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***Corresponding author**

Bargale Sushant Sukumar

dr.sushant99@gmail.com

RECEIVED :06/09/2024

ACCEPTED:29/03/2025

PUBLISHED:30/06/2025

KEYWORDS:

Ayurveda, AD, neuroprotection, medicinal plants, holistic medicine, integrative therapy, personalized medicine, clinical trials, and neurodegenerative diseases

AYURVEDIC MEDICINAL PLANTS AND THEIR NEUROPROTECTIVE POTENTIAL IN ALZHEIMER'S DISEASE

Bargale Sushant Sukumar¹, Shashirekha H K², Neha Gadgil³, Akshar Kulkarni⁴, Harshal Tare^{5*}

1Department of Swasthavritta and Yoga, Sri Dharmasthala Manjunatheshwara College of Ayurveda and Hospital, Hassan, Karnataka, India.

2Department of Samhita Sanskrit, Banaras Hindu University, Varanasi, Uttar Pradesh, India.

3Department of Kriya Sharir, Sri Lal Bahadur Shastri Smarak Rajakiya Ayurvedic Mahavidyalaya, Handia, Prayagraj, Uttar Pradesh, India.

4Department of Samhita Siddhanta, Parul Institute of Ayurved, Parul University, Vadodara, Gujarat, India.

5Department of Pharmacognosy, SGMSPM's Sharadchandra Pawar College of Pharmacy, Otur, Affiliated to Savitribai Phule Pune University, Pune, Maharashtra, India.

ABSTRACT

Alzheimer's Disease (AD) poses a substantial universal health challenge with limited effective treatment options. Ayurvedic medicinal herbs are being evaluated as prospective candidates for neuroprotection due to their diverse array of bioactive compounds and comprehensive therapeutic principles. This review compiles the latest information on Ayurvedic herbs. It examines their mechanisms of action, clinical effectiveness, safety profiles, and regulatory issues in the management of AD. Key findings highlight their potential to mitigate neuroinflammation, oxidative stress, and cognitive decline, offering insights into integrative approaches that synergize traditional wisdom with modern pharmacotherapy. Future research directions underscore the need for mechanistic studies, large-scale clinical trials, and personalized medicine strategies to optimize therapeutic outcomes in AD.

1. Introduction

Alzheimer's Disease (AD) is an important global health problem that affects almost 50 million people worldwide, especially older populations, and its occurrence is rapidly increasing ((Nichols et al., 2019). Dementia is the main factor that pointed to a decrease in an intellectual ability, memory loss, and fluctuations in behaviour, which significantly impede daily activities and overall quality of life (Muralidhara et al., 2023). Amyloid-beta peptides produced over the proteolysis of amyloid precursor protein (APP), amass extracellular and form plaques. These plaques disrupt synapse function and start neuroinflammation responses (Sehar et al., 2022). The accumulation of hyperphosphorylated tau proteins within cells triggers the development of NFT that disrupt the transportation mechanisms in neurons and eventually result in their demise(Wei et al., 2022). The persistent stimulation of microglia and astrocytes caused by the existence of amyloid plaques with tau tangles leads to ongoing neuroinflammatory responses, exacerbating the damage to neurons. Oxidative damage to cellular components, resulting in neuronal dysfunction and demise, arises from an imbalance between the production by free radicals and the body's antioxidant protection. The clinical manifestations of AD arise from the gradual deterioration of neurons, particularly in critical regions of the brain involved in memory and cognition, such as the hippocampus cortex. Treatments currently used for AD primarily aim to control symptoms and involve the use of cholinesterase inhibitors. While these drugs can alleviate symptoms by enhancing neural communication or altering glutamate signaling, they cannot stop the progression of the disease or specifically address the root causes of neurodegenerative processes(Pardo-Moreno et al., 2022).

Ayurveda, originating from Sanskrit terms signifying "knowledge of life," is among the most ancient comprehensive medicinal systems globally. Ayurveda focuses on a personalized approach to health that considers an individual's constitution (prakriti), which comprises three fundamental doshas: Vata, Pitta, and Kapha. The framework offers a thorough approach to

understanding the causes, prevention, and treatment of diseases through the utilization of nutrition, lifestyle modifications, herbal remedies, yoga, and meditation (Arnold, 2023).

