Review Article

A Review on Chemical Composition, Oil Quality, and Bioactivity of Vetiver Essential Oil

A. PANDEY AND S.C. TIWARI*

Department of Forestry, Wildlife and Environmental Sciences, Guru Ghasidas Vishwavidyalaya, Bilaspur, Chhattisgarh, 495009, India

***Chrysopogan zizaniodes* is the well-known eco-friendly plant known for the essential oil obtained from its roots. It is the most popular essential oil which does not have any synthetic substitute available. The essential oil of vetiver is widely utilized in traditional Thai, Chinese, and Ayurvedic medicine to cure a variety of illnesses. The essential oils with various biological properties are employed in the culinary, pharmaceutical, food and beverage and cosmetic industries. The current study is the review of chemical makeup, oil quality (as per bureau of Indian standards) as well as the bioactivities the of the vetiver essential oil. Various pharmacological studies have found that vetiver oil has significant effects as an antifungal, antibacterial, antioxidant, anti-inflammatory, and cytotoxic agent against cancer, as well as being beneficial in aromatherapy. The essential oil used in conventional medicine to cure a variety of illnesses, such as mouth ulcers, fever, headaches, depression, nervous tension, anxiety disorders, insomnia, and sexual dysfunction. Root is used as alexiteric, stomachic, carminative, astringent, and boosts the immune system in addition to treating skin conditions, urinary problems, jaundice, and flatulence as well as anaemia, and haemoptysis.**

Key words: Aromatic plant, chemical composition, essential oil, herbal medicine, vetiver

Essential Oils (EOs) do not need an introduction because they are highly regarded as plant-based products with enormous therapeutic and economic potential. They are obtained from various plant parts such as flowers, buds, stems, leaves, fruits, seeds, and roots, to name a few[1]. Medicinal and aromatic plants are among the most important types of horticulture crops that play a special role in sustaining various pharmaceutical, perfumery, and cosmetic industries in India and abroad[2-4]. The root is the most economically important part of the vetiver plant[5]. Vetiver, botanically known as *Chrysopogon zizanioides* (*C. zizanioides*) (L.) Roberty syn., is a perennial herbaceous grass belonging to the Poaceae family. It is commonly known as Khus or Khas-Khas[6,7]. Its origin is India, and it grows wildly in most parts of the world, from tropical to Mediterranean climates, including regions in Asia, Central and South America, Oceania, and Africa[8-10]. It is grown for its exceptional ability to create an EO, a complex blend of sesquiterpene alcohols and hydrocarbons[11,12]. Due to its distinctive aroma, which is not produced by any synthetic chemical, vetiver oil is also known as the "oil of tranquility"[11-14]. The largest producers of vetiver EO in the international market are Indonesia, Haiti, Brazil, China, India and Guatemala[15-17,10]. The major consumers of vetiver oil are the United States, Europe, India, and Japan[1,18]. In India, vetiver is mostly grown in the southern and peninsular regions, including Uttar Pradesh, Rajasthan, Bihar, Kerala, Tamil Nadu, Karnataka, and other states. There are two strains, South Indian and North Indian, with several vernacular names[19,20,1,4]. India produces only 20-25 tonnes of vetiver EO annually, compared to the estimated 600-700 tonnes produced worldwide. The estimated cultivation area for vetiver has reached nearly 10 000 hectares[10,21]. Vetiver grass is grown for the extraction of an EO with significant commercial value, used in fragrance and aromatherapy[22,23]. It

***Address for correspondence**
E-mail: ankitforestry21@gmail.com

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is mostly employed in high-end perfumery, where its odor persistence makes it valuable as a fixative when combined with other scents[24,25]. The highly complex chemical makeup of vetiver oil consists primarily of sesquiterpenes and its derivatives, of which vetiverols, their carbonyl compounds, and esters are the primary components. The relative abundance of these chemicals determines the oil's quality. The main odour-influencing components in vetiver oils from various sources are three carbonyl compounds, Alpha (α)-vetivone, Beta (β)-vetivone, and khusimone[2,26]. β-Vetivone has a better odor and is regarded as the most important component, while its major isomer, nordihydro β-vetivone, has a strong, rich, woody-peppery note[19,25]. These numerous active components of vetiver oil provide biological properties like antibacterial, antifungal, antiviral, antioxidant, anti-inflammatory, and anticancer properties[25,13,15]. This review focuses on describing the changes in and availability of the chemical composition of vetiver oil from different geographic regions, the quality of the oil, and its uses in various pharmaceutical (bioactivity) and medicinal capabilities of vetiver EOs.

MATERIALS AND METHODS

An extensive search of scientific databases including the Web of Science, Google Scholar, Scopus, ISC, and PubMed was used in this review to gather evidence on vetiver's chemical composition and phytochemical qualities. The keywords used in the database for the literature survey were chemical composition of vetiver, vetiver oil quality, pharmacological uses of vetiver, chemistry of vetiver oil, and bioactivity. The literature in this study has included original research papers, review papers, as well as a few books on herbal and traditional medicines.

