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Essential Oils as A Potential Neuroprotective Remedy for Alzheimer's Disease

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ABSTRACT

Alzheimer's disease is a complex neurodegenerative disorder characterised by cognitive decline and progressive memory deterioration. Multiple hypotheses have been proposed to elucidate the pathophysiology of the phenomenon in question. At present, there exists a limited number of pharmaceutical interventions for the management of Alzheimer's disease, with the treatment options primarily focused on alleviating symptoms rather than addressing the underlying causes of the condition. The objective of this study is to conduct a comprehensive review of the pertinent in vitro, in vivo, and clinical research pertaining to the potential therapeutic applications of essential oils in the management of Alzheimer's disease. Data was collected by conducting a search in scientific databases, including google scholar, Scopus, ScienceDirect and PubMed. A comprehensive investigation was undertaken to explore the utilisation of diverse essential oils in various models of Alzheimer's disease. The findings of our literary investigation indicate promising outcomes concerning the diverse essential oils that have been examined in research on Alzheimer's disease. These oils have demonstrated notable effects in regulating the disease's pathology through their anti-amyloid, antioxidant, anticholinesterase, and memory-enhancement properties.

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Introduction: Alzheimer's disease is a progressive neurological disorder that affects the brain, leading to memory loss, cognitive decline, and changes in behavior. It is the most commoform of dementia, a group of disorders characterized by the loss of cognitive functioning severe enough to interfere with daily life activities [1]. Named after Dr. Alois Alzheimer, who first described the disease in 1906, Alzheimer's primarily affects older adults, although it can also occur in individuals as young as their 30s or 40s [2].

The exact cause of Alzheimer's disease is not fully understood, but it is believed to involve a complex interaction between genetic, environmental, and lifestyle factors [3]. The disease is characterized by the buildup of abnormal protein structures in the brain, including beta-amyloid plaques and tau tangles, which disrupt the normal communication between brain cells and eventually lead to their degeneration and death [4].

The early symptoms of Alzheimer's disease often include mild memory loss, confusion, and difficulty with language and problem-solving [5]. As the disease progresses, individuals may experience significant memory impairment, disorientation, personality changes, and difficulty carrying out everyday tasks. In advanced stages, individuals may become unable to recognize loved ones, communicate effectively, or even perform basic self-care activities [6].

Globally, it is estimated that around 50 million people are living with dementia, and the majority of cases are due to Alzheimer's disease. The prevalence of Alzheimer's disease is expected to increase significantly in the coming years due to aging populations and other factors [7]. In India, the prevalence of Alzheimer's disease is also on the rise as the population ages. According to a study published in the journal Lancet Neurology in 2020, it was estimated that there were around 4.1 million people living with dementia in India. This number is expected to rise to approximately 7.6 million by 2030 and 13.4 million by 2050, primarily due to population aging [8].

The understanding of the aetiology and pathophysiology of the infection is currently insufficient, and the current approach focuses on providing symptomatic relief and addressing the associated cognitive impairments. The neuro-pathophysiological markers

associated with Alzheimer's disease (AD) include amyloid beta (Aβ), phosphorylated-tau (p-tau), glial fibrillary acidic protein (GFAP), and neurofilament light [9,10]. The primary features of neurotic pathology include neuroinflammation, the buildup of extracellular amyloid-β (Aβ) peptides, the formation of intracellular neurofibrillary tangles, the deterioration of tau proteins, and the progressive loss of neural tissue leading to cognitive decline [11]. The amyloid, also known as senile plaques, is composed of proteinaceous components referred to as Aβ-peptides. These peptides are generated through the cleavage of the amyloid precursor protein (APP). The amyloid precursor protein (APP) undergoes sequential cleavage by two enzymes, namely γ-secretase and β-secretase (BACE1), resulting in the production of three prominent amyloid-beta (Aβ) proteins, namely Aβ-38, Aβ-40, and Aβ-42. According to the "amyloid hypothesis," the accumulation of Aβ in the brain leads to the formation of neurofibrillary tangles through the process of tau hyperphosphorylation, initiating various complex biochemical reactions such as local inflammation, cytokine release, oxidative stress, and excitotoxicity [12]. Astrocytes play essential roles in the development and plasticity of neurotransmitters, redox metabolism, and the maintenance of synaptic homeostasis for neurotransmitters and ions [13]. Research findings indicate that mitochondrial function plays a significant role in the ageing process, potentially increasing the susceptibility to Alzheimer's disease (AD). The presence of mitochondrial dysfunction plays a role in the generation of reactive oxygen species, resulting in significant oxidative damage and the advancement of amyloid pathology [14].

Medicinal plants gained significant recognition due to their comparatively reduced adverse effects in comparison to synthetic medications, as well as their possession of anti-inflammatory and antioxidant properties [15]. Numerous studies have documented the utilisation of medicinal plants, such as Centella asiatica, Ginkgo biloba, Bacopa monnieri, Desmodium gangeticum, Emblica officinalis, Cuminum cyminum, Ficus religiosa, Melissa officinalis, Rosmarinus officinalis, and Piper nigrum, in the treatment of Alzheimer's disease [16]. Plants serve as an abundant and diverse reservoir of active compounds, which are harnessed for their therapeutic properties in the management of various disorders, including Alzheimer's disease [17].

Material and Methods

Data was collected by conducting a search on scientific databases, including PubMed, ScienceDirect, Scopus, and Google Scholar, covering the period from 2000 to June 2023. The keywords that were utilised for the search included Alzheimer's disease, essential oils (EOs), the amyloid hypothesis, neurotrophic factors (NTFs), antioxidants, acetylcholinesterase, and dementia. A comprehensive investigation was undertaken to explore the diverse range of essential oils employed in various models of Alzheimer's disease. The inclusion criteria encompassed scholarly articles pertaining to investigations involving human and animal subjects, clinical trials, and research specifically focused on plant-based interventions for neurodegenerative disorders. Nevertheless, the study excluded review articles and letters to the editor. The elimination of duplicate articles was carried out.

