

DRUG DELIVERY APPLICATIONS OF LEMONGRASS

A Project Report Submitted

In Partial Fulfillment of the Requirements

for the Degree of

BACHELOR OF PHARMACY

By

Raj Muraw

Enrollment No.: 18021020199

Admission No.: 18SMAS1020100

Under the Supervision of

Mr. Shriyansh Srivastav

Assistant Professor

Galgotias University

Greater Noida.



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List of abbreviations

S.No.	Name	Abbreviation
1	Calcium	Ca
2	Sodium	Na
3	Magnesium	Mg
4	Selenium	Se
5	Copper	Cu
6	Potassium	K
7	Phosphorus	P
8	Zinc	Zn
9	Iron	Fe
10	Central Nervous System	CNS
11	Half-maximal inhibitory control	IC50
12	Median effective concentration	EC50
13	Red blood cells	RBC
14	White blood cells	WBC
15	Cyclooxygenase-2	COX-2
16	Gastrointestinal tract	GIT
17	Low density lipoprotein	LDL
18	Human immuno virus	HIV
19	Acquired immune deficiency syndrome	AIDS



CERTIFICATE

This is to certify that project work entitled “**Drug Delivery Applications Of Lemongrass**” done by **Mr. Raj Muraw** submitted to Department of Pharmacy, is a bonafide research work done by Mr. Raj Muraw under the supervision and guidance of **Mr. Shriyansh Srivastav**, Assistant Professor, School of Medical and Allied Sciences, Greater Noida. The work is completed and ready for evaluation in partial fulfillment for the award of Bachelor of Pharmacy during the academic year 2021-2022. The project report has not formed the basis for the award of any Degree/Diploma/Fellowship or other similar title to any candidate of any University.

Date:

Prof. Pramod Kumar Sharma
Dean
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BONAFIDE CERTIFICATE

This to certify that the project work entitled “**Drug Delivery Applications Of Lemongrass**” is the bonafide research work done by **Mr. Raj Muraw**, who carried out the research work under my supervision and guidance for the award of Bachelor of Pharmacy under Galgotias University, Greater Noida during the academic year 2021-2022. To the best of my knowledge the work reported herein is not submitted for award of any other degree or diploma of any other Institute or University.

Mr. Shriyansh Srivastav

Guide

Assistant Professor
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Greater Noida (U.P.)

DECLARATION

I hereby declare that the work embodied in this project report entitled “**Drug Delivery Applications Of Lemongrass**” in Partial fulfillment of the requirements for the award of Bachelor of Pharmacy, is a record of original and independent research work done by me during the academic year 2021-22 under the supervision and guidance of **Mr. Shriyansh Srivastav**, Assistant Professor, School of Medical and Allied Sciences, Galgotias University, Greater Noida. I have not submitted this project for award of any other degree or diploma of any other Institute or University.

Date:

Mr. Raj Muraw

Place:

Name and Signature of candidate

Acknowledgement

Praise to be almighty God who made me able to carry out the present study successful. I feel high privileged while starting my dissertation work with acknowledge of the genuine help and support received from others who made this research and project possible for me.

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Last but not the least I wish to express my gratitude to my lovely parents for their patience and constant support they provided me with every opportunity to succeed.

Mr. Raj Muraw

Abstract

Lemongrass (*C. citratus*) is a popular long lasting plant that lives more than two years usually found in the sub-tropical and tropical regions of the world. *Cymbopogon citratus* is a herb having the properties of medicine with chemicals that have the ability of suppressing infections and intensifying herbal resistance to infectious illnesses. The oil of *Cymbopogon citratus* is commonly used in traditional medicine as a decoction or infusion. According to research, lemongrass has antibacterial, antifungal, antiparasitic, antiamoebic, antidiarrheal anti-inflammatory, antigingivitis, and antiperiodontitis qualities. Antimycobacterial, antimutagenicity, antioxidants, antimalarial, neurobehavioral, and hypoglycemic properties also have been investigated. These are the findings exceedingly giving support or confidence indicating that this herbal perennial plant should be investigated further to confirm these findings and examine other possible medicinal properties.

