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# A COMPARATIVE STUDY OF ANTI-ALZHEIMER ACTIVITY IN INDIAN MEDICINAL PLANTS

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**ABSTRACT**

Alzheimer's disease (AD) is a progressive neurodegenerative disorder characterized by cognitive decline, memory loss, and neuronal degeneration, primarily associated with oxidative stress, amyloid-β aggregation, and neuroinflammation. The limitations of current pharmacological therapies, which are mainly symptomatic and associated with adverse effects, have driven interest toward plant-based neuroprotective agents. The present study aimed to evaluate the phytochemical composition and potential anti-Alzheimer activity of selected medicinal plants, namely *Psidium guajava*, *Anthocephalus cadamba*, and *Carissa carandas*. Plant materials were collected, authenticated, shade-dried, and extracted using maceration and Soxhlet extraction methods. Preliminary phytochemical screening revealed the presence of key bioactive constituents such as flavonoids, phenols, alkaloids, and saponins in all extracts. Fourier Transform Infrared Spectroscopy (FTIR) analysis confirmed the presence of functional groups corresponding to polyphenols, aromatic compounds, and glycosides, supporting the phytochemical findings. Thin Layer Chromatography (TLC) analysis demonstrated distinct Rf values, indicating variation in polarity and diversity of phytoconstituents among the extracts. Among the studied plants, *Psidium guajava* exhibited a higher abundance of phenolic and flavonoid compounds, suggesting strong antioxidant potential. *Anthocephalus cadamba* and *Carissa carandas* also showed significant phytochemical presence, indicating their possible therapeutic relevance. The presence of these bioactive compounds suggests potential antioxidant, anti-inflammatory, and neuroprotective activities, which may contribute to the inhibition of acetylcholinesterase and reduction of oxidative stress implicated in Alzheimer's disease. In conclusion, the studied plant extracts demonstrate promising phytochemical profiles and potential anti-Alzheimer activity. These findings support further in vitro and in vivo investigations to validate their efficacy and explore their development as natural therapeutic agents for neurodegenerative disorders.

**KEYWORDS:** Alzheimer's disease, *Psidium guajava*, *Anthocephalus cadamba*, *Carissa carandas*, Phytochemical screening.

## INTRODUCTION

Alzheimer's disease is a progressive neurodegenerative disorder and the most common cause of dementia, characterized by gradual loss of memory, thinking, and behavioral abilities that eventually interfere with daily functioning. It typically begins with mild memory impairment in mid-to-late adulthood and advances over time to severe cognitive and functional decline, with no known cure to date.[1,2]

Core features and pathology include early signs often include difficulty remembering recent events, disorientation, and problems with language, reasoning, and judgment; later stages may involve loss of speech, inability to recognize familiar people, and dependence in basic self-care activities.[1] And neuropathology include key hallmarks are amyloid-β plaques and neurofibrillary tangles (hyperphosphorylated tau-protein), along with loss of synapses and neurons, especially in the hippocampus and association cortex, leading to brain atrophy and ventricular enlargement.[2]

It involves a combination of genetic susceptibility (e.g., APOE-ε4 allele), aging, vascular factors, and environmental-lifestyle influences such as cardiovascular disease, diabetes, and physical inactivity.[3,4]

Approved drugs (acetylcholinesterase inhibitors such as donepezil and NMDA-receptor antagonists such as memantine) can temporarily stabilize or slow cognitive decline and behavioral symptoms in early to moderate disease, but do not halt progression. Alzheimer's Disease is characterized by a cascade of progressive neurodegenerative changes driven by abnormal protein metabolism, synaptic dysfunction, and chronic neuroinflammation, ultimately leading to neuronal loss and cognitive decline.[5,6] Its core pathology centers on two protein aggregates—amyloid-β plaques and hyperphosphorylated tau-containing neurofibrillary tangles—which disrupt information processing and kill vulnerable neurons in memory- and cognition-related brain regions.[7] In most AD cases, the "amyloid cascade" begins with dysregulated processing of amyloid-precursor protein (APP), leading to excessive production and accumulation of amyloid-β (Aβ) peptides, particularly Aβ42.[8] These peptides aggregate into extracellular senile plaques and oligomeric species that are synaptotoxic and pro-inflammatory, disrupting neuronal communication and contributing to early memory deficits.[9]

