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VOLATILE PROFILES AND BIOLOGICAL PROPERTIES OF *CYMBOPOGON CITRATUS, CYMBOPOGON GIGANTEUS, CYMBOPOGON SHOENANTHUS,* AND THEIR ISOLATED COMPOUNDS: A REVIEW

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ABSTRACT:
Essential oils are worldwide used for their several biological properties. As such, the genus *Cymbopogon* is an interesting source of essential oils. Among the genus *Cymbopogon*, the most studied plant species, especially in West Africa, are *C. citratus*, *C. giganteus* and *C. Schoenanthus*. The essential oils extracted from these plants are sought for their various properties such as their insecticidal, analgesic, anti-inflammatory, antioxidant, hypotensive properties. Their anti-leishmaniasis, antimicrobial, antiplasmodial anti-acetylcholinesterase, anti-trypanosomal, anti-nociceptive and anticonvulsant potentials were also noted. These different properties are related to the presence of secondary metabolites in these essential oils. It follows that, the *Cymbopogon* species as well as the volatile compounds contained in their essential oils constitute interesting sources of new bioactive substances likely to fight against several types of resistance phenomena. Thus this literature review constitutes a scientific basis which can contribute to the economic valorization of the genus *Cymbopogon*.
Keywords: *Cymbopogon* species, volatile profiles, biological properties, cytotoxicity.

1. INTRODUCTION

Cymbopogon citratus is a perennial grass with short rhizome up to 2 m high. Fertile culms are rare and the leaves are highly aromatic [1]. The flowers are bisexual or unisexual and the fruit is a dry indehiscent caryopsis with a thin pericarp [2]. *C. giganteus* is a perennial grass, 2.5 meters high, with slightly aromatic glaucous leaves. Its dense panicles are narrow and its flowers appear throughout the year [1]. *C. schoenanthus* is an aromatic vivacious herb of drier parts of tropical Africa that can reach 60 to 80 cm high. This plant species possesses linear and fragrant leaves and its inflorescences are contracted in panicles [1]. Many other species, not as studied as the previous three species also belong to the genus *cymbopogon.* These plant species are traditionally used in many area were they occur, mainly to fight against several diseases. Moreover, scientists are studied this genus to offer scientific bases to traditionally uses. The present review was conducted to highlight the traditional and scientifically demonstrated uses of *cymbopogon* species.

2. TRADITIONAL USES OF *CYMBOPOGON* SPECIES

Cymbopogon species are worldwide traditionally used for several purposes especially in Africa. In Benin [3] and in Nigeria [4], *C. citratus* leaves are used to treat malaria, fever and to repel mosquitoes. The decoction of the leaves and the roots of *Securidaca longepedunculata* is administered orally in the treatment of snakebites and in the treatment of edema, jaundice and anemia [1]. In Congo, the leaves decoction of *Cymbopogon citratus* is used for its hypotensive properties [5]. The decoction of the leaves of *Cymbopogon giganteus* and *Ocimum basilicum,* is used in the treatment of drepanocytosis and the decoction of leafy stems in case of epilepsy crises [1, 6]. *Cymbopogon citratus* and *Cymbopogon giganteus* are traditionally used in Congo, for their anti-ulcerative potential [7]. In Burkina-Faso, the fresh roots decoction is used against toothache, gingivitis and sores in the mouth, the tongue and on the lips [8]. In Congo, the infusion of roots and leaves is drunk against stomachaches [7]. In Benin, the whole plant is burnt for its reppelency property against mosquitoes [3]. In Benin, *C. schoenanthus* is used as insect repellent and natural insecticide [3]. The whole plant, crushed and mixed with

leaves of *Vitex simplicifolia* is indicated in traditional medicine against schizophrenia [1]. In Tunisia, *Cymbopogon* is eaten in salads and used to prepare traditional meat recipes [9]. In Congo-Brazaville the infusion of the leaves is used to treat stomachache [7].

