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CYMBOPOGON CITRATUS (LEMONGRASS): A REVIEW ON ITS PHYTOCHEMISTRY AND BIOLOGICAL ACTIVITIES

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ABSTRACT

Cymbopogon citratus (lemongrass) is a medicinal plant belonging to the family Poaceae that is widely used in traditional medicine for its calming, therapeutic, and health-promoting properties, particularly in Asia, Africa, and South America.[1,6] The aim of this review is to summarize and evaluate existing literature on the phytochemical composition and biological activities of *C. citratus*, with emphasis on its neurocognitive potential. A narrative review design was employed to compile, summarize, and interpret published studies on the phytochemistry and pharmacological effects of *C. citratus*. Literature was retrieved primarily from Google Scholar and other online sources, covering studies published from 2000 to 2025 to ensure both foundational and recent scientific findings were included.[14] Studies focusing on phytochemical screening, essential oil composition, and neuropharmacological effects were analyzed. Based on the reviewed literature, *C. citratus* contains a wide range of bioactive compounds, including flavonoids, phenolic acids, tannins, saponins, and essential oils such as citral, geraniol, and limonene.[4,12] These compounds are strongly associated with antioxidant, anti-inflammatory, antimicrobial, and neuroprotective activities. Existing studies suggest that its neurocognitive effects, including memory enhancement, anxiolytic activity, and neuroprotection, are linked to its ability to reduce oxidative stress, modulate neurotransmitter activity, and inhibit acetylcholinesterase enzymes.[15,10] However, despite promising preclinical evidence, most findings are derived from in vitro and animal studies, with limited clinical trials in humans. Therefore, the neurocognitive benefits of *C. citratus* should still be considered as potential therapeutic effects rather than confirmed clinical outcomes. Further research, particularly well-designed human clinical studies, is needed to validate its safety and efficacy in neurocognitive applications.

KEYWORDS: *Cymbopogon citratus*, lemongrass, phytochemistry, neurocognitive, memory enhancement, anxiolytic effects, neuroprotection, antioxidant activity.

1. INTRODUCTION

Cymbopogon citratus (lemongrass) is a perennial aromatic medicinal plant belonging to the family Poaceae. It is widely distributed in tropical and subtropical regions, particularly in Asia, Africa, and South America, where it is commonly used in traditional medicine for various therapeutic purposes.[1,6] In many ethnomedicinal systems, *C. citratus* is valued for its calming, antipyretic, anti-inflammatory, and neurorelaxant properties, making it a commonly used herbal remedy for stress, anxiety, and sleep disturbances.[14,21]

In addition, lemongrass is traditionally consumed as herbal tea or used in aromatherapy for its soothing and mood-enhancing effects, which are believed to contribute to improved mental well-being and relaxation.[18] Recent scientific studies have also highlighted its potential neurocognitive benefits, including memory enhancement, anxiolytic activity, and neuroprotection.[2,20] These effects are attributed to its bioactive compounds that act on the central nervous system.

The objective of this review is to summarize and evaluate existing literature on the phytochemistry and biological activities of *C. citratus*, with emphasis on its neurocognitive potential. Specifically, this study focuses on the plant's phytochemical constituents, pharmacological properties, and mechanisms of action related to memory enhancement, stress reduction, and neuroprotection.

1.1 Botanical and Taxonomic Description *Cymbopogon citratus*

Cymbopogon citratus (DC.) is a perennial aromatic grass commonly found in tropical and subtropical regions, particularly in Asia, Africa, and South America.[1,6] It belongs to the genus *Cymbopogon*, family Poaceae, order Poales, class Liliopsida, division Tracheophyta, subkingdom Viridiplantae, and kingdom Plantae.[1] The genus *Cymbopogon* includes several economically important species known for their essential oil production and medicinal value.[7]

C. citratus is widely cultivated in tropical countries such as India, Sri Lanka, Thailand, Indonesia, and the Philippines due to its adaptability to warm climates and well-drained soils.[6] It is commonly known as lemongrass and is referred to as "tanglad" in the Philippines, reflecting its cultural and culinary importance in Southeast Asia.[14]

The plant is a densely tufted perennial grass that typically grows to a height of 1–1.5 meters. It is characterized by long, linear leaves with sharp margins and a strong lemon-like aroma due to its high essential oil content, particularly citral.[7,4] The leaves grow in clumps arising from short rhizomes, forming pseudostems composed of tightly packed leaf sheath.[1]

