Comparative Phytochemical Analysis and Therapeutic Properties of Essential Oils from Citrus Limon and Cymbopogon Citratus

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ABSTRACT

Background: *Essential oils of Lemon (Citrus limon) and Lemongrass (Cymbopogon citratus) are commonly used in therapeutic contexts including stress-reduction. There is paucity of detailed phytochemical research on chemical constituents of Citrus limon and Cymbopogon citratus essential oils to delineate their therapeutic potentials including reduction of stress. There is also dearth of comparative studies focusing on their phytochemical composition and their efficacy substantiating stress management.* ***Objective:*** *This study aims to authenticate and compare the chemical composition of essential oils of Citrus limon and Cymbopogon citratus and understand their potential in reduction of stress.* ***Methodology:*** *Leaves of Citrus limon and Cymbopogon citratus were collected, authenticated and hydrodistillation was conducted to produce Essential oils. The essential oils were analyzed qualitatively using Gas Chromatography-Mass Spectrometry (GC-MS). The efficacy in reduction of stress was carried-out utilizing structured questionnaire and observational schedule.* ***Results:*** *GC-MS analysis of essential oils from Citrus limon and Cymbopogon citratus revealed 52 (C.limon) and 82 (C.citratus) compounds, respectively. Essential oils of Citrus limon and Cymbopogon citratus exhibited appreciable composition of monoterpenes and sesquiterpenes with therapeutic potency.* ***Conclusion:*** *The phytochemical composition of essential oils of Citrus limon and Cymbopogon citratus confirmed their therapeutic eminence, especially in reduction of stress. The reported chemical profile of essential oils of Citrus limon and Cymbopogon citratus affirms their efficacy in selective human therapy including aromatherapy.* ***Recommendation:*** *There is dearth of clinical research studies on essential oils of Citrus limon and Cymbopogon citratus substantiating their therapeutic efficacy in reduction of stress. Prevalence of stress and syndromes of anxiety related therapeutic developments are the dire needs of the present generation and therefore, concerted research efforts are worthy to substantiate their value in clinical therapeutics. Future predictive studies on variation in their chemical composition with strict attention on geographical and climatic variations are envisaged.*

Keywords: Citrus Limon, Cymbopogon Citratus, Gas Chromatography-Mass Spectrometry (GC-MS), Phytochemical Analysis

I. INTRODUCTION

Essential oils are the volatile and aromatic organic compounds that are the essence of the plant, removed physically from the plants they populate. Creeping thyme, Thymus serpyllum Anna's Rose coloured var.Low carbon footprint: the product of harvesting by our bees and processing at our farm in the UK 99.99 per cent natural: No added water preservatives 5 200 IU (100 mcg) Essential oils extracted from plants and flowers are complex mixtures of small organic molecules containing a variety of biogenic compounds, such as terpenes, alcohols, esters, aldehydes, ketones and phenols. They are used in aromatherapy treatments, an alternative form of healing that uses natural extracts from plants to stimulate health and well-being. Aromatherapy is used to treat a variety of conditions, including anxiety, depression and stress (Buchbauer, 2010).

II. LITERATURE REVIEW

Citrus limon: Botanical and Phytochemical Overview

Citrus limon or lemon is part of the family Rutaceae, a tree that reaches heights of around 3 meters. It has white flowers borne with a purple hue and produces the yellow fruit made popular for its use in food, cosmetics and pharmaceuticals. Lemon essential oil is extracted through cold pressing the peel and has a fresh, zesty aroma.

Lemon essential oil is a monoterpenoids-dominant volatile oil, where the main components include limonene (69%), β-pinene (11%), γ-terpinene (8.2%), and sabinene (4%). It is important to note that the composition of lemon essential oil is significantly influenced by its geographical provenance and extraction techniques, as well as environmental aspects. Current enantiomer studies revealed that the eugonol (geranyl eugenol, isomers of eugenol) primarily denotes the authenticity of a lemon oil.

Contemporary research on the chemical composition of lemon essential oil showed high variability depending on the geographical origin and climate of the plant, as well as the method of extraction and the time of the year. The major constituents of lemon essential oil are monoterpenoids such as D limonene, γ-terpinene, β-pinene, β-myrcene, sabinene, terpinolene, α-terpinyl acetate, linalool, citral, neral, and α-pinene.

Plate 1
Lemon Tree and Fruit

Cymbopogon citratus: Botanical and Phytochemical Overview

Cymbopogon citratus, known as lemongrass, is a perennial grass that belongs to the Poaceae family. It is characterized by long, slender leaves that emit a strong lemon scent when crushed. Lemongrass is commonly used in culinary applications, traditional medicine, and as a natural insect repellent (Srivastava et al., 2013). The essential oil of Cymbopogon citratus is primarily composed of monoterpenes, with citral (a mixture of geranial and neral) being the major component. Other significant constituents include limonene, β-myrcene, and citronellal (Ganjewala, 2009). The phytochemical profile of lemongrass essential oil can also vary based on the plant's growing conditions and the extraction process used (Vahid et al., 2013).