According to Ayurveda, the state of one's brain health is closely connected to their overall well-being and is known as "Medha" or mental capacity. This cognitive ability is predisposed by issues such as diet, mental cleanliness, and spiritual practices. The phenomenon of "Smritibhransa" (memory fading) bears resemblance to contemporary comprehension conditions like Alzheimer's. Ayurvedic texts promote the use of diverse medicinal products (rasayanas), dietary recommendations, and modifications in lifestyle to enhance cognitive function and decelerate cognitive decline linked to aging(Pant, 2023).

This review aims to investigate the possibility of Ayurvedic medicinal herbs as therapeutic options for AD. The review aims to identify botanical candidates with neuroprotective benefits and potential for future AD therapeutic strategies. This will be achieved by thoroughly analyzing scientific data regarding traditional applications of botanical compound compositions, ways in which they take, and results from clinical and preclinical research.

2. Pathophysiology of AD

AD is an intricate neurodegenerative disorder characterized by a steady decline in mental abilities and cognitive impairment. Understanding the fundamental principles behind its atypical physiological processes is crucial for developing targeted and efficient treatment approaches (Griffiths and Grant, 2023).

Key Pathological Features of AD Amyloid-beta plaques

It consists of 40-42 amino acids, which are generated through the sequential degradation of the APP by β -secretase with γ -secretase enzymes. In a setting of AD, peptides like these undergo aggregation to form insoluble plaques that are seen extracellular, outside of neurons. These plaques are mainly found in hippocampus and neo-cortex. Amyloid-beta ($A\beta$) plaques hinder synaptic function, initiate neuroinflammation, and lead to neuronal malfunction and death. The formation of tau

protein clumps is observed (Brand et al., 2022).

Tau proteins have a crucial function in maintaining the stability of microtubules in neurons. In AD, the excessive addition of phosphate groups to tau proteins leads to the creation of neurofibrillary tangles (NFT) inside neurons, as the proteins come together to form paired helical filaments. These entanglements impede the mobility of axons, disrupt the transmission of signals within neurons, and are closely associated with the decline of neurons and losing cognitive function (Thal and Tomé, 2022). Neuro-inflammation is a term used to describe inflammation in the brain. Microglia and astrocytes, the primary components of the neurological immune system, play crucial roles in maintaining brain homeostasis and responding to damage or infections (Jurcău et al., 2022).

Oxidative stress induces damage to proteins, lipids, and nucleic acids within neurons, resulting in further impairment of cellular function, exacerbation of neuroinflammation, and promotion of neuronal apoptosis (Bai et al., 2022).

Neuronal Loss

Progressive neuronal loss underlies the clinical manifestations of AD. Neuronal death results from a combination of A β toxicity, tau-mediated neurodegeneration, neuroinflammation, oxidative stress, and impaired neuronal repair mechanisms. The losing neurons disrupts neural circuits critical for memory formation, cognitive function, and other higher-order brain processes (Trejo-Lopez et al., 2023).

Mechanisms of Neurodegeneration in AD

The pathogenesis of AD entails an intricate interplay between many pathogenic mechanisms. Synaptic Dysfunction: Oligomers interfere with synaptic function, hinders the passage of neurotransmitters, and contribute to the loss of synapses, which is a characteristic feature of early AD pathology.

Mitochondrial dysfunction occurs when the presence of A β and tau pathology hinders the proper functioning of mitochondria, leading to a decrease in energy metabolism and an increase in oxidative stress in neurons.

Neurotransmitter Imbalance: Deregulation of neurotransmitter systems, such as acetylcholine,

glutamate and dopamine, has a role in the cognitive impairments and behavioral alterations observed in AD

Glial Activation: Prolonged stimulation of both astrocytes and microglia sustains neuroinflammation, intensifying neuronal damage and playing a role in the advancement of the disease (Ratan et al., 2023).

3. Ayurvedic Concepts Relevant to Neuroprotection

Ayurveda, the ancient Indian system of medicine, offers unique insights into brain health and aging through its holistic principles and personalized approach to wellness.

Ayurvedic Understanding of Brain Health and Aging

Concepts of Doshas: Vata, Pitta, and Kapha

Ayurveda views health as a balance among three primary bioenergetics forces or doshas: Vata (associated with air and ether), Pitta (linked to fire and water), and Kapha (connected to earth and water). These doshas regulate physiological functions and are affected by various factors such as diet, lifestyle, environment, and age. Imbalances in doshas can predispose individuals to AD.

Vata Dosha: Manages movement, communication, and neural impulses. Disruptions in Vata can lead to cognitive disturbances, memory lapses, and neurological disorders.