INTRODUCTION

The Cymbopogon is a name that is obtained from the Greek word "Kymbe" which means boat and "pogon" meaning beard, that relates to the configuration like spike of the flower [1]. The genus of lemongrass is 'Cymbopogon' and it lies from the family 'Poaceae' [2, 3]. This grass is known as Lemongrass because of the essential oil's lemony odour in the shoot system [4]. This herbal plant is also called as "Squinant" or "Citronella" in English, in addition with other various names throughout the universe [5-8]. Lemongrass is a bunched perennial (live for more than two years) warm-season grass with hard stem that grows from a short rhizomatous rootstock [9, 10]. Cymbopogon citratus is a genus of about fiftyfive (55) races found in diverse regions throughout the globe (world), each with its own set of materials and chemical characteristics [11]. This herbal plant is mostly grown for its therapeutic essential oil in the sub-tropical and tropical regions of Africa, South America and Central America, Asia, and other tropical nations [9-10, 12]. Members of the Cymbopogon genus generate volatile oils, which is why they are also known as fragrant grasses [2, 3]. The essential oil of lemongrass is derived from the dried leaves of the plant by steam distillation and has a slender consistency and a bright or pale-yellow hue with a distinct fresh citrus and earthy aroma [13]. Hydrosols or fragrant fluids are created during steam distillation and can be utilized to treat inflammatory and microbial infectious disorders [14-16]. Lemongrass essential oil has several commercial applications due to its usage in the production of perfumes, perfumery, tastes, cosmetics, detergents, and medicines [17, 18]. Several research have been undertaken to evaluate the medicinal properties of lemongrass.



Figure 1: Lemon grass (*Cymbopogon citratus*)

1. Origin and Distribution/ Location

Lemongrass thrives well in tropical circumstances that are bright, warm, and damp [19]. It is mostly found in the Indian subcontinent, Australia, North America, South America, Europe and Africa. It spreads rapidly throughout India, from sea level to 4200 metres in elevation. East Indian lemongrass grows naturally in India and is farmed extensively in Assam,

Maharashtra, Uttarpradesh, and Kerala, as well as in China and Guatemala. It is believed that West Indian lemongrass have been originated either in Malaysia or Sri Lanka. It is extensively found across the tropical region and is mostly grown in Brazil, Guatemala, the Congo, the West Indies, India, Tanzania, Bangladesh, Thailand, China, and Madagascar. Jammu lemongrass is restricted to the states of Sikkim, Jammu and Kashmir, Assam, Bengal, and Madhya Pradesh in North India. It is grown on a big scale in the western ghats of India, near the Chinnar wildlife sanctuary [4].

2. Botany and Morphology

Lemongrass could be a large, perennial sedge and monocotyledonous grass with an impenetrable rhizome and dense leaf clusters [20-23]. The ridge is upright and can reach a height of around 1.8m (6ft) with a width of 1.2m (4ft) [20, 24]. The morphology of *Cymbopogon citratus* is given in below table 1;

S.No.	Part	Description	Reference
1.	Leaves	<p>The lemongrass leaf is shaped like a strap (tape), with 1.3-2.5cm width and 0.9cm length, with loose tips of shiny bluish-green hue and citrus scent.</p> <ul style="list-style-type: none"> • Arrangement of leaf; Most of the leaves are emerged from the moisturized soil, generally without a stem. • Type of leaf; Usually Simple • Type of leaf shape; Linear 	25-27

		<ul style="list-style-type: none"> • Type of leaf margin; Entire • Type of leaf venation; Parallel • Type of leaf persistent; Fragrant • Length of leaf blade; 18-36 cm • Color of leaf; green • Fall characteristic; Showy 	
2.	Inflorscence	The inflorescence is approximately thirty to sixty centimeter long and bending downward, and the remaining part of inflorescence consists of paired cluster of spike-lets subtended by a single bract that surrounds the spadix, which is a flowering spike.	24
3.	Flower	Lemongrass plant could be a cultivar which likely to encounter is non- phanerogam plant or in some case may bear flowering panicles.	27

Parts Used

- Leaves and whole plant.

Classification on the basis of TAXONOMY [23]

- Kingdom of lemongrass: Plantae
- Division of lemongrass: Mangoliophyta
- Class of lemongrass: Liliopsida
- Order of lemongrass: Poales
- Family of lemongrass: Poaceae
- Genus of lemongrass: Cymbopogon spreng
- Species of lemongrass: Citratus

3. Chemical Constituents / Phytochemistry

Lemongrass consists of three basic components which are as;

- A). Cellulose
- B). Hemi-cellulose and
- C). Lignin [28, 29]

Lemongrass is a hydrocarbon that is often constituted of carbon and hydrogen.

A). Cellulose

The structure of cellulose molecule is linear with 3 dimensions consisting of both crystalline and amorphous regions and the polymerization degree for it is 100-10000 [30]. It is made by 1,4 β -glucopyranose units [31].

B). Hemi-cellulose

Hemicellulose is constituted mostly of an amorphous area with several crystalline sections, and the polymerization degree is less than 200 [30]. Hemicellulose subunits include galactose, xylulose, arabinose, and mannose [31].