Cymbopogon citratus: Botanical and Phytochemical Overview

Lemongrass, Cymbopogon citratus, is an aromatic perennial grass of the family Poaceae. It is known for its long, thin leaves that give off a lemony scent when gently crushed. It is used for culinary purposes, in traditional medicines, and as an insect repellent. The citral-rich essential oil of Cymbopogon citratus is composed largely of monoterpenes of which citral (a mixture of the compounds geranial and neral) is the main component along with limonene, β-myrcene and citronellal (Ganjewala 2009). The phytochemical composition profile of the essential oil of lemongrass can be influenced by the growth conditions of plants and the method of extraction used to produce the oil (Vahid et al. 2013).

Therapeutic Potential of Essential Oils

Because of the vast and abundant amount of work done to study the usability of essential oils as pharmacological agents, many of the essential oils have established notes of efficacy and claims of utility and efficiency when used for healthcare purposes, both in ancient and modern times. The essential oil from Citrus limon (lemon oil) has been cited to exhibit elevated biological activities such as antimicrobial, antioxidant and anti-inflammatory properties, making it suitable for the treatment of various health diseases including induction of decoction for digestive dysfunctions, topical application against skin problems and inhalation as a regimen against respiratory disorders. Moreover, some of the leading notes on the potential of C limon essential oil in combating stress and anxiety have been attributed to the bioactive compounds, namely terpenes such as limonene that may offer some degrees of sympatholytic activity against stress and anxiety disorders. Further studies also revealed that limonene could lead to a decrease in the level of corticosterone and haemodynamic traits including systolic blood pressure, an implosive finding given that long-term use and abuse of corticosterone may be linked to the onset of diabetes or obesity. 3. Other essential oils with claims of applicability as pharmacotherapy in managing stress and anxiety include those from Cymbopogon citratus (lemongrass oil; Figure 40). The primary component of C citratus essential oil, citral, a monoterpene aldehyde, has been advanced to exert calming effects that could reduce anxiety and improve mood in patients. Figure 40. Cymbopogon citratus (lemongrass) plant.

Comparative Analysis and Therapeutic Implications

Although some studies have examined the chemical composition and bioactivity of Citrus limon and Cymbopogon citratus essential oils, no comparative study has looked at their chemical composition and bioactivity in general, nor their potential to reduce stress in particular. The stress-reducing activity of essential oils is mostly due to their ability to modulate activity of the central nervous system. Odorants interacting with the limbic system cause modulation in the activities of noradrenergic and serotonergic neurons, leading to emotional regulation and stress response (Buchbauer, 2010). Volatile compounds can be inhaled and reach the brain through the olfactory epithelium to produce calming effects which may help relieve stress and anxiety.

Plate 2
Cymbopogon citratus plant

2.1 Problem statement

Unfortunately, to the best of our knowledge, there are no comparative studies made on the chemical compositions and therapeutic efficacy of the essential oils of Citrus limon and Cymbopogon citratus, although there are some individual studies regarding their respective essential oil. These studies could have provided some indication of the possible health benefits of the respective essential oils. For example, in a study performed to establish the geographical origin of specified cold-pressed lemon oils, Mehl and colleagues determined the essential oils' volatile components. These authors reported that there were significant differences in the chemical composition of essential oils from different geographical origins, which were highly dependent on the extraction as well as environmental conditions. These findings highlight the fact that standardised analytical methods in essential oil research are of paramount importance to compare different essential oils (Mehl et al. 2014). However, a few in vitro and in vivo studies have been conducted on lemongrass essential oil and its bioactive constituents. Similar to the lemon essential oil, the chemical profile of lemongrass essential oil could differ from the region it was grown and/or the types of extraction used. For example, a study was conducted to determine the essential oil composition of Cymbopogon flexuosus ssp. malacensis (lemongrass) samples obtained from two different regions of Malaysia and Indonesia. Interestingly, Vahid and colleagues reported significant differences in the essential oil compositions of lemongrass from different anthropogenic plantations, further underscoring the need for comparable research (Vahid et al. 2013). However, it is well known for both monoterpenes and sesquiterpenes are responsible for many of the benefits of both Citrus limon and Cymbopogon citratus essential oils. Moreover, lemon essential oil is also rich in limonene, a monoterpene with stress-reducing properties, which acts on the central nervous system, influencing neurotransmitters and producing a calming action.

Lemongrass essential oil has also been found to acts in a calming manner, and the major chemical component in this oil, citral, can be useful in the treatment of stress and anxiety (Pratama and Permana 2021).