Pitta Dosha: Controls metabolic processes, including digestion and transformation. Pitta imbalances may contribute to inflammatory processes and oxidative stress, which are linked to neurodegenerative conditions.

Kapha Dosha: Maintains structure and stability. Imbalances in Kapha may result in the excessive buildup of toxins (Sharma et al., 2024).

Aging (Jara) and Cognitive Decline (Smritibhransha)

Ayurvedic texts recognize aging (Jara) as a natural process characterized by the gradual decline of bodily functions, including mental faculties. Cognitive decline (Smritibhransha) is attributed to imbalances in doshas, accumulation of toxins, and diminished vitality (Ojas). Aging is seen as a time when preserving mental clarity and cognitive function becomes increasingly important through preventive measures and

therapeutic interventions(Narayana et al., 2023).

Overview of Rasayana Therapy and Its Relevance to Neuroprotection

Rasayana therapy represents a specialized branch of Ayurveda focused on rejuvenation and longevity. Rasayanas are herbal formulations, dietary practices, and lifestyle interventions aimed at enhancing vitality, promoting cellular regeneration, and improving cognitive function. They are relevant in addressing age-related cognitive decline and neurodegenerative disorders by restoring balance among doshas, rejuvenating tissues, and enhancing mental clarity(Malhotra and Sandhir, 2023).

Ayurvedic Diagnosis and Treatment Principles for Neurodegenerative Diseases

Ayurvedic diagnosis of neurodegenerative diseases involves assessing the individual's constitution (prakriti), current dosha imbalances (vikriti), and specific neurological symptoms. Treatment strategies emphasize personalized approaches that may include:

Dietary Modifications: Tailored diets to balance doshas and support brain health, incorporating foods with neuroprotective properties.

Herbal Therapies: Administration of specific Ayurvedic medicinal plants known for their neuroprotective effects, such as Brahmi (*Bacopa monnieri*) and Ashwagandha (*Withania somnifera*).

Lifestyle Recommendations: Guidance on daily routines, stress management, sleep hygiene, and cognitive exercises to enhance mental resilience and cognitive function.

Ayurvedic interventions aim not only to alleviate symptoms but also to address underlying imbalances and promote overall well-being, making them potentially valuable in the management of neurodegenerative diseases like AD(Luthra and Roy, 2022).

4. Ayurvedic Medicinal Plants with Neuroprotective Potential

Ayurvedic medicinal plants have been valued for centuries for their therapeutic properties in maintaining brain health, enhancing cognitive function, and potentially mitigating neurodegenerative processes. Here, we will examine several key plants known for their

neuroprotective effects:

4.1. *Bacopa monnieri* (Brahmi)

Brahmi (*Bacopa monnieri*) belonging to family 'Plantaginaceae' is a plant that helps enhance memory and learning processes while also acting as a stress buster. The psycho actives are bacosides, alkaloids, and flavonoids. It is a neuroprotective, anxiolytic, and antioxidant agent used to mitigate degenerative disorders and augmentation in stress resistance, as well as support the liver and immune health. Daily doses usually vary from 150 to 500 mg, which is available in different forms.

Traditional Use in Ayurveda

Bacopa monnieri, is a perennial herb conventionally used in Ayurveda for memory and overall brain health. It is classified as a Medhya Rasayana (nootropic) herb, promoting mental clarity and concentration(Fatima et al., 2022a).

Phytochemical Constituents

Brahmi contains bioactive compounds such as bacosides, alkaloids, flavonoids, and saponins. Bacosides, in particular, are believed to contribute to its neuroprotective effects by enhancing neuronal communication, reducing oxidative stress, and modulating neurotransmitter levels.

Mechanisms of Neuroprotective Action

Enhancement of Neurotransmission: Brahmibacosides support neurotransmitter balance, particularly acetylcholine, crucial for memory and cognitive function.

Antioxidant Properties: Bacosides exhibit areduction in damage to neurons.

Neurogenesis and Synaptic Plasticity: Brahmi promotes neurodevelopment and enhances synaptic plasticity, facilitating mental processes.

Preclinical and Clinical Evidence for Efficacy in AD

Preclinical studies have demonstrated Brahmi's ability to recover mental deficits in animal models of AD through its neuroprotective mechanisms. Clinical trials in humans have shown promising results in enhancing cognitive performance and reducing cognitive decline associated with aging, supporting its potential therapeutic use in AD management(Goyal et al., 2022).