C). Lignin

Lignin is the three dimensional non-linear and amorphous heterogeneous polymer which holds together of the cellulosic components [32]. It is mainly composed of guaiacyl, syringyl, and para-hydroxyphenyl units [31].

Furthermore, the oil content of lemongrass varies according on genetics, growing location, culture, and agronomic treatment [33]. Citral makes up the majority of the essential oil of lemongrass, which contains 0.2-0.5 percent West Indian lemongrass oil [34]. Citral is a combination of two stereo-isomeric monoterpene aldehydes (RCHO) that is cis-isomer neral and trans isomer geranial which are about 25-38 percent and 40-62 percent respectively [35, 36]. The appearance of flavonoids, alkaloids, anthraquinones, tannins, phenols and saponins, as well as aldehydes, terpenes, alcohols, and esters, was discovered in the phytochemical content of *Cymbopogon citratus*. Several investigations have shown trace amounts of myrcene, limonene, geranial, geraniol, burneol, nerol, citronellol, alpha-terpineol, catechol,

elemicin, luteolin, 6-Carbon and 7-Carbon glycosides, kaempferol, apigenin, geranyl, chlorogenic acid, quercetin, and caffeic acid. Some research identified fumesol, furfural, isopulegol, L-linalool, nerol, isovaleranic aldehyde, decyclic aldehyde, terpinone, methylheptnone, para-coumaric acid, and verelic esters($R^1CO_2R^2$) [37-40]. There are reports on the existence of swertiajaponin, isoscoparin, and orientin(eight carbon glucoside of luteolin) in *Cymbopogon citratus*, as well as several other phytochemicals [41, 42]. It also includes electrolytes, minerals, vitamins, macromolecules, and a trace of fat. Minerals include calcium(Ca), Sodium(Na), magnesium(Mg), selenium(Se), copper(Cu), potassium(k), phosphorus(P), zinc(Zn) , and iron(Fe). Vitamins include pyridoxine, riboflavin niacin, folate, and vitamins include vitamin A(retinol), vitamin C(ascorbic acid), and vitamin E(tocopherol). Macronutrients are carbohydrate and protein-containing nutrients [43].

The major chemical constituents of *Cymbopogon citratus* are presented in following table 2;

Phytoconstituents	Minerals	Vitamins
<i>Flavinoids</i>	<i>Sodium(Na)</i>	<i>Retinol (Vitamin A)</i>
<i>Alkaloids</i>	<i>Calcium (Ca)</i>	<i>Tocopherol (Vitamin E)</i>
<i>Phenols</i>	<i>Selenium (Se)</i>	<i>Ascorbic acid (Vitamin C)</i>
<i>Saponins</i>	<i>Zinc (Zn)</i>	<i>Riboflavin (Vitamin B2)</i>
<i>Essential oils</i>	<i>Phosphorus (p)</i>	<i>Thiamine (Vitamin B1)</i>
<i>Tannins</i>	<i>Magnesium (Mg)</i>	<i>Niacin (Vitamin B3)</i>
<i>Vitamins</i>	<i>Iron (Fe)</i>	<i>Pyridoxine (Vitamin B6)</i>
<i>Steroids</i>	<i>Potassium (K)</i>	<i>Folic acid (Vitamin B9)</i>

Constituents of *Cymbopogon citratus*'s essential oil table 3.

S.No	Constituents	S.No	Constituents
1)	<i>Neral</i>	21)	<i>α-Terpineol</i>
2)	<i>Citral</i>	22)	<i>Dextro-carvone</i>
3)	<i>β-Myrcene</i>	23)	<i>α-Elemol</i>
4)	<i>α-Bergamotene</i>	24)	<i>Gerinacrene-D</i>
5)	<i>1-Octyn-3-ol</i>	25)	<i>Humulene</i>
6)	<i>Burneol</i>	26)	<i>t-Cadinol</i>
7)	<i>β-O-Cimene</i>	27)	<i>Di-n-octylphytalate</i>
8)	<i>Allo-o-cimene</i>	28)	<i>Trans-Chrysanthemal</i>
9)	<i>t-Muurolol</i>	29)	<i>Geranic-acid</i>
10)	<i>Geraniol</i>	30)	<i>γ-Murrolene</i>
11)	<i>3-Undecyene 3-carvomenthenone</i>	31)	<i>β-Sesquiphellandrene</i>
12)	<i>α-Pinene oxide</i>	32)	<i>α-Gurjunene</i>
13)	<i>Methyl-n-nonyl-ketone</i>	33)	<i>Valencene</i>
14)	<i>Virdiflorol</i>	34)	<i>Selinene</i>
15)	<i>α-Gualene</i>	35)	<i>β-eudesmol</i>
16)	<i>α-Farnesene</i>	36)	<i>Geranyl-acetate</i>
17)	<i>d-Cadinene</i>	37)	<i>Linalool</i>
18)	<i>(E,E)-Farnesal pi-melyldihydrazide</i>	38)	<i>Myrcenol</i>
19)	<i>Geranial</i>	39)	<i>α-Muurolene</i>
20)	<i>α-Terpineol</i>	40)	<i>Citronellol</i>

*Phytoconstituents found in the table 2 are from a *Cymbopogon citratus* plant leaf extract [44-48].

