IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 2, November 2025
Impact Factor: 7.67

Neurodegenerative Diseases: The Effect of Omega-3 Fatty Acids in Neuroinflammation.

Siddhi S Thakur and Miss. Jagruti R Salve
Sahakar Maharshi Kisanrao Varal Patil College of Pharmacy, Nighoj, Ahilyanagar

Abstract: *Major Depressive Disorder (MDD) is a common mental health condition. It develops because of many changes happening in the brain, including inflammation, damage to nerve cells, and problems in how brain cells work.Microglia are special immune cells in the brain. When something goes wrong in the brain during MDD, these cells release inflammatory chemicals.Damaged or stressed brain cells release signals called DAMPs (Damage-Associated Molecular Patterns). These signals act like alarms, telling the microglia that something is wrong. This activates the microglia and causes them to release more inflammation-producing chemicals.(1)Recent research shows that long-chain omega-3 fatty acids (n-3 LC-PUFAs) help fight inflammation by producing special molecules called specialized pro-resolving mediators (SPMs). These include resolvins, maresins, and protectins. SPMs play an important role in ending inflammation and helping tissuesheal.Because of this, SPMs may help reduce brain inflammation, protect brain cells, and possibly lead to new treatments for brain diseases caused by inflammation.(2)*
Studies show that taking omega-3 supplements—especially those with DHA and EPA—may improve thinking ability and reduce brain inflammation in people with Parkinson's and Alzheimer's disease.Omega-3 fatty acids work by controlling inflammation in the brain and helping nerve cells communicate.DHA also helps by reducing the buildup of harmful proteins, such as tau and amyloid-beta (Aβ), which are linked to Alzheimer's disease.We can get omega-3s from foods like fatty fish, but some people may still need supplements, especially if they don't eat these foods often or their bodies can't make enough omega-3s.Adding omega-3s to common foods is another simple way to increase intake.(3).

Keywords: Inflammation, Microglia, Braindiseases, omega-3 fatty acid, Alzheimer's, Parkinson's, DHA, EPA, resolvins.

I. INTRODUCTION

Neuroinflammation means inflammation within the central nervous system (CNS)—that is, in the brain and spinal cord.It Is mainly caused by activation of microglia and astrocytes, which are the immune cells of the brain.
Neuroinflammation can be triggered by:
1. Infections (bacterial, viral, fungal)
2. Trauma (head injury)
3. Neurodegenerative diseases (Alzheimer's, Parkinson's)
4. Toxins (pesticides, heavy metals)
5. Autoimmune disorders (multiple sclerosis)
6. Ischemia (stroke)

Key Players in Neuroinflammation :
Microglia -
Act as the first responders.
When activated, they release:
Cytokines (IL-1β, TNF-α)
Reactive oxygen species (ROS)
Nitric oxide

DOI: 10.48175/IJARSCT-29777

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 2, November 2025
Impact Factor: 7.67

Astrocytes-
Support neurons normally.During inflammation, they become reactive and release more inflammatory mediators.
Cytokines & Chemokines -
These chemical messengers amplify the inflammatory response.

