (21). This dysregulation is due to a deficiency in the neurotransmitter chemical messenger L-dopa. Regarding Treg cells, although conflicting results have been reported, it seems that dopamine deficiency leads to a lower reactivity of these T cells, a phenomenon correlated with the severity of the disease.

Dopamine receptors are different, ranging from D1 to D5, and are found to be highly expressed on B cells, memory T cells, and natural killer (NK) cells, while they are expressed in lower quantities by neutrophil granulocytes. It seems that the D3-type dopamine receptor is the one most associated with the pathological state of the disease (22). In PD, the CD95/CD3 ratio in lymphocytes is higher than in healthy subjects, and this appears to be linked to low levels of dopamine (23). In fact, after administration of L-Dopa, the CD95/CD3 ratio was found to be decreased (23). Levels of pro-inflammatory cytokines can also be reduced by dopamine administration, an effect that is mediated by microglia.

The number of dopamine receptors on T cells correlates with the severity of the disease. In fact, in PD, the T lymphocytes showing elevated levels of TNF receptors are more suppressed by this cytokine. Along with the inflammatory cytokine IFN-γ, this reaction increases with consequent immunosuppression and inflammation (Table II).

Table II. *Some of the over 50 immune, non-immune, and inflammatory biomarkers in PD.*

Inflammation factors:	IL-1β, TNF-α, IL-2, IL-6, IFN-γ, IL-15 (in serum), and other cytokines. NLRP3 inflammasome signal, TNFR1 (in serum), macrophage-migration Inhibitory Factor (MIF). Nitric oxide (NO).
Lymphocytes:	CD3+, CD4+, CD8+, CD95/CD3, NK cells, and others.
Chemokines:	RANTES, MCP-1 and MIP-1α (in PBMC supernatant), CCL2, and CXCL8 (IL-8)
Antibodies against different molecules and autoantibodies.	

Patients with PD have microglial cells with excess levels of MHC-II (24) and CD4+ and CD8+ lymphocytes, which is correlated with the severity of the disease and the death of neurons. These immune reactions lead to an increase of cytokines such as IL-1, TNF, IL-6, IFN-γ, and inflammatory IL-2 in cerebrospinal fluid (CSF), which induces pro-inflammatory IL-1 (even in an autocrine loop). Moreover, the increase in TNF is correlated with the degeneration of the substantia nigra and the worsening of the disease (25). Therefore, clinical therapies in PD focus on immune dysregulation and inflammation. The higher the pro-inflammatory cytokines and chemokines in the peripheral blood, the more severe PD is. Inflammation mediated by microglial cells is triggered by the activation of MAPK, JAK-STAT and NF-kB, which can be targeted for therapeutic effects.

CONCLUSIONS

In conclusion, in this report, we state that cytokines play a key role in PD, both as regulators of the immune system and as inflammatory molecules causing neurotoxicity, neuronal death, and neurodegeneration. The most widely used treatments today include L-Dopa, dopamine agonists, and anticholinergics. Recently, improvements have been made in the pharmacological therapies for PD, although specific treatments for this disease are still unknown.

Conflict of interest

The author declares that they have no conflict of interest.

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Letter to the Editor

THE INFLAMMATORY RESPONSE IN MENINGITIS

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INTRODUCTION

Infections of the central nervous system (CNS) are diverse and come with high mortality. Such pathologies can include abscesses, encephalitis, and meningitis. Meningitis is a very ancient infectious disease which was already mentioned by Hippocrates and, in 1805, the first epidemic outbreak appeared in Europe (1). In 1806, the disease was identified in the United States and later appeared in Africa in 1905 (2). Meningitis is an acute inflammation of the meningeal membranes that surround the brain and spinal cord. The disease can occur after an infection caused by a microorganism. Bacterial meningitis can be very serious with a high risk of complications that can lead to death (3), while viral meningitis is normally less serious (4).

Patients with meningitis may present with purulent cerebrospinal fluid (CSF) and seizures, with the latter often occuring in children. The symptoms of meningitis may include headache, stiffness of the neck, nausea and/or vomiting, high fever, drowsiness, and convulsions (Table I). The most common cause of bacterial meningitis is Neisseria meningititis (Nm), which can produce convulsions and coma, and the prognosis is unfavorable for the elderly.