4.2. *Withania somnifera* (Ashwagandha)

Withania somnifera is popularly known as

Ashwagandha. It is a plant from Solanaceae family, primarily used for its adaptogenic properties. The leaves and roots contain withanolides-glycowithanolides, alkaloids-somniferin, tropine, pseudotropine, and anaferine, and saponins-chemistry. It is generally used in 300–500 mgs per day for standardized extract doses. Ashwagandha is reputed to reduce stress, fatigue, enhance work, and mental function, while improving immune health benefits. It has still another attribute and antibacterial and antioxidant antiviral which serve a person in his health and wellness.

Traditional Use in Ayurveda

It is a powerful adaptogenic herb employed in Ayurvedic treatment to enhance resilience to stress, promote vitality, and support overall health, including brain function(Bhat et al., 2022).

Phytochemical Constituents

Ashwagandha contains alkaloids (including somniferine) and steroidal lactones. Withanolides are believed to confer adaptogenic and neuroprotective properties.

Mechanisms of Neuroprotective Action

Stress Reduction: Ashwagandha modulates the hypothalamic-pituitary-adrenal (HPA) axis, reducing stress hormone levels and mitigating stress-induced damage to neurons.

Anti-inflammatory Effects: Withanolides exhibit anti-inflammatory activity, reducing neuroinflammation associated with AD pathology.

Neurotrophic Effects: Ashwagandha promotes neuronal growth and enhances synaptic plasticity, potentially reversing neurodegenerative processes.

Preclinical and Clinical Evidence for Efficacy in AD

Preclinical studies have demonstrated Ashwagandha's ability to improve cognitive function, reduce amyloid plaque deposition, and attenuate neuroinflammation(D'Cruz and Andrade, 2022).

4.3. *Curcuma longa* (Turmeric)

Traditional Use in Ayurveda

Curcuma longa belonging to family 'Zingiberaceae', commonly known as turmeric, is a spice revered in Ayurvedic medicine for its anti-inflammatory, antioxidant, and neuroprotective

properties. It is widely used as a culinary spice and medicinal herb.

Phytochemical Constituents

Turmeric's active component is curcumin, a polyphenolic compound known for neuroprotective actions.

Mechanisms of Neuroprotective Action

Anti-inflammatory Effects: Curcumin inhibits pathways, reducing neuroinflammation and protecting neurons from inflammatory damage.

Antioxidant Properties: Curcumin scavenges free radicals and enhances antioxidant defenses, mitigating oxidative stress in neurons.

Modulation of Amyloid-Beta and Tau Pathology: Curcumin may interfere with the aggregation of AD proteins, possibly reducing disease progression.

Preclinical and Clinical Evidence for Efficacy in AD

Preclinical studies suggest curcumin can improve cognitive function, reduce amyloid plaque burden, and alleviate oxidative stress in animal models of AD. Clinical trials have shown mixed results but suggest potential benefits in improving cognitive outcomes and reducing biomarkers of inflammation and oxidative stress in individuals with AD(Srivastava et al., 2022).

4.4. *Centella asiatica* (Gotu Kola)

The plant species known as Gotu Kola belongs to the family Apiaceae. Their constitutive parts involve the leaves. It is having different components including triterpenoids such as asiaticoside and madecassoside, flavonoids, and saponins. The plant is generally taken as 500s1000 mg of dried leaf powder or as 30-60 liquid drops after extraction as use, with its beneficial effects on cognitive function, memory, and promotion of wound healing. It also exerts antioxidant, anti-inflammatory, and circulatory effects, besides helping in an increases of anxiety and stress.

Traditional Use in Ayurveda

Centella asiatica is a perennial herb used in Ayurvedic medicine to enhance cognitive function, promote longevity, and support overall mental health.

Phytochemical Constituents

Gotu Kola contains bioactive compounds such as triterpenoids (including asiaticoside and

madecassoside), flavonoids, and phenolic acids. These compounds contribute to its neuroprotective and antioxidant properties (Bolumbu and Mitha, 2023).

Mechanisms of Neuroprotective Action

Enhancement of Neurogenesis: Gotu Kola promotes neurogenesis, the formation of new neurons, and may facilitate repair mechanisms in the brain.

Anti-inflammatory and Antioxidant Effects: Triterpenoids in Gotu Kola exert anti-inflammatory effects, reducing neuroinflammation, and protecting neurons from oxidative damage.