EO EXTRACTION:

EOs produced from different herbs and aromatic plants have seen an increase in popularity in recent years. Hydro distillation (traditional method), steam distillation, solvent extraction, microwave assisted extraction, supercritical fluid extraction and CO2 expanded ethanol method are the current vetiver oil extraction techniques[27,28,17,14]. In order to obtain the EOs from medicinal herbs and plants, hydro distillation has been the most popular technique among the various methods of oil extraction[17]. The EO obtained from various extraction methods shows significant differences in yield percentage, chemical composition, extraction time, and other biological activities of vetiver oil, as presented in Table 1. Pripdeevech *et al*.[29] reported that there was no discernible difference between the composition of vetiver oil obtained using the steam distillation and solvent extraction apparatus.

TABLE 1: CARDIOVASCULAR DISTRIBUTION AS PER GENDER DISTRIBUTION

Parameter	Methods of oil extraction		
	HD	CXE	SFE
Yield (%)	0.6	5.12	0.5
Oil colour	Pale yellow	Light yellow	Greenish brown
Time of extraction (h.)	12	3	2
Chemical composition			
Hydrocarbon	90.71	64.46	81.91
Alcohol	2.77	-	-
Carbonyl compound	-	5.42	-
Carboxylic acid	2.66	-	-
Total identified (%)	96.14	69.88	81.91

Note: HD: Hydro Distillation, CXE: Carbon dioxide expanded ethanol extraction and SFE: Supercritical Fluid Extraction

CHEMICAL COMPOSITION OF VETIVER EO:

Numerous studies have been conducted on vetiver oil chemical makeup. Over 300 chemicals have been identified, with sesquiterpenes and their derivatives like alcohols, hydrocarbons, and ketones dominating the majority of them[30]. The oil produced by vetiver grown in regular soil had 37 volatiles, according to analysis. Pripdeevech *et al*.[29] studied vetiver cultivation using different methods and found that 39 volatile components were present in the oil extracted from vetiver grown in normal soil with microorganisms. The major component was (Z)-9,10-dehydro-2-norzizaene, comprising 46.03 % of the oil. The oil produced by vetiver grown in normal soil had 37 volatiles, the three main ones among these were (Z)-9,10-dehydro-2-norzizaene (20.78 %), khusimone (20.57 %), and khusimol (11.11 %). Champagnat *et al*.[30] reported that the EOs of *Vetiveria zizaniodes* (L.) (*V. zizanioides*) Nash from 9 nations-Brazil, China, Haiti, India, Java, Madagascar, Mexico, Reunion, and Salvador have different chemical compositions. About 110 components, mostly sesquiterpenes, were found in oils after analyses using GC/MS. After the GC-MS analysis of vetiver oil, Hammam *et al*.[31] found that the 15 different compounds shows that sesquiterpenes are the most common class of chemicals. The most crucial ingredients were alcohols and acids. The main compounds among the alcohols in vetiver oil include preziza-7(15)-en-12-ol, cedren-5-en-15-ol, preziza-7(15)-en-3-ol, ziza-6(13)-en-12-ol (khusirnol), ziza-5-en-12-ol, 12-nor-ziza-6(13)-en-2-ol, and khusian-2-ol (helifolan-ol). Similarly, Oliveira *et al*.[13] and Lunz, Stappen *et al*.[7] reported that there were 22 different compounds were found, the majority of which (70.4 %±0.1 %) are oxygenated sesquiterpenes. The primary ingredients in vetiver EO were khusimol (30.0 %±0.3 %), eudesmol (10.8 %±0.3 %), muurolene (6.0 %±0.1 %), and patchouli alcohol (5.6 %±0.2 %). The Srilanka ecotype of vetiver from Northeast Thailand was steam-distilled to produce a viscous light-brown oil with a balsamic, earthy, and sweet woody scent that contained between 0.3 and 1.0 % volume by weight. The main components were khusimol (12.7 %), longipinene (4.2 %), valerenol (3.9 %), and epizizanal (3.3 %), with α-vetivone and β-vetivone following closely behind (2.0 % and 1.6 %, respectively)[32]. Similary Lima *et al*.[33] found that after the Gas Chromatography-Mass Spectrometry (GC-MS) analysis revealed a variety of substances, including khusimol (19.57 %), (E)-isovalencenol (13.24 %), α-vetivone (5.25 %), vetiselinenol (5.08 %), α-cadinol (5.01 %), α-vetivone (4.87 %), and hydroxy-valencene (4.64 %) being the main substances in the EO. The chemical composition of *C. zizanioides* EO with number of compounds has been found, compiled from the different geographic location of the world is shown in Table 2.