Table I. *Various forms of meningitis and some symptoms.*

Forms:
Acute bacterial meningitis, viral meningitis, non-infectious meningitis, recurrent meningitis, subacute and chronic meningitis
Symptoms:
Stiffness of the back of the neck, high fever, headache, nausea, vomiting, convulsions, seizures, drowsiness, focal neurologic deficits, papilledema, deterioration of consciousness, photophobia

Microglia and macrophages from the bone marrow are involved in the primary response to infection and release various cytokines including IL-1, tumor necrosis factor (TNF), and IL-6, and the chemokine IL-8 which attracts neutrophils to the inflammatory site (5).

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CNS infection causes damage and clinical syndromes, which can improve after adequate antimicrobial treatment. An efficient host immune response can cause the elimination of the pathogen with relief for the affected patient.

DISCUSSION

When pathogens invade brain tissue, they induce an immune response with secretion of inflammatory molecules, including cytokines. These reactions cause meningitis, a pathological state that is more frequent in newborns and young children. Meningitis causes increased vascular permeability, tissue damage, and disruption of the blood-brain barrier (BBB) which divides the peripheral circulation and the CNS.

Microglia are primary and relevant immune cells of the CNS which are important for the phagocytosis of bacterial microbial agents that can cause meningoencephalitis in children. In meningitis, these cells are altered and therefore unable to carry out their immunological role. The activation of microglia induces the production of cytokines such as IL-1, TNF, and IL-6, which contribute to meningeal inflammation.

The BBB is an obstacle for the penetration of microorganisms and foreign molecules into the CNS but allows the passage of small molecules such as oxygen and CO2. Newborns may become infected with Streptococcus B following delivery and should be treated promptly with antibiotics, including Ampicillin, Rifampicin and Cefotaxime, which are indicated for the treatment of serious bacterial infections. Furthermore, treatment with cortisone was found to be helpful, although in some circumstances it may not be indicated. Treatment with nonsteroidal anti-inflammatory drugs can also help, but in some cases, it has been noted that they do not increase survival for bacterial meningitis infection.

Bacterial meningitis can affect various age groups, and the pathogenic organisms vary based on the age of the patient. Immune-compromised individuals may be more susceptible to infections that cause meningitis. In addition to bacteria, fungi and viruses can also cause brain infections and therefore meningitis.

In a bacterial meningitis infection, IgA immunoglobulin proteases are disrupted, allowing the proliferation of the pathogenic bacterium (6). This brain pathology is usually caused by the following bacteria: Streptococcus pneumoniae (or Pneumococcus), Nm (or Meningococcus), and Haemophilus influenzae type b (or simply, Haemophilus). The bacteria that are produced travel by bloodstream until they reach the CNS and infect it. The infection induces inflammation and consequently, pathological signs appear. This disease is often not very contagious, but when it occurs, it can lead to encephalitis resulting in nausea, vomiting, headache, fever, epilepsy, cognitive impairment, seizures, and death. Convulsions occur in approximately 17% of adults with bacterial meningitis (7), while epileptic seizures, which can be detected with electroencephalogram (EGG), must be treated by the doctor based on the patient's characteristics.

CONCLUSIONS

Bacterial meningitis is an infection that affects the CNS with serious consequences that can cause mortality. It is an important topic in the field of infectious diseases due to its high degree of incidence and severity. The acute form of meningitis can have a rapid onset of symptoms, and identification of the bacterium can be done routinely in the laboratory. There are several bacteria that can cause meningitis and it can also be caused by viruses or fungi. Fortunately, the vaccine has dramatically reduced the incidence of this disease.

In bacterial meningitis in newborns, fever or hypothermia may be found in approximately 60% of cases (8). The disease can present itself within a few days following infection with the clinical signs mentioned above. The diagnosis should be made after isolating the pathogen in cultures of blood or CSF and after neuroimaging.