2.2 Objective

One of the most common ways to harvest these have been medicinally and aromatherapically. Citrus limon (Lemon) and Cymbopogon citratus (Lemongrass) essential oils are amongst the most well-known for stress amelioration, owing to their specific phytocompositions. However, there have been few comparative studies that explicitly tests essential oil phytochemical content or its efficacy in stress amelioration. This study is written to test the phytochemical content of essential oils obtained from C. limon and C. citratus, and its potential helath-improving impact on clients with stress, particularly.

III. METHODOLOGY

Sample Collection and Preparation

Fresh leaves of Citrus limon and Cymbopogon citratus were collected from Kenya Agricultural and Livestock Research Organisation (KALRO) farms in Kiambu and Kakamega Counties, respectively. The specimens were identified by the Botany Department of Masinde Muliro University of Science and Technology (MMUST). Authentication of collected plant samples was done against floras and classical monographs.

Cleaning and Preparation

Once they were authenticated, insects and dirt were separated from the plant samples, and the samples were washed several times with tap water. The processed leaves were air-dried in a cool, dry room for three weeks to lower their moisture content and prepare them for extraction.

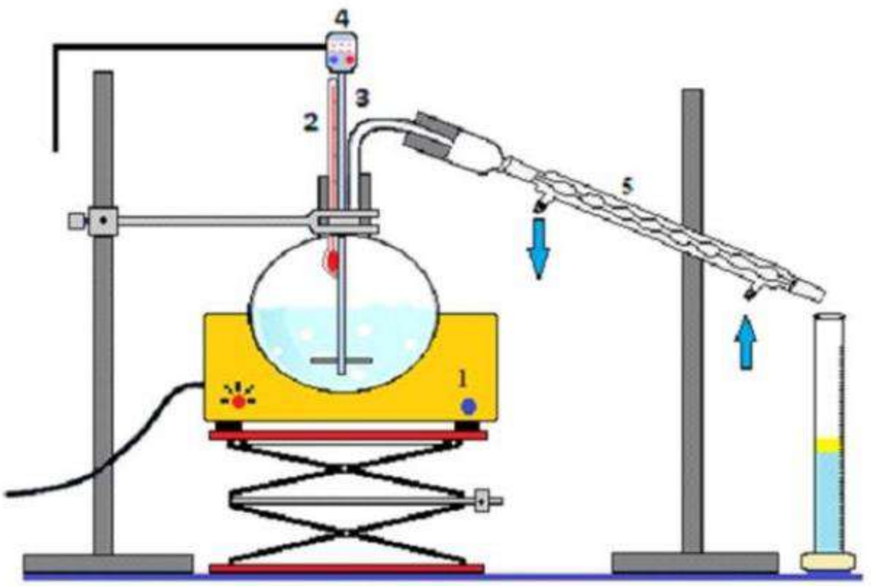
Extraction of Essential Oils

Hydrodistillation Method

Essential oils used in this experiment were taken from the leaves of Citrus limon and Cymbopogon citratus using the hydrodistillation technique because of its ability to yield highly volatile essential oil while retaining the integrity of the composition of the oil from the plant sample.

Equipment Setup

The setup of the hydrodistillation consisted of distillitation chamber, heating mantle, condenser, separation funnel and Clevenger apparatus. This is the figure which shows the setup.



Schematic diagram of the hydro-distillation setup: 1; Water bath, 2; thermometer, 3;stirrer, 4; Electric motor and 5; condenser 2.2. Kinetic Model of Peppermint Oil Extraction

Figure 1
Diagram of the hydro-distillation (El Asbahani et al., 2015)

Procedure

1. Feeding the Still: 10 kg of dry leaves were loaded into the chamber.
2. Adding Water: 30 liters of de-ionized water were added to the chamber.
3. Heating: the mixture was heated in an oil bath with the pressure of the mixture set to 3-4 kPa.
4. Condensation and Collection: Steam carrying the essential oils passed through a cooler condenser (cooling water running through the condenser coils to absorb the heat, resulting in condensation) and ended up as liquid, but a liquid that was now a mixture of water and essential oil and needed separation.
5. Separation: The less-dense essential oil floats on top of the water in the separation funnel. It was allowed to settle, and then was cooled, and the excess water that settled at the base of the funnel was sucked out very carefully with a pipette, leaving the essential oil in the funnel.

Storage

The essential oils were obtained from the leaves by standard steam distillation (around 50 ml for 10 kg of dry leaves) and immediately transferred into the amber glass vial and kept in fridge at 5°C until the time of the analysis.

Authentication of Essential Oil Content

Gas Chromatography-Mass Spectrometry (GC-MS) Analysis

The chemical constituents of the extracted essential oils were verified through GC-MS analysis at the Laboratories, Mpeketoni, JKUAT.