Table 1: List of Essential Oil with Respect to Their Anti-Alzheimer's Intervention

S.NO.	Name of Oils	Study Design	Results	References
1.	Lavender Oil	ICV Aβ (1-42) induced AD in rats	Reduced Aβ(1-42) induced memory and cognitive ability	[18]
2.		Scopolamine-induced amnesia model in rats	Hindered depression, anxiety, and memory deficits	[19]
3.	Peppermint Oil	Scopolamine-induced amnesia model in rats	Improved spatial and working memory, anti-amnesic effect, enhance long term memory	[20]
4.	Eucalyptus Oil	Cell culture propagation induction of RAW267.4 macrophages	Antioxidant, antimicrobial, immunoregulatory, analgesic and anti-inflammatory properties	[21]
5.	Citrus Oil	Scopolamine-induced amnesia model in rats	Improved cholinergic neurotransmission, anti-amnesic effect, antioxidant, enhanced activation of β-actin signaling	[22]
6.	Siparuna Oil	AchE assay, DPPH assay	Anti-inflammatory, antioxidant and strong anticholinesterase activity	[23]
7.	Cinnamon Oil	AchE assay, tau assay	Improved memory and learning, decrease tau-protein phosphorylation and amyloid plaque, anti-inflammatory, anticholinesterase.	[24]
8.	Kaempferia Oil	AchE assay, DPPH assay	Anti-microbial, nematicidal, anti-neoplastic mosquito-repellent, whitening ability, antioxidant, genotoxicity, anti-inflammatory and anti-cholinesterase activity	[25]
9.	Lepechinia Oil	AchE assay, DPPH assay	Antioxidant, anti-inflammatory and anticholinesterase activity	[26]
10.	Salvia Oil	Scopolamine-induced AD like-disorders	Antioxidant, anticholinesterase, decrease amyloid-beta deposition, enhance cognition	[27]
11.	Ginger Oil	DPPH assay, H_2O_2 assay	Antioxidant, anti-alzheimer, anti-inflammatory	[28]
12.	Cherimoya Oil	AchE assay, DPPH assay	Antioxidant, anti-diabetic and antibacterial activity, inhibition of acetylcholinesterase	[29]
13.	Diplosthephium Oil	AChE and BuChE assay, DPPH assay	Antioxidant activity, inhibitory activity against AChE and BuChE	[30]

14.	Fennel Oil	AchE assay	Acetylcholinesterase by improving learning and memory ability, anxiolytic	[31]
15.	Coriander Oil	Aβ (1-42) induced rats' model of AD	Antioxidant, anti-analgesic, improved memory and cognition	[32]
16.	Olive Oil	Scopolamine-induced AD model in rats	Improved spatial and working memory, antidepressant, anxiolytic, anti-alzheimer	[33]
17.	Zataria Oil	ICV Aβ (25-35)-induced AD in rats	Reversed Aβ-induced learning deficits, antioxidant, anti-inflammatory, anti-cholinesterase activities	[34]
18.	Juniper Oil	ICV Aβ (1-42)-induced AD in rats	Reduced memory impairment, antioxidant, anti-cholinesterase activities	[35]
19.	Paeonia Oil	Scopolamine-induced memory deficits, depression and anxiety in rat model of AD	Hindered depression, anxiety and memory deficits	[36]
20.	Clove Oil	ICV colchicine-induced A D in rats	Reversed memory impairment, restored levels of ACh and antioxidants, reduced inflammation mitochondrial dysfunction	[37]

Lavender Oil

Lavender (Lavandula officinalis Chaix), a member of the Lamiaceae family, is an aesthetically pleasing herb commonly found in gardens [38]. The composition of the substance includes camphor, terpinen-4-ol, linalool, linalyl acetate, beta-ocimene, and 1,8-cineole [38]. The quantity and curative properties of its ingredients vary across various species. Linalool and linalyl acetate exhibit notable and significant skin absorption characteristics when applied during massage, resulting in a depressive effect on the central nervous system. Linalool exhibits sedative properties, while linalyl acetate demonstrates pronounced narcotic effects. Both of these effects may potentially account for its utilisation in lavender-infused pillows for individuals with anxiety and disrupted sleep patterns. This application has been observed to enhance overall emotional state, promote cognitive attentiveness, and mitigate aggressive tendencies and anxiety [39]. Lavender oil exhibits antibacterial and antifungal properties against a variety of bacterial species, particularly in cases where conventional antibiotics prove ineffective. However, the precise mechanisms underlying these effects have yet to be fully elucidated. The literature extensively documents the application of lavender essential oil in aromatherapy for various therapeutic purposes, including the management of abrasions, burns, stress, headaches, promotion of new cell growth, skin problems, alleviation of muscular pain, and enhancement of the immune system [40]. The aforementioned oil is utilised for the management of primary dysmenorrheal and has demonstrated encouraging outcomes in a randomised, double-blind clinical trial [41, 42]. The efficacy of Lavender essential oil (EO) in enhancing cognitive functions such as learning and memory can be attributed to its antioxidative properties, which assist in avoiding oxidative damage, as well as its anti-apoptotic properties [43]. The essential oil derived from lavender exhibits a potential anti-dementia impact on memory due to its antioxidant properties and ability to inhibit Aβ-aggregation, neuronal dysfunction, and reduction in non-aggressive physical behaviours in individuals with Alzheimer's disease.