TABLE 2: CHEMICAL COMPOSITION OF VETIVER GRASS FROM THE DIFFERENT LOCATION OF WORLD STUDIED BY VARIOUS RESEARCHERS

S. No.	Location	Chemical composition	Total no. of compound	References
1.	China	2,3,5,5,8,8-Hexamethyl-cycloocta-1,3,6-triene, 1,5,9,9-Tetramethyl-2-methylene-spiro[3.5]non-5-ene, (+)-Sativen, 4,8,8-Trimethyl-2-methylene-4-vinylbicyclo [5.2.0]nonane, a-Amorphene, 2-Isopropenyl-1,3,5-trimethylbenzene, a-Gurjunene, b-Vatirenene, 9 d-Cadinene, b-Guaiene, Dehydro-aromadendrene, Cubenol, (+)-Ledene, Epiglobulol, Widdrol, 6-Isopropenyl-4,8a-dimethyl-1,2,3,5,6,7,8,8a-Octahydro-naphthalen-2-ol, 3-(2-Isopropyl-5-methylphenyl)-2-methylpropionic acid, Cedr-8-en-13-ol, Ethyl 4-(4-methylphenyl)-4-pentenoate, Isovellerdiol, a-Curcumene, 3,3,8,8-Tetramethyl-tricyclo[5.1.0.0(2,4)] oct-5-ene-5-propanoic acid, Solavetivone, 3,8-Dimethyl-4-(1-methylethylidene)-2,4,6,7,8,8a-Hexahydro-5(1H)-azulenone, (-)-Spathulenol.	25	[11]
2.	Turkey	8,9-dehydro-cycloisolongifolene, cadina-1(10),4-diene, ar-curcumene, γ-cadinene, ß- vetivenene, γ-gurjunene, ledene oxide, η-himachalene, valencene, C15H22O, γ-muurolene, ß-guaiene, allaromadendrene oxide, δ-cadinol, junipene, tau-muurolol, trans-caryophyllene, cubenol, caryophyllene oxide, khusinol, 8-cedren-13-ol, C13H18O, ß-gurjunene, thujopsene-13, dehydro-aromadendrene, ß-vetivone, α-vetivone.	30	[26]