Often the signs of meningitis from bacterial infection can be confused with viral, fungal, and parasitic ones. Brain abscesses, CNS tumors, encephalitis, and other infections can also mimic bacterial meningitis.

Therapy should be timely and aggressive to avoid the patient's deterioration or death. Genetic studies are now underway for bacterial meningitis and new therapies utilize the inhibition of complement and metalloproteinases and anti-inflammatory cytokines that can block IL-1, TNF, and IL-6. However, further studies are needed to improve the treatment of meningitis.

Conflict of interest

The authors declare that they have no conflict of interest.

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Letter to the Editor

AUTOANTIBODY-MEDIATED ENCEPHALITIC SYNDROMES

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INTRODUCTION

In recent years, there has been increasing interest focused on the study of autoantibodies that attack neurons. Encephalitis is inflammation of the brain parenchyma that is characterized by neuropsychiatric symptoms and can be mediated by autoantibodies, viruses, vaccines, and other biological agents. In 'autoimmune encephalopathy', autoantibodies can attack neuronal proteins and receptors, resulting in psychosis, decreased levels of consciousness, and cognitive and memory deficits (1). This may produce psychiatric symptoms and movement alterations, convulsions, and severe amnesia, as well as inflammation of the vertebrae and optic nerves, effects which depend on the type of antibody (Table I).

Table I. *Some symptoms of encephalitis.*

• Confusion	• Seizures	• Agitation
• Depression	• Psychosis	• Drowsiness that can lead to coma and death
• Fatigue	• Paralysis	• Personality changes or confusional state
• Headache	• Numbness	• Short-term memory loss
• Fever		

Current therapies present a number of side effects which could overlap with the pathological effects caused by autoantibodies, and therefore, more specific therapies are needed. This paper reports the mechanism of action of autoantibodies in the brain and their biological and pathogenic effects in relation to inflammatory and immunotherapeutic processes.

DISCUSSION

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Autoantibodies are key proteins that cause autoimmune diseases (Table II). They form immune complexes with self-antigens and recruit and activate inflammatory immune cells upon complement activation. When immune complexes are deposited in blood vessels, they cause vasculitis; while if they are deposited in the tissues, they recruit neutrophilic granulocytes and macrophages which release hydrolytic enzymes that cause tissue damage (2).

Table II. *Some symptoms resulting from the attack of autoantibodies in the brainstem.*

a) Eye movement abnormalities	b) Dysphagia	c) Dysarthria	d) Ataxia (facial)
e) Vertigo	f) Hearing impairment	g) Reduced consciousness	h) Hypoventilation

Antibodies are immune system proteins that are produced by B cells and plasma cells and are capable of distinguishing self-cells, tissues, and organs from non-self cells. The aggression of antibodies towards foreign microorganisms allows the human body to remain healthy. When this system no longer works, the organism enters a pathological state.

Autoantibodies are also proteins, and they derive their name from the fact that instead of acting against foreign antigens (such as viruses, bacteria, fungi, protozoa including amoebae, etc.) that react against their own tissues. The action of autoantibodies, a dysfunction of the immune system, can cause tissue hyperreactivity with inflammation (3). Autoantibodies can destroy cells and tissues, creating organ dysfunction and thus producing an autoimmune disease. The autoimmune disease that is generated by autoantibodies is classified based on the type of organ or tissue affected.

Autoantibodies can affect a single organ, such as the thyroid, joints, the immune system, or brain, or more rarely, the disease can be multi-organ. Clinical manifestations may include pain, fever, muscle weakness, fatigue, allergy, or general deterioration of the organism. The diagnosis of an autoimmune disease involves clinical analysis with the search for antineuronal nuclear antibody (ANNA) and extractable nuclear antigen (ENA), which are antigens that can interact with particular antibodies, triggering an immune response.

When autoantibodies react with brain tissue, they can generate encephalitic syndromes (4) (Fig. 1). Encephalitis is inflammation of the brain which can also affect the spinal cord, and it can be caused by various agents such as viruses, bacteria and their products, proteins, antigens, and autoantibodies. It can cause diverse symptoms with a wide range of severity (5).