Propagation of *C. citratus* is mainly vegetative because it rarely produces viable seeds under cultivation conditions. Its root system consists of fibrous roots that firmly anchor the plant in the soil, allowing it to survive in different environmental conditions.[6] The essential oils are mainly concentrated in the leaves, which serve as the primary source of its pharmacologically active compounds.[4]

1.2 Traditional Neurocognitive Uses *Cymbopogon citratus*

Cymbopogon citratus is widely used in traditional medicine systems, particularly in Asia, Africa, and South America, where it is valued for its calming and neuropsychiatric effects.[6,1] It is commonly utilized in herbal medicine for its anxiolytic, antistress, sedative, and mild nootropic properties, supporting its traditional role in managing anxiety, restlessness, and sleep disturbances.[14]

In traditional practice, *C. citratus* is often prepared as herbal tea or infusion from its leaves and consumed to promote relaxation, improve sleep quality, and reduce psychological stress.[1] These preparations are widely used in households that prefer natural remedies for mental well-being and emotional balance.

Furthermore, the essential oil of *C. citratus* is commonly used in aromatherapy, where inhalation or diffusion is believed to produce calming effects and improve mood.[18] According to.[3] the volatile compounds such as citral and other terpenoids may interact with the central nervous system, particularly affecting emotional regulation pathways linked to the limbic system.

Overall, the traditional neurocognitive uses of *C. citratus* are associated with stress reduction, improved sleep quality, enhanced relaxation, and mild cognitive support, which may indirectly contribute to better mental performance.[14,21] The summarized traditional neurocognitive uses of *C. citratus* are presented in Table 1.

Table 1: Traditional Neurocognitive Uses of *Cymbopogon citratus*.

Plant Part	Traditional Neurocognitive Uses	References
Leaves	Used as herbal tea to reduce stress, promote relaxation, and improve sleep	[1]
Essential Oil	Used in aromatherapy for calming effects and mood regulation	[18,3]
Whole Plant	Used as anxiolytic, antistress, sedative, and mild cognitive-support agent	[6,14]

2. METHODOLOGY

This review used a narrative review design to compile, summarize, and interpret existing literature on the phytochemistry, pharmacological activities, and neurocognitive benefits of *Cymbopogon citratus* (lemongrass). A narrative review approach was selected to allow comprehensive synthesis of findings from diverse studies, particularly in relation to phytochemical composition and neurocognitive mechanisms.

Relevant literature was primarily obtained from Google Scholar, while additional open-access journal articles were identified using Google and manual searching of reference lists from related studies. The search was conducted using the following keywords: "*Cymbopogon citratus*," "lemongrass," "phytochemistry," "essential oil," "pharmacological activity," "neurocognitive," "memory enhancement," "Alzheimer's," "antioxidant," and "acetylcholinesterase inhibition".[1,14]

Articles published between 2000 and 2025 were included to ensure coverage of both foundational and recent scientific findings, considering the continuous development of research on medicinal plants and their neurocognitive applications.[6] Additional sources were obtained through manual screening of references cited in

relevant studies to ensure completeness of data collection.

Only peer-reviewed, open-access journal articles written in English were included in this review. Selected studies were required to focus on at least one of the following: phytochemical constituents of *C. citratus*, or its pharmacological and neurocognitive effects. Experimental studies involving in vitro assays, animal models, and biochemical evaluations were included to assess antioxidant activity, neuroprotective potential, and acetylcholinesterase inhibition.[15,12]

Studies were excluded if they were non-English publications, duplicate articles, non-peer-reviewed sources, or lacked relevant data on phytochemical or neurocognitive outcomes. Non-scholarly sources such as blogs, opinion articles, and anecdotal reports were also excluded to maintain scientific validity and reliability.[21]

All collected studies were systematically analyzed to identify recurring findings, proposed mechanisms of action such as oxidative stress reduction, anti-inflammatory activity, and cholinergic modulation, as well as gaps and inconsistencies in the current literature.[10,20]

3. Phytochemistry of *Cymbopogon citratus*

The phytochemical composition of *Cymbopogon citratus* (lemongrass) has been extensively investigated, revealing a complex mixture of volatile and non-volatile bioactive constituents responsible for its wide range of pharmacological activities, including antimicrobial, antioxidant, anti-inflammatory, anxiolytic, antipyretic, and insecticidal effects.[18,1]

The plant is particularly characterized by a high content of essential oil dominated by citral (a mixture of geranial and neral), alongside other monoterpenes, sesquiterpenes, flavonoids, phenolic acids, tannins, sterols, and trace alkaloids.