Mechanism of action -
Trigger (infection, trauma, misfolded proteins) activates microglia.
Microglia release pro-inflammatory cytokines → IL-1β, TNF-α, IL-6.
Astrocytes also get activated and contribute to inflammation.
Blood–brain barrier (BBB) becomes leaky.
Excessive or chronic inflammation causes neuronal damage. (4)
Many studies have shown that polyunsaturated fatty acids (PUFAs) have strong anti-inflammatory effects and may be useful in treating neurodegenerative diseases like Parkinson's disease, dementia, Alzheimer's disease, multiple sclerosis, Huntington's disease, and amyotrophic lateral sclerosis (ALS).This review explains how omega-3 fatty acids—especially DHA and EPA—and omega-6 fatty acids—such as linoleic acid (LA) and gamma-linolenic acid (GLA)—may help in managing these brain disorders. It also summarizes the latest clinical research on how these fatty acids work and how effective they are as possible treatments.(5)Omega-3 fatty acids are essential nutrients that our bodies need, but most Americans consume verylittle of them. Studies have shown that low levels of omega-3s are linked to problems like depression, irritability, aggression, and impulsive behavior in both healthy people and those with mental health conditions. Clinical trials also suggest that omega-3 fatty acids can help in certain psychiatric disorders where mood and impulse control are affected, such as bipolar disorder and borderline personality disorder.(6)
Research shows that adding EPA (an omega-3 fatty acid) to regular antipsychotic treatment may help improve different symptoms in people who are at high risk of psychosis or experiencing their first episode. EPA or DHA, when combined with antipsychotics, helped in several ways:Protected the hippocampus (a part of the brain important for memory) and improved negative symptoms.Reduced oxidative stress in the blood and improved overall and negative symptoms.Increased telomerase levels in blood cells, which was linked to a lower severity of illness.Some studies also found that in people with stable schizophrenia, omega-3 supplements could help reduce positive symptoms such as delusions and hallucinations. Among all PUFAs, EPA was better than both placebo and DHA at reducing positive and negative symptoms. EPA supplementation also helped slow down the worsening of psychosis.(7)
The Dietary Guidelines and the American Dietetic Association recommend getting nutrients from natural foods rather than relying on supplements or fortified foods. This is especially true for omega-3 fatty acids like DHA and EPA.For adults, the minimum daily amount of omega-3 needed to prevent deficiency is 0.35 to 0.40 grams per day, which is about 0.5% of total fat intake. For EPA and DHA specifically, the recommended intake ranges from 0.25 to 2 grams per day.(8)

The role of omega-3 fatty acids in brain health:
Omega-6 fatty acids include Arachidonic Acid (AA), Gamma-Linolenic Acid (GLA), and Linoleic Acid (LA).Omega-3 fatty acids include DocosahexaenoicAcid (DHA) and Eicosapentaenoic Acid (EPA).(9) New research suggests that omega-3 fatty acids may help protect against Parkinson's disease. Although scientists do not yet fully understand how this works, they believe omega-3s help keep cell membranes healthy and may prevent the loss of dopamine-producing neurons.(10)DHA and AA make up about 25% of all fatty acids in the brain and are important parts of the cell membranes found in the brain's gray matter. DHA alone makes up as much as 90% of all omega-3 long-chain fatty acids in the brain.
The body can get DHA In two ways:
1. From ALA, a nutrient in some plant foods, which the body slowly converts into DHA through several enzyme steps.
2. Directly from foods that already contain DHA, mainly fish and other marine sources.
In the brain, DHA is mostly found in the phospholipids of synaptic membranes—these are the areas where nerve cells communicate. DHA becomes part of important membrane molecules like phosphatidylcholine,

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 2, November 2025
Impact Factor: 7.67

phosphatidylethanolamine, and phosphatidylserine.Because DHA has a long chain and many double bonds, it makes cell membranes flexible and fluid, which helps brain cells send signals efficiently.(11)

Arachidonic acid (AA) is a major omega-6 fatty acid. The body converts AA into strong inflammatory chemicals such as thromboxanes, prostaglandins, and leukotrienes.PUFAs (both omega-3 and omega-6) can affect inflammation through a system called STING, which controls the body's inflammatory response to certain signals. In this pathway, PUFAs help reduce STING-related inflammation.Omega-3 fatty acids also compete with omega-6 fatty acids to get into cell membranes. When more omega-3s are present, they can reduce the amount of omega-6 that gets incorporated, helping lower inflammation.(12)

Mechanism of action:

DHA and AA are made from saturated fatty acids through a chemical process that adds double bonds. These double bonds give PUFAs a special structure that makes cell membranes more flexible and stable. This flexibility allows proteins in the membrane to function properly—something saturated fats and some omega-6 fats (like AA) or cholesterol cannot do as effectively.Because of these properties, PUFAs are essential for forming lipid rafts—special membrane areas needed for:Transport of membrane proteins .Formation of synapses (connections between nerve cells)Maintaining the strength and function of neuronal membranes .AA is found in both gray and white matter of the brain. In contrast, DHA is mainly found in the neuronal membranes of gray matter and is the most abundant omega-3 fatty acid in the brain.(13)