3.	Comoros	α-Phellandrene, (E)-Isoeugenol, Khusimene, ar-Curcumene, α-Amorphene, Valencene, γ-Vetivenene, Elemol, β-Vetivenene, β-calacorene, Spathulenol, trans-Sesquisabinene hydrate, Khusimone, 1,10-epi-cubenol, 10-epi-γ-Eudesmol, 1-epi-cubenol, epi-α-Cadinol, α -Cadinol, 7-epi-α-Eudesmol, Valerianol, epi-Zizanone, Khusinol, Khusian-2-ol, Zizanal, (Z)-ß-Santalol, Nootkatol, Juniper camphor, Vetiselinenol, Khusimol, (E)-ß-Santalol, 14-Hydroxy-γ-cadinene, 13-Hydroxy valencene, Bicyclo- vetivenol, Isovalencenol, Nootaktone, β-Vetivone, Khusinol acetate, (Z)-ß-Santalol acetate, α-Vetivone, Epi-Laurenene.	41	[34]
4.	Brazil	Naphthalene, ß-cubebene, Isolongifolene, ß-Gurjunene, α-Patchoulene, ß-Cadinene, α-Muurolene, α-Amorphene, Valencene, α-Bulnesene, α-Elemol, ß-Vatirenene, ß-Eudesmol, Spathulenol, Guaiol, Humulane-1,6-dien-3-ol, Cubenol, Agarospirol, Cedren-13-ol, Patchouli alcohol, Khusimol, Nootkatone,	22	[13]
5.	India	Cycloisolongifolene, All-oaromadendrene, Alpha -copaene, gamma-Muurolene, Germacrene D, Guaia-6,9-diene, Isolongifolol, Isospathulenol, Isoledene, Epiglobulol, Tau.-Muurolol, Cubenol, Isoaromadendrene epoxide, Globulol, Humulane-1,6-dien-3-ol, Caryophyllene, Aristolene, Alpha-Ylangene, 2(1H) Naphthalenone, 3,5,6,7,8,8a- hexahydro-4,8adimethyl- 6-(1- methylethenyl)-, beta-Vatirenene, Alpha - Cedrene, Selin-6-en-4α-ol, Gamma-himachalene, Valerenol, Alpha -Guaiene, Alpha - Gurjunene, Longiverbenone, Alpha -Longipinene, Alpha -Amorphene, bete-Copaene, Nootkatone, Isolongifolene, 4,5dehydro.	32	[18]
6.	Thailand	Tricyclene, Camphene, Camphor, Bornyl acetate, Silphiperfol-5-ene<7-epi->, Presilphiperfol-7-ene, Silphiperfol-5-ene, Silphiperfol-4,7(14)-diene, Silphiperfol-6-ene, Cadina-1(10), 6,8-triene, Cedrene<beta->, Caryophyllene(E-), Copaene<beta->, 9-Methyl-S-octahydroanthracene, Humulene<alpha->, Cadina-1(6), 4-diene<cis->, Neocallitropsene<alpha->. Cuparene, 3-Methyl-2-pent-2-enyl-cyclopent-2-enone, Cameroonan-7-alpha-ol, Humulane-1,6-dien-3-ol, Silphiperfolan-6-beta-ol , Guaia-3,9-diene, Prenopsan-8-ol, Caryophyllene oxide, Alloaromadendrene oxide-(2), Humulene epoxide II, Humulene<beta->, Silphiperfol-6-en-5-one, Acorenol<alpha->, Vatirenene<beta->, Bisabolol<epi-beta->, Himachal-4-en-1-beta-ol<11-alphaH->, 1,4-Methanoazulen-7(1H)-one, octahydro-4,8,8,9-tetramethyl-, (+)-	34	[35]
7.	Taiwan	2,3,5,5,8,8-Hexamethyl-cycloocta-1,3,6-triene, 1,5,9,9-Tetramethyl-2-methylene-spiro[3.5]non-5-ene, (+)-Sativen, 4,8,8-Trimethyl-2-methylene-4 vinylbicyclo[5.2.0]nonane, α-Amorphene, 2-Isopropenyl-1,3,5-trimethylbenzene, α-Gurjunene, β-Vatirenene, δ-Cadinene, β-Guaiene, Dehydroaromadendrene, Cubenol, (+)-Ledene. Epiglobulol, Widdrol, 6-Isopropenyl-4,8a-dimethyl-1,2,3,5,6,7,8,8a-octahydro-naphthalen-2-ol, 3-(2-Isopropyl-5-methylphenyl)-2-methylpropionic acid, Cedr-8-en-13-ol, Ethyl 4-(4-methylphenyl)-4-pentenoate, Isovellerdiol, α-Curcumene, 3,3,8,8-Tetramethyl-tricyclo [5.1.0.0(2,4)] oct-5-ene-5-propanoic acid, Solavetivone, 3,8-Dimethyl-4-(1-methylethylidene)-2,4,6,7,8,8a-hexahydro-5(1H)-azulenone, (−)-Spathulenol,	25	[23]
8.	Egypt	Linaloo, Trans-Rose oxide, Menthone, Trans Methone, Citronellol, D-Carvone, Geraniol, Citronellyl formate, Geranyl formate, Zizanal, Beta-Bourbonene, Acora-3(7),14-diene, Caryophyllene, Daucene, (+)-Epi-bicyclosesquiphellandrene, Prezizaene, Khusimene, Alpha. Gurjunene, (1R,5R)-1-Iso propyl-8-methyl-4-methy lenespiro [4.5] dec-7-ene, Selina-3,7(11)-diene, α-Amorphene, Cis-Eudesma-6,11-diene, Beta-Vetispirene, Beta-Cadinene, Gamma-Muurolene, D-Cadinene, Iso ledene, Cadina-1(10),4-diene D-Amorphene, 11,12,13-tris-nor -trans-Eud esm-5-en-, 7-one, Alpha-Calacorene, ß-Vatirenene, Isolongifolene, 4,5,9,10-dehydro-, 4-(1,3,3-Trimethyl-bicyclo. [4.1.0] he pt-2-yl)-but-3-en-2-one, γ-Vetivenene, Ylangene, Beta-Maaliene, 13-nor-Erem ophil-1(10)-en-11-one, Junenol, γ-selinene, Beta-Cadinene, Valencene, Beta-Guaiene, 2-Isopropyl-5-methyl-9-methylene-bicyclo-1-decene (4.4.0), Cyclocopacamphenol, Spiro [4.5] dec -8-en-7-ol, 4, 8- dimethyl-1-(1-methy lethyl)-, Zizanol, Khusiol, Juniper camphor, Cycloheptane, 4-methylene-1-methyl-2- (2-methyl-1-propen-1-yl)-1-vinyl-, Delta-selinene, Vetiselinenol, α-Isonootkatol, Khusimol, α-Vetivol, α-Costol, Valerenol, ß-Vetivenene, (E)-Eremophila-1(10),7(11)-dien-12-ol (Isoval encenol), (Z)-Isovalencenal, ß-Vetivone, (E)-Isovalencenal [eremophila-1(10),7 (11)-di en-12-al, α-vetivone.	63	[36]