Sample Preparation

The essential oils were diluted in n-Hexane to prepare them for GC-MS analysis.

GC-MS Setup

With the GC-MS system properly calibrated using known standards introduced earlier into the system, the instrumental parameters were properly set to profile essential oil components (injection volume, carrier gas flow rate, etc.).

Analysis

These samples were subsequently injected into the GC-MS apparatus. The compounds present in the essential oils were sequentially separated according to their volatilities at the GC temperatures and their affinity to the stationary phase of the GC column. The separated compounds were then detected by the MS apparatus and their mass spectra were acquired. Each mass spectrum was then checked against the reference spectra stored in the NIST DB for an identification purpose.

Data Interpretation

The GC-MS analysis proved that in the essential oil of Citrus limon it identified 52 compounds, and in the essential oil of Cymbopogon citratus it found 82 different compounds. The percentages of these compounds were estimated by their peak areas of the chromatogram.

IV. FINDINGS & DISCUSSIONS

4.1 Findings

Chemical Composition of Essential Oils

Under hydro distillation, the essential oils were obtained from the leaves of Citrus limon and the stems of Cymbopogon citratus. Then its chemical composition was researched by using Gas Chromatography-Mass Spectrometry (GC-MS) that explained each essential oils volitile compound.

Lemon Essential Oil

The lemon (Citrus limon) essential oil was obtained through the hydrodistillation method from fresh leaves collected by hand and placed in a Clevenger type apparatus. The lemon essential oil obtained from this process was light yellow in colour. This sample was molecularly characterised by gas chromatography-mass spectrometry (GC-MS) to identify and quantify the components. A total of fifty-two compounds were detected (hundreds of ui sample). The main peaks had a relative percentage that was more than one percent of the total. The spoon representation, depicted in figure 2 below and in table 1, shows the compounds were identified. They include, but are not limited to D-Limonene (33.15%), Cyclopentene, 3-isopropenyl-5,5-dimethyl- (26.73%), 6-Octenal, 3,7-dimethyl- (R)- (8.23%) and β-Myrcene (3.44%). Table 1 depicts the components and the relative percentages, when known. Retention times are also included.

Table 1
Compounds Identified in Citrus limon Essential Oil

S. No	RT	Name of Compound	Area %	Grouping
1	5.534	trans-4-Thujanol. sabinene hydrate	0.38	Alkene Hydrocarbon
2	5.732	(1S)-2,6,6-Trimethylbicyclo[3.1.1]hept-2-ene	1.41	Alkene Hydrocarbon
3	6.748	Cyclopentene, 3-isopropenyl-5,5-dimethyl-	26.73	Fatty Acid
4	6.870	Bicyclo[3.1.1]heptane, 6,6-dimethyl-2-methylene-, (1S)-	2.11	Alkane Hydrocarbon
5	7.052	β-Myrcene	3.44	Sesquiterpene
6	7.619	Tricyclene	4.01	Alkane Hydrocarbon
7	7.841	Alpha- terpinene	1.40	Alkene Hydrocarbon
8	8.258	D-Limonene	33.15	Monoterpene
9	8.300	β-Phellandrene	0.88	Monoterpene
10	8.598	β-Ocimene	5.50	Alkatriene
11	8.813	trans-4-Thujanol. sabinene hydrate	0.03	Hydrocarbon
12	8.980	γ-Terpinene	2.46	Monoterpene
13	9.396	trans-4-Thujanol	0.03	Alcohol
14	9.724	Cyclohexene, 3-methyl-6-(1-methylethylidene)-	1.05	Hydrocarbon
15	10.154	Linalool	1.23	Acyclic Monoterpene
16	10.322	Nonanal	0.08	Saturated Fatty Aldehyde
17	11.710	6-Octenal, 3,7-dimethyl-, (R)-	8.23	Aldehyde
18	11.934	cis-Verbenol	0.04	Bicyclic Monoterpene Alcohols
19	12.469	Isogeranial	0.07	Homoallylic Alcohol
20	12.588	Isogeranial	0.97	Alcohol
21	13.030	α-Terpineol	0.05	Phenol
22	13.181	Decanal	0.15	Saturated Fatty Aldehyde
23	13.765	Citronellol	0.25	Monoterpene
24	15.025	2,6-Octadienal, 3,7-dimethyl-, (E)-	1.43	Aldehyde
25	15.976	Undecanal	0.04	Aldehyde
26	16.180	cis-p-Mentha-2,8-dien-1-ol	0.07	Alcohol
27	16.323	trans-Geranic acid methyl ester	0.12	Fatty Acid Ester
28	16.591	Cyclohexene, 4-ethenyl-4-methyl-3-(1-methylethenyl)-1-(1-methylethyl)-, (3R-trans)-	0.06	Alkane Hydrocarbon
29	16.988	6-Octen-1-ol, 3,7-dimethyl-, acetate	0.43	Alcohol
30	17.783	4-Hexen-1-ol, 5-methyl-2-(1-methylethenyl)-, acetate	0.66	Fatty Acid
31	18.080	Cyclohexane, 1-ethenyl-1-methyl-2,4-bis(1-methylethenyl)-, [1S-(1α,2β,4β)]	0.35	Saturated Fatty Acid
32	18.935	Caryophyllene	0.36	Sesquiterpene
33	19.871	Humulene	0.08	Sesquiterpene
34	20.509	β-copaene	0.04	Sesquiterpene
35	20.880	(1S,2E,6E,10R)-3,7,11,11-Tetramethylbicyclo [8.1.0] undeca-2,6-diene	0.15	Alkene Hydrocarbon
36	21.052	β-Bisabolene	0.02	Sesquiterpene
37	21.191	8-Isopropenyl-1,5-dimethyl-cyclodeca-1,5-diene	0.02	Alkene Hydrocarbon
38	21.373	α-Muurolene	0.02	Aromatic hydrocarbon
39	21.933	Cedren-13-ol, 8-	0.02	Alcohol
40	22.330	Bicyclo[7.2.0]undec-4-ene, 4,11,11-trimethyl-8-methylene-, [1R-(1R*,4Z,9S*)]	0.02	Fatty acid
41	22.467	1,5-Cyclodecadiene, 1,5-dimethyl-8-(1-methylethylidene)-, (E,E)-	0.05	Fatty acid
42	22.895	γ-Amorphene	0.02	Alkaloid
43	22.969	(-)-Spathulenol	0.01	Phenol
44	24.152	(8R,8aS)-8,8a-Dimethyl-2-(propan-2-ylidene)-1,2,3,7,8,8a-hexahydronaphthalene	0.03	Aromatic hydrocarbon
45	24.778	τ-Cadinol	0.03	Alcohol
46	25.411	Levomenol	0.02	Alcohol
47	25.524	2,6,11-Dodecatrienal, 2,6-dimethyl-10-methylene-	0.40	Aldehyde