3. CHEMICAL COMPOSITION

3.1. Volatile profile of *Cymbopogon citratus*

The essential oils extracted from leaves and sheets *C. citratus,* collected in several countries have revealed the same main compounds, namely myrcene, neral and geranial in various and specific proportions to each harvest area. The volatile profile of the rhizome was quite different since it was characterized by the presence of selina-6-en-4-ol, -cadinol, neointermediol and eudesma-7(11)-en-4-ol (Table 1).

Table 1: Main volatile compounds of *Cymbopogon citratus*

Countries	Extracts	Main volatile compounds	References
Brazil	Essential oil (fresh leaves)	myrcene (11.1%), neral (31.5%), geranial (47.5%)	[10]
Brazil	Essential oils (blades, sheaths and rhizomes)	Blades: Neral (30.1%), geranial (39.9%); Sheats: Neral (27.8%), geranial (50.0%); Rhizome: selina-6-en-4-ol (27.8%), α--cadinol (8.2%), neointermediol (7.2%), eudesma-7(11)-en-4-ol (5.3%).	[11]
Burkina-Faso	Essential oil (leaves)	myrcene (10.7%), neral (33.0%), geranial (44.6%)	[12]
Burkina-Faso	Essential oil (leaves)	geranial (48.1%), neral (34.6%) , myrcene (11.0%)	[13]
Burkina-Faso	Essential oils (leaves)	geranial/citral A (48.18%), neral/citral B (34.37%).	[14]
Portugal	Essential oil (aerial parts)	myrcene (11.5%), neral (32.5%), geranial (45.7%)	[15]
Cameroon	Essential oil (leaves)	myrcene (11.4%), neral (30.2%), geranial (32.8%), geraniol (8.2%)	[16]
Benin	Essential oil (leaves)	myrcene (12.4%), neral (33.1%), geranial (44.3%)	[17]
Benin	Essential oil (leaves)	geranial (27.04 %), neral (19.93 %), myrcene (27.04 %)	[18]
Benin	Essential oil (leaves)	geranial (39.5%), neral (35.5%), β-pinene (10.1%), cis-geraniol (4.3%)	[19]
Brazil	Essential oil (leaves)	geranial (51.46%), neral (19.83%), -myrcene (16.5%), geraniol (1.28%)	[20]
Togo	Essential oil (leaves)	myrcene (67%)et geranial (12%)	[21]
Togo	Essential oil (aerial parts)	geranial (45.2%), neral (32.4%) and myrcene (10.2%)	[22]
Peru	Essential oil (leaves)	geranial(49.9%), neral (30.9%), geraniol(10.4%)	[23]
Mali	Essential oil (aerial parts)	myrcene (6.2%-9.1%), neral (21.3-32.5%), geranial (45.3%-56.2%)	[24]
Ivory-Coast	Essential oil (aerial parts)	myrcene (8.1%-22.6%), neral (23.6-26.3%), geranial (30.5%-34.0%)	[24]

3.2. Volatile profile of *Cymbopogon giganteus* Chiov (Poaceae)

The volatile profile of *C. giganteus* was characterized by the presence of a set of monoterpene alcohols, namely *E-p*-mentha-1(7),8-dien-2-ol (14.2%), *Z-p*-mentha-1(7),8-dien-2-ol (12%), *E-p*-mentha-2,8-dien-1-ol (5.6%) and *Z-p*-mentha-2,8-dien-1-ol (5.2%) (Table 2).

Table 2: Main volatile compounds of *Cymbopogon giganteus*

Countries	Extracts	Main volatile compounds	References
Burkina-Faso	Essential oils (leaves)	limonene (42%) and a set of monoterpene alcohols, namely *E-p*-mentha-1(7),8-dien-2-ol (14.2%), *Z-p*-mentha-1(7),8-dien-2-ol (12%), *E-p*-mentha-2,8-dien-1-ol (5.6%) and *Z-p*-mentha-2,8-dien-1-ol (5.2%)	[13]
Burkina-Faso	Essential oils (leaves)	Limonene (19.33%), *Z*-Mentha-1(7),8-dien-2-ol (17.34%), *E*-Mentha-1(7),8-dien-2-ol (13.95%), *E-p*- Mentha-2,8-diene-ol (13.91%) et *Z-p*-Mentha-2,8-diene-1-ol (8.10%)	[14]
Benin	Essential oils	*E-p*-mentha-1(7),8-dien-2-ol (19.6%), *E-p*-mentha-2,8-dienol (19.3%), *Z-p*-	[17]