Peppermint Oil

Peppermint, scientifically known as Mentha piperita Linn. (M. piperita), is classified within the botanical family Lamiaceae. To date, a total of 600 varieties of mints have been cultivated, originating from 25 distinct species. The two most significant species in the context are peppermint (Mentha piperita) and spearmint (Mentha spicata). Spearmint possesses a robust fragrance characterised by a pleasant sweetness accompanied by a distinct mentholic subnote [44]. The foliage of the Mentha plant is recognised for its oil content, which constitutes approximately 2% of its overall composition. This particular oil is commonly recognised as the second most notable natural balm, ranking just below citrus oil in terms of prominence. Its primary constituent is menthol, which is responsible for its medicinal properties. Peppermint oil contains a minimum of 44% free menthol [45]. The supplementary components of essential oil (EO) encompass menthone, menthofuran, carvone, menthyl acetate, D-limonene, and 1, 8-cineole. Additionally, the substance comprises of acidic compounds and phenolic acids, namely caffeic acid, p-coumaric acid, ferulic acid, rosmarinic acid, caftaric acid, chlorogenic acid, m-coumaric acid, o-coumaric acid, along with flavonoids such as naringin, luteolin, and riboflavin, as well as monoterpene epoxide like cis-carvone oxide, and tannins [46]. The sensitivity of these components is influenced by factors such as climate, latitude, and plant maturity. The act of inhaling or topically applying menthol has been observed to elicit a dermatological response [47]. The compound is commonly employed in various liniment formulations for the purpose of alleviating pain, muscle spasms, and arthritic conditions. Peppermint oil has been the subject of research and documentation due to its various therapeutic properties, including anti-inflammatory, analgesic, anti-infectious, antimicrobial, antiseptic, antispasmodic, astringent, digestive, carminative, fungicidal effects, nervine stimulant, vasoconstrictor, decongestant, and stomachic properties [48].

Eucalyptus Oil

Eucalyptus globulus, a member of the Myrtaceae family, has been employed for its oil in the management of different conditions such as neuralgia, headaches, and fatigue. The essential oil of Eucalyptus globulus consists primarily of aromadendrene, limonene, terpinene, cineole (comprising 70% to 85% of the oil), pinene, cymene, and phellandrene [49]. The essential oil derived from Eucalyptus globulus has been found to enhance the immune system's response to measles, influenza, the common cold, and chickenpox [50]. Additionally, it has demonstrated efficacy in treating leucorrhea, cystitis affecting the genitourinary system, catarrh, and throat infections such as coughs, bronchitis, asthma, and sinusitis associated with the respiratory system [51]. Furthermore, dermatological conditions such as wounds, lacerations, thermal injuries, herpes infections, pediculosis, insect repellency, and insect bites can be effectively treated using Eucalyptus essential oil. The Eucalyptus essential oil (EO) possesses comprehensive properties that make it suitable for the management of rheumatoid arthritis, as well as muscle and joint pain and discomfort [52]. The utilisation of Eucalyptus essential oil (EO) has been extensively documented in the literature for its effectiveness in managing rheumatoid arthritis,

muscle pain, joint pain, and inflammation [53]. The essential oil derived from Eucalyptus exhibits antibacterial properties, protects against oxidative damage, possesses anti-proliferative and anti-inflammatory effects. Its efficacy has been demonstrated in the treatment of various metabolic and infectious diseases [54]. The essential oil derived from Eucalyptus demonstrates promising therapeutic effects against a range of diseases and has the potential to be utilised in the treatment of complex medical conditions [55, 56]. The process of cell culture propagation results in the activation of RAW264.7 macrophages, which is responsible for the initiation of an inflammatory response [57]. The application of Eucalyptus essential oil (EO) at varying concentrations of 25, 50, and 100 µg/ml has been found to exhibit noteworthy attributes such as antioxidant, antimicrobial, immunoregulatory, analgesic, and anti-inflammatory properties [58].

The inhibitory effect of Eucalyptus globulus essential oil (EO) on acetylcholinesterase (AChE) activity in vitro has been documented [59]. Furthermore, previous research conducted on cellular models has identified the presence of anti-cholinesterase activity in both 1,8-cineole and α-pinene [60, 61]. Furthermore, a recent study reported the inhibitory activity of eucalyptus essential oil (EO) on acetylcholinesterase (AChE) in the hippocampus region of the rat brain exhibiting psychotic symptoms [62]. Furthermore, the cortical mRNA levels of enzymes associated with the metabolism of acetylcholine (ACh) were assessed in animals with induced amnesia using scopolamine. It was observed that the administration of α-pinene reversed the reduction in mRNA levels of choline acetyltransferase (ChAT), an enzyme responsible for the synthesis of Ach [63]. Nevertheless, the administration of scopolamine did not result in any significant changes in the mRNA levels of AChE, regardless of the presence or absence of α-pinene. The aforementioned studies have demonstrated the neuroprotective properties of E. globulus essential oil (EO) and its primary constituents, as they possess the ability to effectively inhibit the activity of acetylcholinesterase (AChE).

Citrus Oil

The lemon, belonging to the Rutaceae family, holds significant importance as a medicinal plant. The primary purpose of cultivating Lemon is to obtain its alkaloids, which have demonstrated anticancer properties [64]. Additionally, research has indicated that crude extracts from various parts of the Lemon plant, such as flowers, stem, roots and leaves possess an antibacterial effect against potentially harmful bacterial strains [65].

