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Ethnobotanical and phytopharmacological notes on *Cymbopogon citratus (DC.)* Stapf

Bibliographic Review

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Abstract – *Cymbopogon citratus* (DC) Stapf is an herbal plant belonging to Poaceae. Commonly known as lemongrass, this plant is used in traditional and modern medicine to cure different diseases, as it has anti-inflammatory and anti-oxidant properties. Studies have shown that *Cymbopogon citratus* (DC) has interesting uses in agronomy as a natural pesticide and insecticide. Its antifungal and antimicrobial activities make it a plant of interest in many fields. Essential Oils, aqueous extracts, phenolic compounds and other extracts from this plant are industrially and economically important. They are used in perfumery, cosmetics and pharmaceuticals. The chemical composition of the *Cymbopogon citratus* (DC) essential Oil showed different molecules responsible of its therapeutic properties such as citral, β-myrcene, limonene, linalool, geranyl acetate, saponins, neryl acetate and tannins. These compounds have considerable antifungal, antibacterial, allopathic, and anti-carcinogenic activities. The following review is a summary of the ethnopharmacological use of *C. citratus*, but also its chemical composition and different biological activities.

Keywords: *Cymbopogon citratus*, citral, essential oil, antifungal activity, antibacterial activity.

1. General presentation of *Cymbopogon citratus (D.C):*

Cymbopogon citratus (DC.) commonly known as Lemongrass, Indian Lemongrass or Lemongrass from Madagascar is an aromatic herb belonging to the Poaceae family (Figure 1) This family is indeed widely distributed counting more than 635 genus and 9000 species. The Cymbopogon genus has for itself more than 140 cultivated species, 52 of them are located in Africa, 45 in India, 6 in Australia, 6 in South America, 4 in Europe, 2 in North America and the rest in South Asia (Suman et *al.*,2004). The rest of the species is distributed between Central America, South America, Africa and other tropical regions (Gagan et *al.*,2011).

Originated from southern India and Sri Lanka, Cymbopogon citratus (DC.) grows nowadays spontaneously all over the world, especially in the tropical subtropical and Savannah regions (Negrelle and Gomes, 2007). In West Africa, it has long been cultivated for its medicinal properties. In Tunisia, *Cymbopogon citratus (DC.)* is an introduced species cultivated for decoration, therapeutics and insecticides uses. Indeed, it is grown in gardens especially for its repelling effect of insects like mosquitoes. The essential oil extracted from the lemongrass is used in local industrial products against cockroaches, flies and mosquitoes (Dhaou et *al.*,2010).

2. Taxonomy classification

Cymbopogon citratus (DC.) is a herb belonging to the Kingdom of Plantae, the Phylum of Spermatophyta (seed plants), the super-branching of Magnoliophyta (flowering plants), the class of Liliopsida (Monocotyledons), the order of Poales, the family of Poaceae (herbaceous), the genus is Cymbopogon and the species is citratus (Karunamoorthi et *al.*, 2010).

3. Morphological and botanical description

Cymbopogon citratus (DC.) Stapf (Figure 1) is a perennial aromatic herb that grows as dense clumps with no ramification (Fig1.A). The total length of this plant can reach 2 meters while its width goes up to 1.2 m. It has short rhizomes which also are its way of multiplication (Fig1.B). The leaves are green, erect, flat, linear in shape and closed at the base (Figure 1.C). The majority emerges directly from the

ground without stem. Their length exceeds 1m while the width varies from 5 to 15 mm. The leaves give off a characteristic lemon flavor, once pressed by hand or crushed. The upper side is glabrous and whitish with ligaments 4 to 5 mm long.
The glumes are equal to subequal. The lower glume is lance-shaped with an acute apex, while the upper glume is lanceolate 4.3 to 4.5 cm long with a rib. *C. citratus* rarely gives flowers. The species identified until now do not show flowers. The inflorescence: *C. citratus* has erect inflorescences with a length of 30 to 60 cm. *C. citratus* is generally propagated by seedling or by tuft division (Negrelle and Gomes, 2007; Gagan et *al.*,2011).