9.	Indonesia	Khusimol (zizanol), Vetiselinenol (isonootkatol), Cyclocopacamphan-12-ol (epimer A), α-Cadinol, α-Vetivone (isonootkatone), ß-Vetivenene, ß-Eudesmol, ß-Vetivone, Khusenic acid, ß-Vetispirene, γ-Vetivenene, α-Amorphene, (E)-Eudesm-4(15),7- dien-12-ol, b-Calacorene, g-Cadinene, (Z)-Eudesm-6-en-11-ol, g-Amorphene, Ziza-5-en-12-ol, b-Selinene, (Z)-Eudesma-6,11-diene, Salvial-4(14)-en-1-one, Khusinol. Cyclocopacamphan-12-ol (epimer B), Selina-6-en-4-ol, Khusian-ol, d-Amorphene, 1-epi-Cubenol, Khusimene (ziza-6(13)- ene), Ziza-6(13)-en-3b-ol, Ziza-6(13)-en-3-one, 2-epi-Ziza-6(13)-en-3a-ol, 12-Nor-ziza-6(13)-en-2bol, a-Vetispirene, Eremophila-1(10),7(11)- diene, Dimethyl-6,7-bicyclo- [4.4.0]-deca-10-en-one, 10-epi-g-Eudesmol, a-Calacorene, (E)-Opposita4(15),7(11)-dien12-ol, Prekhusenic acid, 13-Nor-eudesma-4,6-dien-11-one, Isovalencenol, Spirovetiva-1(10),7(11)-diene, 2-epi-Ziza-6(13)-en-12-al, (E)-Isovalencenal, Preziza-7(15)-ene, (Z)-Eudesma-6,11-dien3b-ol, Intermedeol (eudesm-11- en-4-ol), Isoeugenol, Isokhusenic acid, Elemol, Eremophila-1(10),6-dien12-al, Juniper camphor, Khusimone, Eremophila-1(10),4(15)- dien-2a-ol, Eremophila-1(10),7(11)- dien-2b-ol, (Z)-Isovalencenal, allo-Khusiol, Methyl-(E)-eremophila1(10),7(11)-dien-12-ether, (E)-2-Nor-zizaene, (Z)-Eudesm-6-en-12-al, Funebran-15-al.	61	[37]

An EOs aroma and chemical makeup can differ depending on the region, climate, and growing conditions (such as soil type, altitude, and water availability), the season (such as before or after the flowering period), and even the time of day when it is harvested[1,25,15]. After studying the vetiver oil composition from various countries, as shown in Table 2, it was found that the highest number of compounds were present in Egypt, followed by Indonesia, while the lowest number of compounds were found in Turkey, with only 22 compounds. India has two recognised vetiver varieties: The Bharatpur or North Indian type is primarily found in the Indian states of Rajasthan, Madhya Pradesh, Uttar Pradesh, and Bihar. It has abundant flowering, high seed setting, narrow leaves, and vigorous roots that produce laevorotatory root oil (khush oil) with a low concentration and superior quality. The South Indian cultivated variety can be found in the states of Andhra Pradesh, Karnataka, Tamil Nadu, and Kerala along the east and west coastlines of the Indian peninsula[1,7]. Chahal *et al*.[1] conducted a study on Indian vetiver oil and reported that a total of 29 and 33 compounds in South and North Indian vetiver oils, respectively. The chemical composition of North Indian and South Indian strains of vetiver presented in Table 3.

The antipodal sesquiterpenes of the cadinane class are abundant in North Indian vetiver, while the α and β-vetivones are lacking. The dextrorotation of the south Indian vetiver root oil is visible. It contains the same sesquiterpene ketones, such as vetivones, vetispirenes, eudesmane, and zizaane sesquiterpenes that are present in vetiver root oils produced in other countries[16]. Mallavarapu *et al*.[16] found that 80 components have been identified, accounting for 94.5 %-97.8 % of the oils. Sesquiterpenes, oxygenated sesquiterpenes, and oxygenated sesquiterpenes with cedrane, bisabolane, eudesmane, eremophilane, and zizaane skeletons were abundant in the oils from Bangalore, Hyderabad, Kundapur, and Mettupalayam[34-38].

PHYSICO-CHEMICAL PROPERTIES OF VETIVER EO:

Physico-chemical characteristics of the oil, including an assessment of its aroma, were used to determine its quality. The presence of several ketonic sesquiterpenes, including vetiverol, a-vetivone, and b-vetivone, as well as the ester vetiveryl vetivenate, gives vetiver oil its distinctive aroma. The fixative activity of oil is aided by sesquiterpene alcohols such as vetivol acetate and vetiverol. In a study by Kadarohman *et al*.[39] vetiver EO quality was observed from organic and non-organic vetiver plants and found that compared to oil obtained from inorganic cultivation, organic was higher in quality. In terms of appearance, organic vetiver oil was more concentrated and had no black spots. Chemically, vetiver EO from organic cultivation includes more vetiverol and less pesticide residue[40]. The quality of vetiver oil from different geographic locations as compared to Bureau of Indian Standards (BIS) and Karnataka Soaps and Detergents Limited (KSDL) value has been presented in Table 4.