Citrus flavonoids exhibit a wide range of biological activities, encompassing antiviral, antidiabetics, antibacterial, anticancer and antifungal properties. The essential oil obtained from the plant also possess prominent therapeutic effects and is primarily composed of terpenes, specifically d-limonene and l-limonene, which collectively make up approximately 90% of the total oil content. Additionally, it has been observed that there are traces of phellandrene, pinene, and sesquiterpene [66]. The remaining 10 percent of the oil is considered to be the valuable fraction, primarily composed of oxygenated compounds, particularly the aldehyde citral. This aldehyde is responsible for the predominant odour of the oil, with approximately 3.5% to 5% of the oil's composition being attributed to its aromatic presence [67]. In comparison to other types of essential oils, the constituents of this particular oil possess antiseptic, astringent, and detoxifying properties that are beneficial for addressing blemishes commonly associated with oily skin [68]. The oil possesses the ability to enhance and revitalise lacklustre skin. Lemon essential oil is primarily utilised for enhancing immune function and promoting the production of white blood cells. It also aids in neutralising acidity and treating ulcers due to its citric acid content, which facilitates digestion by generating potassium and calcium carbonates and bicarbonates [69]. A recent clinical trial employing a double-blinded, randomised, controlled design has indicated that the use of citrus oil in aromatherapy may be beneficial for alleviating pain during the initial stage of labour. The efficacy of this treatment in managing nausea and vomiting, as well as its potential to improve mood, has been demonstrated in previous studies [70,71]. Additionally, it has been claimed that lemon essential oil influences vitamin E's antioxidant activity and enhances the condition of blood vessels close to the skin. Despite the paucity of studies on the use of aromatherapy in senile dementia, it has been hypothesised that aromatherapy may result in some sense of relief and the capacity to respond to outside stimuli, removing the block to action that exists in this condition [72].

Siparuna Oil

Siparuna muricata is a member of the botanical family Siparunaceae, which possesses notable economic, medicinal, and phytochemical importance. The Siparunaceae family encompasses a variety of leafy plant species that have been traditionally employed in the field of medicine for the treatment of gastrointestinal ailments, fever, cough, and rheumatism. Additionally, these plants are utilised as a source of timber [73]. The optional substances found in the methanolic concentrate of these species include cardiac glycosides, sesquiterpene lactone, alkaloids, coumarins, steroids, flavonoids, and tannins [74,75]. The in-vitro investigation of Siparuna muricata essential oil (EO) has demonstrated its efficacy in inhibiting bacterial and fungal growth, as well as its antioxidant properties and potent anticholinesterase activity. A study was conducted by researchers to examine the correlation between the essential oil derived from Siparuna guianensis Aubl. and the activity of acetylcholinesterase. The aim of the study was to discover a potentially new bioactive compound that could be employed in the therapeutic intervention of Alzheimer's disease [76]. The investigation of the inhibitory mechanism involved the analysis of spectrofluorimetric interactions between the enzyme and essential oil, 1H NMR titration, and molecular docking. The fluorescence quenching titration method was utilised for the investigation of the binding mechanism in the experiment. The findings of the study revealed that a significant portion of the binding process demonstrated an exothermic behaviour, which was characterised by a favourable alteration in enthalpy. Additionally, it was observed that the participation of hydrogen bonds and van der Waals forces played a substantial role in this binding interaction. Upon conducting the titration of acetylcholinesterase with the inhibitor solution, a notable observation was made regarding the peaks associated with shyobunone/derivative. These peaks displayed a gradual shift towards the high field. The observed change is suggestive of the phenomenon known as hydrogen shielding. The aforementioned discovery suggests that the interaction between the inhibitor and acetylcholinesterase is mediated by hydrogen bonds [77].

Cinnamon Oil

Cinnamomum zeylanicum is a member of the Lauraceae family. Cinnamomum species are commonly used as sources of natural antioxidants, primarily due to their significant phenolic content resulting from the presence of flavonoids and proanthocyanidins [78]. The foliage and outer layer of Cinnamomum zeylanicum possess significant quantities of (E)-cinnamaldehyde, (E)-cinnamylacetate, and eugenol. In addition, (E)-cinnamaldehyde,

the prominent constituent present in the bark oil derived from C. zeylanicum, exhibits diverse bioactive properties. The essential oil derived from various species of Cinnamomum includes C. zeylanicum (also known as C. verum), C. burmannii, C. loureiroi, and C. cassia [79]. The economic importance of cinnamon leaves and bark can be attributed to their high content of eugenol, (E)-cinnamaldehyde, and (E)-cinnamylacetate. The compound known as (E)-cinnamaldehyde, which is a prominent component found in the bark oil derived from C. zeylanicum, exhibits various bioactivities [80]. Moreover, Cinnamomum zeylanicum is recognised as the species with the highest concentration. A dried aromatic strip derived from C. zeylanicum serves as the primary materialistic by-product, exhibiting various bioactivities, notably antifungal properties. According to available evidence, cinnamon oil has been deemed safe for human consumption and possesses antibacterial properties that can effectively combat drug-resistant strains of H. pylori, a bacterium known to cause ulcers. Cinnamon oil has been employed as a therapeutic agent for promoting well-being and has demonstrated efficacy against gastroenteritis [81]. The primary compound found in the root of cinnamon is camphor. Cinnamon essential oil is employed for the purpose of mitigating oxidative stress, exhibiting anti-Alzheimer's effects, promoting skin brightening, and possessing anti-diabetic properties [24]. The in-vitro study demonstrates enhanced cognitive abilities, reduced phosphorylation of tau-protein and amyloid plaque, anti-inflammatory properties, inhibition of cholinesterase activity, neural preservation, and neurotrophic effects [24].

