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Ethnobotanical Insights into Plants Used for Brain Health From Traditional Practices to Modern Applications

V. Uma Maheswara Rao¹, Sudhir Kumar², , Shaweta Sharma³, Akhil Sharma⁴, Zeba Siddiqui⁵, Yatindra Kumar⁶, Gaviraj.E.N^{7*}

¹Raghavendra Institute of Pharmaceutical Education and Research (Autonomous), Anantapur -515721, Andhra Pradesh State

²Faculty of Pharmaceutical Sciences, DAV University, Jalandhar

³School of Medical and Allied Sciences, Galgotias University, Yamuna Expressway, Gautam Buddha Nagar, Uttar Pradesh-201310, India

⁴R. J. College of Pharmacy, 2HVJ+567, Raipur, Gharbara, Tappal, Khair, Uttar Pradesh 202165

⁵Institute of Pharmacy Shri Ram Swaroop Memorial University, Lucknow, Dewa Road, Barabanki, Uttar Pradesh

⁶Department of Pharmacy, GSVM Medical College, Kanpur, U.P.

⁷B.L.D.E. As SSM College of Pharmacy and Research Center, B.L.D.E Deemed to be University Campus, VIJAYAPURA-586103, Karnataka State

Corresponding author details:Dr. Gaviraj.E.N,Email Id: kleraj2009@gmail.com

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Abstract: Ethnobotany, the study of traditional plant use by indigenous cultures, provides valuable insights into medicinal applications that have stood the test of time. This review delves into the ethnobotanical practices surrounding plants used for brain health, juxtaposing traditional wisdom with modern scientific applications. Understanding brain health and addressing neurological conditions such as Alzheimer's, Parkinson's, and cognitive decline is of paramount importance. Traditional knowledge from various cultures, including Indigenous practices, Ayurvedic medicine, Traditional Chinese Medicine (TCM), African traditional medicine, and Native American practices, reveals a rich repository of plant-based remedies. Key plants like *Ginkgo biloba*, *Bacopa monnieri* (Brahmi), *Panax ginseng*, *Withania somnifera* (Ashwagandha), and *Huperzia serrata* have been traditionally used for their brain-enhancing properties. These plants contain active compounds such as flavonoids, alkaloids, terpenoids, glycosides, and saponins, which contribute to their neuroprotective, antioxidant, anti-inflammatory, and cognitive-enhancing effects. Modern pharmacology has begun to harness these ethnobotanical insights, integrating them into the development of standardized extracts and supplements. Clinical studies support the efficacy of these plants, but considerations of safety, proper dosage, and ethical sourcing are crucial. Despite these advances, challenges such as ethical use of traditional knowledge and conservation of ethnobotanical resources persist. The future of brain health treatments lies in the intersection of traditional practices and modern science, offering promising avenues for new discoveries and therapeutic applications. This review aims to highlight the importance of bridging these worlds, advocating for continued research and collaboration in the field of ethnobotany and brain health.

Keywords: Ethnobotany, brain health, neurological conditions, Alzheimer's, Parkinson's, *Ginkgo biloba*, *Bacopa monnieri* (Brahmi), *Panax ginseng*, *Withania somnifera* (Ashwagandha), *Huperzia serrata*, flavonoids, alkaloids, terpenoids, glycosides, saponins, neuroprotection, antioxidant, anti-inflammatory, cognitive-effect

Introduction

Ethnobotany is the scientific study of the relationships between people and plants, encompassing how different cultures use and perceive plants for various purposes, including medicinal, nutritional, and ceremonial uses. It combines the disciplines of botany and anthropology, aiming to understand how traditional knowledge of plant use has been developed and maintained across generations. Ethnobotany is crucial for several reasons; it helps preserve indigenous knowledge, promotes biodiversity conservation, and aids in the discovery of new medicinal compounds (Kefalew *et al.*, 2015).

The relevance of ethnobotany in modern times is increasingly recognized as we face global challenges such as biodiversity loss and the need for sustainable healthcare solutions. By documenting and validating traditional plant uses, ethnobotany contributes to the scientific community's understanding of natural products and their potential applications, bridging the gap between traditional wisdom and modern science (Rinto *et al.*, 2023).

Brain health is a multifaceted concept that involves maintaining cognitive function, mental health, and overall neurological well-being. The brain is the control center of the body, responsible for managing thoughts, emotions, movements, and vital bodily functions. Maintaining brain health is crucial for quality of life, especially as we age. Neurological conditions such as Alzheimer's disease, Parkinson's disease, stroke, and various forms of dementia are major public health concerns, affecting millions of people worldwide. These conditions often result in significant cognitive decline, loss of motor function, and impaired quality of life (Goel *et al.*, 2023; Sejvar, 2017).

Alzheimer's disease, characterized by memory loss and cognitive dysfunction, is the most common cause of dementia among older adults. Parkinson's disease, marked by tremors, rigidity, and bradykinesia, affects motor control and can also impair cognitive function. Stroke, resulting from interrupted blood supply to the brain, can lead to permanent neurological damage. The increasing prevalence of these conditions highlights the urgent need for effective prevention and treatment strategies. Ethnobotanical research offers promising insights into how traditional plant-based remedies can contribute to brain health and potentially mitigate the impact of these neurological conditions (Yang *et al.*, 2016; Enogieru, *et al.*, 2018).

Traditional knowledge, particularly in the context of medicinal plant use, plays a vital role in the development of modern medicine. Indigenous and traditional cultures have amassed a

wealth of knowledge about plant-based treatments through centuries of observation, experimentation, and transmission of practices. This knowledge forms the basis of many modern pharmaceuticals and therapeutic approaches. For example, the discovery of aspirin was inspired by traditional uses of willow bark, and the anti-malarial drug artemisinin was derived from a plant used in Chinese medicine (Jacob *et al.*, 2016).