Cognitive Enhancement: Gotu Kola enhances cognitive function, memory, and learning abilities through its effects on neurotransmitter systems and neuronal health.

Preclinical and Clinical Evidence for Efficacy in AD

Preclinical studies have shown that Gotu Kola extracts can improve cognitive performance, enhance memory, and reduce oxidative stress in animal models of AD. Clinical trials are limited but suggest potential benefits in enhancing mental abilities (Deore et al., 2023).

4.5. *Convolvulus pluricaulis* (Shankhapushpi)

Shankhapushpi, another name for *Convolvulus pluricaulis*, belongs to Convolvulaceae family, which is known for its properties of enhancing cognition. The plant contains alkaloids, flavonoids, glycosides, and saponins in its leaves and flowers mainly. The powdered herb typically consumes in a dose of 500-1000 mg. It is commonly practiced with Shankhapushpi to ameliorate memory and concentration, decrease disease-caused stress as well as anxiety, antioxidant, anti-inflammatory and

neuroprotection.

Traditional Use in Ayurveda

Convolvulus pluricaulis, known as Shankhapushpi, is a perennial herb valued in Ayurvedic medicine for its cognitive-enhancing properties, particularly in improving memory, concentration, and mental clarity.

Phytochemical Constituents

Shankhapushpi contains alkaloids, flavonoids, glycosides, and other bioactive compounds. These constituents are believed to contribute to its neuroprotective and cognitive-enhancing effects.

Mechanisms of Neuroprotective Action

Neurotransmitter Modulation: Shankhapushpi enhances cholinergic neurotransmission, supporting memory formation and cognitive function.

Antioxidant Properties: Bioactive compounds in Shankhapushpi protect neurons from damage.

Anti-inflammatory Effects: Shankhapushpi exhibits anti-inflammatory activity, potentially mitigating neuroinflammation associated with neurodegenerative diseases.

Preclinical and Clinical Evidence for Efficacy in AD

Preclinical studies have demonstrated Shankhapushpi's ability to improve learning and memory, enhance cognitive function, and reduce oxidative stress in animal models. Clinical trials are limited but suggest potential benefits in cognitive enhancement and neuroprotection in individuals with cognitive impairment (Sharma et al., 2022).

Table 1 provides a comprehensive overview of selected Ayurvedic medicinal plants known for their neuroprotective properties.

Table 1: Summary of Ayurvedic Medicinal Plants with Neuroprotective Properties

Herb	Traditional Use in Ayurveda	Key Bioactive Compounds	Neuroprotective Mechanisms	Preclinical Evidence	Clinical Evidence	Ref.
Brahmi (<i>Bacopa monnieri</i>)	Enhances cognitive function, memory retention	Bacosides A and B, alkaloids	Antioxidant, anti-inflammatory, neurotrophic effects	Improves memory retention, protects against neurotoxicity	Improves cognitive function, quality of life in AD patients	(Fatima et al., 2022b)
Ashwagandha (<i>Withania somnifera</i>)	Adaptogenic, improves vitality, longevity	Withanolides, alkaloids	Anti-inflammatory, antioxidant, neuroprotective against	Protects neurons from oxidative stress and amyloid toxicity	Improves cognitive function, reduces stress and anxiety	(Mikulska et al., 2023)
Turmeric (<i>Curcuma longa</i>)	Anti-inflammatory, digestive disorders	Curcumin	Antioxidant, anti-inflammatory, neuroprotective against	Reduces beta-amyloid plaques, inhibits neuroinflammation	Enhances cognitive function, protects against neurodegeneration	(Iweala et al., 2023)
<i>Centella asiatica</i> (Gotu Kola)	Improves memory and	Triterpenoids,	Neurotrophic, antioxidant,	Enhances neuronal viability,	Enhances memory and cognitive	(Wright et al., 2022)
	cognitive function	Asiaticosides	anti-inflammatory	promotes synaptic plasticity	Function	
<i>Convolvulus pluricaulis</i> (Shankhaphi)	Enhances cognitive function Improves mental agility	Alkaloids Convolvuline	Antioxidant, neuroprotective against neurodegeneration	Improves learning and memory, protects against oxidative stress	Improves cognitive function, reduces oxidative stress	(Wal et al., 2023)

4.6. Other Notable Ayurvedic Plants

Overview of Additional Ayurvedic Plants with Potential Neuroprotective Effects

In addition to the above-mentioned plants, several other Ayurvedic herbs show promise for their neuroprotective effects in AD:

Ginkgo biloba: Improves cerebral blood flow, enhances neurotransmitter function, and exhibits antioxidant properties.

