

A Short Review on Chemical Composition Therapeutic Use and Enzyme Inhibition Activities of *Cymbopogon species*

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Abstract

Background/Objectives: *Cymbopogon* species is a universally accepted oil bearing grass. It is very much valuable for both Industrial as because of its main components like Geraniol, Geranial, Citral, Myrcene, Neral, Nerol, and Citronellol, Limonene etc. and Medicinal value. Therefore, it is just a little attempt to survey the literature of this important grass. **Materials and Methods:** For this literature survey, basically library data was collected and digital resources were also included. From these sources we obtained reliable information about different works of *Cymbopogon* sp. **Findings:** These grasses have considerable medicinal importance as all parts of it are used extensively in Ayurvedic, unani and other some traditional health treatments. Studies by different researchers indicate that *Cymbopogon* species possesses various pharmacological activities such as anti-bacterial, anti-diarrheal, anti-amoebic, anti-filarial, anti-fungal and anti-inflammatory properties, and various other effects like anti-mutagenicity, anti-malarial, anti-oxidants, anti-mycobacterial, hypoglycaemic etc. There are many literatures demonstrating the therapeutic use, enzyme inhibition activities of Citronella oil and also simultaneously analysed the different components of the oil. **Application/Improvement:** Till date very scanty information is available from different –different sources so, we try to collect this information in one review article. This review article gives an account of updated information on its chemical constituents, therapeutic uses, antimicrobial, anti-fungal and enzyme inhibitory activities of *Cymbopogon* species.

Keywords: *Cymbopogon*, Chemical Constituents, Enzyme Inhibition, Medicinal Properties, Pharmacological Activities, Therapeutic Use

1. Introduction

Plants have been identified as the potent therapeutic agent, due to the presence of nutritional (minerals and vitamins) and non-nutritional (fibres, active phytochemicals etc.) components. Different workers have been studied on chemical composition, therapeutic use and enzyme inhibition of *Cymbopogon* sp. from different times. Therefore, it was a little attempt to present a study related to chemical composition, therapeutic use and enzyme inhibition of *Cymbopogon* sp. an aromatic grass.

Cymbopogon is a genus of about 45 species of grasses under the family of Poaceae, native to India and tropical Asia. There are different *Cymbopogon* viz.,

C. bombycinus, *C. ambiguous*, *C. obtectus*, *C. refractus*, *C. citratus*, *C. nardus*, *C. schoenanthus*, *C. flexuosus*, *C. winterianus* etc. which are found in the different countries like Australia, China, Africa, India, Java and others. It is a tufted perennial grass growing to a height of 2.5 meter with numerous stiff leafy stems arising from short rhizomatous roots. Leaves are not basally aggregated; non-articulate. The leaf-blade is linear, tapered at both ends and can grow to a length of 50 cm and width of 1.5 cm. The leaf-sheath is tubular in shape and acts as a pseudo stem. Leaves are long glaucous, green, linear tapering upwards and along the margins. This plant produces flowers at matured stages of growth which are bisexual in nature.

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It is an aromatic grass which gives essential oil upon steam distillation. One of the important essential oils extracted from aromatic grasses is citronella oil obtained from citronella grass. This oil is used extensively as a source of important perfumery chemicals like citronellol, citronellal and geraniol, which finds its extensive use in soap, perfumery, cosmetic and flavouring industries throughout the world. It is classified in trade into two types –Ceylon citronella oil, obtained from *Cymbopogon nardus* (inferior type), while Java type citronella oil obtained from *Cymbopogon winterianus* (superior type). Use of alkaloids and terpenoids in the medicinal plants holds a great promise in the field of medicine in ancient as well as modern era. *C. citratus* has highest larvicidal activity against *Culex quinquefasciatus*¹. According to World Health Organization (WHO), definition of a medicinal plant is, a plant that can be used for therapeutic purposes and or its compounds be used as a pioneer in the synthesis of semi-synthetic chemical drugs as shown in Figure 1².