TABLE 3: CHEMICAL COMPOSITION OF NORTH AND SOUTH INDIAN STRAINS OF VETIVER[38]

S. No	Component	Concentration percent	
		North India	South India
1	ß-caryophyllene	-	0.37
2	Sativen	0.65	-
3	Khusimene	0.66	1.59
4	α-Humulene	-	0.03
5	α-Amorphene	0.22	1.68
6	α-Bisabolol	0.19	-
7	γ-Cadinene	0.82	-
8	ß-Caryophyllene oxide	0.28	-
9	Allo-aromadendrene	0.17	-
10	Cubenol	1.64	-
11	δ-Guaiene	-	1.42
12	Valencene	-	1.31
13	ß-Vetivenene	-	0.14
14	ß-Vatirenene	-	0.72
15	Caryophyllenyl alcohol	-	2.3
16	Humulene 1,6-diene-ol	0.87	1.42
17	10 Epi-γ-eudesmol	0.46	-
18	ß-Lonol	0.46	-
19	ß-Bisabolol	0.57	1
20	Epiglubulol	1.95	-
21	Selina-6-en-4ol	-	2.11
22	Globulol	-	1.91
23	Junipene	5.54	1.6
24	α-Cadinol	1.46	1.74
25	Guaiol	1.03	1.58
26	α-Eudesmol	0.49	-
27	ß-Eudesmol	0.97	1.28
28	Allo-aromadendren oxide	-	0.83
29	ß-Cedren-9-α-ol	1.76	-
30	Farnesol	2.65	-
31	Khusinol	10.28	-
32	γ-Muurolene	4.56	-
33	E-Caryophyllene	0.74	-
34	γ-Cadinene aldehyde	1.28	-
35	Patchouli alcohol	-	1.61
36	γ-Gurjunepoxide	-	1.14
37	Cyclosativene	-	2.06
38	Cedryl acetate	-	0.29
39	Spathulene	1.28	2.37
40	γ-Maaline	1.57	-
41	Calerene	1.57	-
41	γ-Himachalene	0.23	-
42	Viridiflorene	-	4.64
43	Khusimol	16.25	15.77
44	Bicyclovetivenol	2.88	10.76
45	α-Vetivone	2.01	3.04
46	Velerenol	-	-3.44
47	Germacrene-D	9.73	-
48	Cedrene-13-ol-8	2.23	1.05
	Total	33	29

TABLE 4: PHYSICO-CHEMICAL PROPERTIES OF VETIVER OIL

S.No.	Parameter	BIS Value	KSDL value	Putrawan et al.[40]	Kadarohman et al.[39]	Dubey et al.[38]	Khalil et al.[41]	Yanto et al.[2]
1.	Colour	Brown to reddish viscous liquid	Brown to reddish viscous liquid	Pale yellow to reddish brown	Yellow to reddish brown	Brown to yellowish brown clear liquid	-	Reddish brown
2.	Specific gravity	0.9926-1.0444	0.985-1.020	0.980-1.003	0.980-1.003	1.0118-1.0026	1.002	1.0097
3.	Refractive index@ 24°	1.588-1.5306	1.5132-1.5242	1.52-1.53 @200C	1.520-1.530	1.5147-1.5220	1.5112	1.5308
4.	Optical Rotation		+150 to 350		-	-57.70 to +28.23	+40.0	-
5.	Acid value	8.4-40.1	35	Oct-35	-	21.30-28.45	46	11.5
6.	Ester value	5.6-24.6	May-16	--	May-26	8.36-11.27	14	18.57
7.	Saponification value	-	-	-	-	--	60	-
8.	Odour	Rosy odour	Woody aroma	Vetiver characteristics		Heavy earthy, green to heavy woody	-	Slightly smoky

BIOACTIVITY OF VETIVER EO:

Antimicrobial activity:

The vetiver EO had excellent antibacterial efficacy against all of the clinical pathogens that were tested, with no discernible difference in susceptibility between gram-positive and gram-negative bacteria[41-43]. By measuring the zone of inhibition, ethanolic root extract of *V. zizanioides* Linn is shown to have antibacterial activity. The ethanolic root extracts exhibit antimicrobial properties due to presence of flavonoids, terpenoids, and tannins included in vetiver[44]. Sangeetha *et al*.[45] obtained similar findings and found that vetiver leaf extract had the highest mean zone of inhibition against *Staphylococcus aureus*. Soni *et al*.[46] studied that vetiver solvent extracts have the potential to be utilised as an antimicrobial medication against infectious agents and as a treatment for a variety of infectious disorders. According to the Efe *et al*.[43] findings, vetiver EO showed an inhibitory impact against the tested microorganisms that was greater than or comparable to that of antibiotics at high VEO concentrations. In a study conducted by *Nantachit et al*.[47] found that the root of the Surat Thani cultivar of C. zizanoides (L.) showed antimicrobial activity due to presence of vetiverin compound in oil. Jayashree *et al*.[48] reported that the root extracts of vetiver showed maximum zones of inhibition of 30 mm against *Staphylococcus aureus* and 33 mm against *Candida albicans*, while the lowest zones of inhibition were 24 mm against *Escherichia coli* (*E. coli*) and 28 mm against *Cryptococcus neoformans*, respectively.