Oxidative stress plays a central role in neurodegeneration by driving mitochondrial dysfunction, protein misfolding, lipid peroxidation, and neuronal death in disorders such as Alzheimer's disease, Parkinson's disease, and amyotrophic lateral sclerosis.[10] The brain is especially vulnerable because of its high oxygen consumption, abundant lipid content, and relatively limited antioxidant defenses, so even small but chronic imbalances between reactive oxygen species (ROS) and antioxidant systems can accumulate into significant neural damage.[11,12] Mitochondria are major sources of ROS; when their function is impaired (e.g., by aging, toxins, or genetic factors), ROS production increases and ATP supply declines, directly damaging neurons and glia.[12] ROS attack neuronal membranes (causing lipid peroxidation), misfold proteins such as amyloid-β and tau, and oxidize DNA, leading to proteotoxic aggregates, synapse loss, and apoptosis or necrosis of affected cells.[13] Oxidative stress activates microglia and astrocytes, releasing pro-inflammatory cytokines and further ROS, while also promoting calcium dysregulation and excitotoxic neurotransmitter release, which together amplify neurodegenerative cascades.[11]

Because oxidative stress is a shared pathway across many neurodegenerative diseases, strategies that enhance antioxidant defenses (e.g., glutathione, vitamin E, curcumin-like polyphenols, or fulvic-acid-derived compounds) or directly scavenge ROS have been widely explored as neuroprotective or disease-modifying agents. Although clinical

trials of generic antioxidants have yielded mixed results, newer approaches focus on targeted, brain-penetrating, or formulation-optimized antioxidants (including natural-product-based delivery systems such as liposomes or transdermal-patch-driven substrates) to counteract oxidative damage while minimizing systemic toxicity.[11]

**Limitations of Current Anti-Alzheimer Drugs**

Current anti-Alzheimer drugs including acetylcholinesterase inhibitors (donepezil, rivastigmine, galantamine) and the NMDA-receptor antagonist memantine—mainly alleviate symptoms and temporarily stabilize cognition, but they do not halt or reverse the underlying neurodegenerative process, and their clinical utility is substantially limited by several key drawbacks.[14]

Major limitations of current anti-Alzheimer drugs include symptomatic, not disease-modifying Existing drugs target neurotransmitter deficiencies (especially cholinergic reduction) or excitotoxicity, leading to modest, reversible improvements or delays in decline, but they do not address the core pathologies of amyloid-β plaques, tau tangles, or progressive neuronal loss.[14] Modest clinical benefit and short-term effect The cognitive and functional gains are typically small and time-limited, often measurable only in early-to-moderate stages, with diminishing returns as disease advances.[14] Tolerability and side-effect burden Cholinesterase inhibitors frequently cause nausea, vomiting, diarrhea, and bradycardia, while memantine can produce dizziness, confusion, and fatigue, limiting dose escalation and compliance, especially in older or frail patients.[14] Treatment complexity and caregiver burden Polypharmacy to manage cognitive, behavioral, and neuropsychiatric symptoms increases regimen complexity, drug-interaction risk, and the burden on caregivers, who must ensure daily, often multiple-times-daily dosing.[14] Late-stage intervention and poor neuroprotection. Most patients are diagnosed after significant amyloid and tau pathology and neuronal loss have already occurred, so available drugs primarily modulate downstream symptoms instead of preventing early oxidative stress, inflammation, or synaptic failure.[14] High-risk disease-modifying agents (anti-amyloid mAbs) Newer monoclonal antibodies (e.g., aducanumab, lecanemab, donanemab) can modestly slow progression but are associated with serious adverse events such as amyloid-related imaging abnormalities (ARIA, brain edema/hemorrhage), high cost, and complex infusion regimens, limiting broad clinical use.[15]