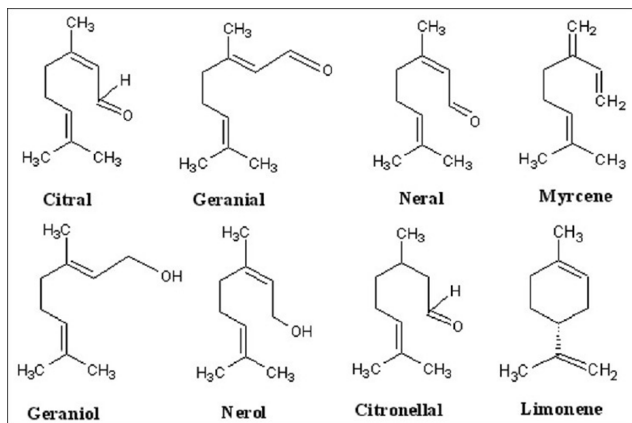


Figure 1. Structures of the main constituents of the essential oil of *Cymbopogon* species.

2. Materials and Methods

For this survey, basically library data was collected and digital resources such as Google scholar, Scopus, PubMed, and Research gate etc. also helped for this literature survey method. Through Medicinal and Aromatic Plant Abstract (MAPA), different journals, books we could obtain reliable information to continue this work. From these resources we have reviewed the various works related to chemical composition, therapeutic uses and enzyme inhibition activities and various phytochemical studies

on *Cymbopogon citratus*, *C. nardus*, *C. flexuosus*, *C. jwarancusa* and *C. winterianus* as well as the therapeutic uses of these same species are given below.

3. Results and Discussion

Different Chemical composition, Therapeutic uses and Enzyme Inhibition activities are summarised below.

4. Chemical Composition

The chemical composition of the essential oil of different species of *Cymbopogon* and its different plant parts were studied from many years ago. In 1996 the study on *C. citratus* only reported that citral was a major component in the essential oil of the plant³.

Gradually the methodology for this experiment was developed and the researchers now able to analyse sophisticatedly. The major and traces constituent of the essential oils of *C. jwarancusa* are – terpenes-piperitone (20%–70%) and Δ -carene (20%–24%), citronellal (30%–40%), *p*-cymene (0.6%–3.5%), geraniol (0.04%–22.5%), β -pinene (3.5%), and γ -terpinene (7.5%). Traces—alloaromadendrene, *cis*- and γ -allo-ocimene, α -bisabolene, β -bisabolene, borneol, *d*-cadinene, calamene, camphene, camphor, β -caryophyllene, β -caryophyllene oxide, α -chamigrene, 1,8-cineole, citronellol, α -cubebene, cuprene, *o*-cymene, 5,6-dimethyl-5-norbornen-2-ol, dipentene, β -elemene, *d*-elemene, elemol, eucarvone, eudesmol, α -farnesene, β -farnesene, fenchone, geranyl acetate, geranyl formate, geranyl propionate, germacrene, α -humulene, iso-borneol, kasuralcohol, lavendulol, linalool, longifolene, *cis*- and γ -*p*-mentha-2-en-1-ol methyl heptenone, *p*-mentha-2,8-dien-1-ol, methyl thymyl ether, α -muurolene, myrcene, myrtenal, phellandrene, α -pinene, γ - and *cis*-peperitol, terpinen-4-ol, α -terpineol, terpinolene, γ -thuj-2-en-4-ol, verbenone, and β -ylangene⁴.

The major constituents of leaves of *C. flexuosus* oil are geraniol and geranyl acetate. The proportion of geraniol and geranyl acetate distinctly fluctuates during leaf development. The proportions of geraniol and geranyl acetate in the essential oil recorded at day 10 after leaf emergence were ~59% and ~33% respectively. However, the level of GA went down from ~59 to ~3% whereas the level of G rose from ~33 to ~91% during the leaf growth

period from day 10 to day 50⁵.

They reported that major constituents of essential oil of *C. jwarancusa* were Linalool -0.13 ± 0.03 , Citral a 14.96 ± 0.8 , Citral b 3.36 ± 0.3 , Geraniol 2.93 ± 0.5 and Elemol 1.14 ± 0.3 ⁶.

Extraction of *C. citratus* oil contains saponins, tannins, anthrax quinines, alkaloids, steroids, phenols and flavonoids⁷.

Only two components viz., Piperitone 54.36 % and α Phellandrene 30.86 % were found as major components of the essential oil of *C. jwarancusa*⁸.

In *C. citrates* terpenes, alcohols, ketones, aldehyde and esters were found as main compounds in the essential oil. The major phytoconstituents of the essential oils that contain Citral α , Citral β , Geraniol, Nerol, Citronellal, Geranyl acetate, Terpinolene, Myrcene and Terpinol Methyl heptenone and flavonoids and phenolic compounds, which consist of luteolin, isoorientin 2'-O-rhamnoside, quercetin, kaempferol and apigenin⁹.