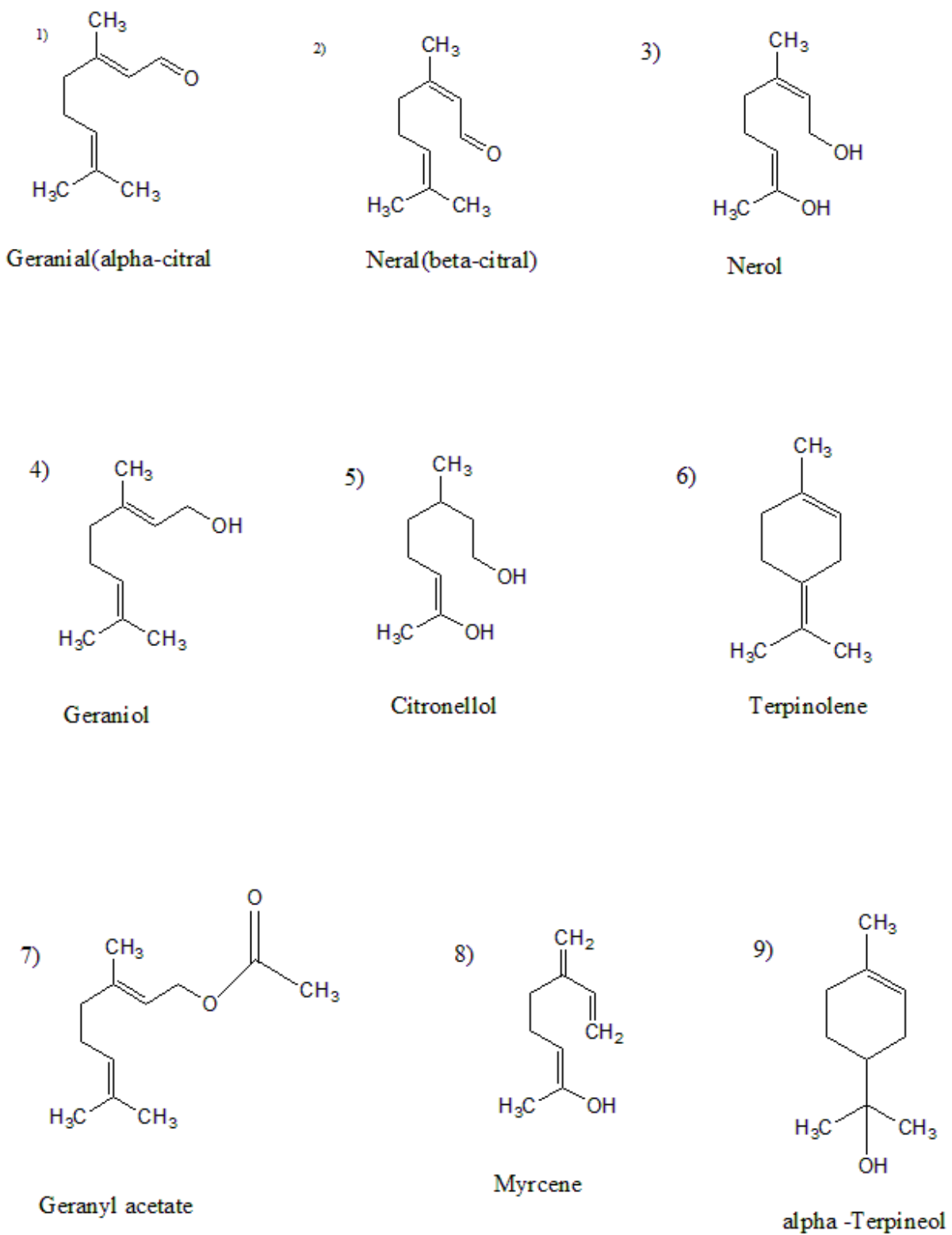


Figure 2. Structures of the major constituents of the essential oil of the *Cymbopogon citratus*