Medicinal plants play a crucial role in neuroprotection because they provide a rich source of multi-target, often low-toxicity phytochemicals that can counteract oxidative stress, neuroinflammation, protein misfolding, and excitotoxicity key drivers of neurodegenerative diseases such as Alzheimer's and Parkinson's. Their use is particularly attractive in the context of current anti-Alzheimer drugs, which are only partially effective, prone to side effects, and mainly symptomatic rather than disease-modifying.[16]

Many medicinal plants contain polyphenols, flavonoids, and terpenoids that scavenge free radicals, reduce lipid peroxidation, and boost endogenous antioxidant systems (e.g., glutathione, SOD), thereby protecting neurons from oxidative damage.[17] Anti-inflammatory and immunomodulatory effects include bioactives from plants such as Withania somnifera (ashwagandha), Bacopa monnieri, Ginkgo biloba, and Curcuma longa suppress pro-inflammatory cytokines, microglial activation, and NF-κB-driven signaling, helping to dampen chronic neuroinflammation linked to neurodegeneration.[18,19] Modulation of protein-aggregation and cell-death pathways include several plant-derived compounds inhibit amyloid-β and tau aggregation, promote clearance of misfolded proteins via autophagy, and regulate apoptosis-related proteins (Bcl-2, Bax, caspases), preserving neuronal viability.[20]

Enhancement of neuroplasticity and neurotransmission: Certain herbs and their constituents (e.g., ginsenosides, withanosides, bacopaside-type triterpenes) support synaptic plasticity, cholinergic function, and neuronal growth-factor signaling, which can translate to improved memory and learning in animal models of cognitive decline.[16,19,21]

Several Indian medicinal plants have shown promising anti-Alzheimer potential in preclinical and some clinical studies, primarily through antioxidant, anti-amyloidogenic, anti-inflammatory, and cholinergic-enhancing mechanisms.[23] These are increasingly investigated as complementary or preventive-type therapies alongside conventional Alzheimer's treatment.[24,25]

Curcuma longa (turmeric, haldi) Curcumin, the major polyphenol, exhibits strong antioxidant, anti-amyloidogenic, and anti-inflammatory activity, reduces amyloid-β aggregation, and modulates NF-κB-related neuroinflammation in animal models of Alzheimer's disease.[23,24,25] Withania somnifera (ashwagandha) Withanolides from ashwagandha show neuroprotective, anti-stress, and cognition-enhancing effects, including reduction of oxidative stress, amyloid-β-induced toxicity, and improvement in learning and memory in rodent models.[24,25,26] Bacopa monnieri (brahmi) Bacosides (triterpenoid saponins) enhance synaptic plasticity, cholinergic function, and antioxidant defenses, and are reported to improve memory and reduce Aβ-associated neurodegeneration in experimental Alzheimer's-like models.[24,25,26] Centella asiatica (mandukaparni / gotu kola) Triterpenes such as asiaticoside and madecassoside improve cognitive performance and reduce oxidative stress, with evidence of protection against Aβ-induced neuronal damage and improved memory in animal studies.[24,25] Celastrus paniculatus (jhām, jyotishmati) Jyotishmati oil and seed extracts enhance memory and learning and are believed to act via cholinergic modulation and antioxidant mechanisms relevant to Alzheimer's-type cognitive decline.[24,25] Phyllanthus emblica (Amla, Indian gooseberry) Amla is rich in vitamin C and polyphenols and has demonstrated anti-amyloidogenic and antioxidant effects in memory-loss and Aβ-based models, supporting its traditional use in cognitive-decline-related conditions.[24,26] Ocimum sanctum (Tulsi, holy basil) Eugenol and other volatile compounds contribute antioxidant and neuroprotective activity, with experimental evidence of reduced oxidative stress and improved brain-function parameters in ageing and neurodegeneration models.[23,28] Other notable plants Additional Indian herbs such as Cinnamomum verum (cinnamon), Zingiber officinale (ginger), Glycyrrhiza glabra (mulethi), and certain polyherbal Ayurvedic formulations (e.g., Brahmi-rasayana, Shankhpushpi-based mixtures) are also reported to exert cholinergic-, antioxidant-, and anti-inflammatory-driven cognitive benefits in Alzheimer's-related experimental and ethnomedical settings.[23,25,29]