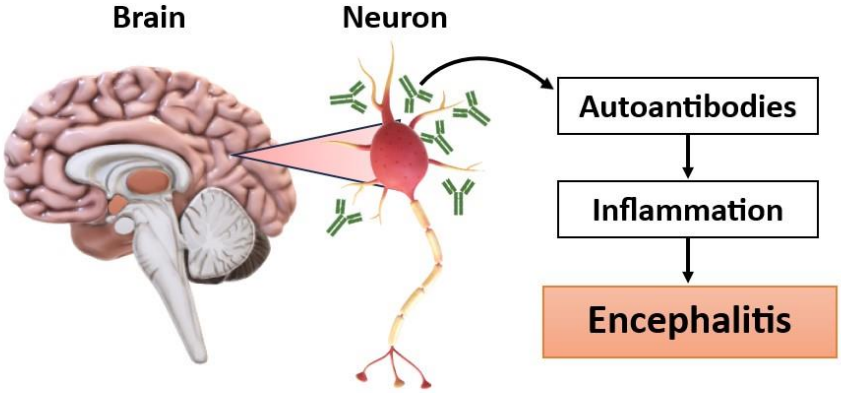

Fig. 1. *In the brain, autoantibodies can attack neurons, causing inflammation and encephalitis.*

The diagnosis of encephalitis is often made after performing magnetic resonance imaging (MRI) of the brain and a lumbar puncture. If the encephalitis is caused by a viral agent, therapy involves the use of antivirals which, by lowering the viral load, also reduce inflammation.

Autoantibody-mediated encephalitis is a type of autoimmunity against the CNS with serious and sometimes long-lasting neurological damage (5). This acute onset disease, which progresses in a period of days to weeks, may have a correlation with epilepsy and other neurologic dysfunctions (6). The syndromes can be different but are both caused by autoantibodies that attack neuronal antigens (which can be extracellular or intracellular). One of the receptors to which the autoantibody binds may be N-methyl-d-aspartate (7), which can cause convulsions, inflammation, psychosis, and

mood disorders in the affected subject. Autoantibody encephalitis may be mediated by damage to voltage-gated potassium channels and this effect is treatable with immunotherapy (8).

CONCLUSIONS

The study of autoantibody-mediated encephalitis has advanced greatly in the past decade, with *in vivo* and *in vitro* models helping to further the understanding of this disease. However, there are still many questions to be answered about the mechanisms and research must continue to advance the diagnosis process and identify new therapeutic approaches.

Conflict of interest

The authors declare that they have no conflict of interest.

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THE EFFECTS OF GARLIC ON HUMAN HEALTH

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ABSTRACT

Garlic is a well-known dietary supplement that has numerous health benefits for the human body. It contains different antioxidant compounds that protect the body against cardiovascular and neuroinflammatory diseases. In addition, garlic reduces the activation of microglia in the brain and reduces neuroinflammation. Research has already shown the protective effects of garlic in tumor growth and other diseases. However, more studies are necessary to clarify the specific beneficial effects of garlic and its individual components.

KEYWORDS: *garlic, health, allium sativum, inflammation, oxidative stress*

INTRODUCTION

Garlic, or Allium sativum L., is a widely consumed spice around the world and contains water-soluble antioxidant compounds such as S-allyl cysteine (SAC) and S-allyl-mercaptocysteine, as well as 5-hydroxymethylfurfural, organosulfur compounds, and polyphenols, amongst others. These compounds have antioxidant, anticancer, antibacterial, antifungal, and immunoregulatory properties, and help protect the body against cardiovascular and neuroinflammatory diseases (1-4). There are many beneficial effects of garlic. However, this paper summarizes only some important clinical aspects and benefits for human health.

DISCUSSION

After 4,000 years of folkloric praise of garlic, which found use by various populations as a restorer and preserver of health and youth (5), modern science has confirmed some of its beneficial actions and researchers are working to define the important medicinal effects of garlic (6). Recent scientific results suggest that garlic may help prevent, and maybe cure, vascular, ageing, and neurological diseases.