Antibacterial activity:

Numerous studies have revealed that vetiver EO has antibacterial properties that can combat a variety of bacterial strains, including *Staphylococcus aureus, Streptococcus pyogenes, Escherichia coli, Corynebacterium ovis, Mycobacterium smegmatis, Acinetobacter baumannii, Aeromonas veronii, Klebsiella pneumoniae, Pseudomonas aeruginosa*[49,1,50,43]. *Nantachit et al*.[47] and Pawar *et al*.[50] found that crude root extract from the 'Surat Thani' cultivar of *V. zizanioides* (L.) Nash exhibited antibacterial efficacy against four pathogenic microorganisms. The EO of *C. zizanioides* contains alkaloids, terpenoids, flavonoids, saponins, phenols, and tannins that, either singly or in combination, have antibacterial characteristics[51]. Putiyanan *et al*.[52] showed that *C. zizanioides* (L.) Roberty has antibacterial action against *Pseudomonas aeruginosa*, *E. coli*, and *Staphylococcus aereus*. conducted an investigation and proposed that Cedr-8-en-13-ol, 6-isopropenyl-4, 8a-dimethyl-1, 2, 3, 5, 6, 7, 8, 8a-octahydro-naphthalen-2-ol, Delta (δ)-Selinene, Gamma (γ)-Gurjunenepoxide-(2), and solavetivone are the most important compounds in

the antibacterial activity of vetiver oil against the Multidrug Resistance (MDR) bacteria models used in their study.

In a study Efe *et al*[25] found that the vetiver EO had strong antibacterial activity for Enterobacter *cloacae, Enterococcus faecalis*, *E. coli*, and *Proteus* vulgaris in the Minimum Inhibitory Concentration (MIC) values, 15.63, 31.25, 15.63, and 15.63 g/ml, respectively. Similarly, Oliveira *et al*.[13] found that when tested against *Prevotella nigrescens, Fusobacterium nucleatum, Prevotella melaninogenica*, and *Aggregatibacter actinomycetemcomitans*, vetiver oil exhibited strong antibacterial activity, with MIC values ranging from 22-62.5 µg/ml and Minimum Bactericidal Concentration (MBC) values ranging from 22-400 µg/ml.

Antioxidant activity:

Vetiver oil showed antioxidant activity and has applications in both fragrance and medicine. Two separate *in vitro* assays, the 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radical scavenging assay and the Fe^{2+} metal chelating assay, were used to assess the antioxidant capabilities of vetiver oil[50-54]. Many studies have shown the biological activity of the EO of *V. zizanioides* roots. Kim *et al*.[55] found that the antioxidant property of vetiver has been identified by three distinct compounds vetivenene, both β-vetivone and and α-vetivone. The ethanolic extract of vetiver root is used for various antioxidant activities, lowering oxidation ability, superoxide anion radical capturing ability, and overall antioxidant capacity[44]. Subhadra *et al*.[49] was conducted research and found that that *V. zizanioides* scavenges free radicals, reducing the harm caused by oxidative stress in many illness states, and acting as a possible natural source of antioxidant. Similarly, in a study Samman *et al*.[36] concluded that the overall antioxidant capacity of the vetiver EO was 75.5 % at 0.1 mg/ml (100 ppm), and the total phenolic content was 6.7 mg GAE/g.

The antioxidant activity of EO is depending upon their chemical composition particularly the presence of compound which have radicle function. Soidrou *et al*.[34] reported that antioxidant action is dosage dependant and found that the concentration of 0.5 mg/ml was highest concentration which shows the strong activity (60.43 %). The concentration of 0.03125 mg/ml, the lowest concentration tested, showed the lowest antioxidant activity, 52.74 %.