	(Leafy stems)	mentha-2,8-dienol (10.2%), *Z*-*p*-mentha-1(7),8-dien-2-ol (2.1%), Z-carveol (17.0%), *E*-carveol (6.0%), *p*-menth-6-en-2,3-diol (3.2%), carvone (3.2%).	
Benin	Essential oil (leaves)	*E*-1- mentha-1(7),8-dien-2-ol (19.9%), *Z*-mentha-1(7),8-dien-2-ol (18.4%), *E*-*p*-mentha-2,8-dien-1-ol (17.4%), *Z*-*p*--mentha-2,8-dien-1-ol (8.9%), limonene (7,8%), *E*-carveol (5.1%)	[25]
Benin	Essential oil (fresh leaves)	*E*-*p*-1(7),8-menthadien-2-ol (22.3%), *Z*-*p*-1(7),8-menthadien-2-ol (19.9%), *E*-*p*-2,8-menthadien-1-ol (14.3%), *Z*-*p*-2,8-menthadien-1-ol (10.1%).	[26]
Benin	Essential oil (leaves)	*E*-*p*-mentha-1(7),8-dien-2-ol (18.3%), *E*-carveol (17.4%), *E*-*p*-mentha-2,8-dienol (15.5%), *Z*-*p*-mentha-2,8-dienol (11.3%), *Z*-*p*-mentha-1(7),8-dien-2-ol (8.3%), limonene, *Z*-carveol (7.3%), *Z*-carvone (3.4%);	[19]
Togo	Essential oil (leaves)	limonene (23%) and *Z*-*p*-mentha-2,8-dien-1-ol (14.3%) and *E*-*p*-mentha-2,8-dien-1-ol (5.6%), p-mentha-1(7),8-dien-2-ol (12.63%), *p*-mentha-1(7),8-dien-2-ol isomer (14.06%)	[27]
Mali	Essential oil (aerial part)	*E*-*p*-mentha-2,8-dien-1-ol (13.3%-16.2%), Z-*p*-mentha-2,8-dien-1-ol (8.2%-10.2%), *E*-*p*-mentha-1(7),8-diène-2-ols (24.0%-35.2%), *Z*-*p*-mentha-1(7),8-diène-2-ols (16.6%-24.0%)	[24]
Ivory-Coast	Essential oil (leaves)	de *E*-*p*-mentha-2,8-diène-1-ol ((18,4%), *Z*-*p*-mentha-2,8-diène-1-ol (8,7%), *Z*-*p*-mentha-1(7),8-diène-2-ols (16,0%) et *E*-*p*-mentha-1(7),8-diène-2-ols (15,7%), limonene (12,5 %).	[28]
Cameroon	Essential oil (flower, leaf, stem)	*Z*-*p*-mentha-1(7),8-dien-2-ol (22.8%- 29.1%), *E*-*p*-mentha-1(7),8-dien-2-ol (21.6%- 28.1%), *E*-*p*-mentha-2,8-dien-1-ol (16.3%- 22.1%), *Z*-*p*-mentha-2,8-dien-1-ol (1: 8.3%, 2: 5.4%, 3: 4.6%, 4: 9.7%).	[29]
Togo	Essential oil (leaves)	*E*-*p*-2,8-Menthadiène-1-ol (20,7%), *Z*-*p*-2,8-Menthadiène-1-ol (9,2%), *E*-*p*-1(7),8-Menthadiène-2-ol (19,6%), *Z*-*p*-1(7),8-Menthadiène-2-ol (19,0%)	[21]

3.3. Main volatile compounds of *Cymbopogon schoenanthus* (L.) Spreng (Poaceae)

The main compounds identified in the essential oils of extracted from leaves and leafy stems of *C. schoenanthus* were commonly piperitone and δ–2-carene (Table 3). But sample from Brazil have a quiet different profile since it was characterized by geraniol, geranial and neral [30] .