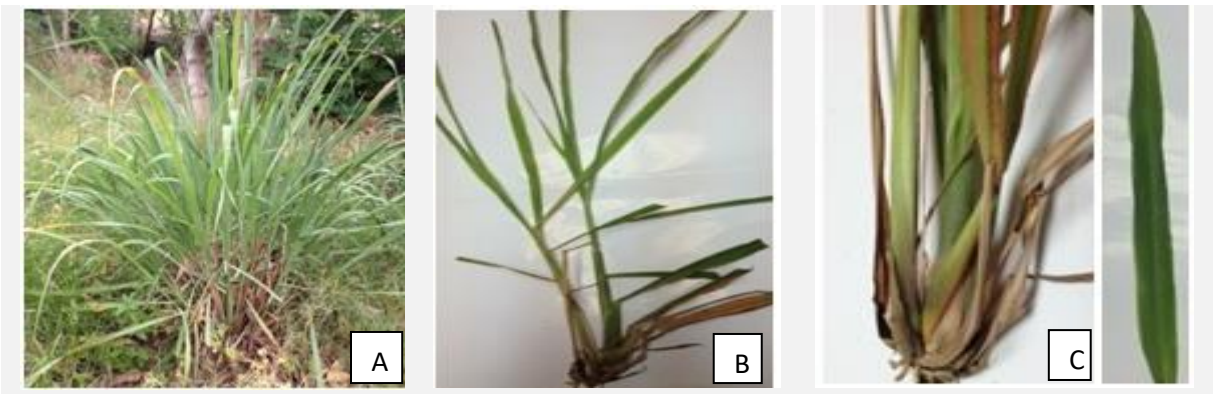

Figure 1. *Cymbopogon citratus:* A: the aerial part, B: The root system, C: one leaf

4. Common names

Cymbopogon citratus (DC.) has different names depending on the country in which it grows. In France and Tunisia, it's called "Citronnelle" or "Herbe Citron". In USA and England, English, they call it "Lemongrass" or "Lemon Grass" which is also the common name in India and Egypt. In Brazil it's called "Capim-cidrao" or "Capim-santo", in Ethiopia "Tej-sar". For the rest of the countries, the most used names are the following: Sereh (Indonesia), Cimbopogone (Italy), Sakumau (Malaysia), Zacate limon (Mexico City), Citrongräss (Sweden), Ta-khrai (Thailand), Limon out (Turkey) (Gagan et *al.*,2011).

5. Ethnopharmacological uses of *Cymbopogon citratus (DC.)*

C. citratus has always been grown all over the world for decoration but also for medical purposes (Tarkang et *al.*, 2012). In traditional medicine, it was used for its virtues on human health depending on the country or even the continent where it is located. In Egypt, dried leaves were boiled and orally administered as a renal anti-spasmodic and diuretic. Leaves and essential oil (EO) showed significant results in treating cough, fever, vomiting, headache and even insomnia and depression (Oloyede, 2009). In Indonesia and Malaysia the whole plant is boiled and the liquid obtained is administered orally for its emmenagogue effect (stimulation of the pelvic blood flow and uterine region). In the United States of America, the boiled liquid is used as an external lotion to heal wounds and bone fractures, especially in the Minnesota region (Spring, 1989). In South America, precisely in Brazil, tea obtained from the leaves of *C. citratus* is drunk for its antispasmodic, anti-inflammatory and analgesic effects (Fransisco et *al.*, 2013). In India: the plant itself of *C. citratus* is grown in gardens to ward off snakes. Indian also give children lemongrass tea with slices of lemon to heal stomatitis. A few drops of the EO diluted in warm water is administered orally to treat gastrointestinal problems. In Africa, it is used as an antitussive, antiseptic, sudorific and to treat back pain.
Lemongrass leaves are also brought to a boil with the leaves of bamboo (Bambusa vulgaris) and ginger to reduce fever. In Nigeria and Ghana, decoctions of *C. citratus* leaves with *Cassia occidentalis* and/or key lime (*Citrus aurantifolia*) is used to treat malaria especially for pregnant women. Patients take one cup per day until complete healing. Chineese treat colds and oral bleeding with C. *citratus* essential oil (Negrelle et *al.*, 2007; Tchoumbougnang and *al.*, 2005).
Studies have also shown that lemongrass has allelopathic properties, which means it can be used as a herbicide (Dudai et *al.*, 1999). Lemongrass essential oil concentrated at 10% in an aqueous suspension has a total herbicidal effect on many weed species such as *Digitaria horizontalis*, *Sorghum halepense*,

Bidens pilosa, *Euphorbia heterophylla* and *Raphanus raphanistrum* (Valarini et *al.*,1996). Even animals are treated with *C. citratus*. In Brasil, the tea made out of leaves and roots is given as a remedy for colic. The oil showed its effeciency against body odors (Lachman-White and *al.*, 1992). Macerate leaves reduces swelling, mosquito's bites, wounds and eczema (Asase et *al.*,2010). Moreover, *C. citratus* is known for its domestic use. In aerosols, deodorants, *C. citratus* is used as insect repellent. Roots extracts are added to perfumes, shampoo, soaps and cosmetics. It is also used as a household detergent (Ritter et *al.*,2012).