## METHODOLOGY

Fresh plant materials of Psidium guajava, Anthocephalus cadamba, and Carissa carandas were collected and authenticated. The collected plant materials were thoroughly washed with distilled water, shade-dried at room temperature, and subsequently pulverized into coarse powder using a mechanical grinder for further experimental analysis.

### 1. Extraction of Plant Samples

#### Extraction of *Psidium guajava*

Approximately 150 g of dried leaf powder of *Psidium guajava* was subjected to maceration with deionized water for 24 h at room temperature. The obtained mixture was boiled for 10 min and filtered using Whatman filter paper. The filtrate was concentrated by evaporation to obtain the crude extract.

**Figure No. 1: Extraction of *Anthocephalus cadamba.***

**Anthocephalus cadamba**

The bark of *Anthocephalus cadamba* was shade-dried and coarsely powdered. About 150 g of powdered material was extracted with hexane using a Soxhlet apparatus. After completion of extraction, the solvent was removed using a water bath to obtain the concentrated extract, which was further dried.

***Carissa carandas***

The leaf extract of *Carissa carandas* showed moderate presence of flavonoids, phenols, and saponins, while alkaloids were detected in low amounts. The presence of these phytoconstituents indicates that the plant possesses antioxidant and medicinal potential. Saponins and flavonoids may contribute to membrane stabilization, anti-inflammatory, and protective biological activities.

**Figure No. 2: Soxhlet extraction process.**

**2. Preliminary Phytochemical Screening**

Test for Alkaloids (Wagner's Test): To 2 mL of test solution, 2–3 drops of Wagner's reagent were added and shaken gently. Formation of a reddish-brown precipitate or turbidity indicated the presence of alkaloids.

Test for Flavonoids (Shinoda Test): To 2 mL of test solution, 3–4 small pieces of magnesium ribbon were added followed by the dropwise addition of concentrated hydrochloric acid. Development of a red or crimson color confirmed the presence of flavonoids.

Test for Phenols and Tannins: To 2–5 mL of test solution, 2–3 drops of ferric chloride solution were added. Formation of dark green, blue-black, or violet coloration indicated the presence of phenolic compounds and tannins.

Test for Saponins (Foam Test): About 5 mL of test solution was mixed with 10 mL of distilled water and shaken vigorously for a few seconds. Formation of a stable foam layer indicated the presence of saponins.

### 3. Fourier Transform Infrared Spectroscopy (FTIR)

A small quantity of finely powdered, shade-dried plant material was directly placed on the ATR crystal (diamond/ZnSe crystal). The pressure arm was gently pressed to ensure proper contact between the sample and the crystal surface. A background scan was performed prior to sample analysis. Each sample was scanned within the spectral range of 4000–400 $cm^{-1}$ at a resolution of 4 $cm^{-1}$ with 32–64 scans per sample. After each analysis, the ATR crystal was cleaned thoroughly using alcohol.

### 4. Thin Layer Chromatography (TLC)

The plant extracts along with Donepezil hydrochloride as a positive control were dissolved in suitable solvent and spotted onto pre-coated TLC plates. The plates were developed using a mobile phase consisting of hexane:ethyl acetate:methanol (2:7:1 v/v/v). After development, the plates were air-dried and sprayed with acetylcholinesterase (AChE) enzyme solution followed by incubation at 37°C for 20 min. Subsequently, the plates were sprayed with a reagent mixture containing potassium ferricyanide and ferric chloride for visualization of inhibitory zones.