Kaempferia Oil

Kaempferia galanga is a member of the Zingiberaceae family and possesses aromatic qualities as a medicinal plant, exhibiting diverse therapeutic attributes. K. galanga is commonly employed for therapeutic purposes in the treatment of various ailments such as colds, migraines, asthma, inflammation, hypertension, acid reflux, cancer, pectoral and abdominal pains, dyspepsia, and stiffness [82]. K. galanga is employed in aromatherapy for the purpose of alleviating stress, depression, anxiety, and nervousness. The rhizome of K. galanga is of great economic importance due to its various pharmacological properties, particularly its high concentration of essential oil, which is abundant in the regions where it is cultivated. The essential oil derived from K. galanga contains a variety of bioactive compounds that are responsible for its diverse therapeutic uses. Ethyl p-methoxycinnamate is a compound found in K. galanga that possesses significant therapeutic properties [83]. It exhibits skin whitening, insecticidal, antibacterial, antiangiogenic, and anticancer properties. Due to these properties, it finds diverse applications in the fields of beauty care products and food production. K. galanga has been found to possess a composite containing ethyl p-methoxycinnamate, which exhibits a sedative effect. This composite has been observed to inhibit locomotor activities and decrease the level of melanin synthesis in B16F10 murine melanoma cells that have been stimulated with α-melanocyte [84]. The presence of melanin in the skin can be attributed to the enzymatic action of tyrosinase. Nevertheless, the occurrence of hyperpigmentation, which refers to the excessive deposition of melanin in the skin, has been identified as a causative factor in various dermatological conditions, including melasma, age-related pigmentation, freckles, and skin spots. Previous research has indicated that ethyl p-methoxycinnamate exhibits anti-inflammatory, ulcerative, antidiabetic, and antihypertensive properties [85]. Furthermore, the essential oil derived from K. galanga also exhibits antimicrobial, nematicidal, anti-neoplastic, mosquito-repellent, whitening, antioxidant, genotoxicity, anti-inflammatory, and anti-cholinesterase properties [86].

Lepechinia Oil

Lepechinia paniculata is classified within the Lamiaceae family. Various phytochemicals, including diterpenes, flavonoids, triterpenes, and sesquiterpenes, have been identified in other species. The chemical composition of Lepechinia EO consists primarily of monoterpene hydrocarbons (72%), with significant amounts of Limonene (8%), α-Pinene (3%), 3-Carene (6%), Camphene (13%), and β-Phellandrene (30%). The latest assessments have revealed that the extract of L. paniculata (Kunth) exhibits promising inhibitory effects on butyrylcholinesterase (BuChE) and acetylcholinesterase (AChE) enzymes [87, 88]. Certain species are utilised for their medicinal properties in the treatment of various conditions such as anti-tumor effects, headaches, intrauterine infections, inflammation, wound infections, insulin-like activities, and abdominal pain [89]. Acetylcholine (ACh) is a significant neuromodulator involved in neuronal transmission, particularly in the context of memory formation [90]. The hydrolysis of acetylcholine is catalysed by specific enzymes, namely acetylcholinesterase (AChE) and certain isoforms of butyrylcholinesterase (BuChE). A diminished quantity of these neuromodulators assumes a significant function in the pathogenesis of Alzheimer's disease (AD). Nevertheless, numerous medications inhibit the degradation of acetylcholine, which is marketed as acetylcholine, although their effectiveness is constrained [91]. A study has demonstrated that the utilisation of plant concentrates and essential oils to inhibit the properties of acetyl- and butyrylcholinesterase represents a significant advancement in the search for novel approaches to enhance the well-being of individuals afflicted with Alzheimer's disease. Specifically, the essential oil derived from Lepechinia plants has been found to possess antioxidant, anti-inflammatory, and anticholinesterase properties [26].

Rosemary Oil

Rosmarinus officinalis L. (rosemary) is a member of the Lamiaceae family and is widely distributed in the Mediterranean region. This plant species, specifically Rosmarinus officinalis L., is classified within the aforementioned family [92]. Rosemary essential oil is composed of phenolic diterpenes, including carnosic acid and carnosol, as well as flavonoids such as apigenin derivatives and luteolin derivatives. Additionally, pentacyclic triterpenoids such as ursolic acid, oleanolic acid, and betulinic acid, along with phenolic acids like rosmarinic acid and chlorogenic acid, are present in rosemary leaves. The documented effects of rosemary in various in-vivo and in-vitro studies indicate its potential for preventing oxidative stress, exhibiting antimicrobial properties, enhancing resistance, reducing inflammation, and inhibiting growth [93]. Research has demonstrated that the clinical investigation of rosemary products for the treatment of mental symptoms, such as cognitive decline, confusion, and issues with thinking and reasoning, has revealed significant effects [94]. A recent study demonstrated that the daily consumption of 1000 mg of dried rosemary powder for a duration of one month resulted in significant and measurable enhancements in memory among a group of healthy young individuals. However, another study suggests that older adults (with a mean age of 75 years) who consumed tomato juice supplemented with 750 mg of rosemary powder experienced improvements in cognitive function [95]. A study conducted by found that a blended concentrate of Rosmarinus officinalis L., Melissa officinalis L., and Salvia officinalis L., which had been aged for approximately 60 years, demonstrated improved cognitive function in the elderly population. Nevertheless, similar results were cited regarding the cognitive performance when a combination of lavender and rosemary was utilised [96]. A recent

study demonstrated that the regular consumption of 1000 mg of dried rosemary powder over the course of one month resulted in significant and measurable enhancements in both immediate and delayed memory among a group of healthy young individuals. Previous studies have reported that the inhalation of rosemary essential oil (EO) has been found to enhance the ability of students aged 13-17 to remember numbers and improve their short-term memory recall [97]. Additionally, it has been observed to have a positive impact on cognitive tasks in children [98]. The intensive utilisation of rosemary water also yields comparable results in healthy adults. According to the reported information, the inhalation preparation of rosemary essential oil has been found to improve the retention of numbers and short-term memory recall in various individuals. Additionally, it has been observed to enhance memory capacity in individuals aged 13-17 [99]. However, its effects on cognitive tasks in children have been investigated. The administration of scopolamine at a dosage of 1 mg per kilogramme was employed to induce amnesia and a dementia-like state resembling Alzheimer's disease. The essential oil of Rosmarinus officinalis, when administered at doses of 25 and 50 mg/kg, demonstrates a significant anti-amnesic effect. This effect is attributed to its ability to improve both working and spatial memory. Additionally, the essential oil promotes hippocampal growth and neural plasticity, ultimately leading to enhanced long-term memory. This finding is supported by previous research [20, 100].