The analysis established that Citrus limon essential oil is a complex mixture of hydrocarbon monoterpenes, oxygenated monoterpenes and aldehydes. The most abundant components identified in the Kenyan sample were Cyclopentene, 3-isopropenyl-5,5-dimethyl- (26.73%), D-Limonene (33.15%), Linalool (1.23%), 6-Octenal, 3,7-dimethyl- (R)- (8.23%), β-Myrcene (3.44%), and γ-Terpinene (2.46%).

Lemongrass Essential Oil

It was obtained by hydrodistillation of fresh leaved fresh Cymbopogon citratus, displaying an obtained colour that ranges from dark yellow to amber. It was revealed identified eighty-two different compounds from GC-MS, the major constituents are: Geranial at 18.19%; Neral at 11.40%; B My1.34%. Table 2 shows identified compounds with relative percentage, and Retention time.

Table 2

GC-MS Analysis of Cymbopogon Citratus Essential Oil

S. No	RT	Name of Compound	Area %	Grouping
1	6.168	Camphene	0.05	Aromatic hydrocarbon
2	7.050	β-Myrcene	11.34	Sesquiterpenoids
3	7.172	Ethanone, 1-(2-methyl-1-cyclopenten-1-yl)-	0.05	Ketone
4	8.089	o-Cymene	0.03	Hydrocarbon
5	8.171	D-Limonene	0.07	Sesquiterpenoids
6	8.278	trans-β-Ocimene	0.33	Hydrocarbon
7	8.571	β-Ocimene	0.15	Sesquiterpenoids
8	9.344	4-Nonanone	0.56	Ketone
9	9.904	Undecane	0.10	Alkane
10	10.150	Linalool	2.04	Sesquiterpenoids
11	10.904	p-Mentha-1(7),8-dien-2-ol	0.04	Alcohol
12	10.993	(E)-6-Methylhept-4-en-1-ol	0.04	Alcohol
13	11.733	Camphor	3.80	Sesquiterpenoids
14	11.930	cis-p-mentha-1(7),8-dien-2-ol	0.08	Alcohol
15	12.388	p-Mentha-1,5-dien-8-ol	0.85	Alcohol
16	12.465	Isogeranial	0.17	Sesquiterpenoids
17	13.128	p-Mentha-1,5-dien-8-ol	0.86	Aromatic hydrocarbon
18	13.803	Citronellol	7.10	Sesquiterpenoids
19	14.219	2,6-Octadienal, 3,7-dimethyl-, (E)-	7.38	Aldehyde
20	14.518	geranyl bromide (GERANIAL)	18.19	Alkene hydrocarbon
21	15.060	2,6-Octadienal, 3,7-dimethyl-, (E)- (Neral)	11.40	Aldehyde
22	15.547	2-Undecanone	0.39	Ketone
23	16.204	cis-3-Cyclopropyl-7-(2-methoxyethyl) norcarane	1.81	Arene
24	16.993	Citronellol acetate	0.12	Phenol
25	17.378	Phenol, 2-methoxy-3-(2-propenyl)-	0.47	Phenol
26	17.780	lavandulyl acetate	0.23	Alcohol
27	18.936	Caryophyllene	0.44	Bicyclic sesquiterpene
28	19.159	trans-α-Bergamotene	0.05	Sesquiterpenoids
29	19.595	cis-β-Farnesene	0.02	Sesquiterpenoids
30	19.810	(3aR,4R,8R,8aS)-3a,4,8a-Trimethyl-7-methylenedecahydro-4,8-methanoazulene-rel-	0.02	Fatty acid
31	19.875	Humulene	0.02	Sesquiterpenoids
32	20.585	Spiro [5.5] undec-2-ene, 3,7,7-trimethyl-11-methylene-, (-)-	0.04	Fatty acid
33	20.762	2-Tridecanone	0.19	Ketone
34	20.847	Isoledene	0.02	Alkene Hydrocarbon
35	21.196	alpha-chamigrene	0.02	Fatty acid
36	21.306	γ-Muurolene	1.02	Sesquiterpenoids
37	21.375	α-Muurolene	0.04	Aromatic hydrocarbon