The integration of traditional knowledge into modern medicine not only enhances our understanding of natural remedies but also provides a more holistic approach to healthcare. In the context of brain health, traditional practices offer valuable insights into the use of plants for cognitive enhancement, neuroprotection, and mental well-being. Plants like *Ginkgo biloba*, *Bacopa monnieri* (Brahmi) and *Panax ginseng* have been used for centuries in various cultures to support brain function. Modern scientific research has begun to validate these traditional uses, revealing the mechanisms by which these plants exert their effects (Ghosh, 2020).

For instance, *Ginkgo biloba* has been shown to improve cognitive function and protect against neurodegenerative changes, while *Bacopa monnieri* has been found to enhance memory and learning. The collaboration between traditional knowledge holders and modern scientists is essential for developing safe, effective, and sustainable treatments. It ensures that valuable ethnobotanical knowledge is preserved and utilized, fostering innovation in the field of brain health and beyond. As we continue to explore the potential of traditional plant-based remedies, it is crucial to do so with respect for cultural heritage and an emphasis on ethical research practices (Singh *et al.*, 2019).

Traditional Practices

Historical Use of Plants for Brain Health in Different Cultures

The use of plants for maintaining and improving brain health has deep roots in the history of many cultures worldwide. Traditional practices have utilized a variety of plants for their cognitive and neurological benefits, reflecting a profound understanding of natural remedies that modern science is only beginning to fully appreciate. These practices have been passed down through generations, offering a wealth of knowledge that informs contemporary research and application (Reyes-Garcia, 2010).

Indigenous Practices

Indigenous communities across the globe possess a rich tapestry of knowledge regarding the use of plants for brain health, reflecting a deep-seated connection to their natural environment.

This traditional knowledge has been handed down through generations, combining practical experience with cultural and spiritual beliefs. The integration of medicinal plants into their daily lives demonstrates an advanced understanding of the therapeutic potential of nature, especially in promoting cognitive function and addressing neurological disorders (Kumar and Lakshminarayana, 2024).

1. South American Indigenous Practices

In the Amazon rainforest, indigenous tribes such as the Shuar and Achuar have long relied on plants like guayusa (*Ilex guayusa*) for its cognitive-enhancing properties. Guayusa leaves are brewed into a tea that is consumed for mental clarity and alertness. The stimulating effects of guayusa, due to its caffeine content and other bioactive compounds, help the tribes maintain sharpness during hunting and other demanding activities. Additionally, the use of coca leaves (*Erythroxylum coca*) by Andean cultures is notable. Chewed or brewed into tea, coca leaves provide energy, improve mood, and alleviate fatigue, aiding cognitive function in high-altitude environments (Kapp *et al.*, 2016; Sanabaria *et al.*, 2023).

2. North American Indigenous Practices

Native American tribes have utilized a variety of plants to support brain health. The Cherokee, for instance, have used the roots of American ginseng (*Panax quinquefolius*) to enhance cognitive function and relieve headaches. American ginseng is known for its adaptogenic properties, which help the body resist stress and improve mental performance. Another example is the use of sage (*Salvia* species) by various tribes, such as the Lakota and Navajo. Sage is used in smudging ceremonies to purify the mind and spirit, and it is also consumed as a tea to enhance memory and cognitive clarity (Cichoke, 2001; McIntyre, 2019).

3. Australian Indigenous Practices

Aboriginal Australians have a profound understanding of the medicinal properties of native plants. One notable example is the use of the Kakadu plum (*Terminalia ferdinandiana*), which is highly valued for its neuroprotective and antioxidant properties. Rich in vitamin C and other phytonutrients, Kakadu plum helps protect brain cells from oxidative stress. Additionally, the use of bush tomatoes (*Solanum centrale*), also known as desert raisins, is common. These fruits are believed to support mental clarity and overall well-being, highlighting the Aboriginal emphasis on holistic health (McIntyre, 2019; Botsman, 2018).

4. African Indigenous Practices

African traditional medicine, diverse and region-specific, encompasses numerous plants used for brain health. In West Africa, the leaves of the African shrub *Centella asiatica*, commonly known as Gotu Kola, are used to enhance memory and cognitive function. Gotu Kola is renowned for its ability to improve circulation and support neurogenesis. In Southern Africa, the roots of the *Sceletium tortuosum* plant, known locally as Kanna, are used to alleviate anxiety and depression. Kanna's mood-enhancing effects are attributed to its ability to increase serotonin levels, promoting mental well-being and cognitive function (Ncube, 2016; Bennett, 2018).

5. Asian Indigenous Practices

In addition to widely known Ayurvedic and Traditional Chinese Medicine practices, various indigenous groups in Asia have their own unique plant-based remedies for brain health. For example, in the Himalayan regions, the Sherpa people use *Rhodiola rosea*, known as golden root, to enhance cognitive function and combat mental fatigue. Rhodiola is known for its adaptogenic properties, helping the body manage stress and improve mental performance in high-altitude, low-oxygen environments (Li, *et al.*, 2017).

Ayurvedic Medicine

Ayurvedic medicine, originating in India over 3,000 years ago, is one of the world's oldest holistic healing systems. It is based on the belief that health and wellness depend on a delicate balance between the mind, body, and spirit. Ayurveda incorporates various practices, including diet, herbal treatments, and yogic breathing, to maintain this balance and promote overall health. Within this framework, the use of medicinal plants for brain health is a significant aspect, emphasizing both prevention and treatment of cognitive and neurological conditions (Ansari, 2021).

Ayurveda is built on the concept of three doshas: Vata, Pitta, and Kapha, which represent different combinations of the five elements (earth, water, fire, air, and ether) and govern physiological and psychological functions. A balanced state of these doshas is crucial for maintaining health. Imbalances in doshas can lead to various health issues, including those affecting the brain and nervous system. Ayurvedic treatments aim to restore balance through personalized approaches, which often include the use of specific herbs known for their neuroprotective and cognitive-enhancing properties (Lad, 2018).

Modern scientific research has begun to validate many of the traditional uses of these Ayurvedic herbs, uncovering their mechanisms of action and therapeutic potential. Clinical studies on *Bacopa monnieri* have shown significant improvements in cognitive performance and reductions in anxiety. Ashwagandha has been found to reduce stress and improve cognitive function in both healthy individuals and those with cognitive impairment. Gotu Kola's neuroprotective and cognitive-enhancing effects have been supported by studies demonstrating its ability to promote neuronal growth and improve memory (Pase, *et al.*, 2012; Choudhary *et al.*, 2017).