Citral is considered the principal bioactive marker of *C. citratus* and is largely responsible for its characteristic lemon-like aroma as well as many of its biological properties. However, the pharmacological effects of the plant are not attributed to a single compound but rather to the synergistic interaction among multiple phytochemicals. The concentration and profile of these compounds vary significantly depending on plant part, environmental conditions, harvest stage, and extraction technique, which directly influence biological potency and therapeutic applications. The summarized major phytochemical compounds found in the different parts of *Cymbopogon citratus* are shown in Table 2, while their distribution across plant parts is illustrated in Figure 1.

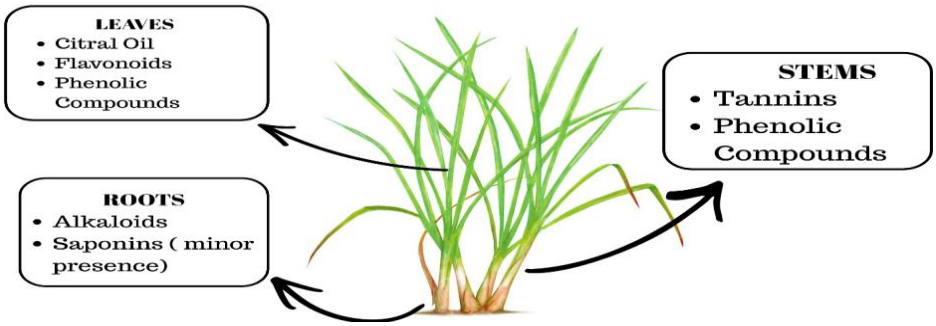


Figure 1. Distribution of Major Phytochemical Compounds in *Cymbopogon citratus.*

Table 2: Major Phytochemical Compounds Identified in Different Parts of *Cymbopogon citratus.*

Plant Part	Major Compounds	Reported Pharmacologic Activities	References
Leaves	Citral (geranial, neral), flavonoids, phenolic acids, tannins, limonene, myrcene	Antioxidant, antimicrobial, anti-inflammatory, sedative, anxiolytic	[18,1]
Essential Oil	Citral, geraniol, limonene, myrcene, β-caryophyllene, citronellal (trace)	Antibacterial, antifungal, insecticidal, anti-inflammatory, analgesic	[19,1]
Stems	Phenolic compounds, lignin derivatives, trace flavonoids, minor volatiles	Antioxidant, mild antimicrobial, protective effects	[18]
Roots	Sterols (β-sitosterol), trace alkaloids, phenolic compounds	Anti-inflammatory, antioxidant (limited evidence), adaptogenic potential	[1]

Leaves

The leaves of *C. citratus* are the most extensively studied plant part and serve as the primary reservoir of its phytochemicals. They contain high concentrations of essential oil, particularly citral, which is composed of the isomers geranial and neral. These compounds are responsible for the plant's strong aromatic profile and significant biological activities.

In addition to citral, the leaves contain a variety of secondary metabolites including flavonoids (such as quercetin derivatives), phenolic acids (including caffeic and chlorogenic acid derivatives), tannins, limonene, and myrcene. These compounds collectively contribute to the plant's strong antioxidant capacity by neutralizing free radicals and inhibiting lipid peroxidation.[18,1] reported that leaf extracts demonstrate significant antimicrobial activity against both Gram-positive and Gram-negative bacteria, attributed to membrane-disrupting effects of terpenoids and phenolic compounds. Furthermore, the presence of flavonoids and phenolics contributes to anti-inflammatory activity through the inhibition of pro-inflammatory mediators such as nitric oxide and prostaglandins.

The mild sedative and anxiolytic properties of lemongrass tea have also been linked to the synergistic effect of citral and flavonoid compounds, which may influence central nervous system activity through modulation of neurotransmitter pathways.