4. TRADITIONAL USES AND DRUG DELIVERY OF CYMBOPOGON CITRATUS IN DIFFERENT COUNTRIES; table 4

S.No	Country	Uses	Reference
1.	India	Snakes are supposed to be repelled by the fresh whole plant. For gastrointestinal issues, 2 or 3 drops of essential oil of Cymbopogon citratus in steam is given by mouth. A few teaspoons of oil mixed with citrus juice are administered orally to treat cholera. In situations of severe headache and fever, a decoction of the dehydrated leaves is utilised for bathing. Cymbopogon citratus tea is being used as a sedative for the central nervous system (CNS).	104-106
2.	USA	Laotian Hmong in Minnesota have used hot water extract of the entire plant to cure fracture of bones and wounds.	107
3.	Cuba	A decoction of the dehydrated leaves is used orally as a blood pressure lowering medication for excessive discharge or mucus build-up in the nose or throat, which is related with mucous membrane irritation and rheumatism.	108
4.	Thailand	The entire plant is breathed as a scent and consumed as a spice when it is fresh. As a stomachic, a decoction of the leaves of the dehydrated whole plant is administered orally. For diabetes, a decoction of the leaves of the dehydrated root is administered orally.	109-111
5.	Egypt	A decoction of the dehydrated leaves and stem is used orally as a diuretic and antispasmodic for the kidneys.	112
6.	Indonesia	Decoction of the leaves of the whole plant given orally acts as medicine that promotes the menstrual discharge.	113
7.	Brazil	Its leaves are commonly used for making tea, which is	

		anti-inflammatory, antispasmodic, sedative, antipyretic, diuretic, and analgesic.	114,115
8.	Malaysia	The boiled water extract of the whole plant administered orally acts as emmenagogue (menstrual discharge).	116
9.	Argentina	For throat infection, empacho, and vomiting, a decoction of the leaf is administered orally.	117