The integration of Ayurvedic knowledge into modern medicine offers a holistic approach to brain health, combining ancient wisdom with contemporary scientific validation. This synergy can lead to the development of effective, natural treatments for cognitive and neurological conditions, providing alternatives or complementary options to conventional pharmaceuticals (Balkrishna *et al.*, 2024).

Specific Plants Used Traditionally for Brain Health

Plants used traditionally for brain health are discussed below and summarized in “figure 1”.

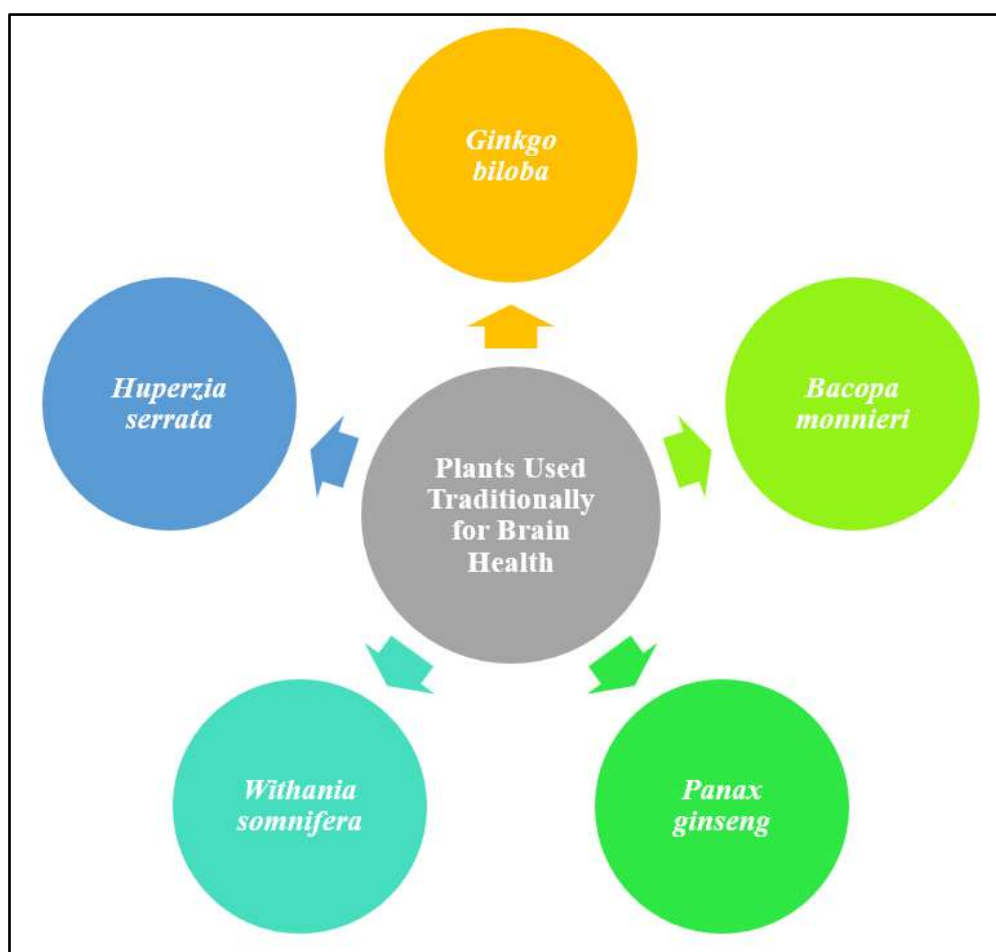


Figure 1. Plants used traditionally for brain health

Ginkgo biloba

Ginkgo biloba has garnered significant attention for its potential in treating and managing various brain diseases. Its long history in traditional medicine and extensive research have highlighted its efficacy in supporting cognitive function and offering neuroprotection. Alzheimer's disease and other forms of dementia, characterized by progressive cognitive decline, memory loss, and behavioral changes, are among the conditions where *Ginkgo biloba* has shown promise. Studies suggest that *Ginkgo* can enhance memory, attention, and overall cognitive abilities, potentially slowing disease progression by protecting neurons from damage and reducing amyloid plaque formation. Additionally, it can help manage behavioral symptoms such as depression, anxiety, and agitation, improving the quality of life for both patients and caregivers (Liu *et al.*, 2024; Shi *et al.* 2010).

The beneficial effects of *Ginkgo biloba* are attributed to several mechanisms. Its flavonoids and terpenoids act as powerful antioxidants, protecting brain cells from oxidative stress and

damage, key contributors to neurodegenerative diseases. *Ginkgo* also has anti-inflammatory properties, reducing brain inflammation by inhibiting pro-inflammatory cytokines. By enhancing cerebral blood flow through vasodilation and reduced blood viscosity, *Ginkgo* ensures better oxygen and nutrient delivery to brain cells. Furthermore, it influences neurotransmitter systems, particularly acetylcholine, which is crucial for memory and learning, helping maintain neurotransmitter balance and improve neuronal communication (de Souza *et al.* 2020).

Parkinson's disease, another neurodegenerative disorder characterized by the loss of dopamine-producing neurons, may also benefit from *Ginkgo biloba*. Although research in this area is less extensive, *Ginkgo*'s antioxidant and anti-inflammatory properties may protect dopamine-producing neurons and improve motor function. Similarly, for stroke and vascular dementia, *Ginkgo biloba* can protect brain cells from damage during a stroke and support recovery by enhancing blood flow and reducing inflammation. Post-stroke patients may experience improved cognitive function and a reduced risk of vascular dementia with *Ginkgo* supplementation (Corona, 2018; Mahomoodally *et al.* 2018).