Omega-3 fatty acids have been shown to reduce inflammation caused by microglia (the brain's immune cells) after traumatic brain injury. They do this by blocking the HMGB1/TLR4 pathway, which lowers therelease of inflammatory chemicals.Studies also show that a type of omega-3 called DPA can protect microglial cells. When microglia were exposed to an inflammatory substance (LPS), DPA reduced harmful cell activity by affecting two key signaling pathways: NF-κB and MAPK p38. It also helped balance microglia between their "M1" (inflammatory) and "M2" (anti-inflammatory) states.Another study found that certain omega-3–derived compounds (EDP-EAs and EEQ-EAs) reduced the inflammatory cytokine IL-6 and increased the anti-inflammatory cytokine IL-10, depending on the dose. Omega-3s also compete with arachidonic acid (AA) in the body. EPA, an omega-3, binds to COX-2 and LOX enzymes and prevents AA from being converted into inflammatory molecules like prostaglandin E2 and leukotriene B4. At the same time, omega-3s help produce anti-inflammatory molecules such as RvD1 and PD1, which reduce oxidative stress and prevent nerve cell death.

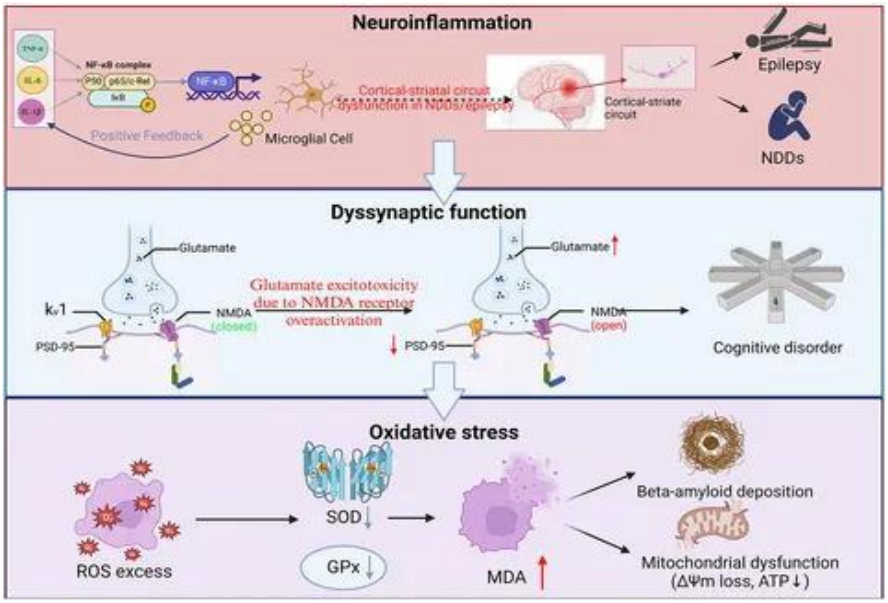

Figure 1: Three key mechanisms underlying the anti-inflammatory effects of omega-3 fatty acids (14)

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 2, November 2025
Impact Factor: 7.67