Table 3: Volatile profile of *Cymbopogon schoenanthus*

Countries	Extracts	Main volatile compounds	References
Brazil	Essential oil (leaves)	geraniol (62.5%), geranial (12.5%), neral (8.2%)	[30]
Togo	Essential oil (leaves)	piperitone (61.0-69.0%), δ–2-carene (16.9-23.4%)	[31-33]
Burkina-Faso	Essential oil (leaves)	piperitone (42.0%) and δ–2-carene (8.2%)	[34]
Tunisia	Essential oils (fresh leaves)	limonene (24.2-27.3%), β-phellandrene (13.4-16.0%), δ-terpinene (8.4-21.2%) and α-terpineol (9.1-11.7%)	[9].
Benin	Essential oils (Leafy stems)	δ-2-carene (15.5%), piperitone (58.9%);	[17]
Saudi Arabia	Essential oils (Leaves)	piperitone (14.6%), cyclohexanemethanol (11.6%), β-elemene (11.6%), α–eudesmol (11.5%), elemol (10.8%), β–eudesmol (8.5%), 2-naphthalenemethanol (7.1%) and γ-eudesmol (4.2%).	[35]
Benin	Essential oil (leaves)	piperitone, (+)-2-carene, limonene, elemoland, β-eudesmol	[19]

3.4. Main volatile compounds of other *Cymbopogon species*

The other species of *cymbopogon* are characterized by other main compounds such as piperitone, citronellal α-eudesmol , geranial, neral etc… (Table 4).

Table 4: Volatile profile of other *Cymbopogon* species

Plante species	Countries	Extracts	Main volatile compounds	References
Cymbopogon jawarancusa	India	Essential oil (aerial part)	piperitone (58.6%), elemol (18.6%)	[36]
Cymbopogon Olivieri Boiss)	Iran	Essential oil (aerial part)	δ-3 carene (22.46%), piperitone (44.90%), α-eudesmol (13.33%).	[37]
Cymbopogon nardus.	Togo	Essential oil (aerial part)	citronellal (35.5%), geraniol (27.9%), citronellol (10.7%)	[22]
Cymbopogon nardus.	Benin	Essential oil (leaves)	β-citronellal (35.9%), nerol (24.3%), β-citronellol (11.6%), elemol (9.0%), limonene (2.2%)	[19]
Cymbopogon martinii	Brazil	Essential oil	geraniol (81.4%), Isomenthyl isomenthyl acetate (10.1%), Linalool (2.6%), Geranial (2.1%)	[30]

4. BIOLOGICAL PROPERTIES OF *CYMBOPOGON* SPECIES

4.1. Biological properties of *Cymbopogon citratus* (DC.) Stapf (Poaceae)

The biological properties of *Cymbopogon citratus* have been demonstrated in various domains. Indeed the essential oil extracted from *C. citratus* in Brazil revealed to be active against larvae of *Aedes aegypti* with LC_{50} (0.28 µg/mL) and LC_{90} (0.56 µg/mL) [38]. When tested against larvae of *Culex tritaeniorhynchus* and *Anopheles subpictus*, a good repellency and larvicidal activity was observed and the lethal concentrations LC_{50} and LC_{90} were 136.58 ppm and 243.18 ppm for *Cx. Tritaeniorhynchus;* 77.24 ppm and 128.39 ppm for *A. subpictus* [39]. Larvicidal, insecticidal and repellent activities have been detected against *A. arabiensis* with LC_{50} = 74.02 ppm and LC_{90} = 158.20 ppm [40, 41], and *Tribolium castaneum* with a mean repellent dose after 4 hours exposure of 0.021 ml/L [42]. Insecticidal properties against *Sitophilus oryzae* by topical application assays was noticed with the essential oil extracted from the fresh leaves of *C. citratus*. LC_{50} = 0.027 µL mL^{-1} and 70% and 100% mortality recorded respectively after 24 h and 48 h were obtained [10]. This leaves essential oil has also demonstrated its insecticidal properties against *Anopheles funestus* larvae with LC_{50} = 35.5 ppm and 34.6 ppm, respectively, for larval stages III and IV after 6 h of exposure [16]. It adulticidal activity again *Tribolium castaneum*, by fumigation, with LC50 value of 4.2 mL/L air after 24 h, was reported. Following WHO test procedures for insecticide resistance monitoring in malaria vector mosquitoes, a diagnostic dose of 0.77% for *C. citratus* compared to permethrin 0.75%, was obtained against the resistant strain of *Anopheles gambiae* [17].