The essential oil of *C. winterianus* is rich in citronellal, geraniol and citronellol but has often constituents like citronellyl acetate, L-limonene, elemol and other sesquiterpene alcohols. It also consists of monoterpene constituents like citral, elemol, linalool, 1, 8-cineole, limonene, geraniol, β -caryophyllene, methyl heptenone, geranyl acetate and geranyl formate¹⁰.

The major constituents of *C. jwarancusa* oil were Piperitone 33.05%, Geraniol 20.30%, Δ^4 -Carene 16.9%, γ -terpinen 6.5%, β -Piniene 3.5%¹¹.

The essential oil extracted from the stalk of *C. citratus* a total of 68 compounds were characterized while the essential oil of the leaves of this plant consists of 72 compounds. GC-MS analysis revealed that geranial (32.10% and 29.64%), neral (22.36% and 21.73%), geraniol (5.40% and 7.75%), limonene (5.71% and 5.92%) and β -myrcene (2.20% and 2.28%), were the major constituents of the stalks and leaves of lemongrass essential oil respectively, comprising 67.77% and 67.33% of the total oil. From the GC-MS analysis it's reported that the major constituents of the essential oil are geranial (44.29%), neral (31.36%), geraniol (10.01%), limonene (6.09%) and β -myrcene (3.56%), comprising 95.31% of the essential oil¹².

Study on two different species viz., *C. flexuosus* and *C. citratus* revealed that the major constituents of the root stem and leaves of *C. flexuosus* were geraniol 30.5%, citronellol 24.1%, neral 10.3% and geranial 13.6% and the

constituents of *C. citratus* oil were citral 31.5%, Z- citral 28.82%, linalool 4.82%, geranyl acetate 3.57% and trans-geraniol 3.66%¹³.

Extraction of essential oil of both *C. nardus* and *C. citratus* showed different oil constituents. *C. nardus* oil composed of geraniol 55.57%, geranial 10.18%, and neral 8.34% as major constituents and other minor components were α -copaene 6.61%, citronellol 4.33%, γ - and δ -cardinene 4.26%, eugenol 2.51%, β -caryophyllene 2.32%, humulene 1.63%, α -cubebene 1.23%, α -pinene 1.14%, citronellal 0.63%, δ -cardinol 0.58%, limonene oxide 0.47%, and germacrene-D 0.20%. For the essential oil of *C. citratus*, the major components were geranial 49.40%, neral 27.48%, and myrcene 9.73% and other minor ones were geraniol 3.23%, citronellal 2.72%, humulene 1.81%, limonene oxide 1.50%, cis- β -ocimene 1.22%, trans- β -ocimene 1.03%, α -thujene 0.90%, citronellol 0.59%, and α -copaene 0.38%¹⁴.

The chemical composition of the oil varies according to the genetic differences, geographical origin, part of the plant used, method of extraction, age/stage of maturity, and season of harvest. Despite these differences, a number of classes of compounds are reproducibly found, including alkaloid, tannins, saponins, flavonoids, phenols and anthraquinones. There are some compounds such as, citral, myrcene, geranial, geraniol, limonene, burneol, citronellol, nerol, neral, α -terpineol, elemicin, caffeic acid, apigenin, luteolin, kaempferol, quercetin, chlorogenic acid, and geranyl acetate found in the essential oil. In addition to this, isolation of furfural, fumesol, aldehyde, isopulegol, isovaleric L-linanol, methylheptenone, n-decyclicaldehyde, p-coumaric acid, valeric esters, terpeneone, and other compounds has been reported. Irrespective of its geographical origin, this species contains a high percentage (about 80%) of citral, which is a mixture of terpenoids, neral and geranial. A variation in the myrcene constitution 12-15% in West Indian *C. citratus*, in comparison to the East Indian type has been reported. However, there was an exception that the essential oil from the Ethiopian *C. citrates* contains geraniol (40%) as its main compound, followed by citral 13% and α -oxobisabolene 12%¹⁵.

The major compounds of essential oil were geranial 42.4%, neral 29.8%, myrcene 8.9% and geraniol 8.5%³. Again in the same year GC-MS analyses revealed that the presence of same 23 compounds representing 90.6% of the total oil, out of which geranial 42.2%, neral 31.5%,

and b-myrcene 7.5% were the major components and Geranyl acetate 4.3% and isopulegol 1.4% were minor but significant components¹⁶.