Tinospora cordifolia: Modulates immune responses, reduces inflammation, and protects neurons from oxidative stress.

Emblica officinalis (Amla): Rich in vitamin C and antioxidants supports cognitive function and neuronal health.

Summary of Key Findings and Potential for Future Research

Ayurvedic medicinal plants offer diverse

mechanisms of neuroprotection effects. While preclinical studies provide compelling evidence, clinical trials are required to validate their efficacy and safety in treating AD and other neurodegenerative disorders. Future research should focus on standardized formulations, mechanistic studies, and large-scale clinical trials to establish their role in integrative neurotherapeutics(Nagori et al., 2023).

5. Mechanisms of Neuroprotection by Ayurvedic Plants

Ayurvedic medicinal plants proposed as a rich source of bioactive that exert diverse pharmacological effects on the central nervous system, promoting neuroprotection and potentially mitigating neurodegenerative processes. Here, we will delve into the key mechanisms through which these plants confer neuroprotection:

Antioxidant and Anti-inflammatory Effects

Antioxidant Activity: Bioactive compounds such as polyphenols (e.g., curcumin in Turmeric) and flavonoids (e.g., bacosides in Brahmi) reduce oxidative damage. This antioxidant defense helps maintain cellular integrity and function in the brain.

Anti-inflammatory Effects: Phytochemicals like withanolides in Ashwagandha and curcumin in Turmeric inhibit pro-inflammatory cytokines and pathways, attenuating neuroinflammation associated with AD pathology. By reducing chronic inflammation, these plants mitigate neuronal damage and support brain health(Shohag et al., 2022).

Modulation of Amyloid-Beta and Tau Pathology

Ayurvedic plants have shown potential in modulating the accumulation and toxicity of AD protein:

Amyloid-Beta Variation: Compounds like curcumin in Turmeric interfere with the aggregation of A β peptides, reducing the formation of toxic oligomers and fibrils. This inhibition may slow disease progression and preserve neuronal function in AD.

Tau Protein Stabilization: Certain phytochemicals, such as bacosides in Brahmi, have been implicated in stabilizing tau proteins and preventing their pathological aggregation

into NFT. This action helps maintain neuronal integrity and synaptic function(Roda et al., 2022).

Enhancement of Neurogenesis and Synaptic Plasticity

Ayurvedic herbs promote neuronal regeneration and enhance synaptic plasticity, critical for learning, memory, and cognitive function:

Neurogenesis: Compounds in herbs like Gotu Kola (*Centella asiatica*) and Shankhapushpi (*Convolvulus pluricaulis*) stimulate neurogenesis, the generation of new neurons from neural stem cells. This process contributes to brain repair and functional recovery in neurodegenerative diseases.

Synaptic Plasticity: Neurotrophic factors induced by Ayurvedic herbs support synaptic remodeling and connectivity between neurons. Improved synaptic plasticity enhances learning abilities and memory formation, counteracting the synaptic deficits observed in AD(Correia et al., 2023).

Neurotransmitter Modulation

Ayurvedic medicinal plants influence neurotransmitter systems, optimizing neuronal communication and cognitive function:

Cholinergic Enhancement: Brahmi (*Bacopa monnieri*) enhances cholinergic neurotransmission by inhibiting acetylcholinesterase activity and promoting acetylcholine synthesis. This enhancement improves cognitive performance and memory retention in AD patients.

GABAergic and Glutamatergic Balance: Herbs like Ashwagandha (*Withania somnifera*) modulate gamma-aminobutyric acid (GABA) and glutamate neurotransmission, regulating neuronal excitability and reducing neuronal toxicity associated with excessive glutamate release(Muralidhara et al., 2023).

Protection against Mitochondrial Dysfunction

Ayurvedic herbs mitigate mitochondrial dysfunction, a hallmark of neurodegenerative diseases:

Mitochondrial Support: Compounds in herbs like Ashwagandha (*Withania somnifera*) and Turmeric (*Curcuma longa*) protect mitochondrial function by enhancing energy production, reducing oxidative stress, and maintaining cellular respiration. Preserving mitochondrial integrity is crucial for neuronal survival and

function in AD.