Depression and anxiety, common in patients with neurodegenerative diseases, can exacerbate cognitive decline. *Ginkgo biloba* has been found to alleviate symptoms of depression and anxiety, improving overall mental health and cognitive function. By modulating neurotransmitter levels, such as serotonin and dopamine, *Ginkgo* helps improve mood and reduce anxiety (Bruggemann *et al.* 2021).

The effectiveness of *Ginkgo biloba* for brain diseases depends on the dosage and quality of the extract used. Standardized extracts containing 24% flavonoid glycosides and 6% terpenoids are commonly recommended, with typical dosages ranging from 120 to 240 mg per day, divided into two or three doses. While *Ginkgo biloba* is generally safe, it can cause side effects in some individuals, such as gastrointestinal upset, headaches, and dizziness. It may also interact with certain medications, including anticoagulants and antiplatelet drugs, increasing the risk of bleeding. Therefore, consulting a healthcare provider before starting *Ginkgo biloba* supplementation is essential, especially for individuals with existing health conditions or those taking other medications (Diamond *et al.* 2000; Tsai *et al.* 2013).

Bacopa monnieri (Brahmi)

Bacopa monnieri, commonly known as Brahmi, is a revered herb in Ayurvedic medicine known for its profound effects on cognitive enhancement and brain health. Used for centuries in India, Brahmi is celebrated for its ability to improve memory, enhance concentration, and reduce anxiety and stress. Its name "Brahmi" is derived from Brahma, the Hindu god of creation, reflecting its reputation as a brain tonic that promotes intellect and wisdom (Joshi *et al.*, 2021).

The active compounds in *Bacopa monnieri*, known as bacosides, play a crucial role in its therapeutic effects. These bacosides are believed to enhance synaptic transmission and promote nerve cell communication in the brain. By supporting the growth of dendrites, which are extensions of neurons that receive signals from other cells, Brahmi helps improve cognitive function and memory retention. Furthermore, Brahmi exhibits antioxidant properties, protecting brain cells from oxidative stress and damage caused by free radicals (Fatima *et al.*, 2022).

Bacopa monnieri supplementation can lead to significant improvements in memory formation, learning ability, and information processing speed. It is particularly beneficial for older adults experiencing age-related cognitive decline and individuals under stress or dealing with anxiety-related disorders. Brahmi's adaptogenic properties also contribute to its ability to reduce cortisol levels, thereby mitigating the effects of stress on cognitive function (McPhee *et al.*, 2016).

Bacopa monnieri is typically consumed in the form of standardized extracts, with recommended dosages ranging from 300 to 600 mg per day. While generally well-tolerated, Brahmi may cause minor gastrointestinal discomfort in some individuals. As with any herbal supplement, it is advisable to consult with a healthcare provider before starting *Bacopa monnieri*, especially if combining it with other medications or supplements (Kongkeaw *et al.*, 2014).

Panax ginseng

Panax ginseng, commonly referred to as Korean ginseng or Asian ginseng, holds a revered status in traditional medicine, particularly in East Asia, for its adaptogenic properties and health benefits. Known for over 2,000 years, *Panax ginseng* is celebrated for its ability to boost energy, enhance cognitive function, and improve overall well-being. The name "Panax" is

derived from the Greek word "panacea," reflecting its traditional use as a cure-all herb (Panossian *et al.*, 2021).

Panax ginseng contains active compounds called ginsenosides, which are believed to be responsible for its therapeutic effects. These ginsenosides act on various pathways in the body to exert adaptogenic, antioxidant, and anti-inflammatory actions. In terms of brain health, *Panax ginseng* has been shown to enhance cognitive function, improve memory, and increase mental alertness. It achieves this by modulating neurotransmitter activity, promoting neuronal growth and survival, and enhancing synaptic plasticity (Ratan *et al.*, 2021).

Panax ginseng supplementation can enhance cognitive performance in tasks involving memory, attention and executive function. It is particularly beneficial in combating mental fatigue and improving concentration, making it popular among students and professionals seeking cognitive enhancement. Additionally, *Panax ginseng's* adaptogenic properties help the body adapt to stress, thereby reducing the negative impact of stress on cognitive function and overall mental health (Kennedy, 2019).

Panax ginseng is typically consumed in the form of standardized extracts, with recommended dosages varying depending on the specific health goals. Common dosages range from 200 to 400 mg per day, taken in divided doses. While generally considered safe when used as directed, *Panax ginseng* may cause side effects such as insomnia, gastrointestinal upset, and headaches in some individuals. It may also interact with certain medications, including blood thinners and diabetes medications, necessitating caution and consultation with a healthcare provider before use (Coleman *et al.*, 2003; Shergis *et al.*, 2013).

Withania somnifera (Ashwagandha)

Withania somnifera, commonly known as Ashwagandha or Indian ginseng, is a revered herb in Ayurvedic medicine renowned for its adaptogenic properties and wide-ranging health benefits. Traditionally used for over 3,000 years in India, Ashwagandha is prized for its ability to promote vitality, increase longevity, and improve overall well-being. The name "Ashwagandha" is derived from Sanskrit, with "Ashwa" meaning horse and "Gandha" meaning smell, reflecting the herb's traditional use to impart the strength and vigor of a horse (Khare and Naharwar, 2020).

Ashwagandha contains active compounds known as withanolides, which are believed to contribute significantly to its therapeutic effects. These withanolides exert adaptogenic,

antioxidant, anti-inflammatory, and immune-modulating actions throughout the body. In terms of brain health, Ashwagandha has been extensively studied for its ability to enhance cognitive function, support memory retention, and reduce stress and anxiety. It achieves these benefits by regulating neurotransmitter activity, particularly enhancing the production of acetylcholine, a neurotransmitter crucial for learning and memory (Daneshwar *et al.*, 2021).

Ashwagandha supplementation can improve cognitive performance, memory recall and information processing speed. It is particularly beneficial in reducing stress-related cognitive decline and improving overall mental clarity and focus. Ashwagandha's adaptogenic properties help the body cope with stress by balancing cortisol levels and supporting adrenal gland function, thereby promoting resilience to stress-related disorders (Leonard *et al.*, 2024).