Essential Oil

The essential oil of *C. citratus* is one of its most valuable phytochemical products and has been widely studied for its therapeutic and industrial applications. It is predominantly composed of citral (up to 60–85%), followed by other monoterpenes such as limonene, myrcene, geraniol, and β-caryophyllene.[19]

Citral is primarily responsible for the oil's antimicrobial and antifungal activities, acting by disrupting microbial cell membranes, increasing permeability, and leading to leakage of cellular contents. This mechanism explains its broad-spectrum efficacy against foodborne and pathogenic microorganisms.[18] also reported that lemongrass essential oil exhibits significant anti-inflammatory, analgesic, and antioxidant activities, making it useful in both traditional and modern medicinal systems. Additionally, its insecticidal and repellent properties are attributed to monoterpenes such as citronellal and limonene, which interfere with insect nervous system signaling.

Because of these multifunctional properties, lemongrass essential oil is widely utilized in aromatherapy, pharmaceutical formulations, cosmetic products, and natural food preservatives.

Stems

The stems of *C. citratus* contain comparatively lower concentrations of essential oils than the leaves but still possess a notable range of bioactive phytochemicals. These include phenolic compounds, structural lignin derivatives, and trace flavonoids.

Although less pharmacologically potent than leaf extracts, stem constituents contribute to mild antioxidant activity by scavenging free radicals and supporting cellular protection against oxidative stress.[18] Some studies suggest that stem extracts may also exhibit weak antimicrobial activity, likely due to residual terpenoids and phenolic constituents.

The structural role of stems also explains their lower phytochemical concentration, as they primarily function in mechanical support and nutrient transport rather than secondary metabolite accumulation.

Roots

The roots of *C. citratus* remain the least studied plant part, yet preliminary phytochemical analyses indicate the presence of sterols (notably β-sitosterol), trace alkaloids, and phenolic compounds. These constituents may contribute to mild anti-inflammatory and antioxidant activities, although scientific evidence remains limited compared to leaves and essential oil.[1]

Sterols such as β-sitosterol are known for their membrane-stabilizing and anti-inflammatory effects, potentially contributing to the plant's traditional use in managing pain and inflammatory conditions. Trace alkaloids may also play a role in modulating physiological responses, although their specific mechanisms in *C. citratus* remain unclear.

Overall, the roots may provide supportive but secondary pharmacological value, and further phytochemical and pharmacological investigations are necessary to fully characterize their therapeutic potential.

Cymbopogon citratus exhibits a chemically diverse phytochemical profile dominated by citral-rich essential oil and supported by a wide range of flavonoids, phenolics, terpenes, sterols, and trace alkaloids. The synergistic interaction of these compounds across different plant parts contributes to its broad pharmacological spectrum, including antimicrobial, antioxidant, anti-inflammatory, sedative, and insecticidal activities.

The leaves and essential oil represent the most bioactive and extensively studied components, while stems and roots remain underexplored but potentially valuable sources of complementary phytochemicals. This chemical diversity underpins the plant's extensive use in traditional medicine, food applications, and pharmaceutical development.

4. Pharmacological Activities of *Cymbopogon citratus* (Lemongrass)

Cymbopogon citratus has been extensively studied for its pharmacological activities, reflecting its long-standing use in traditional medicine and its well-documented phytochemical composition. The plant contains a complex mixture of bioactive constituents, including citral (geranial and neral), flavonoids, phenolic acids, tannins, monoterpenes, sesquiterpenes, sterols, and trace alkaloids, all of which contribute to its biological effects.[18,1]

Among these compounds, citral is recognized as the principal bioactive and chemotaxonomic marker of *C. citratus*. It is responsible not only for the plant's characteristic lemon-like aroma but also for many of its pharmacological properties, particularly antimicrobial, anti-inflammatory, and antioxidant effects.[18] However, the overall biological activity of the plant is not due to a single compound but rather to the synergistic interaction of multiple phytochemicals such as flavonoids and phenolic acids, which enhance and stabilize its therapeutic effects.[1]

In traditional medicine systems across Asia, Africa, and Latin America, *C. citratus* has been used for the treatment of fever, infections, digestive disorders, hypertension, anxiety, insomnia, inflammation, and pain.[1] It is also widely consumed as an herbal infusion for its calming and digestive benefits. Modern pharmacological investigations have validated many of these traditional uses by demonstrating antioxidant, antimicrobial, anti-inflammatory, analgesic, sedative, anxiolytic, antipyretic, antidiabetic, and insecticidal activities.[18,1] The reported pharmacological activities of *C. citratus* are summarized in Table 3.