Therapeutic uses

In 1995 the researchers reported that urinating difficulties and water retention can be treated with *C. citratus* (lemongrass) tea due to the presence of diuretic properties³⁴.

In the next year the other workers did experiment on Minimum Inhibitory Concentration (MIC) and Minimum Lethal Concentration (MLC) values on *C. citratus* indicating the fungicidal effect of *C. citratus* oil, since MLCs were almost equal to MICs of the test strains. The highest MIC and MLC was showed by *Microsporum gypseum*, which was followed by *Trychophyton rubrum* and *Epidermophyton floccosum*, respectively. This study revealed that citral functioned as a fungicidal agent and citral was able to form a charge transfer complex with e- donor of fungal cells resulting in fungal death. The comparative study of the efficacy of cream containing four different concentrations (1.5%, 2%, 2.5% and 3%) of lemon grass oil was performed *in vitro* by hole diffusion assay. 2.5% oil was demonstrated to be the minimum concentration for preparation of an antifungal cream for subsequent clinical study³.

The main compounds obtained from *C. citratus* were glycosyl flavones orientin and isoorientin as well as chlorogenic acid. Isoorientin and chlorogenic acid have been shown recently to display hypoglycaemic effects in streptozotocin diabetic rats¹⁸.

C. citratus has some anti-cancer properties. The oil extract of this plant has been shown to inhibit rat colon carcinogenesis¹⁹.

The research on the antioxidant property of *C. citratus* (lemon grass) showed that the dry lemon grass contains more phenol and flavonoids than fresh one. Hence, the dried lemon can be inferred as potent antioxidant than the fresh lemon grass²⁰. Again the stem extract of this plant showed antimicrobial properties against *Staphylococcus aureus* strain only when acetone and hexane were used as extraction solvents. It was also revealed that oven dried extracts of lemongrass stems gave a greater antimicrobial activity than that of the freeze dried extracts. From this study the research workers concluded that harvesting of lemongrass in the month of November had higher antimicrobial properties than that from October harvest²¹.

At a concentration of 60 µg/mL, the extraction of

C. citratus showed a significant scavenging ability of 2,2-diphenyl-2-picryl hydrazyl (DPPH; (85%), nitric oxide (78%), 2,2-azinobis (3-ethyl benzothiazoline-6-sulphonic acid) (ABTS; 77%), superoxide (76%), hydroxyl (70%), free radicals generated using *in vitro* and also moderate anti lipid per oxidative effect (57%) and concluded that it has high antioxidant properties²².

Decoction of 250 ml of *C. citratus* to the 31 hypertensive individuals in Barangay Situbo for the period of 16 weeks to evaluate the effect of twice-a-day intake of lemon grass decoction, among these individuals and found that twice-a-day intake of lemon grass decoction had a significant effect on the mean arterial pressure. However, no significant effect was observed on the mean heart rate and on the clinical symptoms in relation to hypertension²³.

The researchers did experiment on cold water extract and hot water extract of *C. citratus* and reported that in a dose dependent manner, hot water extract had significantly higher DPPH radical scavenging ability, Fe²⁺ chelating ability and OH^{*} scavenging ability than cold water extract and they concluded that the heat treatment may affect antioxidant properties due to release of phenolic phytochemicals. Hence these phenolic phytochemicals contribute the health promoting and disease preventing abilities of *Cymbopogon citratus*²⁴.

The cardioprotective effect of *C. citratus* in isoproterenol, it induced cardio toxicity. By using male Wistar albino rats it was found that administration of lemon grass decreased the toxic levels of lipid peroxidation (TBARS) in both heart tissue and serum, by increasing the level of enzymatic antioxidants and non-enzymatic antioxidants significantly in both heart homogenate and serum sample ($p < 0.05$). Lemon grass pre-treatment exhibited cardio protective activity by decreased activity of cardiac markers in serum and increase of the same in heart homogenate ($p < 0.05$)²⁵.

In vitro Growth and Sporulation study of two rice pathogens, *Rhizoctonia solani* and *Bipolaris oryzae* were in *C. jwarancusa* it was reported that the fungal radial growth was inhibited at very low concentration (25 ppm) of the essential oil. Similarly fungal spore production was also inhibited up to ≥80% at 500 ppm. The IC₅₀ value of essential oil was 365.45 and 420.16 against *B. oryzae* and *R. Solani* respectively⁸.