Anti-Leishmania activity of *C. citratus* essential oil and a mixture of its main compounds obtained from 40% neral and 60% geranial, has been noticed against *L. infantum*, *L. tropica* and *L. major.* IC_{50} concentrations ranged from 25 to 52 µg/ml for *C. citratus* essential oil, and from 34 to 42 µg/mL, for the mixture of citral were obtained [15]. By topical application assays, the essential oil of *C. citratus* demonstrated a strong toxicity (LC_{50} = 0.027 µL mL^{-1}) at a short exposure. After 24 h and 48 h, 70% and 100% mortality of *S. oryzae* was noticed, respectively [10].

A potent antimicrobial activity has been demonstrated against various microorganisms. The minimal inhibitory concentrations obtained were 1.0 mg/ml *for Enterococcus faecalis*, 2.1 mg/ml for *Salmonella enteric* and 2.5 mg/mL for *S. typhimurium* [13]. Moreover the essential oil of *C. citratus,* originating from Congo, has shown interesting antibacterial activity against 17 different bacteria species [43].

The *in vitro* antiplasmodial activity against the resistant strain of *Plasmodium falciparum* was observed with an IC_{50} value of 4.2 ± 0.5 µg/mL [16]. Moreover, the aqueous extract of *C. citratus* at 310 mg/kg/day was more effective as bood schizonticide against *Plasmodium berghei (*71.4% of suppression of parasitaemia), compared to chloroquine (22.5%). Its efficiency was closed to that of sulphadoxine/pyrimethamine (79.7%) [44].

C. citratus lipid- and essential oil-free leaves infusion, and its polyphenolic compounds, were shown to be natural and safe sources of new anti-inflammatory drugs [45]. Other antioxidant, antiradical and anti-inflammatory properties were also noticed, as well [12, 45-47]. Indeed, *C. citratus* has demonstrated nitric oxide (NO) scavenging activity and has inhibited inducible NO synthase (iNOS) protein expression [46]. Beside the inhibition of iNOS expression and NO production, the polyphenolic compounds extracted from *C. Citratus* has also inhibited various lipopolysaccharide (LPS)-induced pathways like p38 mitogen-activated protein kinase (MAPK), c-jun NH2-terminal kinase (JNK) 1/2 and the transcription nuclear factor (NF)-KB [45]. Lemongrass pretreatment has demonstrated a cardio-protective activity at a dose of 200 mg/kg b.wt, by decreasing activity of cardiac markers in serum, and the toxic events of lipid peroxidation (TBARS) in both serum and

heart tissue. The consequence is the increasing of cardiac markers in heart homogenate, the level of enzymatic antioxidants and non-enzymatic antioxidants in both heart homogenate and serum sample [48]. Its property to reduce the blood cholesterol level was reported as well [20]. When tested by formol-induced edema in the animals, *C. citratus* essential oil has demonstrated an anti-inflammatory activity by reducing the edema over time in a dose dependent manner and a preventive effect at 3,000 mg/kg of animal weight [18].

The promising *in vitro* antitrypanosomal properties of *C. citratus* against *Trypanosoma brucei brucei* with IC_{50} values of 1.837±0.13 µg/mL, was demonstrated, compared to the strandard compound (suramine) wich IC_{50} was 0.11±0.02 µg/mL) [19].