Table 3: Summary of Reported Pharmacological Activities of *Cymbopogon citratus.*

Extract/Compound	Experimental Model	Observed Effect	Mechanism Proposed	Reference
Leaf ethanol extract	In vitro bacterial strains (*S. aureus*, *E. coli*)	Broad-spectrum antibacterial activity	Disruption of lipid membrane, leakage of intracellular components	[18]
Essential oil (citral-rich)	In vitro fungal pathogens (*Candida*, *Aspergillus*)	Strong antifungal activity	Ergosterol inhibition and membrane permeability disruption	[19]
Aqueous leaf extract	DPPH, ABTS radical assays	High antioxidant activity	Free radical scavenging and electron donation	[1]
Methanolic extract	COX enzyme and inflammatory models	Anti-inflammatory activity	Inhibition of COX pathway and cytokine suppression	[18]
Essential oil vapor	Rodent behavioral studies	Sedative and anxiolytic effects	Modulation of GABAergic neurotransmission	[1]

Antimicrobial Activity

Antimicrobial activity is one of the most widely documented pharmacological properties of *C. citratus*. This activity is primarily attributed to citral and other monoterpenes such as limonene, myrcene, and geraniol, which are lipophilic compounds capable of penetrating microbial cell membranes and disrupting their structural integrity.[18]

[20]reported that lemongrass essential oil exhibits strong antibacterial activity against both Gram-positive bacteria such as *Staphylococcus aureus* and Gram-negative bacteria such as *Escherichia coli*. The mechanism involves disruption of the phospholipid bilayer, resulting in increased membrane permeability, leakage of essential cellular components, enzyme inactivation, and ultimately bacterial cell death.

Similarly,[19] demonstrated that the essential oil exhibits potent antifungal activity against *Candida albicans* and *Aspergillus* species. This antifungal effect is attributed to inhibition of ergosterol biosynthesis, which is essential for fungal membrane stability, thereby causing structural collapse and growth inhibition.

The broad antimicrobial spectrum of *C. citratus* supports its potential application as a natural alternative to synthetic antibiotics, especially in addressing the global challenge of antimicrobial resistance.[18,19]

Antioxidant Activity

Cymbopogon citratus exhibits strong antioxidant activity due to its high content of phenolic compounds and flavonoids, which play a critical role in neutralizing reactive oxygen species (ROS) and preventing oxidative stress-induced cellular damage.[1]

Flavonoids such as quercetin derivatives and phenolic acids such as caffeic and chlorogenic acids contribute significantly to this activity by acting as hydrogen or electron donors that stabilize free radicals and terminate oxidative chain reactions.[1]

In addition, citral has been reported to indirectly enhance antioxidant defense by upregulating endogenous antioxidant enzymes such as superoxide dismutase (SOD), catalase, and glutathione peroxidase, which protect cells from oxidative damage.[18]

This antioxidant potential is particularly important because oxidative stress is a major contributing factor in chronic diseases such as cancer, diabetes mellitus, cardiovascular disorders, and neurodegenerative diseases.[1]

Anti-inflammatory and Analgesic Activities

The anti-inflammatory activity of *C. citratus* is primarily attributed to citral and flavonoid compounds, which regulate key inflammatory pathways involved in disease progression.[18]

[18]reported that extracts of *C. citratus* inhibit cyclooxygenase (COX-1 and COX-2) enzymes, leading to reduced synthesis of prostaglandins, which are major mediators of inflammation and pain. In addition, flavonoids inhibit nuclear factor-kappa B (NF-κB), a transcription factor responsible for activating pro-inflammatory genes, thereby reducing cytokine production such as TNF-α and IL-6.

The analgesic effects of *C. citratus* have also been demonstrated in animal models, where extracts significantly reduced pain responses. This effect is believed to result from both peripheral inhibition of inflammatory mediators and central modulation of pain perception pathways.[1]

Sedative and Anxiolytic Effects

Cymbopogon citratus is traditionally used as a calming herbal tea for stress, anxiety, and insomnia, and this use has been supported by pharmacological studies.[1]

The sedative and anxiolytic effects are mainly attributed to citral and other volatile compounds that interact with the central nervous system.[1] proposed that lemongrass essential oil enhances gamma-aminobutyric acid (GABA) neurotransmission, which is the primary inhibitory system in the brain responsible for reducing neuronal excitability and promoting relaxation.