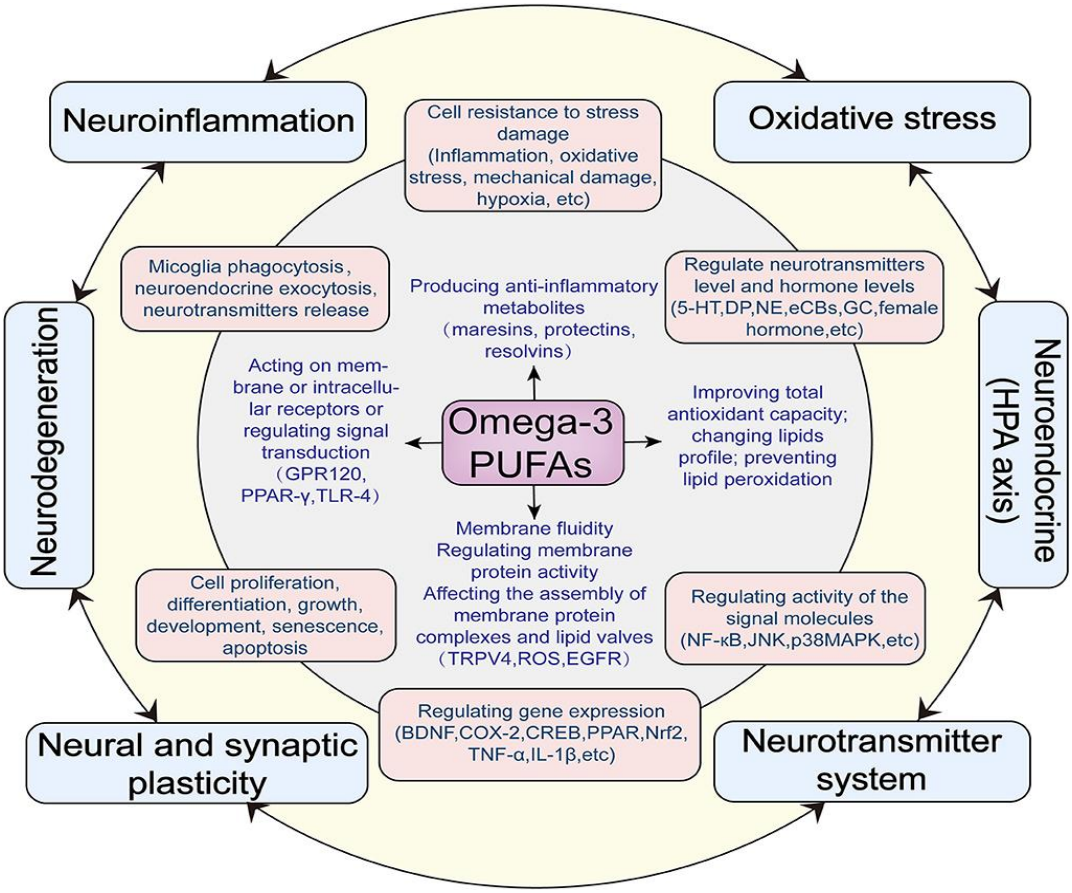

Figure 2 – Hypothesized antidepressant mechanisms of omega-3 PUFAs acting on the central nervous system (15)

Research from evidence studies: Omega-3 fatty acids (O3FAs) can activate special receptors in the brain called FFARs. Scientists have studied this using computer-based molecular docking, which has helped them design new medicines that target these receptors for treating neurodegenerative diseases.

N-3 PUFAs (a type of omega-3) help the brain in several ways:

They reduce neuroinflammation and lower the overactivity of microglia (the brain's immune cells).

They protect astrocytes, which are support cellsin the brain that produce important growth factors (neurotrophins).

They reduce damage by balancing n-6 PUFAs, which normally form inflammatory chemicals.

Omega-3s are also used by COX-2 and LOX enzymes to make helpful molecules called resolvins and protectins, which calm inflammation in brain tissue.

Seafood is the main source of omega-3 PUFAs. These fatty acids may help decrease the effects of Alzheimer's disease by:

Improving glial cell function

Maintaining healthy cell membranes

Competing with inflammatory n-6 fats

Helping reduce tau protein phosphorylation and Aβ plaque buildup

Lowering pro-inflammatory cytokines

Blocking the NF-κB pathway (which triggers inflammation) .Overall, omega-3s can reduce brain inflammation, slow neurodegeneration, and help improve memory. (16)

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 2, November 2025
Impact Factor: 7.67

Sources of Omega 3 fatty acids : Some foods—like certain brands of eggs, yogurt, juices, milk, and soy drinks—have extra DHA and other omega-3 fatty acids added to them. These are called fortified foods .Since 2002, companies in the United States have also been adding DHA and arachidonic acid (ARA) to most infant formulas. Thesetwo fats are the main long-chain PUFAs found in the brain and are importantfor a baby's brain development.(17) Fish is the best source of omega-3 fattyacids. Oily fish like salmon, mackerel, sardines, tuna, herring, and albacore contain high amounts of DHA and EPA.Some plant foods, like flax seeds, pecans, hazelnuts, and walnuts, also contain omega-3s.These foods are very good for health. So, it is recommended to eat omega-3-rich foods regularly. (18)
(19)