## RESULTS

### 1. Percentage yield

| Plants | Weight taken (g) | Dried weight (g | % Yield |
|---|---|---|---|
| Anthocephalus cadamba | 150 | 6.01 | 4.01 |
| Psidium guajava | 150 | 6.11 | 4.07 |
| Carissa carandas | 150 | 6.00 | 4 |

### 2. Phytochemical screening

**i. Phytochemical screening test of Psidium guajava**


**Figure No. 3: Phytochemical screening test of Psidium guajava.**

**ii. Phytochemical screening test of Carissa carandas**


**Figure No. 4: Phytochemical screening test of Carissa carandas.**

**iii. Phytochemical screening test of Anthocephalus cadamba**


**Figure No. 5: Phytochemical screening test of Anthocephalus cadamba.**

The preliminary phytochemical investigation of the extracts obtained from Psidium guajava, Anthocephalus cadamba, and Carissa carandas revealed the presence of various bioactive secondary metabolites, including alkaloids, flavonoids, phenolic compounds, and saponins.

| Plant name | Part used | Alkaloids | Flavanoids | Phenol | Saponins |
|---|---|---|---|---|---|
| Psidium guajava | Leaves | ++ | +++ | +++ | ++ |
| Anthocephalus cadamba | Bark | ++ | ++ | +++ | + |
| Carissa carandas | Leaves | + | ++ | ++ | ++ |

+++ = Abundantly present, + = Present in low amount

++ = Moderately present, - = Absent

**3. Interpretation of Results**

The phytochemical screening demonstrated that all three plant extracts contained important classes of secondary metabolites known for their therapeutic and pharmacological activities.

***i. Psidium guajava***

The leaf extract of *Psidium guajava* showed abundant presence of flavonoids and phenolic compounds, while alkaloids and saponins were moderately present. The high concentration of phenolic and flavonoid constituents suggests strong antioxidant potential, as these compounds are known to scavenge free radicals and reduce oxidative stress. The presence of alkaloids and saponins may additionally contribute to antimicrobial, anti-inflammatory, and neuroprotective activities.