Animal studies have shown that exposure to lemongrass essential oil leads to reduced locomotor activity and decreased anxiety-like behavior, supporting its CNS depressant and anxiolytic effects.[18] These findings provide scientific validation for its use in aromatherapy and natural stress management.

Antipyretic and Metabolic Effects

Cymbopogon citratus also exhibits antipyretic activity, which is associated with its ability to inhibit prostaglandin synthesis involved in fever regulation.[18] This supports its traditional use in treating fever and infectious conditions.

In addition, emerging evidence suggests potential antidiabetic activity, which may be linked to its antioxidant properties and possible modulation of carbohydrate metabolism enzymes. However, these effects remain preliminary and require further in vivo and clinical validation.[1]

Insecticidal and Food Preservation Applications

The essential oil of *C. citratus* demonstrates strong insecticidal and repellent activity against mosquitoes and agricultural pests. Citral and limonene disrupt insect neurotransmission by affecting ion channels and enzymatic pathways, leading to paralysis and death.[19]

Furthermore, due to its antimicrobial and antioxidant properties, *C. citratus* essential oil has been investigated as a natural food preservative. It inhibits spoilage microorganisms and foodborne pathogens, thereby extending shelf life and reducing reliance on synthetic chemical preservatives.[18]

Moreover, *Cymbopogon citratus* exhibits a broad spectrum of pharmacological activities that are strongly supported by both traditional knowledge and modern scientific studies. Its bioactivity is mainly driven by citral, flavonoids, phenolic compounds, and monoterpenes, which act synergistically to produce antimicrobial, antioxidant, anti-inflammatory, sedative, analgesic, antipyretic, and insecticidal effects.[18,19]

The pharmacological versatility of *C. citratus* highlights its strong potential for applications in pharmaceutical development, functional foods, cosmetics, and natural health products. Further studies, particularly clinical trials, are recommended to fully establish its safety, efficacy, and mechanisms of action in humans.

5.1 Discussions & Limitations

Overall, the available evidence on the pharmacological activities of *Cymbopogon citratus* mainly comes from preclinical studies, including in vitro assays and animal model experiments. Studies investigating its antimicrobial, antioxidant, anti-inflammatory, sedative, and insecticidal effects.[18,19,1] consistently demonstrate promising biological activity. However, despite these encouraging findings, the majority of the evidence remains limited to laboratory and animal-based research, which restricts direct translation to human clinical applications.

Although in vitro and in vivo studies are valuable for identifying bioactive compounds and potential mechanisms of action, they cannot fully replicate the complexity of human physiological systems. For instance, antimicrobial activity observed in laboratory conditions may not reflect actual therapeutic effectiveness in humans due to factors such as absorption, metabolism, bioavailability, and dosage variability. Similarly, antioxidant and anti-inflammatory effects demonstrated in experimental models may differ significantly under clinical conditions where multiple biological pathways interact simultaneously.

In addition, most pharmacological studies on *C. citratus* rely on crude extracts or essential oils with varying compositions. There is a lack of standardization in extraction methods, plant parts used, solvent systems, dosage concentrations, and routes of administration. This variability makes it difficult to compare results across studies and to determine consistent therapeutic doses or establish standardized pharmacological profiles.[1]

Geographically, many studies have been conducted in tropical and subtropical regions where *C. citratus* is traditionally cultivated and used. Environmental factors such as soil type, climate, altitude, and harvesting conditions significantly influence the phytochemical

composition of the plant, particularly citral and other volatile compounds. These variations may affect the reproducibility and generalizability of findings across different populations and regions.

A major limitation of the current body of literature is the absence of well-designed human clinical trials, such as randomized controlled trials (RCTs), which are necessary to confirm safety, efficacy, pharmacokinetics, and appropriate therapeutic dosing in humans. While preclinical studies provide strong foundational evidence, they are insufficient for establishing clinical recommendations or pharmaceutical standardization.

Furthermore, this review is limited by the availability of published literature, potential exclusion of non-English studies, and reliance on a relatively small number of core pharmacological sources. Some older studies were also included due to the limited availability of recent high-impact clinical research on *C. citratus*.

Although *Cymbopogon citratus* demonstrates significant pharmacological potential based on preclinical evidence, these findings should be interpreted with caution. Future research should prioritize well-designed clinical trials, standardized extraction and formulation protocols, and comprehensive pharmacokinetic and toxicological evaluations. Such studies are essential to fully validate its therapeutic potential and support its development into evidence-based medicinal and pharmaceutical applications.