6. Pharmacological uses of *C. citratus*

Different pharmaceutical and medical studies showed that *C. citratus* essential oil has antimicrobial, antiparasitic and antifungal activities (Tzortzakis and Economakis, 2007). Inhibiting the proliferation of cancer cells, lemongrass EO is also an antioxydant, anti-tumoral and anti-inflammatory. This EO helps reducing blood pressure and protect the cardiovascular and gastric system (Manosroi et *al.*,2006).

7. Chemical composition of *C. citratus* essential oil

The essential oil of *C. citratus*, is obtained by hydrodistillation. The yield varies according to the part of the plant from which the extraction took place. Generally speaking, the leaves yield varies from 0.28 to 1.4% (Kasali and *al.*,2001), given that the maximum value obtained is 3% from the dry and non-green leaves (Chisowa and *al.*,1998). The chemical compounds obtained from the roots are different from those obtained from the leaves. These molecules are classified in four groups
oxygenated monoterpenes, oxygenated sesquiterpenes, monoterpene hydrocarbons and hydrocarbons sesquiterpenes. Other components have also been identified from leaves and roots, including alkaloids, saponins, flavonoids, caffeic acids and sugars (Akhila, 2010). *C. citratus* is most of the times grown for its high content of Citral, a component that is used in cosmetic and chemical industries (Miean and Mohamed, 2001). Citral is also the active ingredient responsible for the antifungal and antimicrobial activity which accounts for 70% to 80% of the total yield obtained.
Previous studies of *C. citratus* have shown that the chemical composition also depends on the geographical origin. Moreover, the essential oil contains terpene carbons, alcohols, ketones, esters and aldehydes. Organic obtained with methanol and ethanol and aqueous extracts obtained with infusion of the leaves showed that *C. citratus* contains tannins, phenolic acids and flavonoid glycosides. *C. citratus* also contains vitamines A, C, E but also niacin, pyridoxine, riboflavin and folate. Concerning minerals, *C.citratus* contains sodium, potassium, manganese, zinc, calcium, magnesium, copper selenium, phosphorus and iron in addition to electrolytes, macronutrients (carbohydrates, proteins), and a small quantity of fat (Cheel and *al.*, 2005). Other compounds were reported such *as* orientin, swertiajaponin and isoscoparin as well as other phytochemicals (Bahrati et *al.*, 2013). Table 1 summarized the components found in *C.citratus* EO.

8. Biological activities of *Cymbopogon citratus* EO

8.1. Antimicrobial activity

The essential oil extracted from lemongrass leaves is widely used for its antimicrobial activity. Concerning the bacteria, *C. citratus* seems to be more efficient against Gram negative ones than Gram positive (Mayaud et *al.*,2008). Against *E.coli*, the EO showed over 80% of efficiency. It was even more active against *Enterococcus faecali* and *Salmonella typhimurium* than two standard antibiotic which are erythromycin tetracycline (De Oliveira et *al.*,2013). *C.citratus* EO was more efficient than *Mentha arvensis var. piperacens* EO against enteropathogenic germs which can contaminate and affect food quality. Moreover, this EO inhibits the activity of *Salmonella enteritidis* responsible for deterioration of preserved meat. Patients who have been given 05ml/day of *C. citratus* was healed from *Helicobacter pylor*, the pathogen responsible of gastric ulcer. Its action in acid medium was bactericidal (Ohno et *al.*,2003). Genrally speaking, the antimicrobial activities of *C. citratus* EO are mainly attributed to geraniol (α-citral), neral (β-citral), 1, 8- cineole, *p*-cymene, α- and β-pinene, limonene, α-terpineol and camphene (Cimanga et *al.*,2002). The essential oil also exhibits good antibacterial activity, in particular against *Escherichia coli*, which is harmful to humans (Ogunlana et *al.*,1986).