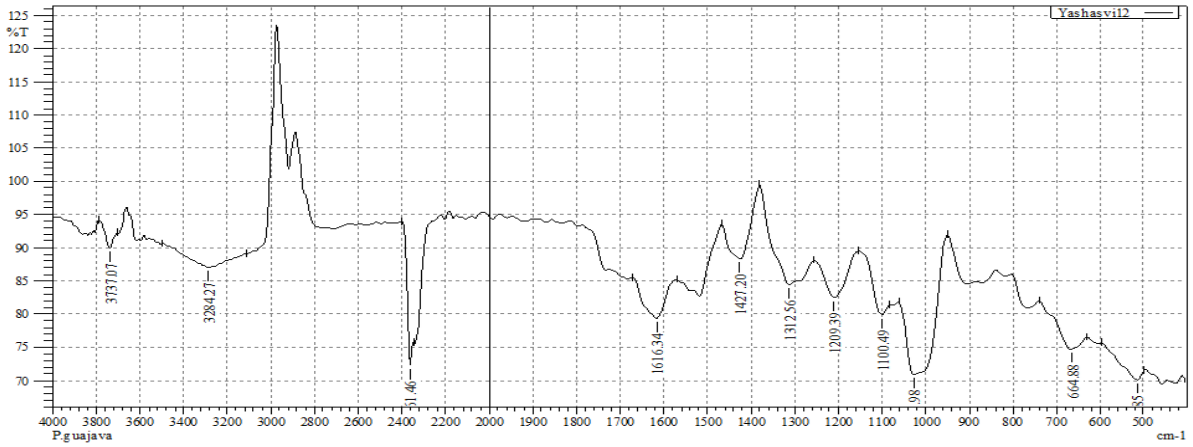



**Figure No. 6: IR spectra of *Psidium guajava.***

The FTIR spectrum of Psidium guajava extract revealed characteristic absorption peaks corresponding to various bioactive functional groups. The peaks observed at 3731.07 $cm^{-1}$ and 3284.21 $cm^{-1}$ indicated O–H stretching vibrations associated with phenolic compounds, alcohols, polyphenols, and flavonoids. The absorption peak at 1616.34 $cm^{-1}$ confirmed aromatic C=C stretching, while the peaks at 1421.20 $cm^{-1}$ and 1312.56 $cm^{-1}$ suggested the presence of aromatic compounds and amines/alkaloids, respectively. Further, the peaks at 1209.39 $cm^{-1}$ and 1100.40 $cm^{-1}$ corresponded to C–O and C–O–C stretching vibrations indicating phenols, ethers, glycosides, and alcohols. The bands observed at 987 $cm^{-1}$ and 664.88 $cm^{-1}$ confirmed the presence of alkenes and aromatic compounds. Overall, the FTIR analysis confirmed the presence of important phytoconstituents such as flavonoids, phenols, alkaloids, and glycosidic compounds in the extract.

### *ii. Carissa carandas*

The leaf extract of *Carissa carandas* showed moderate presence of flavonoids, phenols, and saponins, while alkaloids were detected in low amounts. The presence of these phytoconstituents indicates that the plant possesses antioxidant and medicinal potential. Saponins and flavonoids may contribute to membrane stabilization, anti-inflammatory, and protective biological activities.

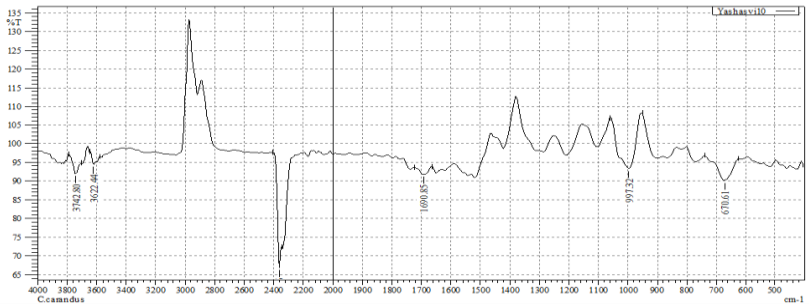
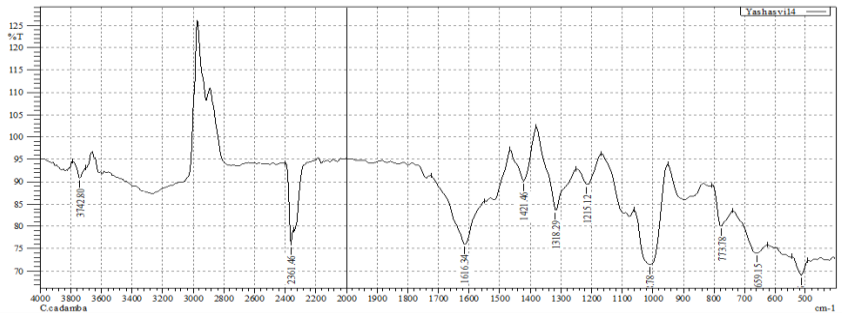



**Figure No. 7: Figure No. 6: IR spectra of *Carissa carandas.***

The FTIR spectrum of Carissa carandas extract showed characteristic absorption peaks corresponding to various functional groups present in bioactive phytoconstituents. The peaks at 3742.80 $cm^{-1}$ and 3602.44 $cm^{-1}$ indicated O–H stretching vibrations associated with alcohols, phenols, and polyphenolic compounds. The absorption band observed at 1609.85 $cm^{-1}$ corresponded to aromatic C=C stretching vibrations, confirming the presence of aromatic compounds.