38	21.514	(E)-γ-Bisabolene.	0.10	Alkene Hydrocarbon
39	21.864	α-ylangene	0.08	Sesquiterpenoids
40	22.187	Linalyl butyrate	0.13	Ester

41	23.091	Caryophyllene oxide	0.04	Sesquiterpenoids
42	23.815	α-Copaene	0.02	Sesquiterpenoids
43	24.074	δ-Selinene	0.06	Sesquiterpenoids
44	24.230	γ-Selinene	0.01	Sesquiterpenoids
45	24.826	β-Humulene	0.03	Sesquiterpenoids
46	27.886	(1Alpha,3beta,4beta)-p-menthane-3,8-diol	0.05	Alcohol
47	28.303	Carbamic acid, N-phenyl-, 1,5-dimethyl-1-vinyl-4-hexenyl ester	0.02	Ester
48	28.592	5-(1-Bromo-1-methyl-ethyl)-2-methyl-cyclohexanol	0.01	Alcohol
49	28.838	Pulegone	0.01	Monoterpene
50	28.973	Cyclopropanemethanol, 2,2-dimethyl-3-(2-methyl-1-propenyl)-	0.02	Aromatic hydrocarbon
51	29.292	Methanol, [6,8,9-trimethyl-4-(1-propenyl)-3-oxabicyclo [3.3.1] non-6-en-1-yl]-	0.01	Alcohol
52	29.540	Carbamic acid, N-phenyl-, 1,5-dimethyl-1-vinyl-4-hexenyl ester	0.08	Fatty Acid Ester
53	30.219	5-(1-Bromo-1-methyl-ethyl)-2-methyl-cyclohexanol	0.81	Alcohol
54	30.586	Dispiro[2.1.2.4]undecane, 8-methylene-	0.05	Hydrocarbon
55	30.672	Cycloheptene, 5-ethylidene-1-methyl-	0.07	Fatty Acid
56	30.804	Bicyclo[2.2.1]heptane, 2-[9-borabicyclo[3.3.1]non-9-yloxy]-, 1,7,7-trimethyl-	0.23	Alkane hydrocarbon
57	31.053	4-Thujanol, cis-(+/-)-	4.58	Ketone
58	31.230	trans-isocarveol	0.40	Alcohol
59	31.423	Methyl (Z)-5,11,14,17-eicosatetraenoate	0.10	Ester
60	31.596	2-Isopropenyl-5-methylhex-4-enal	6.66	Aldehyde
61	31.781	2-Isopropylidene-5-methylhex-4-enal	2.04	Aldehyde
62	31.916	Cyclopropanemethanol, 2-methyl-2-(4-methyl-3-pentenyl)-	0.24	Alcohol
63	32.044	trans-Verbenol	0.20	Alcohol
64	32.167	geranyl bromide	0.06	Alkene
65	32.261	1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)-	0.29	Alcohol
66	32.369	(-)-(Z)-Verbenol	0.22	Alcohol
67	32.520	2-Isopropenyl-5-methylhex-4-enal	3.89	Aldehyde
68	32.590	(-)-(Z)-Verbenol	0.77	Alcohol
69	32.704	2-Octen-1-ol, 3,7-dimethyl-	0.08	Alcohol
70	32.887	α-Citral	0.42	Aldehyde
71	33.040	trans-isocarveol	0.57	Alcohol
72	33.119	5,8,10-Undecatrien-3-ol	0.04	Alcohol
73	33.221	2,6-Octadienal, 3,7-dimethyl-, (E)-	1.49	Aldehyde
74	33.482	Ethanol, 2-(3,3-dimethylcyclohexylidene)-, (Z)-	2.42	Alcohol
75	33.578	Nerolidol	1.08	Alcohol
76	33.634	Formic acid, 3,7,11-trimethyl-1,6,10-dodecatrien-3-yl ester	0.38	Ester
77	33.804	Bicyclo[3.1.1]hept-3-en-2-ol, 4,6,6-trimethyl-, [1S-(1α,2β,5α)]-	0.08	Alcohol
78	33.905	Ethanol, 2-(3,3-dimethylcyclohexylidene)-, (Z)-	0.51	Alcohol
79	34.338	Formic acid, 3,7,11-trimethyl-1,6,10-dodecatrien-3-yl ester	1.52	Acid Ester
80	34.526	6-Octen-1-yn-3-ol, 3,7-dimethyl-	0.08	Alcohol
81	34.835	7-epi-cis-sesquisabinene hydrate	0.07	Sesquiterpene
82	34.926	trans-p-mentha-1(7),8-dien-2-ol	0.06	Alcohol