In vitro cytotoxicity of *C. jwarancusa* oil and its constituents on human cancer cell lines THP-1 (leukaemia), HEP-2(liver), A-549 (lung) and IGR-OV-1

(ovary) was evaluated by Sulforhodamine - B assay. The oil was found to be more potent than its components against cancer cell lines tested with IC₅₀ of 6.5 µg/ml (THP-1), 6.3 µg/ml (A-549), 7.2 µg/ml (HEP-2) and 34.4 µg/ml (IGR-OV-1)²⁶.

The methanol extract of the plant leaf essential oil of *C. citratus* prevented bacterial growth of *Staphylococcus aureus*, *Bacillus cereus* and *Escherichia coli* at 1000 mg/ml concentration. With the increase of concentration, the antibacterial effect is also high. This study showed that there was no inhibitory effect of growth of *Pseudomonas aeruginosa*²⁷.

Like methanol extract different workers did experiment on *C. jwarancusa* by using ethanol extract. They found it as very effective against *Fusarium oxysporum* sp-*lini* (85.31 ± 0.25 mm) and *Staphylococcus aureus* (94.37 ± 0.28 mm) at 500 ppm while water extract was found less effective against *Aspergillus flavus* (03.72 ± 0.19 mm) at 100 ppm concentration. The ethanol extract can be used as food preservation and as a remedy and against dental diseases. It was also reported that the water extract showed highest antioxidant activity in βCL (54.76 ± 1.37 %) at 1mg/10ml concentration while the ethanol extract showed highest antioxidant activity in DPPH (31.99 ± 0.50 % inhibition) and FRAP (38.79 ± 0.54 Fe (II) micromole per litre) assay²⁸.

The therapeutic activities of *C. citratus* revealed that the infusion and decoction of this species can be used in different parts of the world for treatment of fevers, digestive disorders, rheumatism, other joint pains, inflammation menstrual disorder and nervous disorder as well as other health problems²⁹.

Essential oil of *C. winterianus* is used as an analgesic anticonvulsant and anxiolytic agents. In traditional medicine, the oil has been used as an aromatic tea, diuretic, and antispasmodic. It can be used as massage oil for joint and muscle pain. It can also be used as anti-parasitic, nematocidal, antifungal, anti-bacterial agents and mosquito repellent³⁰.

The leaves of *C. flexuosus* and *C. citratus* are used in the treatment of cough, fever, nervous disorder, depression and skin irritation. Plant decoction is usually used in digestive complaints, headache and promote sweating. These two plants have extensive medicinal value as, anti-fungal, anti-bacterial, anti-septic, anti-asthmatic, Urinary tract infections, Pesticides and preservatives¹³.

C. citratus is a folk remedy for coughs, flu,

gingivitis, headache, elephantiasis, leprosy, malaria, pneumonia, ophthalmic, and vascular disorders. The researchers reported that due to its antibacterial and antifungal properties mixing with pepper, it can be used as home therapy for menstrual troubles and nausea. Lemon grass serves as a good cleanser so that it can detoxify the liver, kidney, bladder, pancreas and the digestive tract. It lowers the uric acid level, Cholesterol, excess fats and other toxins in the body while stimulating digestion, lactation and blood circulation, therefore, it can also reduce blood pressure; it also alleviates indigestion and gastroenteritis. It is said that lemongrass also helps improve the skin by reducing acne and pimples³¹.

The antimicrobial assay of *C. jwarancusa* oil distinctly suppressed the growth of several species of *Klebsiella pneumonia*, *Citrobacter*, *Proteus mirabilis*, *Salmonella enteric* sertyphi and *Shigella flexneria* at the dose of 105 CFU/ml. The most active compounds among the 19 namely geraniol that completely inhibited the growth of the bacteria than fungi and β - Pinene, Linalool, and α - terpeniol showed an inhibitory activity against some bacteria and fungi³².

C. citrates should be used with caution by individuals with pregnant or lactating women, kidney and liver diseases, patients on antiplatelet medication or clotting disorders, and in combination with drugs that depend on the cytochrome P₄₅₀ enzyme system for their metabolism. High doses and prolonged usage of *C. citratus* tea or decoctions should be discouraged¹⁵.