5. Applications of Lemongrass

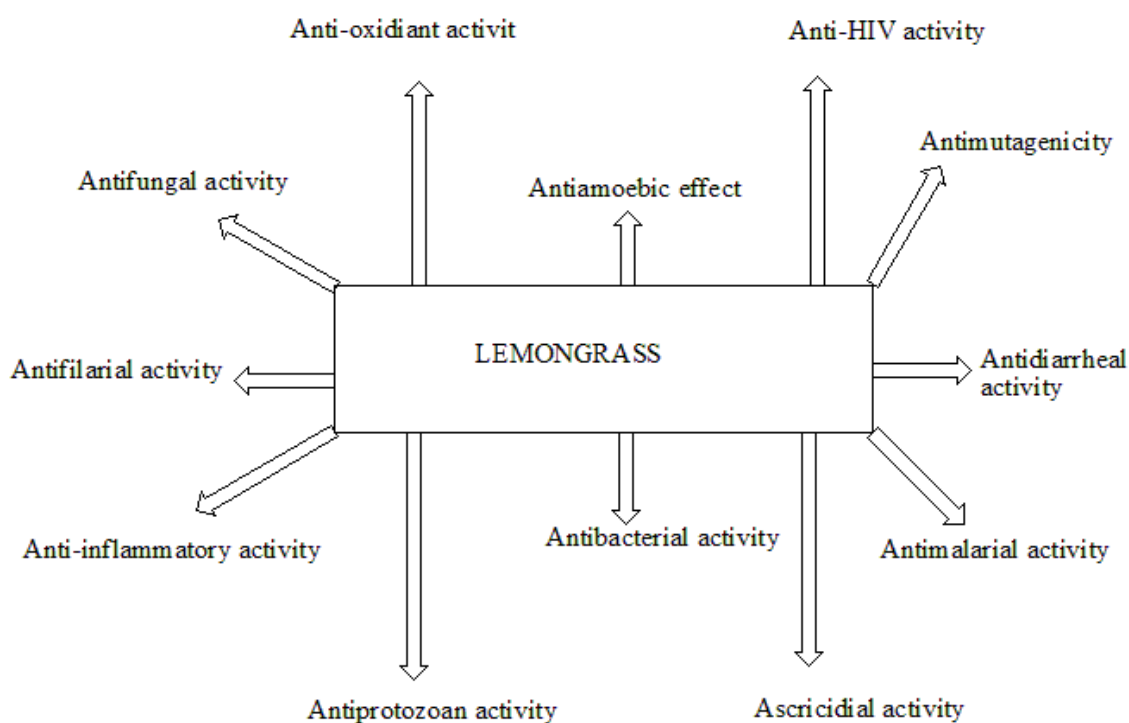


Figure 2. Applications of Lemongrass

5.1 Hematologic effect

C. citratus essential oil was examined for antiplatelet action in guinea pigs and rats, and it demonstrated the maximum antiplatelet activity relative to adenosine diphosphate (ADP), arachidonic acid, and a thromboxane A₂ agonist (IC₅₀, 4-132 microgram per mL). It also has a significant power to disrupt clot evacuation (IC₅₀, 19-180 microgram per mL). There is a substantial association between antiplatelet efficacy and phenylpropanoid concentration (54 percent 86 percent) of this oil, suggesting that this moiety plays an important role in the prevention of clot formation [102]. Furthermore, *Cymbopogon citratus* has been shown to enhance leukocytes (WBC), erythrocytes (RBC), and thrombocytes (platelets) in rats. These findings may give justification for the use of lemongrass extract in ancient medicine as a "plasma enhancer," in the cure of jaundice, and in the prevention of bleeding among some Cameroonian tribes [103].

5.2 Antibacterial activity

The potent antibacterial chemicals alpha-citral (geranial) and beta-citral (neral) show activity against both Gram positive and Gram negative micro-organisms [50]. The agar well diffusion technique was used to test the inhibitory impact of lemon grass essential oil at various dosages on bacterial cultures (5%, 10%, 15%, 20%, 25%, and 30%). The Nutrient agar medium having 0.5 percent tween eighty was melted, and twenty millilitre of the medium was placed on individualized sterile petriplates on a flat plate form and allowed to solidify. Using sterile swabs, one millilitre of active cell suspension of organisms was equally disseminated on the agar surface. Three 5 mm diameter wells were cut in agar patriplates of the solidified agar media using a sterile hollow stainless steel gel cutter. A twentyfive microlitre sample of each concentration was pipetted out and aseptically filed into the wells using a sterile pipett. In the well of the control plate, only Tween-80 was employed. Before incubating the plates at 37degree Celsius for twentyfour to forty eight hours, the oil was allowed to evaporate in the well for 1 hour. After incubation, the zone of inhibition was measured by using a graduated scale [88].

5.3 Antidiarrheal Activity

Stem decoction of *Cymbopogon citratus* lowers faecal production based on dose-dependent manner [51]. To cure diarrhoea, the entire stem and leaves of *C. citratus* are steamed and the decoction is drunk. Because of its widespread usage in conventional medicine, the anti-diarrheal effectiveness of lemongrass stalk decoction and its principal chemical ingredient were examined [86].

5.4 Antiamoebic activity and anti filarial activity

The lemongrass is used to treat the amoebic disorder by inhibiting or killing them. *Entamoeba histolytica* was activated by oil in broth culture [81, 49]. The freshly obtained leaves of *Cymbopogon citratus* are active on *Setaria digitata* [52].

5.5 Anti-fungal Activity

Essential oil of lemongrass is active against dermatophytes like *Epidermophyton floccosum*, *T.rubrum*, *Trichophyton mentagrophytes*, and *Microsporungypseum*. Also, this shows activity against ringworm fungi, Keratinophilic fungi, and food storage fungi [53-56]. *Candida albicans* is a prominent human pathogen; however, other species may be implicated in various disorders. Lemongrass oil and citral were tested for antifungal activity against *Candida* species, and the results indicated that *C.citratus* oil and Citral exhibited considerable in-vitro activity against *Candida* species [83].

5.6 Anti-Inflammatory activity

The extracted hot water from dehydrated leaves of lemongrass was delivered intragastrically to rats and was active in contrast to carrageenan-induced pedal edema. [57]. The anti-inflammatory activity of *C. citratus* leaf was investigated and used to treat inflammatory illnesses, particularly those of the gastrointestinal system [87]. Citral which is obtained from

Cymbopogon citratus inhibits inflammatory mediators significantly and can be used as an ingredient in lotions and ointments to treat topical inflammation. It has been found to suppress tumour necrosis factor α -induced neutrophil adherence at 0.1 percent concentration, inhibit inducible nitric oxide synthase, nitric oxide production, and other lipopolysaccharide-induced pathways, covalently bind to the receptors, thereby inhibiting the nuclear factor- κ pathway, 60–70 percent suppression of cyclooxygenase-2 (COX-2) and the GIT ingestion inhibit the inflammation of the tissue [118].

5.7 Anti-mutagenicity

The ethanolic extract of *C. citratus* shows antimutagenic effect towards chemical induced mutation in Salmonella typhimurium strains TA98 and TA100 in different model and retards the expansion of Fibrosarcoma cells transplanted in mice in association with the prevention of lung metastasis [58-61, 90].