The major aroma constituents identified in the fresh citronella oil from Kenya were β-Myrcene (11.34%), Geranial (18.19%), Neral (11.40%), 2-Isopropenyl-5-methylhex-4-enal (6.66%), Citronellol (7.10%), Camphor

(3.80%), and Linalool (2.04%). The minor volatile components present in less than 1% were, p-Mentha-1,5-dien-8-ol (0.86%); Isogeranial (0.17%), Caryophyllene (0.50%), and Humulene (0.02%).

4.2 Discussion

Citrus limon Essential Oil

Through GC-MS analysis, this lemon essential oil was found to be a complex mixture of 52 compounds. D-Limonene (33.15%), Cyclopentane (26.73%), and 6-Octenal (8.23%) were some of the most potent components. Many papers state that citrus essential oils such as lemons have a rich variety of monoterpenes, of which limonene was found in high concentration. Russo et al. (2015) also identify limonene as a major component of lemon essential oil. However, the exact percentages vary depending on the geographical or environmental part of the lemon used for oil production. For example, comparing this study with another study that tested lemon essential oil of Tunisian origin (Hsouna et al, 2017), the composition of oil was quite different. While limonene was in 39.74 per cent, it was only 9.81 per cent in our Kenyan sample. Environmental conditions and phytochemicals of the plants change due to geographical variations. Linalool in Iranian lemon oil (Hojjati et al, 2017) was 30.62 per cent, which was much higher than in the Kenyan sample (1.23 per cent).

Kamiyama (1967) found that geranial was the main component of Japanese lemon oil, followed by limonene and neral. This picture is the opposite of the Kenyan sample, where oil of limonene predominated over geranial. This indicates that chemotypes are also influenced by variation within regions compared with other countries. In a similar vein, Gülay Kirbaslar and İsmail Kirbaslar (2004) found that the Turkish lemon oil was dominated by limonene (44.2 per cent) (see Table 2 below) followed by geranial (14.1 per cent) and β-pinene (10.6 per cent). The presence of β-pinene – conspicuously absent in the Kenyan sample – in the Turkish sample further emphasises regional totality. Table 2: Percentage contents

In their study of Italian lemon oil, Dugo et al. (1997) reported on limonene (28.4-34.8%), β-pinene (12.0-16.0%) and geranial (9.9-14.1%) as the major components. Comparing the data from the Kenyan sample and that of the Italian lemon oil sample, one can see that both have a relatively higher percentage of limonene but a higher percentage of β-pinene in the Italian sample. Ayedoun (1996) stated that the major components of Beninese lemon oil were limonene, β-pinene and citronellal – a profile very different from that of the Kenyan oil, with a low percentage of β-pinene and citronellal.

Moreover,lemon oil from Cyprus, Italy and Israel has been evaluated by Singh et al. (2020) and its therapeutic effects are believed to be due to its highly concentrated monoterpene, Limonene, which is regarded to have anti-oxidant, anti-diabetic and anti-cancer properties. (Murali and Saravanan (2012) reported the use of D-Limonene as an agent in the management of dyslipidemia and hyperglycemia in streptozotocin -induced diabetic rats This remarkable report endorses the great therapeutic implications of lemon essential oil.