6. Future Research

Future research on *Cymbopogon citratus* should focus on addressing the current gaps in the literature, particularly the limited number of well-designed human clinical trials evaluating its pharmacological and therapeutic effects. While existing preclinical studies have demonstrated promising antimicrobial, antioxidant, anti-inflammatory, sedative, and insecticidal activitie,[18,19,1] further research is needed to confirm these effects in clinical settings and determine their safety, efficacy, and appropriate therapeutic dosages in humans.

In addition, future studies should prioritize the identification and isolation of specific bioactive compounds responsible for its pharmacological effects, particularly citral, flavonoids, and phenolic acids. Understanding the individual and synergistic actions of these compounds will help clarify the mechanisms underlying the biological activities of *C. citratus*. This will also support the development of standardized phytopharmaceutical products with consistent therapeutic outcomes.

Another important direction for future research is the standardization of extraction methods, plant parts used, and formulation techniques. Variations in extraction solvents, environmental growing conditions, and harvesting stages significantly affect the phytochemical composition and biological activity of the plant. Establishing standardized protocols will improve reproducibility and allow more reliable comparison between studies.

Furthermore, more advanced pharmacological studies should explore the pharmacokinetics, pharmacodynamics, toxicity profiles, and long-term safety of *C. citratus* in both animal models and human subjects. Special attention should also be given to dose-response relationships and potential drug interactions, particularly for its use in combination with conventional medications.

Future research should also expand into clinical trials, particularly randomized controlled trials (RCTs), to validate its therapeutic potential in humans. These studies are essential for translating preclinical findings into evidence-based medical applications, especially for conditions involving infection, inflammation, anxiety, and oxidative stress-related diseases.

Finally, since this study is a narrative review, it is limited to synthesizing available literature rather than generating experimental data. Therefore, future research should include systematic reviews and meta-analyses, as well as experimental and clinical investigations, to provide stronger and more comprehensive evidence regarding the pharmacological potential of *Cymbopogon citratus*.

Addressing these research gaps will significantly strengthen the scientific understanding of *C. citratus* and support its development into safe, standardized, and effective therapeutic agents in pharmaceutical and biomedical applications.

7. CONCLUSION

This review highlights the phytochemical composition and pharmacological activities of *Cymbopogon citratus* (lemongrass). *C. citratus* contains a wide range of bioactive compounds, including citral (geranial and neral), flavonoids, phenolic acids, tannins, monoterpenes, and sterols, which collectively contribute to its diverse biological activities. Among these, citral serves as the principal active compound responsible for its characteristic aroma and many of its pharmacological effects.

Compounds such as flavonoids and phenolic acids exhibit strong antioxidant and anti-inflammatory properties, which help protect cells from oxidative damage and reduce inflammatory responses. In addition, the essential oil of *C. citratus* demonstrates significant antimicrobial activity against a wide range of bacteria and fungi, supporting its traditional use in treating infections and food preservation. These findings provide scientific evidence supporting the traditional use of lemongrass as a medicinal plant with broad therapeutic potential.

This review also highlights that extracts derived from the leaves and essential oil of *C. citratus* have demonstrated various pharmacological activities, including antimicrobial, antioxidant, anti-inflammatory, analgesic, sedative, anxiolytic, and insecticidal effects. These biological properties suggest that *C. citratus* may be a promising natural source for managing conditions related to oxidative stress, microbial infections, inflammation, anxiety, and pain.

Furthermore, *C. citratus* shows potential applications in pharmaceutical, cosmetic, food, and agricultural industries due to its bioactive and preservative properties. However, most of the current evidence is based on preclinical studies, particularly in vitro and animal models, which limits direct application to human clinical use.

Future studies should include well-designed human clinical trials to confirm these pharmacological effects, as most existing research does not fully establish safety, efficacy, and appropriate dosage in humans. Future research should also focus on isolating and characterizing key bioactive compounds, standardizing extraction methods, and conducting comprehensive pharmacokinetic and toxicological evaluations. *Cymbopogon citratus* holds significant potential as a natural source of bioactive compounds with diverse pharmacological applications, particularly in promoting health, preventing disease, and supporting the development of plant-based therapeutic agents.

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Conflict of Interest

The authors declare that there are no conflicts of interest.

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