5.8 Anti-malarial activity

The essential oils of *C. citraus* such as citral, myrcene, and citronella are characterized as anti-malarial compounds which suppress the growth of Plasmodium species [62-64]. Cymbopogon citratus dichloromethane extract was evaluated against Plasmodium berghei and Plasmodium falciparum with notable activity of 2–10 microgram per mililitre[94]. EC50 antiplasmodial activity of ethanolic extracts against 2 strains of Plasmodium falciparum (multidrug resistant) and CQ-sensitive. It may also enhance the antioxidant state of oxidative stress-related malarial problems [95].

5.9 Anti-microbial activity

Mycobacterium smegaris was killed by Cymbopogon citratus oil in an agar plate [65]. At a concentration of 10⁵ CFU/ml, *C. jwarancusa* oil significantly inhibited the development of

various *Klebsiella pneumoniae*, *Citrobacter*, *Proteus mirabilis*, *Salmonella enteric sertyphi*, and *Shigellalexneria* species. The most active chemicals among the 19 were geraniol, which fully prevented the growth of bacteria with some fungus, and β – Pinene, Linalool, and α – Terpeniol, which reduced the development of certain bacteria and fungi.[89]. Lemon grass leaf ethanolic preparations have antibacterial action against *Staphylococcus aureus*. The action is caused by flavonoids and tannins contained in the extract [91].

5.10 Anti-protozoan activity

The essential oil of *Cymbopooncitratus* has a dose-dependent anti-protozoan activity on two strains of Crithidadeanei [66]. Trypanosomatidae protozoans cause devastating illnesses in animals, plants and humans. Also, the family includes trypanosomatids that are monoxenous protozoans that live in insect hosts, such as *Crithidia*, *Blastocrithidia*, and *Herpetomonas*. *Cymbopogon citrate* essential oil inhibited the growth of *Crithidia deanei*. [84].

5.11 Acaricidal activity

An acaricide is a pesticide that kills the mites and ticks. The essential oil produced from fresh *Cymbopooncitratus* leaves has acaricidal activity [67]. We used two distinct types of mites to test the acaricidal effects of the essential oil of lemongrass extract: *Dermatophagoides farinae* and *Dermatophagoides pteronyssinus*. At 50% dosage, both the topical and the contact exposures to lemongrass result in more than 91% mortality for both species of mites. Lemongrass oil has strong acaricidal effect against scabies mites *Sarcoptes scabiei* var. *cuniculi*. In-vitro, a petroleum extract of lemongrass oil was shown to be more effective than crude lemongrass oil against *sarcoptes scabiei* var. *cuniculi* larvae. In general, as the concentration of lemongrass increases, so increased the number of deaths [92].

5.12 Antinociceptive activity

In traditional medicine, lemongrass reduces pain and anxiety in living creatures. In ancient times, it was employed as an analgesic or pain reducer for surgical procedures [50, 68-71]. *Cymbopogon citratus* essential oil has excellent antinociceptive effect. We may infer that the essential oil operates at both the central and the peripheral levels based on the outcome obtained with 3 separate experimental models of nociception (hot-plate, acetic acid-induced writhings, formalin test and hot plate) [93].

5.13 Anti-oxidant activity

Caffeoylquinic acid, flavonoids, phenolic acids, chlorogenic acids, iso-orientin and swertiajaponin are the natural antioxidants obtained from *C. citratus* responsible for decreasing beta-lipoprotein (LDL) oxidation induced by Cu^{+2} [72], decreasing function of plasma, beta-carotene and diphenyl picrylhydrazyl assays [73]. Because of their pharmacological properties, flavonoids and phenolic acid have been studied as natural anti-oxidants and free radical scavengers. The phenolic acids obtained from plants demonstrated an anti-oxidant characteristic [85].

5.14 Neurobehavioral effect

Sedative/hypnotic activity was assessed using pentobarbital sleeping duration, anxiolytic activity was assessed using elevated plus maze and light/dark box procedures, and anticonvulsant activity was assessed using seizures caused by pentylene-tetrazole and maximum electroshock. The *C. citratus*'s essential oil increased sleeping time, the proportion of entries and time spent in the open arms of the raised plus maze, and the time spent in the light compartment of the light/dark box. Furthermore, the essential oil delayed clonic seizures generated by pentylene-tetrazole and inhibited tonic extensions induced by maximum electroshock, indicating that the seizure threshold was raised and/or the seizure spread was blocked [96].