II. CONCLUSION

Omega-3 fatty acids play an important role in protecting the brain and slowing the progression of neurodegenerative diseases. They reduce inflammation support healthy brain cell function, and help prevent damage caused by harmful proteins like tau and amyloid-β. By improving communication between brain cells and loweringinflammatory responses, omega-3s may help preserve memory and cognitive function. Regular intake of omega-3-rich foods or supplements can therefore be beneficial inmanaging and possibly reducing the risk of conditions such as Alzheimer's andParkinson's disease.Omega-3 fatty acids are important nutrients that help keep the brain healthy, especially as we age. Research shows that they can lower inflammation in the brain, protect nerve cells, and improve the functioning of glial cells, which support and nourish neurons. Omega-3s also help reduce the buildup of harmful proteins like amyloid-β plaques and prevent excessive tau phosphorylation—both of which are linked to neurodegenerative diseases such as Alzheimer's.By maintaining cell membrane stability and supporting better communication between brain cells, omega-3s may slow down memory loss and cognitive decline. They also compete with inflammatory omega-6 fats, leading to a more balanced and less inflammatory environment in the brain.

REFERENCES

[1]. https://www.mdpi.com/2073-4409/13/21/1791?hl=en-IN#:~:text=Eicosapentaenoic%20acid%20(EPA)%20and%20docosahexaenoic,27%2C28%2C29%5D.
[2]. https://pmc.ncbi.nlm.nih.gov/articles/PMC6755339/?hl=en-IN#:~:text=Recent%20data%20show%20that%20n,in%20the%20resolution%20of%20inflammation.
[3]. Indian Journal of Pharmacy Practice., 2025; 18(4):362-366.https://www.ijopp.org

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 2, November 2025
Impact Factor: 7.67

[4]. https://chatgpt.com/s/t_6926c70723e0819193ea567651d18006.
[5]. DHA/EPA (Omega-3) and LA/GLA (Omega-6) as Bioactive Molecules in Neurodegenerative Diseases https://share.google/kuOYBFY48T7rkUcIA
[6]. Omega-3 supplementation and the neural correlates of negative affect and impulsivity: A double-blind, randomized, placebo-controlled trial in midlife adults – PMC https://share.google/0oSuROk67Zl2fsc9r
[7]. Effects of Omega 3 Fatty Acids on Main Dimensions of Psychopathology https://share.google/KFeV8lZP7Do0EVfQ1
[8]. Beneficial Effects of Omega-3 Fatty Acid on Neurological Disorder and Macular Degeneration: Beneficial Effects of Omega-3 Fatty Acid | Asian Journal of Allied Health Sciences (AJAHS) https://share.google/7WTGxX0tZE44TY6Hh
[9]. Indian Journal of Pharmacy Practice., 2025; 18(4):362-366.https://www.ijopp.org
[10]. Impact of Omega-3 Fatty Acids on Brain Function https://share.google/ZkhJF96Ko7QBuJgs6
[11]. Docosahexaenoic and Arachidonic Acids as Neuroprotective Nutrients throughout the Life Cycle https://share.google/ZgAo7vD8gC2oVbVNU
[12]. Full article: An analysis of omega-3 clinical trials and a call for personalized supplementation for dementia prevention https://share.google/sxxHChXtxbx7aSXsi
[13]. Omega-3 fatty acids: potential role in the management of early Alzheimer's disease – PMC https://share.google/yiiV4JrcgFCdFFg5M
[14]. Frontiers | Omega-3 fatty acids: multi-target mechanisms and therapeutic applications in neurodevelopmental disorders and epilepsy https://share.google/vWtgjtW2FqFBBbGqV
[15]. Frontiers | Possible antidepressant mechanisms of omega-3 polyunsaturated fatty acids acting on the central nervous system https://share.google/rbw2xKmLLR4K9z06Q
[16]. Indian Journal of Pharmacy Practice., 2025; 18(4):362-366
[17]. https://www.ijopp.org
[18]. Omega-3 Fatty Acids – Health Professional Fact Sheet https://share.google/iU9FXb15JwNG3boNw.
[19]. OMEGA 3: Health Benefits of Nutrition https://share.google/mX27nskMHTNrCk2Nr
[20]. Omega-3 Fatty Acids & the Important Role They Play https://my.clevelandclinic.org/health/articles/17290-omega-3-fatty-acids