4.2. Biological properties of *Cymbopogon giganteus Chiov. (Poaceae)*

Concerning the biological activities, *C. giganteus* essential oil has shown insecticidal, larvicidal and ovicidal activity against *Callosobruchus maculatus* through the destruction of growing eggs or larvae [25], against *C. maculatus* and *C. subinnotatus* with an oviposition reduction of 91% in *C. subinnotatus* population at 5 µL/L versus 81% in *C. maculatus* population [27]. The hight antimicrobial properties of essential oils extracted from flowers, leaves and stems of *Cymbopogon giganteus* against Gram-(+)- and Gram-(-)-bacteria as well as the yeast *Candida albicans* was shown [29].

The high *in vitro* antitrypanosomal property of essential oil extracted from *C. giganteus* against *Trypanosoma brucei brucei* with IC_{50} values of 0.25±0.11 µg/mL compared to the strandard compound(suramine) wich IC_{50} was 0.11±0.02 µg/mL), was reported [19].

4.3. Biological properties of *Cymbopogon schoenanthus (L.) Spreng. (Poaceae)*

The insecticidal activity of *C. schoenanthus* essential oil and its main constituent, piperitone has been demonstrated on *Callosobruchus maculatus* with LC_{50} values of 1.6 µL/L and 2.7 µL/L, respectively [32]. Its adulticidal activity against *Dinarmus basalis* has been also reported [31]. The insecticidal activity of *C. schoenanthus* by fumigation against *Tribolium castaneum*, with the LC_{50} values after 24 h, of 2.1 mL/L air, and a mortality of 72% was reported [49]

Its activity against ovine trichostrongylids and gastrointestinal nematodes (*Haemonchus contortus* and *Trichostrogylus spp*.) has been demonstrated [30].

The antimicrobial, antioxidant and antiacetylcholinesterase properties of *C. schoenanthus* have been shown as well [9, 33, 50]. Indeed *C. schoenanthus* essential oil was effective against *Escherichia coli*, *Staphylococcus aureus*, methicillin-sensitive (MSSA) *S. aureus* (MRSA) and *Klebsiella pneumonia* with the following MIC values of 9.37 µg/mL for *E. coli* 4.69 µg/mL for *S. aureus* (MRSA), 2.34 mg/mL for MSSA and 2.34 µg/mL for *K. pneumonia* [35].

The good antioxidant activity of the proanthocyanidin extract, by DPPH test, and the methanol extract, by b-carotene/linoleic acid test, of *C. schoenanthus* was demonstrated with IC_{50} of 17.1 µg/mL and 0.11 mg/mL, respectively. Its moderate acetylcholinesterase inhibition activity was reported as well with IC_{50} ranged between 0.23 and 0.75 mg/mL [50]

The goog *in vitro* antitrypanosomal proppertie of essential oil extracted from *C. schoenanthus* against *Trypanosoma brucei brucei* with IC_{50} values of 2.10±0.89 µg/mL was revealed [19].

4.4. Biological properties of other *Cymbopogon species*

Cymbopogon martini and *Cymbopogon flexuosus* essential oils originated from Colombia were more effective as repellents than the commercial repellent IR3535. Indeed the percentages of repellency obtained at 0.002 µL/cm^2, 0.02 µL/cm^2, 0.2 µl/cm^2, were 51%, 82% and 94% for *Cymbopogon flexuosus* and 73%, 89% and 95% for *Cymbopogon martini,* after two hours of exposure, compare to IR3535, for which 39%, 50% and 72% of repellency were recorded [51].

The good *in vitro* antitrypanosomal proppertie of *C. nardus* against *Trypanosoma brucei brucei* with IC_{50} values of 5.71±1.40 µg/mL, was shown.

The promising acaricide property of the essential oil extracted from the dry sample of *C. nardus* against *Anocentor nitens* larvae, was reported as 0.0%, 90.8%, 100.0%, and 100.0% at the concentrations of 6.25%, 12.5%, 25.0%, and 50.0%, respectively [52].

When evaluated by Sulphorhodamine-B assay, *Cymbopogon jawarancusa* has demonstrated a potent cytotoxic effect against human cancer cell lines THP-1 (leukemia), A-549 (lung), HEP-2 (liver) and IGR-OV-1 (ovary) with the following IC_{50}: 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). Its antioxidant potential, using DPPH assay was demonstrated as well with a IC_{50} of 48.9 µg/ml [36].