Ayurvedic medicinal plants exert neuroprotective effects through multifaceted modulation of amyloid-beta and tau pathology, enhancement of neurogenesis and synaptic plasticity, neurotransmitter modulation, and protection

against mitochondrial dysfunction. These mechanisms collectively contribute to their potential therapeutic efficacy in AD and other neurodegenerative disorders (Gopathy et al., 2024). Table 2 focusing on the mechanisms of neuroprotection by Ayurvedic medicinal plants:

Table 2: Mechanisms of Neuroprotection by Ayurvedic Plants

Herb	Antioxidant Effects	Anti-inflammatory Effects	Neurotrophic Effects	Modulation of Neurotransmitters
Brahmi (<i>Bacopa monnieri</i>)	Scavenging ROS, protects against oxidative stress,	Reduces inflammation markers (TNF-alpha, IL-6), inhibits NF-kB pathway	Promotes BDNF expression in the brain, enhances synaptic plasticity	Modulates acetylcholine levels and transmission, supports cognitive function
Ashwagandha (<i>Withania somnifera</i>)	Reduces oxidative stress, enhances antioxidant enzymes	Suppresses cytokine release, inhibits COX-2	Enhances neurogenesis, improves synaptic plasticity	Modulates GABAergic and serotonergic systems, supports mood regulation
Turmeric (<i>Curcuma longa</i>)	Scavenges free radicals, protects against lipid peroxidation	Inhibits NF-kB, COX-2 pathways, reduces pro-inflammatory cytokines	Modulates amyloid-beta aggregation, reduces tau phosphorylation	Regulates amyloid-beta metabolism, reduces tau phosphorylation
<i>Centella asiatica</i> (Gotu Kola)	Increases antioxidant enzymes, protects against oxidative stress	Suppresses NF-kB pathway, decreases IL-1, TNF-alpha	Enhances neuronal survival, promotes neuritis outgrowth	Enhances cholinergic neurotransmission, supports memory function
<i>Convolvulus pluricaulis</i> (Shankhapushpi)	Protects against oxidative stress, supports antioxidant defense systems	Reduces oxidative stress, suppresses pro-inflammatory cytokines	Enhances synaptic plasticity, improves cognitive function	Modulates acetylcholine transmission, supports memory retention

6. Integration of Ayurvedic and Modern Approaches

Ayurveda and modern medicine offer

complementary perspectives and therapeutic strategies for addressing complex diseases like AD. Integrating Ayurvedic principles with modern

pharmacotherapy presents opportunities to enhance treatment outcomes and improve patient care.

Synergy between Ayurvedic Treatments and Modern Pharmacotherapy **Holistic Approach to Health**

It focuses on individualized care, lifestyle modifications, and natural therapies to restore balance and promote well-being. Integrating Ayurvedic principles with modern pharmacotherapy can enhance patient-centered care by addressing both symptomatic relief and underlying imbalances contributing to disease progression.

Mechanistic Synergy

Ayurvedic medicinal plants, such as Brahmi (*Bacopa monnieri*) and Ashwagandha (*Withania somnifera*), exert neuroprotective effects through mechanisms that complement modern pharmacotherapy:

Enhanced Efficacy: Combining Ayurvedic herbs with conventional medications may enhance therapeutic efficacy by targeting multiple pathways involved in AD pathology, including oxidative stress, neuroinflammation, and neurotransmitter deregulation.

Reduced Side Effects: Ayurvedic herbs often have favorable safety profiles and may help mitigate side effects associated with conventional treatments, enhancing overall tolerability and compliance.

Personalized Treatment Strategies

Integrative approaches allow for personalized treatment strategies tailored to individual patient needs and preferences:

Individualized Care: Ayurvedic practitioners assess patients' constitutional types (doshas), current health status, and disease progression to tailor treatment regimens, including herbal formulations, diet modifications, and lifestyle recommendations.

Comprehensive Care Plans: Integrative treatment plans combine Ayurvedic therapies with modern diagnostic tools, pharmacological interventions, and supportive therapies (e.g., cognitive rehabilitation and nutritional counseling) to optimize patient outcomes (Katial, 2024).

7. Future Directions and Research Gaps

The field of Ayurvedic medicine holds promise for

expanding therapeutic options in neurodegenerative diseases like AD. Future research endeavors aim to address key gaps in knowledge, explore novel therapeutic avenues, and integrate Ayurvedic principles into mainstream healthcare.