Ashwagandha is typically consumed in the form of standardized extracts or powdered root, with recommended dosages varying depending on the specific health goals. Common dosages range from 300 to 600 mg per day of standardized extract, taken in divided doses. While generally well-tolerated, Ashwagandha may cause minor gastrointestinal discomfort or drowsiness in some individuals. As with any herbal supplement, it is advisable to consult with a healthcare provider before starting Ashwagandha, especially for individuals with existing health conditions or those taking other medications (Ziegenfuss *et al.*, 2018).

Huperzia serrata

Huperzia serrata, commonly known as Chinese club moss or Toothed Clubmoss, is a plant native to Southeast Asia and is highly valued in traditional Chinese medicine for its medicinal properties. The active compound in *Huperzia serrata* is huperzine A, which has gained attention for its potential cognitive-enhancing effects (Moodie *et al.*, 2019).

Huperzine A works primarily as an acetylcholinesterase inhibitor, meaning it prevents the breakdown of acetylcholine, a neurotransmitter crucial for memory and learning. By maintaining higher levels of acetylcholine in the brain, *Huperzia serrata* helps improve cognitive function, enhance memory retention, and support overall brain health. This mechanism is particularly beneficial for individuals experiencing cognitive decline associated with aging or neurodegenerative diseases (Odorcyk *et al.*, 2017).

Research on *Huperzia serrata* has focused on its efficacy in improving memory and cognitive performance. Studies suggest that supplementation with huperzine A can enhance learning ability, information processing speed, and cognitive flexibility. It has also shown promise in

the treatment of Alzheimer's disease and other forms of dementia, where deficits in acetylcholine are prominent (Wessinger, 2018).

Huperzia serrata is typically consumed in the form of standardized extracts, with recommended dosages varying depending on the specific health goals. Common dosages range from 50 to 200 mcg of huperzine A per day, taken in divided doses. While generally considered safe when used as directed, *Huperzia serrata* may cause side effects such as nausea, diarrhea, or insomnia in some individuals. It may also interact with certain medications, including acetylcholinesterase inhibitors and medications for Alzheimer's disease, necessitating caution and consultation with a healthcare provider before use (Zagami and Alabboud, 2023; Ha *et al.*, 2011).

Phytochemical Constituents

Key Active Compounds in Brain Health-Promoting Plants

Phytochemicals are bioactive compounds found in plants that contribute to their medicinal properties and health benefits. Several classes of phytochemicals play crucial roles in promoting brain health, each with specific effects which is described below.

Flavonoids

Flavonoids, a diverse group of phytochemicals prevalent in fruits, vegetables, tea, wine, and medicinal plants, are renowned for their antioxidant and anti-inflammatory properties that contribute significantly to overall health, particularly brain health. Able to penetrate the blood-brain barrier, flavonoids exert direct effects on brain cells. They act as potent antioxidants, scavenging free radicals and reducing oxidative stress within neurons, thereby preserving their structural integrity and function (Bakoyiannis *et al.*, 2019).

This antioxidant capacity is pivotal in preventing neurodegenerative diseases such as Alzheimer's and Parkinson's. Moreover, flavonoids possess anti-inflammatory properties that mitigate chronic inflammation in the brain, a factor linked to cognitive decline. By promoting neuronal survival, stimulating neurogenesis, and enhancing synaptic plasticity, flavonoids support crucial brain functions like learning and memory. Additionally, certain flavonoids improve cerebral blood flow, ensuring neurons receive ample oxygen and nutrients.

They also modulate neurotransmitter levels, including dopamine and serotonin, which can enhance mood, cognition, and mitigate mood disorders. Examples of beneficial flavonoids

include quercetin, found in apples and berries; catechins from green tea; and epicatechin from cocoa. Incorporating a variety of flavonoid-rich foods into the diet offers cumulative benefits for brain health, bolstering cognitive function and reducing the risk of age-related cognitive decline and neurodegenerative diseases (Flanagan *et al.*, 2018; Habauzit and Morand, 2012).

Alkaloids

Alkaloids represent a diverse class of nitrogen-containing compounds found in numerous plants, known for their pharmacological activities and potential health benefits. In the context of brain health, certain alkaloids have demonstrated significant effects on neurotransmitter systems, cognitive function, and mood regulation. Examples include caffeine from coffee and tea, which acts as a central nervous system stimulant by blocking adenosine receptors, thereby enhancing alertness, attention, and cognitive performance. Another notable alkaloid is nicotine, primarily found in tobacco, which stimulates nicotinic acetylcholine receptors, influencing neurotransmitter release and cognitive processes (Street *et al.*, 2017; Fiani *et al.*, 2021).

Additionally, alkaloids such as berberine from plants like goldenseal and Oregon grape have been studied for their neuroprotective effects, potentially reducing oxidative stress and inflammation in the brain. While alkaloids can offer therapeutic benefits, their effects can vary widely depending on dosage and individual sensitivity, necessitating careful consideration and consultation with healthcare professionals when used for cognitive enhancement or brain health support (Imenshahidi and Hosseinzadeh, 2020).

Terpenoids

Terpenoids, also referred to as terpenes, are aromatic compounds widely distributed in plants, particularly abundant in essential oils and resinous substances. These bioactive molecules play diverse roles in plant physiology and have garnered attention for their potential health benefits, particularly in promoting brain health. Within the realm of cognition and neurological function, terpenoids exhibit several crucial properties. They have demonstrated neuroprotective effects, shielding neurons from oxidative stress, inflammation, and other detrimental processes in the brain, thereby potentially preventing or ameliorating neurodegenerative diseases like Alzheimer's and Parkinson's (Mabou and Yossa, 2021; Hussain *et al.*, 2018).