The good larvicidal potential of the essential oil extracted from *Cymbopogon olivieri* (Boiss.) Bar, has been attested against *Anopheles stephensi* with a LD_{50} value of 321.902 p.p.m.[37]

4.5. Biological properties of some isolated compounds of Essential oils extracted from *Cymbopogon* Species

Major and minor compounds from essential oils have exhibited variable biological properties. Indeed the antinociceptive effect of essential oil have been demonstrated and correlated with their major/minor compounds [53]. Moreover several of these

major/minor compounds have demonstrated potential therapeutic alternatives for synthetic drugs. Several compounds of essential oil are effective as an analgesic compound in various pain models. Indeed, 3-tetradecanone is among chemical compounds present in essential oil that exhibiting anti-inflammatory and anti-oxidant activities [54].

Citronellal has the property to attenuate the mechanical nociception mediated by the NO-iGMP-ATP sensitive K channel pathway in mice [55]. By intraperitoneal injection, citronellal provoked the reduction of spontaneous activity, ataxia, analgesia, and sedation. In pentobarbital induced hypnosis, citronellal 50, 100, and 200 mg/kg (i.p.) significantly increased sleeping time (88.0±11.4, 100.2±16.4, and 119.5±20.9 min) when compared to vehicle solution injections (43.0±6.1). It can also reduce at 100 and 200 mg/kg, i.p., by central analgesic properties, the number of writhes (66.4 and 81.9%) in a writhing test, the number of paw licks in phase 1 (47.0 and 66.8%) and phase 2 (71.1 and 79.2%) of a formalin test [56]. These results were confirmed by Melo et al. (2011), which research has demonstrated the anti-inflammatory (50, 100, 200 mg/kg) and redox protective activities (200mg/kg) by inhibiting the enzymes involve in the arachidonic acid pathway [57]. Citronellal is also an alternative for the management and the treatment of orofacaial pain since the intraperitoneal injection of citronellal exhibited significant antioxidant activity at the doses of 0,1 and 1 mg/mL, and antinoceptive property in a capsicum and glutamate tests [58, 59].

Citronellol has demonstrated antinociceptive and anti-inflammatory properties, by the inhibition of peripheral mediators as well as central inhibitory mechanisms related to its strong antioxidant effect. Indeed citronellol (25, 50 and 100 mg/kg, i.p.) reduced the amount of writhing compared to the control group in mice, when evaluated against acetic-acid-induced abdominal writhing. Citronellol inhibited both the early (neurogenic pain) and the late (inflammatory pain) phases of formalin-induced licking when tested in the formalin test. Moreover when tested in a thermal model of pain, Citronellol (100 mg/kg, i.p.) caused a significant increase in the latency response on the hot-plate test [60]. The hypotensive and vasorelaxant effect of citronellol was demonstrated in rats by the antagonization of the contraction induced by the 10 µM phenylephrine or 20 mM caffeine [61]. Citronellol has also reduced nociceptive and inflammatory activities in rodents linked with the inhibition of peripheral mediators as well as central inhibitory mechanisms. It also demonstrated anticonvulsant activity by reducing convulsion induced by pentylenetetrazol and eliminating the extensor reflex of a maximal electroshock-induced seizures test in about 80% of experimental animals [62]. The good insecticidal activity of citronellal, by fumigation with a LC_{50} of 1.2 mL/L air was reported. After 24 hours, at 2.1 mL/L air, a mortality of 82% was recorded as well [49].

The antinoceptive activity of R-(+)-limonene has been demonstrated related to peripheral analgesia [63].

1,8-cineole (eucalyptol) is a compound extracted from essential oils which is able to attenuate the cerulean-induced acute pancreatitis through an anti-inflammatory mechanism and to fight against oxidative stress [64-66].

The significant anticonvulsant potential of terpinen-4-ol has been demonstrated since at 100-200 mg/kg, it produced a significant dose-dependent increase in the duration of sleeping in mice, inhibited the induced seizures of picrotoxin at 200-300 mg/kg and decreased at 300 mg/kg the tonic hind convulsions percentage [67].