Table 1. Natural compounds reported in *C.citratus* EO with possible amounts 16 18 190 192

Chemical composition of *C.citratus* Essential Oil: main components	References
α-citral (geranial) (29,4 - 60,3%)	(Ekpenyong et *al.*,2015)
limonen (3-5.4%)	
6-methyl-hepten-2-one (2,9 - 3,21%)	
citronella (0.2-1.32%)	
germacren-D (0,2 - 0,5%)	
, n-octanal (0,2%)	
1,8-cineol (0,2%)	
z-carveol (0,2%)	
γ-cadinen (1,3%)	
α-terpinéol (0,29 - 9 %)	
β-citronellal (0,2 - 0,7%)	(Nambiar et Matela, 2012)
β-caryophylen (1,9%)	
***α*-Amorphene**	
***β*-Sesquiphellandrene**	
Isolongifolene-4-5-9-	
10-dehydro Levo-	
***β*-elemene**	
***α*-Bergamotene**	
***t*-Cadinol**	
α-citral (geranial) (29,4 - 60,3%)	(Bassolé et *al.*, 2011)
limonen (3-5.4%)	
6-methyl-hepten-2-one (2,9 - 3,21%)	
citronella (0.2-1.32%)	
germacren-D (0,2 - 0,5%)	
, n-octanal (0,2%)	
1,8-cineol (0,2%)	
z-carveol (0,2%)	
γ-cadinen (1,3%)	
α-terpinéol (0,29 - 9 %)	
β-citral (neral) (21,39 - 40%)	(Asaolu et *al.*,2009)
Neryl acetate (2,0 - 6,3%)	
aromadendrene (0,6%)	
methyl heptone (1-1.4%)	
3-caren (0,1%)	
β-myrcen (0,8 - 20%)	
tricyclen (0,2%)	
verbenone (0,2%)	
sabinol (0,5%)	
linalool (0,2 - 3,2%)	(Faruq, 1994)
α-cyclocitral (0,5%)	
genaryl acetate (0,2 - 3,6%)	
***α*-Muurolene**	
d-Cadinene	
3-Undencyne	
3-carvomenthenone	
γ-Muurolene	
Dextro-carvone	
nerol acetate (10,8%)	(Tzortzakis and Economakis, 2007)
geranial (3,25 -4%)%)	
α-pinen (0,4 - 1,1%)	
myrtanal (0,2%)	
terpinen-4-ol (0,5 - 3%)	
camphen (0,9 - 1,5%)	
eugenol (0,24 - 0,3%)	
borneol (0,2 - 3,7%)	(Akhila, 2010)
isoeugenol (0,5%)	
nerol acid (0,8%)	
caryophylen oxide (0,8%)	
β-ocimen (0,3%)	
bomeol (1-2.16%)	
Germacrene-D	
(*E*, *E*)-Farnesal pimelyl	
Dihydrazide	
***α*-Gurjunene**	

8.2. Antifungal activity

Pathogen resistance to a certain number of chemical treatements and target mutation is becoming a serious issue. For this perticular reason, natural products are used today as a promising alternative. The essential oil extracted from lemongrass leaves is widely used for its antifungal activity. The EO obtained by hydrodestillation was effective against 42 microorganisms including 7 yeasts and 15 fungi (Negrelle and Gomez, 2007). These fungi include rice pathogens such as *Rhizoctonia solani* (Shimoni, 1993). Antifungal activities of the *C. citratus* oil can be attributed to the presence of a number of compounds among which citral, *β*-myrcene, linalool, and geraniol (Alvanioano et *al.*, 2005). Studies showed that the mixture of geranium and neral, also called citral, that is responsible for the antifungal activity. Moreover, with the presence of myrcene with one of the two compounds, this activity is further enhanced (Di Pasqua et *al.*, 2006).

C.citratus is also effective againt fungi causing mold such as *Aspergillus niger, Aspergillus ochraceus, Alternaria alternata, Fusarium oxysporum and Penicillium roquefortii*, at a concentration going between 500 ppm and 700ppm (Helal et *al., 2006*). The EO also inhibits the production of aflatoxine B1, a toxine produced by *d'Aspergillus flavus* (Singh et *al.,* 2010). The effective doses against these following yeasts were ranged beween 0.062 µl/ml and 10µl/ml: *C. albicans, Candida oleophila, Hansenula anomala, Schizosaccharomyces pombe, Saccharomyces cerevisiae, Saccharomycesuvarum et Metschnikowia fructicola*. Genrally speaking, fungi were more sensitive to *C.citratus* EO than Yeasts (Irkin and Korukluoglu, 2009). This shows that this aromatic plant can be a perfect substitute to chemical treatements on plants, human and animals.