Cymbopogon citratus Essential Oil

The GC-MS analysis showed the presence of 82 bio-active compounds in essential oil of Cymbopogon citratus with major components of Geranial (18.19%), Neral (11.40%), β-Myrcene (11.34%). The current findings were surely a support for literatures that had been shown citral [(geranial + neral)] as the main essential oil of lemongrass like Randitha et al (2014). This consistency possibly reflects the conserved chemical fingerprints of lemongrass essential oil from different studies.

Other comparative studies confirmed the predominance of geranial and neral with slight variations in the percentage (eg, Ganjewala 2009). For example, while in the Kenyan sample, geranial and neral make up 75 per cent and 10 per cent respectively, Brügger et al. (2019) show that in the Brazilian lemongrass oil, these values are higher – 31.5 and 19.6 per cent respectively. The exact reasons for this are unknown but might be due to different cultivation conditions and different extraction techniques. It is also important to note that these differences might be due to slightly different definitions of plant varieties (C diagnacum or C citratus). Nevertheless, there is evidence that environmental conditions in Brazil contribute to enhanced accumulation of certain phytochemicals.

The study of Ecuadorian oil of lemongrass by Pino et al. (2018) reported geranial (39.8%) and neral (33.20%) as major components. The percentage are close to the Kenyan sample, but both geranial and neral's percentages in the Ecuadorian sample are higher. It is not surprising to find different geographical factors, contribute to variation of the constituents' chemical composition of essential oils. Hadjilouka et al. (2016) studied the oil of lemongrass (C. citratus), grown in Greece. They reported geranial (38.5%), neral (28.7%) and limonene (6.9%) as major constituents in the composition. These major constituents found in this study are being seen in this study but geranial and neral's percentages are higher in the Greek sample.

Mukhtar et al. (2023) reported the therapeutic potential of lemongrass oil as an antimicrobial, anti-inflammatory and antioxidant agent. The high levels of β-Myrcene and citronellol, identified and quantified in the present study, are

therapeutic bioactives. Pratama and Permana (2021) also reported anti-cancer effect of lemongrass oil and its action could be due to the high levels of citral and other bioactive components.
In addition, the economic value of lemongrass oil as an ingredient in the pharmaceutical, food and cosmetic industry was mentioned in a review by Gupta and Ganjewala in 2015 with lemongrass oil having a consistent occurrence of the major components geranial and neral in these studies, supporting a broad application potential. Cortes-Torre et al made a note of the hepatoprotective and cholesterol-lowering effect of lemongrass oil which is described with the heterogenity of the chemical profile of lemongrass oil.

To summarise, there is a great variability in the chemical composition of essential oils of C itrus limon and C ymbopogon citratus from different geographic regions of the world. The presence of the same compounds (D-Limonene in lemon oil and citral in lemongrass oil) in similar quantities in all the samples indicates the stability of both oils and their possible use in therapeutical purposes. Therefore, the results of this study emphasise the importance of phytochemical studies at a regional level in order to determine the complete chemical profile of essential oils that may be of beneficial importance for the studies of the relationship between essential oils and health issues, as well as for industrial purposes in records such as EU.

V. CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions

Among others, this exhaustive phytochemical analysis demonstrated that Citrus limon and Cymbopogon citratus essential oils have a hefty phytochemical diversity comprised mainly of monoterpenes and sesquiterpenes. Such diverse phytochemical profiles are the hallmark of essential oils that are endowed with multiple therapeutic properties. The relatively higher concentration of D-limonene in Citrus limon essential oil, and Geranial in Cymbopogon citratus essential oil makes them a valuable tool for a wide-range of applications, especially in aromatherapy, as well as natural preservatives. Hence, this work provides a helpful reference database for future research on developing therapeutic and commercial applications of the essential oils. The chemical variability observed with respect to chemical compositions, informed by geographic locations and extraction methods further emphasises the need to have consistent protocols in standardising the quality and ultimate usage of EOs.

5.2 Recommendations

To increase the potential and spread of application of the essential oils of Citrus limon and Cymbopogon citratus, some recommendations were proposed: 1. Standardisation of essential oil extraction methods to ensure the quality of the obtained product by optimising extraction parameters, such as temperature, pressure and extraction time. This leads to the maintenance of integrity of the essential oil volatile compounds and the reproducibility of the chemical profile. 2.Further research on the therapeutic applications of essential oils and develop some little clinical trials in order to investigate the efficiency of these essential oils in the management of several health problems such as the stress, anxiety, depression and other disorders related to stress. 3.Geographical and seasonal variation studies, given the impact of geographical region and environmental conditions on the chemical composition which could modulate the chemical composition of essential oils. This could determine the optimal growing conditions to obtain a high-quality essential oil.

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The author, Sharon Jepchumba Kosgey, declares that there are no competing interests regarding the publication of this paper.

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