Salvia Oil

Salvia officinalis is a member of the botanical family Lamiaceae and is widely recognised as one of the primary sources of essential oil in traditional medicine. Although the compound manufacturing of Salvia officinalis essential oil (EO) has been addressed, it is worth noting that its high alcoholic content exhibits antimicrobial properties. Additionally, higher levels of ketones have been found to promote improved skin injury healing [101]. Ethylene oxide (EO) is rapidly absorbed through the skin and enters the circulatory system, allowing it to reach the brain and other organs [102]. The reduction in discomfort associated with headaches is the result of a combination of various factors, including a decrease in the perception of pain, neurogenic inflammation, and vasodilation. The use of fragrance-based treatment as a therapeutic intervention for improving sleep disorders has been explored in previous studies [103]. It has been suggested that inhaling essential oils (EO) may have a stimulating effect on both the immune and limbic systems. The essential oil (EO) is utilised in the treatment of various ailments including colds, tuberculosis, bronchitis, gastrointestinal illnesses, inflammation, as well as possessing antibacterial, antifungal, antitumor, and antioxidant properties [104]. Additionally, it has been found to enhance memory and exert a stimulating effect on the nicotinic and muscarinic receptors. Numerous studies have investigated the inhibitory effects of acetylcholinesterase, a compound known to have a specific impact on Alzheimer's disease [105]. Salvia essential oil (EO) is employed for the purpose of mitigating nausea and vomiting in individuals afflicted with cancer who are undergoing chemotherapy. Rosa damascene EO is utilised to alleviate anxiety and enhance the quality of sleep in patients with cardiovascular conditions [106]. Aromatherapy has been suggested as a potential intervention for improving insomnia symptoms. It has been proposed that the inhalation of essential oils (EO) may have the ability to stimulate both the immune and limbic systems, which could contribute to the observed benefits [107]. Essential oil (EO) is commonly utilised for the treatment of various ailments such as colds, gastrointestinal diseases, antifungal infections, tuberculosis, inflammation, bronchitis, bacterial infections, antitumor effects, and antioxidant properties [108]. Salvia is employed for the purpose of treating cognitive functions, enhancing memory, and exerting a stimulating effect on the nicotinic and muscarinic receptors. Several studies have been reported that discuss the influence of acetylcholinesterase and amalgam examination in the treatment of Alzheimer's disease, specifically focusing on its evident manifestations [109]. Salvia essential oil (EO) is employed for the purpose of reducing nausea and vomiting in individuals undergoing chemotherapy for cancer. The administration of Salvia essential oil (EO) resulted in a significant decrease in β-amyloid accumulation. Additionally, the levels of oxidative stress markers and acetylcholinesterase activity were also reduced [110].

Ginger Oil

The Zingiberaceae family is the largest family that includes Zingiber officinale. The product contains synthesised components such as phenolic acid paradols, gingerols, and shogoals. The phytoconstituents mentioned exhibit significant effects in relation to diabetes, mitigation, antioxidant activity, pain relief, antimicrobial action, anti-hypertensive properties, gastrointestinal health, and antiulcer effects [111]. The essential oil derived from the separation of ginger typically consists of sesquiterpenes, monoterpene hydrocarbons, and a blend of alcohols. Furthermore, ginger contains non-volatile compounds such as zingerone, shogoals, gingerols, and paradols. The ginger essential oil contains several therapeutically active components, namely Zingiberene, shogoals, gingerols, and zingerone, which have been found to possess antioxidant properties. Ginger possesses significant constituents that are employed in the management of diverse ailments such as stroke, muscular discomfort, constipation, catarrh, helminthiasis, sore throats, diabetes, gum disease, toothache, nervous disorders, nausea, fever, dyspepsia, sprains, and infectious conditions. Nevertheless, it is worth noting that this substance possesses carminative properties, which can effectively stimulate the gastrointestinal tract [112]. Furthermore, it is commonly utilised as an additive in food products to enhance their flavour and diversity, while also offering various therapeutic benefits. Ginger is employed in the treatment of juvenile colic, respiratory illnesses such as asthmatic bronchitis and cough, and for alleviating digestive ailments. It is commonly consumed in combination with milk or water, and in some cases, blended with honey. In addition to its well-known culinary uses, ginger has been attributed with various medicinal properties, such as blood-cleansing abilities, invigorating effects on sexual function, anti-sickness properties, aphrodisiac qualities, anti-nausea effects, appetising properties for treating haemorrhoids, anti-gas properties, and antispasmodic effects [113]. Several studies have reported that ginger essential oil (EO) exhibits antimicrobial properties against various microorganisms, including E. coli, S. aureus, and Salmonella typhi. Ginger essential oil exhibits antioxidant properties, displays antimicrobial activity against cancer-causing microorganisms, and has potential therapeutic applications in the treatment of infections caused by free radicals [114]. Ginger oil and concentrates have commonly been employed in the field of natural medicine due to their documented therapeutic and biological effects [70]. According to in-vitro studies, it has been observed that Ginger EO demonstrates analgesic properties and is also capable of reducing neuropathic pain, inflammatory pain, and exhibiting anti-alzheimer's activity [115].