8.3. Insecticide activity

C.citratus has always been grown in gardens to repulse insects like cockroaches and mosquitoes. *In vitro* experiments on the common housefly, *Musca domestica* L. (Diptera: Muscidae) showed that Assay of oil against housefly larvae and pupae through contact toxicity assay showed lethal concentration $(LC)_{50}$ value of 0.41 µl/cm^2 and of percentage inhibition rate (PIR) of 77.3 %, respectively (Kumar et *al.*, 2013). While oil from C. citratus demonstrated complete larvicidal action on the yellow fever mosquito *Aedes aegypti* L. Twenty giving 100% mortality of at 200 ppm (Sosan et *al.*, 2001). Against Culex quinquefasciatus and Anapheles dirus, 10% of *C.citratus* EO applied in soybean oil 1%, gave a 100% mortality rate 24 hours after the application. This shows the potentiality of *C.citratus* to be used as a natural insecticide instead of chemical products (Phasomkusolsil & Soonwera, 2011). Using also contact toxicity against *Tribolium castaneum* (Herbst.) (Coleoptera: Tenebrionidae), *C.citratus* EO was repellent at a dose of 0.021 ml/L after 4 hours of exposure. Its effeciency was much higher than the active ingredient IR3535 repellent found in a variety of insect repellent products used at the dose of 0.686 ml/L. This insecticide activity is mostly due to the presence of geranial and neral in the chemical composition of the EO (Olivero-Verbel et *al.*, 2010). The essential oil of lemongrass is also used against insects, especially mosquitoes, stopping certain phases of its development cycle. This has been proven for the mosquito *Aedes aegypt* (the tiger mosquito) vector of yellow fever (Osmani and Sighamony, 1980).

9. Medical uses and benefits on human health

The use of lemongrass in traditional medicine depends on the country where it is grown. However, tea or infusion prepared from dry leaves is used in broad spectrum treatment (Tarkang et *al.*,2012).

Table 2. Uses of *C. citratus* in traditional medicine

Country	General use of *C.citratus*	References
South Africa	Antitussive, antiseptic, sudorific, antirheumatic, treatement of back pain and sprains.	(Ekpenyong et *al.*, 2015; Negrelle and Gomes EC, 2007)
Asia: India	Treatment of Gastrointestinal Problems	
Suriname	cough, asthma, bladder problems, wound management and headaches	
Indonesia	facilitate digestion, diuresis, sweating and used as an emmenagogue	
Brazil	colds, coughs, heart disease, urinary tract inflammations and allergies. It is also used to treat women neuropsychological problems	
Niger	antipyretic and antispasmodic.	

9.1. Regulation of the cardiovascular system

In traditional medicine, *C.citratus* is used for hypotension treatment. Tested on rats at different doses going from 1 to 20 mg/Kg, *C.citratus* EO induces hypotension, by reduction in vascular resistance caused by inhibition of the Ca^{2+} influx, and bradycardia probably due to an activation of cardiac muscarinic receptors (Moreira et *al.*, 2010). Furthermore, aqueous extracts obtained from pulverized dry leaves of *C. citratus* were tested on cardiac rate and contractile force on the isolated hearts of rats. These extracts provoked significant Cardiac Rate reduction without altering the Contractile Force. This activity is due to the presence of alkaloids, tannins and flavonoid (Gazola et *al.*, 2004). Another experiment was conducted on aqueous crude extracts of *C. citratus* showed its efficiency on the osmotic stability of human erythrocytes. The extracts protected the erythrocytes against hypotonic shock by a decrease of the value of the intensity of the lysis effect in NaCl solutions (De Freitas et *al.*, 2008).

9.2. Anti-inflammatory properties

C.citratus is an aromatic herb that contains dietary components responsible for an anti-inflammatory activity. Infusion of dried leaves inhibits the lipopolysaccharide (LPS) induced by NO production and inducible NO synthase (iNOS) protein expression. These two later are involved in inflammatory cells activation and chronic inflammation. *C.citratus* its polyphenolic fractions,lavonoid, tannin and phenolic acid-rich fractions reduced iNOS protein levels and NO production especially in gastrointestinal diseases (Figueirinha et *al.*, 2010). Moreover, polyphenols obtained from *C.citratus* extracts inhibited cytokine production on human macrophages. Chlorogenic acid (CGA), main phenolic acid of the infusion, is the agent responsible of this anti-inflammatory activity (Francisco et *al.*, 2013). The EO was also shown effective against ileum inflammation in mices. It inhibits β7-expression, responsible of lymphocytes migration (Watanabe et *al.*, 2010).