Moreover, certain terpenoids are known to enhance cognitive function by influencing neurotransmitter systems, facilitating neuronal communication, and fostering synaptic plasticity essential for the adaptability of synapses over time. Their anti-inflammatory

properties are also significant; they can mitigate chronic brain inflammation linked to cognitive decline and neurodegenerative disorders. Additionally, terpenoids can modulate neurotransmitter activity, affecting mood, anxiety levels, and cognitive performance. Notable examples include ginkgolides from *Ginkgo biloba*, renowned for improving cerebral circulation and protecting neurons, and cannabinoids such as CBD and THC from cannabis, which impact mood regulation, pain perception, and cognitive function (Al-Khazaleh *et al.*, 2023; Mony *et al.*, 2022).

Essential oils containing terpenoids like linalool and limonene are recognized for their calming and mood-enhancing effects. Incorporating terpenoid-rich foods and supplements into one's diet holds promise for enhancing brain health, supporting cognitive function, safeguarding against neurodegeneration, and promoting overall mental well-being. However, individual responses to these compounds may vary, necessitating consideration of optimal dosages and consultation with healthcare professionals, especially for individuals managing neurological conditions or seeking cognitive enhancement (Orey, 2019; Sharifi-Rad *et al.*, 2022).

Glycosides

Glycosides, a diverse group of compounds found in plants, are characterized by a sugar molecule (glycone) bound to a non-sugar molecule (aglycone). These bioactive constituents play crucial roles in plant metabolism and defense mechanisms and offer various medicinal properties beneficial to human health, including significant impacts on brain function. In the realm of cognitive health, glycosides exert several key actions. Certain glycosides, such as cardiac glycosides found in plants like foxglove (*Digitalis* spp.), are known for their effects on heart function and circulation, indirectly supporting brain health by ensuring optimal oxygen and nutrient delivery to brain cells (Riaz *et al.*, 2023; Joubert, 2023).

Glycosides possess potent anti-inflammatory and antioxidant properties that shield brain cells from oxidative stress and inflammation, thereby potentially preventing or slowing neurodegenerative diseases. Moreover, glycosides can modulate neurotransmitter systems in the brain, influencing mood, cognition, and overall mental well-being. For instance, glycyrrhizin from licorice root has been studied for its effects on neurotransmitter levels and mood regulation. Additionally, certain glycosides may directly protect neurons, maintaining their function and integrity an attribute particularly valuable in conditions like Alzheimer's disease where neuronal damage occurs (Sarkar *et al.*, 2024; Ahmed-Farid *et al.*, 2019).

Examples of relevant glycosides include salicin from willow bark, known for its anti-inflammatory and pain-relieving properties; oleuropein from olive leaves, studied for its antioxidant effects and potential neuroprotective benefits; and ginsenosides from *Panax ginseng*, which may enhance cognitive function through various mechanisms. Incorporating glycoside-rich foods and supplements into the diet holds promise for supporting brain health, enhancing cognitive function, and protecting against neurodegeneration. However, individual responses to these compounds can vary, necessitating consideration of optimal dosages and consultation with healthcare professionals, especially for individuals managing neurological conditions or seeking cognitive enhancement (Riaz *et al.*, 2023; Kulic *et al.*, 2022).

Saponins

Saponins are bioactive compounds found in various plants, known for their ability to create a foamy solution in water. They serve important roles in plant defense mechanisms and offer diverse physiological benefits for humans, including potential advantages for brain health. In terms of cognitive function, saponins exert several significant effects. Certain saponins, such as those found in legumes like chickpeas and soybeans, have demonstrated cholesterol-lowering properties (Kregiel *et al.*, 2017).

This contributes to improved cardiovascular health, indirectly supporting brain function by enhancing blood flow and nutrient delivery to brain cells. Saponins possess anti-inflammatory properties that can mitigate inflammation within the brain, which is associated with cognitive decline and neurodegenerative diseases. By reducing inflammation, saponins help safeguard neuronal function and overall brain health (Abduljawad *et al.*, 2022).

Additionally, some saponins exhibit immunomodulatory effects, influencing immune cell activity in the brain and the body. This modulation supports a healthy immune response and may protect against neuroinflammatory conditions. Furthermore, research indicates that saponins may directly protect neurons from oxidative stress and other forms of damage, potentially preserving cognitive function and lowering the risk of neurodegenerative disorders (Song *et al.*, 2024).

Examples of relevant saponins include ginsenosides from *Panax ginseng*, noted for their adaptogenic properties and cognitive benefits, and glycyrrhizin from licorice root, studied for its anti-inflammatory and neuroprotective effects. Incorporating saponin-rich foods such as legumes, herbs, and specific vegetables into the diet may help support brain health and

cognitive function. However, individual responses to these compounds can vary, and it is advisable to consult with healthcare professionals, especially for those managing neurological conditions or seeking cognitive enhancement (Ozdemir *et al.*, 2018).

Application of Ethnobotanical Insights in Brain Health

Ethnobotanical insights offer valuable contributions to brain health through various mechanisms, including neuroprotective effects, antioxidant properties, anti-inflammatory effects, enhancement of cognitive functions, and support for neurogenesis and synaptic plasticity which is described below and summarized in “figure 2”.