The peak at 997.32 $cm^{-1}$ represented =C–H bending of alkenes, while the peak at 670.61 $cm^{-1}$ indicated aromatic C–H bending vibrations. Overall, the FTIR analysis confirmed the presence of important phytochemical constituents such as phenolic compounds, flavonoids, and aromatic bioactive molecules in the extract.

### *iii. Anthocephalus cadamba*



A weak to moderate broad band observed around 3742 $cm^{-1}$ suggests the presence of O–H stretching, corresponds to free hydroxyl groups or trace moisture. The region near 3000–2850 $cm^{-1}$ (though not sharply defined) indicates aliphatic C–H stretching vibrations, confirming the presence of alkyl groups. A notable sharp absorption at approximately 2501 $cm^{-1}$ attributed to O–H stretching of carboxylic acid (broad and shifted) or possibly hydrogen-bonded systems, although this requires correlation with other peaks. A strong and distinct absorption band at 1616 $cm^{-1}$ indicates C=C stretching or possibly N–H bending in amine groups, suggesting unsaturation or aromaticity in the structure. The peaks observed at 1421 $cm^{-1}$ and 1318 $cm^{-1}$ are characteristic of C–H bending and C–N stretching vibrations, supporting the presence of amine or substituted hydrocarbon groups. The band at 1215 $cm^{-1}$ further confirms C–N stretching or C–O stretching, indicating possible amine or ether functionalities. A strong absorption around ~1000–1100 $cm^{-1}$ (notably near 1018 $cm^{-1}$) corresponds to C–O stretching, which is typical for alcohols, ethers, or esters. The peak at 773 $cm^{-1}$ suggests aromatic C–H out-of-plane bending, indicating the presence of a substituted aromatic ring. Additionally, the absorption at 659 $cm^{-1}$ may be attributed to C–Cl or C–Br stretching, suggesting possible halogen substitution.

**4. Thin Layer Chromatography**

Visualize white spots against blue background. Calculate Rf value.

**Figure No. 8: TLC of Anthocephalus cadamba.**

**Figure No. 9: TLC of Psidium guajava.**

**Figure No. 10: TLC of Carissa carandas.**

Thin Layer Chromatography (TLC) analysis revealed distinct Rf values for each plant extract, indicating the presence of different phytoconstituents with varying polarity. *Anthocephalus cadamba* exhibited the highest Rf value (0.45), suggesting the presence of comparatively less polar compounds with greater mobility in the selected mobile phase.

*Psidium guajava* showed an intermediate Rf value (0.30), indicating moderately polar phytoconstituents. *Carissa carandas* displayed the lowest Rf value (0.20), which may indicate the presence of more polar compounds having lower migration on the TLC plate.

## CONCLUSION

The present study highlights the significant phytochemical potential of *Psidium guajava*, *Anthocephalus cadamba*, and *Carissa carandas* as promising natural sources for neuroprotective agents in the management of Alzheimer's disease.

Preliminary phytochemical screening confirmed the presence of important bioactive constituents such as flavonoids, phenolic compounds, alkaloids, and saponins, which are well known for their antioxidant, anti-inflammatory, and neuroprotective properties.

Among the investigated plants, *Psidium guajava* demonstrated a comparatively higher abundance of phenols and flavonoids, indicating strong antioxidant capacity, while *Anthocephalus cadamba* and *Carissa carandas* also exhibited appreciable levels of phytoconstituents contributing to their therapeutic potential. FTIR analysis further validated the presence of functional groups associated with these bioactive compounds, and TLC profiling revealed distinct Rf values, confirming the diversity of phytochemicals present in the extracts.

The observed phytochemical composition suggests that these plant extracts may play a beneficial role in combating oxidative stress and inhibiting acetylcholinesterase activity, both of which are key factors involved in the pathogenesis of Alzheimer's disease. Therefore, these plants could serve as potential candidates for the development of safer, plant-based therapeutic alternatives or adjuncts to conventional anti-Alzheimer drugs.

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## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this research work.

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