5.15 Hypoglycaemic, hypolipidemic and anti-hypertensive activity

A fresh leaf aqueous extract of *Cymbopogon citratus* given to normal rats reduced fasting plasma glucose, total cholesterol, triglycerides, low-density lipoproteins, and reduced lipoprotein levels while increasing plasma high-density lipoprotein levels in a dose-dependent manner but had no effect on plasma triglyceride levels [97]. In folk and ayurvedic medicine, *C. citratus* was assimilated in hypoglycemic and hypolipidemic drugs which had been accustomed to regulate glucose, lipid and fat level within the blood serum to prevent fatness and high blood pressure [75].

5.16 Anti-HIV activity and Anti-diabetic activity

Citronella oil cures *Candida albicans*-caused mouth thrush in Human Immuno Virus (HIV) / Acquired Immuno Deficiency Syndrome (AIDS) victims within one to five days [76].

Diabetes is one of the 20th century's most fatal diseases. It prevents the pancreas from producing enough insulin and may hinder blood sugar management. *Cymbopogon citratus*'s in-vivo antidiabetic efficacy was examined using molecular docking at dose rates of four hundred and eight hundred milligram. The extracts significantly lower insulin, glucose, and lipid levels. The invitro anti-diabetic potential of *Cymbopogon citratus* against Type II diabetes was examined using glucosidase and amylase inhibitory tests. For alpha-glucosidase and alpha-amylase, 99.9% (one milligram per millilitre) inhibition and median effective concentration (EC50) (0.31 milligram per millilitre) inhibition were found respectively [98].

5.17 Dermatotoxicity activity

C. citratus herbal stores are used to cure rashes, itching, and swollen skin [77]. Clinical samples were used to test the dermatotoxicity potency of herbal soap made from *Cymbopogon citratus* leaf, orange peel and tea plant oil. After 40 days of therapy with the soap, significant activity of 60 percent was detected [99]. A similar study found that when administered with *Cymbopogon citratus* oil (1 microlitre/mL), it inhibited *Microsporum canis* by 85.35 percent [100]. Shampoo containing citral proved efficient against the fungus *Malassezia furfur* that causes dandruff [101].

5.18 Effect on Rheumatoid arthritis

Rheumatoid arthritis is defined as, a type of arthritis that causes pain, inflexibility, inflammation and alteration in the movement of the joints.

Oil of lemongrass helps to relax and tone the body muscles and also relieve the muscle pain [13].

5.19 Anti-dandruff property of Lemongrass

Dandruff is defined as an accumulation of parakeratotic cells in a clump of corneocytes separated from stratum corneum of the scalp.

When it is used as scalp therapy, *Cymbopogon flexuosus* oil controls *Malassezia* species, dominant yeast responsible for scalp dandruff [78].

5.20 Anti-gingivitis activity and Anti-periodontitis activity

Gingivitis is defined as the early stage in the swelling of the gums due to the deposition of plaque. Mouthwash having 0.25% oil of lemongrass has antibacterial, anti-inflammatory and anti-oxidant property seems to be most effective for control of gingivitis [79].

Periodontitis is a chronic inflammatory response leading to irreversible destruction of tissues and bone that supports the teeth. 2% essential oil of lemongrass is an effective agent used for the treatment of periodontitis [80].

5.21 Anti-hepatotoxic activity with other miscellaneous activity

In rats, the aqueous leaf extracts of *C. citrates* demonstrated antihepatotoxic activity against cisplatin induced liver damage. As a result, the extracts might be employed to treat hepatopathies and as a therapeutic adjuvant in cisplatin toxicity. [82]

C. pendulus oil nourishes the stomach, promotes digestion, increases hunger, and controls vascular expansion and nervous system function. It is also a stimulant, carminative, febrifuge, antiseptic, diuretic, and anti-rickets agent [4].

6. Conclusion

Lemongrass is one of the perennial herbal plant which is included in Ayurveda from the ancient time. It is mostly cultivated in the Australia, North America, South America, Europe, Africa and widely spread throughout India from the sea level to 4200 meters in altitude. It possesses different chemical constituents which have their own medicinal importance. The basic components of lemongrass consists of cellulose, hemicellulose and lignin with major chemical constituents such as flavinoids, alkaloids, phenols, steroids, sodium, calcium, zinc, iron, retinol, tocopherol, and riboflavin. Similarly, essential oil obtained from *C. citratus* consists of major constituents which are citrol, geraniol, nerol, citronella, terpinolene, geranyl acetate, and myrcene. The main parts of this plant are root, leaf, stalk and inflorescence which are used for various medicinal purpose. Traditionally, people of different countries used the leaves and rhizomes to treat fever, digestive disorders, diabetes, inflammation, anxiolytics and antihypertensive, against cold and flu, stomach upsets and as decoction for malaria. It is also used as toothbrush and for pest control in some countries. The main purpose of this review is to display the different chemical constituents and the drug delivery applications of lemongrass.

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