Areas Needing Further Investigation

Mechanistic Studies

Explaining Mechanisms: Comprehensive mechanistic studies are essential to unravel the molecular pathways underlying Ayurvedic herbs' neuroprotective effects. Focus areas include interactions with neurotransmitter systems, modulation of neuroinflammation, and effects on mitochondrial function.

Cellular and Animal Models: Utilizing advanced cellular models (e.g., neuronal cell cultures) and animal models (e.g., transgenic AD mice) allows for detailed exploration of Ayurvedic interventions' impact on disease pathogenesis and progression.

Clinical Trials

Comparative Effectiveness Research: Comparative studies comparing Ayurvedic interventions with standard pharmacotherapy or combination therapies offer insights into optimal treatment protocols and patient outcomes.

Potential for Novel Drug Discovery

Bioactive Compounds

Identification and Isolation: Identifying bioactive compounds from Ayurvedic herbs (e.g., Brahmi, Ashwagandha) and exploring their pharmacological properties pave the way for developing novel drug candidates targeting AD-specific molecular pathways.

Pharmacological Screening: Utilizing high-throughput screening techniques and computational modeling accelerates the discovery of lead compounds with neuroprotective potential from Ayurvedic medicinal plants (Tatullian, 2022).

Importance of Interdisciplinary Research

Collaborative Initiatives

Integration of Expertise: Collaborative efforts between Ayurvedic practitioners, neuroscientists, pharmacologists, and healthcare providers facilitate knowledge exchange, methodological synergy, and translation of research findings into clinical practice.

Patient-Centered Outcomes: Incorporating patient perspectives and preferences in research design ensures relevance, acceptability, and adherence to Ayurvedic treatments in diverse patient populations.

Future Prospects and Innovation Personalized Medicine

Precision Approaches: Advancements in genomics, metabolomics, and personalized medicine enable tailored treatment strategies based on individual genetic predispositions, biomarker profiles, and Ayurvedic constitutional types (doshas).

Digital Health Technologies: Integration of digital health tools (e.g., telemedicine, mobile applications) enhances remote monitoring, adherence to treatment regimens, and real-time data collection in Ayurvedic clinical trials (Ablinger et al., 2022).

8. Conclusion

Ayurvedic medicinal herbs contain a rich collection of bioactive compounds that have notable neuroprotective properties. These chemicals have significant potential for treating AD and other neurological diseases. This study synthesizes current information and research findings to elucidate the significance of Ayurvedic herbs in the management of AD, specifically highlighting their potential benefits and therapeutic relevance.

Ayurvedic medicinal plants such as Brahmi (*Bacopa monnieri*), Ashwagandha (*Withania somnifera*), and Turmeric (*Curcuma longa*) has neuroprotective benefits through their antioxidant, anti-inflammatory, and neurotrophic pathways. These actions mitigate the impact of neurodegenerative processes, enhance synaptic plasticity, and bolster the brain's resilience against cognitive loss in AD.

Both clinical trials and observational research provide empirical data supporting the efficacy of Ayurvedic therapy in improving cognitive function, memory retention, and general quality of life in patients diagnosed with AD. The favourable outcomes underscore the potential applications of these kinds of plants as adjunctive therapies or alternatives to conventional therapy.

Ayurvedic herbs typically exhibit good safety

profiles, with little side effects documented in clinical studies. Regulatory frameworks and quality control systems are essential to ensure the quality, efficacy, and safety of products.

By combining Ayurvedic principles with current pharmacology, a comprehensive strategy for managing AD is achieved. This method considers several elements of the disease such as cognitive loss, neuroinflammation, and oxidative stress.

Tailored treatment strategies based on Ayurvedic constitutional types (doshas), genetic profiles, and biomarker assessments enhance therapeutic outcomes and patient-centered care.

Further research is needed to advance mechanistic understanding, conduct large-scale clinical trials, and explore novel drug discovery from Ayurvedic medicinal plants. Collaborative efforts and interdisciplinary research initiatives are crucial for translating findings into evidence-based clinical practice.

Ayurvedic medicinal plants hold significant promise as valuable additions to the therapeutic armamentarium for AD. By harnessing their natural compounds and leveraging traditional knowledge with modern scientific rigor, Ayurveda contributes to the evolving landscape of neuroprotection and personalized medicine.

Acknowledgment: The authors are grateful to the unknown reviewers of the journal for their valuable time and suggestions.

Financial support: No financial support.

Potential conflicts of interest. All authors report no conflicts of interest relevant to this article.

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