Cherimoya Oil

The Annona cherimola, a member of the Annonaceae family, is commonly referred to as "chirimoya" or "chirimoyo" and "custard-

apple". This particular plant species has been found to possess antimalarial properties [116]. The chemical compounds derived from these species are classified as alkaloids, including rumocosine H, cherimoline, annocherine A, cherianoine, and annocherine B [29]. Additionally, a few amides have been identified, namely N-cis-feruloylmethoxytyramine, N-p-coumaroyltyramine, cherinonaine, N-trans-feruloyltyramine, cheritamide, N-trans-caffeoyltyramine, dihydro feruloyltyramine, N-cis-caeoyltyramine, and N-trans feruloylmethoxytyramine [117]. Numerous secondary metabolites that have been documented are phenols and other bioactive compounds. However, the primary chemical constituents of interest are polyketides known as acetogenins. These compounds are closely associated with their anti-proliferative effects on cancer cell lines. The essential oil extracted from A. cherimola has been found to contain several significant constituents, including bicyclogermacrene, sabinene, (E)-caryophyllene, β-pinene, germacrene D, β-caryophyllene, germacrene-D, bicyclogermacrene, trans-caryophyllene, α-amorphene, α-copaene, germacrene D, α-thujene, α-pinene, terpinen-4-ol, and germacrene D [118]. Furthermore, different components of the plant have been utilised for medicinal purposes in the treatment of several ailments, such as diabetes, gastrointestinal disorders, hypertension, Malaria, Chagas disease, and Leishmaniasis. A. muricata possesses a diverse range of medicinal properties, encompassing the treatment of malarial infection, liver ailments, migraines, malarial disease, and fever. Recent studies have revealed that custard apple leaves possess flavonoids and other phenolic compounds that exhibit therapeutic properties. Additionally, alcoholic extracts derived from these leaves have been found to possess pro-apoptotic and antidepressant properties [119]. Annona cherimola is commonly employed in traditional medicine for the management of boils and various dermatological conditions, and it is also anticipated to have applications in the fields of cosmetics, food, pharmaceuticals, and agrochemical products [120]. The essential oil derived from A. cherimola demonstrates antioxidant, anti-diabetic, and antibacterial properties, as well as the ability to inhibit acetylcholinesterase [121].

Fennel Oil

Ferula gummosa is a member of the botanical family Apiaceae. The chemical composition of F. gummosa EO comprises monoterpenes, specifically β-pinene, α-pinene, and myrcene [122]. The essential oil of F. gummosa is composed of β-pinene, α-pinene, δ-3-carene, and limonene, which have demonstrated antifungal properties. F. gummosa exhibits various pharmacological activities, including anticonvulsant, anti-rheumatic, anti-inflammatory, anti-neurological, anti-diabetic, and antioxidant properties [123]. Additional scientific investigations on the resins of F. gummosa have reported various biological properties, including analgesic, expectorant, antimicrobial, laxative, antiepileptic, digestive, anti-catarrh, carminative, aphrodisiac, and antibacterial effects. The findings of several studies indicate that extracts derived from the leaves, fruits, and stems of F. gummosa exhibit anti-hemolytic and anti-oxidant properties [124]. Additionally, these extracts have been observed to inhibit the multiplication of gastric cells and induce apoptosis in gastric cells. The essential oils derived from diverse plant sources have demonstrated a range of activities, including antibacterial, antiviral, antioxidant, antinociceptive, and anti-inflammatory effects [125]. Furthermore, they are also recognised for their ability to alleviate stress and are widely employed in the treatment of sleep disorders. Comprehensive investigations have revealed the beneficial impact of the examined substances on various conditions, including Alzheimer's disease, cardiovascular disease, cancer, antifungal and antimycotoxigenic activities, immunomodulation, antispasmodic effects, cytotoxicity, and anxiolytic properties [126]. F. gummosa has been found to demonstrate efficacy against acetylcholinesterase, thereby enhancing cognitive functions such as learning and memory [127].

Coriander Oil

Coriander essential oil is derived through the process of steam distillation from the desiccated and fully matured fruits of the plant species Coriandrum sativum L., which belongs to the botanical family Apiaceae. The oil exhibits a distinctive olfactory profile consisting of linalool notes, accompanied by a gentle, pleasant, and comforting taste profile with aromatic qualities. Coriander oil serves as a flavouring agent and adjuvant within the food industry [128]. In addition to its culinary applications, coriander is recognised for its presence of secondary metabolites that contribute to its therapeutic properties, such as anticonvulsant, antidiabetic, antimicrobial, antioxidant, and others [129]. The enzyme known as EO primarily finds its regular applications within the gastrointestinal system, as well as in the realms of food and pharmaceuticals. The use of essential oils (EO) in aromatherapy provides notable psychological support and is also efficacious in the treatment of muscular issues, such as pain and spasms [130]. Coriander essential oil (EO) exhibits various pharmacological properties, including antimicrobial effects against microorganisms and parasites, antioxidant activity for cancer prevention, antidiabetic properties, anxiolytic effects, anthelmintic activity, insecticidal properties, anti-inflammatory and digestive effects, hepatoprotective properties, and anti-aging properties. There are several species of coriander, including Coriandrum majus Gouan, Coriandrum testiculatum Lour, Coriandrum sativum L. (also known as Coriandrum diversifolium) Gilib, and Selinum Coriandrum (Vest) [131]. The chemical composition of Coriandrum essential oil (EO) consists of various compounds which include phellandrene, terpineol, cineole, terpinolene, coriandrol, cymene, dipentene, linalool, Borneol, and geraniol. The oil possesses medicinal properties attributed to the presence of phytochemicals, including linalool, a volatile flavour compound [132]. The utilisation of leaves as flavour enhancers in various culinary applications such as seasoning refreshments, mayonnaise salad toppings, and garnishes has been observed. In addition to its culinary applications, coriander has been recognised for its secondary metabolites that possess various biological properties, including but not limited to antioxidant, anticonvulsant, antimicrobial, and antidiabetic activities [133]. The digestive system is the primary domain in which EO finds its most prevalent applications, particularly in the realms of food and medicine. The utilisation of essential oils (EO) in the practise of aromatherapy has been found to offer significant psychological relief. Furthermore, these oils have demonstrated notable efficacy in the treatment of muscular ailments such as spasms and aches [134]. Coriander essential oil (EO) exhibits various pharmacological properties, including antimicrobial effects against bacteria and fungi, insecticidal action, soothing properties, gastrointestinal benefits, antioxidant activity, antidiabetic effects, hepatoprotective properties, anxiolytic activity, anthelmintic effects, and anti-aging properties [135]. The rat's model of Alzheimer's disease (AD) induced by Aβ (1-42) demonstrates impairment in memory and cognition. However, administration of Coriander EO has been found to possess antioxidant and analgesic properties, and it also improves memory and cognition [136].