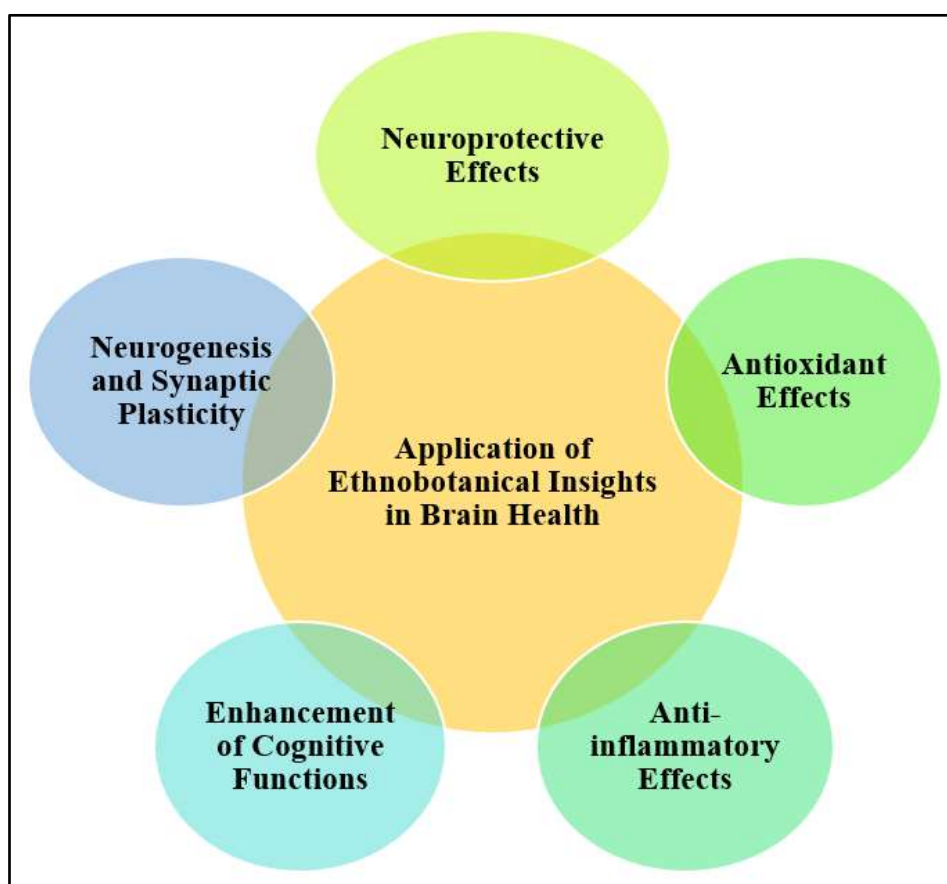


Figure 2. Application of ethnobotanical insights in brain health

Neuroprotective Effects

Ethnobotanical plants, such as *Ginkgo biloba* and *Panax ginseng*, contain bioactive compounds like ginkgolides and ginsenosides, known for their neuroprotective effects. Ginkgolides from *Ginkgo biloba* act as antioxidants and improve vascular health, safeguarding neurons from oxidative stress and enhancing cerebral blood flow. Ginsenosides in *Panax ginseng* support neuronal resilience by modulating cell survival pathways, reducing neuroinflammation, and

promoting neurogenesis and synaptic plasticity. These actions collectively help mitigate neuronal damage and decrease the risk of neurodegenerative diseases like Alzheimer's and Parkinson's, highlighting the potential of ethnobotanical plants in developing neuroprotective therapies for preserving cognitive function and combating age-related brain disorders (Li *et al.*, 2022; Zameshan *et al.*, 2022).

Antioxidant Properties

Many ethnobotanical plants are rich in antioxidants like flavonoids, polyphenols, and carotenoids, which play a crucial role in brain health. These compounds neutralize free radicals and reduce oxidative stress, protecting brain cells from damage. This protection is vital for preventing cognitive decline and neurodegenerative diseases associated with aging. For example, flavonoids in plants like *Ginkgo biloba* and polyphenols in green tea are known for their potent antioxidant effects, safeguarding neurons and maintaining cognitive function. Incorporating antioxidant-rich ethnobotanical plants into the diet can thus significantly support brain health and longevity (Akbari *et al.*, 2022).

Anti-inflammatory Effects

Chronic brain inflammation is linked to neurological disorders such as Alzheimer's and Parkinson's. Ethnobotanical plants like turmeric (*Curcuma longa*), with its active compound curcumin, and *Boswellia serrata*, containing boswellic acids, have potent anti-inflammatory properties. These compounds help reduce neuroinflammation, thereby preserving neuronal function and supporting overall brain health. Curcumin and boswellic acids inhibit inflammatory pathways and cytokine production, mitigating inflammation-related neuronal damage. Incorporating these anti-inflammatory ethnobotanicals into the diet can help maintain cognitive function and protect against neurodegenerative diseases, promoting long-term brain health (Srivastava *et al.*, 2019).

Enhancement of Cognitive Functions

Certain ethnobotanicals promote cellular repair and regeneration in the brain, enhancing overall brain health. These plants support mitochondrial function, crucial for energy production, and promote autophagy, the process of cellular waste removal. Additionally, they enhance neurotrophic factors that aid in neuron growth and survival. For example, compounds in herbs like Ginseng and Ashwagandha are known to boost mitochondrial efficiency, encourage autophagy, and increase levels of brain-derived neurotrophic factor (BDNF). By incorporating

these ethnobotanicals into the diet, it's possible to support neuronal repair, improve cognitive function, and protect against neurodegenerative diseases (Abdi and Mahalaxmi; Mohd. Sairazi and Sirajudeen, 2020).

Neurogenesis and Synaptic Plasticity

Ethnobotanical compounds can stimulate neurogenesis the growth of new neurons and enhance synaptic plasticity, crucial for learning and memory. Examples include epicatechin from cocoa and resveratrol from grapes, which have been studied for their roles in promoting brain plasticity and cognitive flexibility. Epicatechin supports neuron growth and synaptic function, while resveratrol enhances synaptic plasticity and protects against cognitive decline. By incorporating these compounds into the diet, it's possible to boost brain health, improve cognitive function, and support the brain's ability to adapt and learn throughout life (Karim *et al.*, 2020).

Modern Applications

The rich ethnobotanical knowledge accumulated over centuries provides a valuable foundation for modern pharmacology. Integrating traditional knowledge into contemporary medical practices can enhance the development of effective treatments for brain health.

Integration of Traditional Knowledge into Modern Pharmacology

Traditional uses of plants for brain health, documented across various cultures, provide invaluable insights into potential therapeutic compounds. These ethnobotanical practices offer a rich source of bioactive substances that have been utilized for centuries to enhance cognitive function, memory, and overall brain health. Modern pharmacology can greatly benefit from this traditional wisdom by identifying, isolating, and studying these bioactive compounds to understand their mechanisms and efficacy (Adams *et al.*, 2007).

The process begins with ethnobotanical surveys and documentation, where traditional knowledge is recorded and analyzed. Researchers then focus on isolating the active compounds within these plants, using techniques such as chromatography and mass spectrometry. Once isolated, these compounds undergo rigorous testing in laboratory settings to determine their pharmacological effects and potential mechanisms of action (Porrás *et al.*, 2020).