HYBRID and FRED docking were performed for 48 documented essential oil phytoconstituents of *C. citratus* for putative action mechanism concerning three proteins viz., PTP-1B, PPAR-γ and DPP IV having diabetic therapeutic properties. Phytoconstituents like linalool, myrcenol, α-elemol and β Eudesmol showed significant interaction with PPAR-γ and DPP-IV while only pimelyldihydrazide showed interaction with PTP-1B. These results provided a pharmacological evidence of *C. citratus* essential oil as antidiabetic, mediated by interaction of various phytoconstituents with multiple targets operating in diabetes mellitus³³.

There are some reports stating the common human pathogenic bacteria like *Enterobacter aerogenes* and *Klebsiella pneumoniae* are inhibited by the leaf essential oil of *C. flexuosus*³⁴.

The essential oil extracted from *C. citratus* exhibited prominent antifungal effect against *Candida albicans*,

C. tropicalis, and *Aspergillus niger*, having different inhibition zone diameters (IZDs) (35-90 mm). IZD increased with increasing oil volume. Anti-candida activity was higher in the vapour phase. Further, the oral administration of essential oil 10 mg/kg, significantly reduced carrageenan-induced paw edema with a similar effect which was observed for oral diclofenac 50 mg/kg, used as the positive control. Oral administration of the oil showed dose-dependent anti-inflammatory activity also. In addition to this, topical application of the essential oil *in vivo* has potent anti-inflammatory effect, as demonstrated by using the mouse model of croton oil-induced ear edema. The topical application of the oil at doses of 5 and 10 mL/ear significantly reduced acute ear edema induced by croton oil in 62.5 and 75% of the mice, respectively. Histologically it can be concluded that lemon grass essential oil inhibits the skin inflammatory response in animal models¹⁶.

5. Enzyme Inhibition Activities

Lipoxygenase activity was significantly inhibited (96%) by *C. winterianus* oil at 12.5 µg/ml concentration. Concentration providing 50% inhibition (IC_{50}) value of *C. Winterianus* oil for lipoxygenase inhibitory activity was 3.98 µg/ml. Lipoxygenase inhibition at 12.5 µg/ml concentration, was 60 and 51% by *Cymbopogon martini* and *Cymbopogon flexuosus* oil, respectively and IC_{50} values were in the range of 10-12.2 µg/ml. Among major terpene components of the oils, lipoxygenase inhibitory activity was highest in the citronellal (IC_{50} value 1.66 µg/ml) followed by citronellol and citral³⁵.

The IC_{50} value of the positive acarbose showed 91.2 µL/mL while the inhibitory activity of *C. nardus* and *C. citratus* oils were ~15 times more as compared to positive commercial standard drug acarbose that can be used for reducing glucose level in blood. The inhibitory activity of *C. nardus* ($6.59 \pm 0.20 \mu\text{L mL}^{-1}$) and *C. citratus* ($6.97 \pm 0.12 \mu\text{L mL}^{-1}$) was very similar and showed a strong overlap, due to the presence of α -amylase inhibitory activities, the active components were not much different. The α -amylase inhibitory activities decreased with increasing essential oil concentrations¹⁴.

By using an *in-vitro* model for antidiabetic test, β -glucosidase inhibition assay in *C. citrates* stalk essential oil showed highest degree of inhibitory activity i.e., 89.63 at the ratio of 1:2 for the volume concentration of essential

oil per volume of solvent. The leaves and standard essential oil showed small percentage difference in their antidiabetic activity with the highest β -glucosidase activity of 79.26% and 73.8% respectively at the same ratio value of 1:2. The β -glycosidase activities tend to decrease as the concentration of lemongrass essential oil decreases. Again anti-gout test was examined by Xanthine Oxidase Inhibition (XOI) assay with the maximum percentage of xanthine oxidase inhibition of 81.34% obtained from lemongrass stalk essential oil. Essential oil which scored the highest percentage inhibition was the one extracted from the stalks with 81.34% inhibition activity at the ratio of volume concentration of essential oil per volume of solvent of 1:2, followed by the standard essential oil (80.02%) and essential extracted from leaves with 74.51% inhibition at the same volume ratio. The inhibition activity decreases as the essential oil concentration decreases¹².