Moreover the complex α-terpineol and β-cyclodextrin has demonstrated a reduction of the hyperalgesia followed by the chronic muscle pain model, using the descending inhibitory pain system, specifically through opioid and serotoninergic receptors [68]. □-terpinene (p.o.) has demonstrated an antinociceptive effect in the formalin, capsaicin, and glutamate tests through the cholinergic and opioid systems involvement [69]. The antioxidant potential of α-terpinene was discovered since it was proven that it autoxidizes rapidly compared to other compounds [70].

Isopulegol and neo-isopulegol have demonstrated a sedative property in the pentobarbital-induced sleep test [71]. The gastroprotective and antioxidant properties of isopulegol was demonstrated both in ethanol- and indomethacin- induced ulcer models, mediated by endogenous prostaglandins, KATP channel opening [72]. Other research has suggested the anticonvulsant and bioprotective effects of isopulegol against pentylenetetrazole-induced convulsions related to the positive modulation of benzodiazepine-sensitive $GABA_A$ receptors and to its antioxidant properties [73]. Moreover isopulegol (25 and 50 mg/kg) presented depressant and anxiolytic-like effects with no effect on the motor coordination of animals in the rota rod test unlike to diazepam (2 mg/kg) [74].

When the antioxidant potential of *p*-cymene was evaluated in the hippocampus of mice by determining the levels of thiobarbituric acid reactive substances, nitrite content, activity of catalase and superoxide dismutase, it showed an antioxidant potential *in vivo* [75]. Moreover *p*-cymene possess analgesic and anti-inflammatory properties which are increased by □-cyclodextrin [75].

The potent *in vivo* anti-inflammatory activities of synthesized methyl salicylate derivatives were demonstrated against xylol-induced ear edema and carrageenan-induced paw edema in mice [76].

Piperitone has demonstrated its insecticidal activity against *Tribolium castaneum*. Indeed by fumigation after 24 hours, the LC_{50} values of 0.5 mL/L and a mortality of 100% at 2.4 mL/L air, were noticed [49]. By contact "no choice" test, after 72 hours, a mortality of 87% was recorded with piperitone at 4.7% w/v [49]

5. CYTOTOXICITY OF *CYMBOPOGON* SPECIES

The low cytotoxicity of extracts from *Cymbopogon* species was demonstrated since the *in vitro* cytotoxicity bioassays on human epidermic cell line HaCaT was shown with IC_{50} of 150 $\mu L.mL^{-1}$ for *C. citratus* oil and 450 $\mu L.mL^{-1}$ for essential oil extracted from *C. nardus* [22]
The *in vitro* cytotoxicity tests against the Chinese Hamster Ovary (CHO) cells and the human non cancer fibroblast cell line (WI38), had demonstrated the low cytotoxicity of *Cymbopogon giganteus*, *Cymbopogon nardus* and *Cymbopogon schoenantus* (IC_{50} >50 µg/mL). In contrary, the cytotoxic property of *Cymbopogon citratus* essential oil against CHO cells (IC_{50}=10.63 µg/mL) and WI38 cells (IC_{50}=39.77 µg/mL) was shown [19]. Other compounds such as neral and geranial (citral) was toxic against CHO cells (IC_{50}=20.62 µg/mL) and moderately toxic against WI38 cells (IC_{50}=39.48 µg/mL) [19]. But, the safety of the use of *Cymbopogon* species at the doses used in folk medicine, was noticed since a high lethal dose (LD_{50}) of *C. citratus* was revealed to be (≈ 3500 mg/kg by 24 h) [20].

CONCLUSION

The present review has focused on the volatile profiles and biological properties of *cymbopogon* species mainly *Cymbopogon citratus*, *Cymbopogon giganteus and Cymbopogon shoenanthus.* Essential oils extracted from species of the genus *Cymbopogon*, have demonstrated a wide range of biological properties in relation to their volatile profiles. These findings have validated the several traditional uses of these plant species.

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