Combining this traditional wisdom with advanced scientific research involves not only pharmacological testing but also clinical trials to evaluate the safety and efficacy of these

compounds in humans. This holistic approach helps in developing novel treatments that are both scientifically validated and rooted in traditional medicine. Ultimately, integrating traditional ethnobotanical knowledge into modern pharmacology can lead to the discovery of new, effective treatments for brain health, bridging the gap between ancient practices and contemporary medicine (Moreira *et al.*, 2014).

Development of Standardized Extracts and Supplements

The development of standardized extracts and supplements represents a significant advancement in utilizing ethnobotanical knowledge for modern medicine. Standardization involves creating products with consistent concentrations of active ingredients, which enhances their reliability and effectiveness. This process ensures that consumers receive a predictable and therapeutic dose of the bioactive compounds, crucial for achieving the desired health benefits (Paul and Kumar, 2024).

Standardized extracts of plants like *Ginkgo biloba* and *Bacopa monnieri* serve as prime examples of this advancement. *Ginkgo biloba* extracts, standardized to contain specific percentages of ginkgolides and bilobalide, are widely used for their cognitive benefits, including improved memory and mental clarity. Similarly, *Bacopa monnieri* extracts, standardized for bacosides, are recognized for their neuroprotective and cognitive-enhancing properties (Sinha and Mukhopadhyay, 2021).

The development of these standardized products involves rigorous research and quality control processes. Initially, extensive studies identify the key active compounds and their therapeutic dosages. Following this, advanced extraction techniques are employed to isolate these compounds in precise concentrations. Quality control measures, such as high-performance liquid chromatography (HPLC), ensure that each batch of the extract meets the established standards (Yu, 2008).

Moreover, clinical trials are conducted to confirm the safety and efficacy of these standardized extracts. Regulatory frameworks, including those set by organizations like the FDA and EMA, oversee the approval process, ensuring that these supplements are safe for consumer use. By standardizing extracts and supplements, the reliability and effectiveness of ethnobotanical products are significantly enhanced, making them valuable tools in modern healthcare for promoting cognitive health and overall brain function (Komala *et al.*, 2023).

Safety, Efficacy and Dosage Considerations

While ethnobotanical compounds offer promising therapeutic benefits, addressing safety, efficacy, and dosage considerations is crucial for their effective use. Determining the appropriate dosages and understanding potential side effects and interactions with other medications require thorough clinical trials and pharmacological studies. These studies are essential to ensure that the active compounds in ethnobotanical products provide the intended health benefits without adverse effects (Kakooza-Mwesige, 2015).

Regulatory frameworks play a vital role in this process. Organizations such as the FDA (Food and Drug Administration) and EMA (European Medicines Agency) establish guidelines and standards to ensure that supplements and extracts are safe for consumption. These frameworks mandate rigorous testing and quality control measures, including pharmacokinetics, toxicity assessments, and long-term safety evaluations, before products can be marketed to the public (Komala *et al.*, 2023).

Consulting healthcare professionals before using ethnobotanical products is highly advisable, especially for individuals with existing health conditions or those taking other medications. Healthcare providers can offer personalized advice, taking into account the specific health status and medical history of the individual. This consultation helps prevent potential adverse interactions and ensures that the use of these supplements is safe and beneficial (Tabuti *et al.*, 2012).

Challenges and Opportunities

The use of ethnobotanical knowledge in modern medicine presents both challenges and opportunities. Ethical considerations are paramount, as traditional knowledge often belongs to indigenous and local communities. Respecting intellectual property rights and ensuring fair compensation for these communities is crucial. This ethical approach fosters trust and promotes sustainable collaborations between researchers and traditional knowledge holders (Ahmad *et al.*, 2021).

Conservation of ethnobotanical resources is another critical challenge. Many medicinal plants are threatened by overharvesting, habitat loss, and climate change. Sustainable harvesting practices, cultivation, and conservation efforts are essential to preserve these valuable resources for future generations. Organizations and governments must work together to implement policies that protect biodiversity and support sustainable use (Jovonic and Kratovalieva, 2015).

Future research directions hold significant potential for new discoveries. Advances in biotechnology, genomics, and pharmacology can uncover novel bioactive compounds from ethnobotanical sources, leading to the development of new therapies for brain health and other conditions. Interdisciplinary collaborations between ethnobotanists, pharmacologists, and other scientists can accelerate these discoveries and translate traditional knowledge into innovative medical applications (Rahman *et al.*, 2021).

Integrating traditional ethnobotanical knowledge with modern science offers immense opportunities for advancing healthcare. Addressing ethical considerations, ensuring resource conservation, and fostering collaborative research are essential steps in unlocking the full potential of ethnobotanical compounds and their applications in modern medicine (Sheng, 2001).

Conclusion

In conclusion, the exploration of ethnobotanical insights into plants used for brain health highlights a profound intersection between traditional practices and modern scientific applications. Traditional knowledge, accumulated over centuries, offers a wealth of information on the use of plants like Ginkgo biloba, Bacopa monnieri, and Panax ginseng for cognitive enhancement and neuroprotection. These plants, rich in bioactive compounds, provide promising therapeutic benefits, including antioxidant, anti-inflammatory, and neuroprotective effects. Modern pharmacology leverages this traditional wisdom, integrating it with advanced scientific research to develop standardized extracts and supplements that ensure consistent efficacy and safety. Rigorous clinical trials and regulatory frameworks further support this integration, ensuring that these natural remedies are both effective and safe for public use. The ethical use of traditional knowledge and the conservation of ethnobotanical resources are crucial to sustaining this valuable heritage. Future research holds the potential for groundbreaking discoveries, enhancing our understanding of these plants' mechanisms and expanding their applications in brain health. By bridging traditional practices with modern science, we can harness the full potential of ethnobotanical plants, offering innovative solutions for cognitive health and fostering a deeper appreciation for the wisdom embedded in traditional medicine.

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