Garlic is a chemically unstable vegetable that contains more than 200 different compounds that can favorably influence the course of many diseases. For example, in laboratory studies, and presumably also *in vivo*, high concentrations of garlic suppress the formation and growth of tumor cells (7-10) and help prevent and counteract atherosclerosis (11) and cardiovascular attack (12). Recently, researchers began investigating the possible role of garlic as a cancer prevention agent. These studies began after it was seen that the Chinese and Italian populations, who consume elevated amounts of garlic as food, seem to suffer less from certain tumors. However, further research is needed to understand the exact mechanisms of garlic compounds in this context.

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The consumption of garlic as a food does not necessarily have to be taken raw, but rather consumed in large quantities (13). It has been noted that it would be better to take it cooked, as it does not lose its beneficial characteristics and causes fewer side effects and adverse reactions such as allergy, anemia, and gastric ulcers (14-17). So, the smell and freshness of garlic do not seem to be related to its beneficial power. Dehydrated garlic extracts appear to be less toxic than fresh garlic. However, garlic is recommended in the diet as a healthy element, but not for therapeutic use, as it has been used for centuries by Asian people.

Laboratory studies on animals have shown that garlic: a) suppresses hepatic cholesterol synthesis, lowering serum cholesterol levels and reducing the harmful effect of low-density lipoprotein (LDL) while leaving high-density lipoprotein (HDL) unchanged (18 -20); b) lowers the concentration of blood triglycerides linked to cardiovascular risk (21-23); c) reduces blood clotting with effects similar to aspirin, preventing the formation of clots and cerebral stroke (24); d) promotes the regression of fat deposition on the venules (25); e) negatively influences the action of chemical carcinogens, preventing the formation of tumors (26, 27); and f) protects cells from oxidizing agents and heavy metals, counteracting the ageing process (28). Some of the positive effects of garlic consumption have been reported in the table below (Table I).

Table I. *Effects of garlic consumption.*

- Reduces the activation of microglial cells
- Inhibits oxidative stress
- Improves spatial learning memory and neurobehavioral outcomes
- Prevents neuronal death
- Protects against toxic effects due to amyloid beta (Aβ)
- Protects against neurodegenerative disorders
- Increases antioxidant power
- Reduces levels of neuroinflammation
- Improves general health

The mechanism of action of the beneficial effects of garlic is not yet known. A possible explanation is due to garlic's ability to inhibit the formation of nitrosamines, powerful carcinogens of the digestive tract (29, 30). Therefore, the compounds in garlic would be chemopreventive and would counteract the action of some carcinogens that can cause tumors such as breast, esophagus, colon, rectal, and brain tumors. Studies on animals have confirmed the beneficial action of garlic against heart disease by reducing blood pressure values (31-33).

SAC is an important molecule contained in garlic. It is a stable element formed by sulfur linked to a thiol group and is the most prominent bioactive compound in black garlic. SAC has numerous health benefits, giving protection against free radicals, oxidation, tumors, cardiovascular diseases, and neurodegenerative diseases (28, 34, 35).

The odor of garlic can be eliminated by soaking it in about 18% aqueous ethanol for a year at room temperature. This ageing leads to the elimination of odor without altering its antioxidant power, which reduces oxidative damage by eliminating reactive oxygen species (ROS) and lowers the chances of cerebrovascular damage.

Studies on garlic show that it attenuates oxidative action and neuroinflammation, reducing the chances of contracting neurodegenerative diseases, including Alzheimer's disease (AD) (35,36). *In vitro*, it has been observed that these healthy effects of garlic protect against cellular damage and the harmful effects caused by the amyloid beta peptide (Aβ) (37), a characteristic molecule of AD that forms in brain regions and triggers inflammatory responses, causing neuronal degradation.

Furthermore, garlic has been found to have neuroinflammatory effects by reducing the activation of microglial cells (38,39). When microglia are activated, they release pro-inflammatory cytokines such as IL-1 and tumor necrosis factor (TNF) that are involved in neuroinflammation.

CONCLUSIONS

Garlic has numerous health benefits for the human body. However, more studies are necessary to confirm the specific beneficial effects of garlic and its individual components.

Conflict of interest
The author declares that they have no conflict of interest.

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