Olive Oil

Olea europaea, a member of the Oleaceae family, is commonly referred to as 'liquid gold'. Olive oil contains various phytochemicals, namely superfatted compounds, polyphenols,

tocopherol, and oleic acid. This oil contains a significant amount of intensified polyphenols, such as hydroxytyrosol, oleuropein, and other crucial compounds [137]. These compounds have been shown to possess anti-cancer, anti-inflammatory, and anti-angiogenic properties [138]. Similarly, the presence of high levels of oleic acid and superfatted acid plays a crucial role in mitigating the risk of chronic diseases such as obesity, cardiovascular disease, Alzheimer's disease, type-2 diabetes, metabolic disorders, cancer, atherosclerosis, and hypertension [139]. The experimental investigation reveals that the mixture of olive oil possesses medicinal properties, including antioxidant, vasodilator, anti-cancer, antiarrhythmic, antimicrobial, and anti-inflammatory effects. Research studies have demonstrated that the consumption of olive oil, combined with different phenolic compounds, has been found to reduce the risk factors associated with the development of high-density lipoprotein cardiovascular disease, oxidised glutathione, and serum triglyceride levels [140] . Several studies have indicated that olive oil possesses biological, therapeutic, and nutritional properties [10]. Additionally, it has been recognised for its potential as a source of nutritious food, medicine, and cosmetic applications. Additional advantageous effects of olive oil include the reduction of coronary heart disease, the lowering of blood pressure, the mitigation of coronary heart disease, as well as its anti-diabetic properties and its potential to reduce the risk of Alzheimer's disease [141]. The administration of scopolamine at a dosage of 0.7 mg/kg via intraperitoneal injection has been observed to induce amnesia in a rat model. This amnesia is characterised by a decrease in both spatial and working memory. However, when treated with olive oil, the rats exhibited a significant improvement in both spatial and working memory. Additionally, the olive oil treatment demonstrated anxiolytic, antidepressant, and anti-Alzheimer activity, as supported by previous research [142].

Discussion

In recent years, there has been a notable surge in research focused on naturally occurring phytochemicals. This heightened interest can be attributed to the absence of significant adverse reactions associated with these compounds, as well as their demonstrated efficacy in the clinical treatment of various pathogenic conditions. The plant harbours an essential oil (EO), which is a hydrophobic liquid substance comprising volatile compounds produced through secondary metabolism. The bioactive compounds found in essential oils derived from plants are believed to be responsible for their pharmacological properties. The utilisation of essential oils extends beyond medicinal purposes, as they also offer advantages as additives and packaging materials in the food industry, as well as in perfumes and cosmetics. Essential oils (EO) consist of synthetic groups such as unsaturated hydrocarbons, alcohols, terpenes, oxides, ketones, esters, saturated hydrocarbons, ethers, phenols, and aldehydes. These compounds can be extracted from various components of plants, including roots, flower petals, leaves, resins, stems, and bark. A recent study conducted by multiple organisations has demonstrated a notable inhibitory effect on acetylcholinesterase (AChE) by various EO. These findings suggest that EO may hold promise as a potential neuroprotective therapy for age-related neurodegenerative diseases. Alzheimer's disease (AD) is a persistent neurodegenerative condition characterised by impaired memory and cognitive function, along with alterations in behaviour and personality. Atopic dermatitis (AD) is a complex infection characterised by a combination of hereditary and environmental factors, as well as other intricate causes such as familial lineage, sexual orientation, age, and Down syndrome. The aetiology of Alzheimer's disease (AD) is characterised by a combination of factors, including the development of neurofibrillary tangles, the accumulation of Aβ-peptide, neuroinflammation, and cerebral atrophy leading to a gradual decline in cognitive function. Several essential oils (EO) have been identified as having potential benefits for mental and physical well-being. Examples of these oils include citrus oil, ginger oil, peppermint oil, rosemary oil, lavender oil, and cinnamon oil. These oils have been associated with improvements in cognitive function, alleviation of discomfort, enhancement of mood, maintenance of memory, and potential positive effects on physical and mental conditions affected by distress.

Summary

In summary, our analysis has underscored the multifaceted advantages of essential oils (EOs) beyond their conventional applications as flavours and fragrances, particularly in relation to their notable contributions to the treatment of neurodegenerative diseases. The roles played by these entities in mitigating the impact of diseases are influenced by distinct mechanisms that differ depending on their source. While our search did not include any human studies, we hold a firm belief that the inclusion of crucial constituents within the essential oils could have substantial implications in the endeavour to avoid and cure neurodegenerative conditions. Hence, it is imperative to sustain the pursuit of new species of essential oils (EOs) in order to investigate oils that may have potential applications in EO-based therapies or treatment approaches for neurological conditions.

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Conflicts of Interest

The authors declare no conflict of interest.

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