Anti-inflammatory activity:

The action that relieves pain is anti-inflammatory. Vetiver EO had an anti-inflammatory activity. It is mostly utilised as an anti-inflammatory in the neurological and circulatory systems. It is also effective for treating inflammations caused by sunburn, dehydration, and dry winds[56,44]. Chou *et al*.[11] found that 25 compounds that make up *V. zizanioides*-EO, with cedr-8-en-13-ol (12.4 %), a-amorphene (7.80 %), b-vatirenene (5.94 %), and a-gurjunene (5.91 %) being the main constituents. Vetiver EO may suppress the inflammatory responses of Lipopolysaccharide (LPS) -stimulated RAW 264.7 macrophages, including nitric oxide production and cell apoptosis, through the regulation of the expression of the inflammation-related enzymes Heme Oxygenase-1 (HO-1), inducible and Nitric Oxide Synthase (iNOS) and cyclooxygenase-2 and the inflammatory cytokines Tumor Necrosis Factor (TNF)-α, Interleukin (IL)-1β and Interferons (IFN-β). Lima *et al*.[33] found that vetiver EO can stop abdominal writhes, reduce the second phase of formalin-induced pain, and inhibit carrageenan-induced inflammation, providing evidence of its analgesic and anti-inflammatory properties. Lima *et al*.[35] studied that EO reduces abdominal writhes, prevents the second phase of formalin-induced pain, and reduces carrageenan-induced inflammation supports its analgesic and anti-inflammatory properties.

Anti-cancer activity:

Vetiver EO is cytotoxic to cancer cells[37]. Chen *et al*.[57] conducted research and found that vetiver oil reduced the development of SiHa cervical cells by 89 %, CaSki cervical cells by 88 %, and MCF-7 breast cancer cells by 89 %. Similar results were found by Hanifa *et al*.[58] that the substances found in vetiver oil principally responsible for the cytotoxic actions are β-caryophyllene and α-humulene, which are especially influence Triple Negative Breast Cancer (TNBC) directed at Cannabinoid Receptor 2. South Indian vetiver grown for commercial purposes contained 0.37 % β-caryophyllene (Table 2). Additionally, β-caryophyllene has received a lot of attention as a potential cancer treatment and prevention agent[58]. Sinha *et al*.[59] reported that in human lymphocytes, vetiver acetate was found to be considerably genotoxic and cytotoxic at high doses, but vetiver oil is safe for consumption at moderate quantities.

In a study Chitra *et al*.[60] found that the root extract of vetiver showed cytotoxicity when applied to a cancer cell line. The result reveals that the human breast cancer MCF-7 cell line has an half maximal Inhibitory Concentration (IC_{50}) concentration ranging from 5-50 g/ml. MIC was seen between 31 and 37 g/ml.

Anti-fungal activity:

Phytopathogenic fungi were examined for resistance to the antifungal effects of sesquiterpenoids of vetiver oil[42,50,1]. The antifungal action of vetiver has also been demonstrated in numerous investigations against *Alternaria alternate, Fusarium oxysporium*[50], *Rhizoctonia bataticola, Sclerotium rolfsii*, *Aspergillus niger*, *Candida albicans*, and *Cryptococcus neoformans*[37,43]. Khusinodiol monobrosylate, one of the several substances examined, has been found to be an efficient antifungal agent against fungi[1]. Putiyanan *et al*.[52] found that six different species of vetiver have been found to have antifungal activity against *Trichophyton mentagrophytes*. Dubey *et al*.[38] studied that antifungal activity against the phytopathogenic fungus *Rhizoctonia solani*, 50 % Effective Dose (ED50) (µg/ml) showed that South Indian vetiver oil was substantially more effective than North Indian oil. Similarly, Samman *et al*.[36] was conducted a study and found that vetiver oil showed a considerable inhibition in radial growth of all the studied fungus species, including *Fusarium oxysporum*, *Alternaria citri*, and *Rhizoctonia solani* at the lowest application rate (500 g/ml), and it was strengthened when concentration was raised to (1000 g/ml). In a Study by Power *et al*.[61] revealed that EOs from vetiver shown significant antifungal activity against C. neoformans (MIC = 20 g/mL) and cytotoxic action against MCF-7 cells (IC_{50} = 23.9 g/mL). Sesquiterpene alcohols and khusimol are abundant in vetiver EO. The development of A. niger and C. albicans was inhibited by vetiver oil (MIC=78 and 313 g/ml),

CONCLUSION

The EO of *C. zizanioides* has promise for usage in novel care products and that it can be further used to develop new medications, cosmetic and various industrial products. The complexity of the oils' chemical makeup and the variety of their constituents and chemical structures are responsible for the wide range of biological activities. It can be concluded that vetiver oil has been shown effectiveness against bacterial, fungal, microbial, cancer diseases with great economic importance. It is also a complex mixture of various sesquiterpenes, hydrocarbons, flavonoids, saponins, phenols, and tannins, and is used in various medical and cosmetic industries.

Furthermore, as biological activity can strongly vary depending on a species chemical makeup inside it, future research should concentrate on plant culture and EO standardisation. Various chemical compounds of vetiver are still unidentified and needs to identify their properties and uses in various pharmacological activities.

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Authors' Contributions:

Ankit Pandey: Data curation, data analysis, drafting, writing, and formatting. S.C. Tiwari: Conceptualization, draft correction and editing, and suggestions for improvements.

Conflict of interests:

The authors declared no conflict of interests.

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