C. martini can inhibit the maltase activity to the tune of 98% while it has less sucrose inhibition activity. On the contrary acarbose has 15,000 times more affinity for inhibiting the sucrase activity and can also inhibit digestion of starch and maltose. Acarbose has 100% inhibition activity for all the substrates. *C. martini* as abroad-based inhibitor, showing about 73% inhibition for bacterial amylase and almost 85% inhibition of the yeast alpha glucosidase. *C. martini* decreases the blood glucose level on maltose load. It should be noted that although *C. martini* shows a 98% inhibition *in vitro*, it demonstrates better lowering of blood glucose, that is, $153 \pm 8.6 \text{ mg/dL}$ in 2 hours as compared to acarbose. With sucrose as the substrate, acarbose which has very high affinity for sucrose shows lower blood glucose value after two hours. *C. martini* which demonstrates about 68% inhibition *in vitro* shows an increase by $50 \pm 7.05 \text{ mg/dL}$ as compared to acarbose. In normal animals too, a decrease in the glucose shoot up is seen at 16 min for maltose and sucrose. Administration of *C. martini* to normal rats also showed a lowering of postprandial glucose level as compared to the normal rats. *C. martini* is also a good inhibitor of maltose transport showing 69% inhibition as against positive control acarbose which demonstrates a 62% inhibition. Acarbose is a better inhibitor of sucrase activity showing a 73% inhibition. In comparison *C. martini* showed 53% inhibition. *In vivo* studies with maltose load of 2mg and 3mg/gm body weight showed a non-competitive pattern of inhibition at 5 mg/kg body weight of *C. martini* as against 60mg/kg body weight of acarbose. Thus *C. martini*

is more effective alpha glucosidase inhibitor speedy at lower concentration than acarbose³⁶.

In *C. flexuosus* the level of geranyl acetate was declined during the early stage of day 10 to day 30 of leaf growth. The trend of changes in the proportion of geranyl acetate and geraniol has clearly indicated the role of an esterase that must be involved in the conversion of geranyl acetate to geraniol during leaf development. The researchers isolated an esterase from leaves of different ages that converts geranyl acetate into geraniol. During the leaf development cycle the geranyl acetate esterase activity markedly varied; it was closely correlated with the monoterpene (geranyl acetate and geraniol) composition throughout leaf development. Geranyl acetate esterase appeared as several isoenzymes but only three (GAE-I, GAE-II, and GAE-III) of them had significant geranyl acetate cleaving activity. The geranyl acetate esterase isoenzymes pattern was greatly influenced by the leaf developmental stages and so their geranyl acetate cleaving activities. Like the geranyl acetate esterase activity, geranyl acetate esterase isoenzyme patterns were also found to be consistent with the monoterpene (geranyl acetate and geraniol) composition. Geranyl acetate esterase had an optimum pH at 8.5 and temperature at 30°C. Besides geranyl acetate esterase, a compound with phosphatase activity capable of hydrolysing Geranyl Diphosphate (GPP) to produce geraniol has also been isolated¹⁴.

The oils of *C. nardus* and *C. citrates* containing citronellol and geraniol showed no tyrosinase inhibition activity which may not facilitate chelating of Cu in tyrosinase enzyme. This study showed that the mechanism of tyrosinase enzyme inhibition of oils were not free radical scavenging pathway, and can be possibly used in anti-wrinkle and whitening products³⁷.

6. Conclusion

The genus *Cymbopogon* is one of the important oil bearing plants of all over the world. It has a various functions in various fields. *Cymbopogon* oil is important oil obtained from the leaves, stems and roots also, which is used extensively as a source of perfumery chemicals. Citral, Geraniol, methyl eugenol, Citronellal, citronellol are the main components of *Cymbopogon* oil. Geraniol is an effective plant-based mosquito repellent. Although geraniol and other flavour compounds are found naturally in well-aged tobacco. Methyl eugenol (allylveratrol) is a phenylpropene a type of phenylpropanoid compound,

the methyl ether of eugenol. It is used in soap, perfumery, cosmetic, candles and incense and flavouring industries throughout the world.

This genus has a greater medicinal value and the highest numbers of works for therapeutic uses were done on *C. citratus*. Different species of *Cymbopogon* like *citratus*, *martinii*, *flexuosus*, and *winterianus* have the inhibition of enzymatic activities. The antifungal, antimicrobial, antioxidant activities, remedy of dental disease are the important aspects to study this genera widely.

This study will further enhance the knowledge of the researcher in the field of chemical composition, therapeutic and enzyme inhibition activity of different species of *Cymbopogon* as the paper contains wide and useful information from 1994 to till date. Moreover different researches may be carried out based on these data.

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