9.3. Antioxidant activity

C. citratus has been used for medical purposes to treat pathogenesis neurological disorders. Containing antioxidant compounds, it helps reduce the oxidative stress important in the pathogenesis of several neurological diseases. Quercetin, gallic acid, quercetin and rutin are the phenolic compounds found in *C. citratus* extracts. These laters protect against oxidative damage induced by various pro-oxidant agents that induce lipid peroxidation. Thus *C. citratus* could be considered an effective agent in the prevention of various neurological diseases associated with oxidative stress (Pereira et *al.*, 2009). However, 1% of *C. citratus* dried powder added to pork raw meat, improves its conservation by significantly reducing Thiobarbituric Acid Reactive Substances (TBARS) (Olorunsanya et *al., 2010)*. Methnolic, aqueous extracts as well as infusion and decoctation of *C.* citratus showed significant activity in inhibiting the enzyme xanthine oxidase (XO) and lipid peroxidation in human erythrocytes. Isoorientin and orientin presented similar activities toward the DPPH (IC_{50}: 9−10 μM) reducing lipid peroxidation by 70% at 100 μg/mL. Caffeic and chlorogenic acid were active superoxide anion scavengers with IC_{50} values of 68.8 and 54.2 μM, respectively, and a strong effect toward DPPH. Caffeic acid inhibited lipid peroxidation by 85% at 100 μg/mL **(**Cheel et *al.*, 2005).

9.4. Anti-carcinogenic and antimutagenic activities

Numerous studies have been carried out on the antitumor activity of citronella extracts. All of them indicated that *C. citratus* has a promising anticancer activity causing loss in tumor cell viability. Tested on Fischer rats, *C. citratus* extracts against hepatocarcinogenesis, ethanolic extracts at a dose going from 0.2% to 1.8% reduces the incidence of hyperplasic lesions and mammary murine epithelial cells apoptosis (Puatanachokchai et *al.*, 2002). *In vitro,* polysaccharides extracted from *C. citratus* have shown anticancer activities due to the presence of (1-4) linked b-D-Xylofuranose moiety. These polysaccharides are also responsible of apoptosis in cancer cells *via* intrinsic pathway through the events of up-regulation of caspase 3, down-regulation of bcl-2 family genes followed by cytochrome *c* release (Thangam et *al.*, 2014). In a cup of tea prepared with 1g of *C. citratus* leaves, 44.5μM of Citral induces apotesis in hematopoietic cancer lines. The apoteisis was accompanied by DNA fragmentation and caspase-3-catalytic activity induction. However, citral apotetic activity was dependent on the α, β-unsaturated aldehyde group. This anticancer effect was higher than a reference compound

called staurosporine (Dudai et *al.*, 2005). Against solid and ascitic Ehrlich and Sarcoma-180 tumor models in mice, *C. citratus* showed a dose dependent effect going from 4.2 to 79 µg/ml. The highest cytotoxicity was noticed against 502713 (colon) and IMR-32 (neuroblastoma) cell lines with an IC50 of 4.2 to 4.7 µg/ml. The total tumor inhibition with both ascitic and solid tumor forms of Ehrlich Ascites carcinoma needed doses of 97.34 and 57.83 respectively. Moreover, the EO tested on Sarcoma-180 solid tumor cells from animals showed condensation and fragmentation of nuclei typical of apoptosis (Sharma et *al.*, 2009). Citral also showed activity against leukemic cells called P388 (Dubey and *al.*, 1997). The ethanolic extracts of *C. citratus* also have anti-mutagenic activity (Vinitketkumnuen et *al.*, 1994). Myrcene, showed an antimutagenic effect specifically on mammary cells. While α-limonene and geraniol have been able to inhibit liver and intestinal mucosal membrane in mices (Zheng and *al.*,1993). It has also been shown that juices extracted from *C. citratus* leaves, showed inhibiting activity containing inhibitors of cutaneous tumors development (Lima et *al.*, 1993).

9.5. Blood glucose regulation and hypolipidemic effects

Aqueous extract of *C. citratus* has hypoglycemic effects. A daily dose going from 125-500 mg per kilogramme tested on Wistar rats' lowers fasting plasma glucose (FPG) but also total cholesterol and lipid parameters such as high-density lipoprotein (HDL). And because ths used dose did not show any type of toxicity, *C.citratus* can be used as a treatment against type 2 diabetes (Adeneye et *al., 2007)*. Moreover, a treatment with *C.citratus* exctracts during 4 weeks on diabetic rats lowers blood glucose, TG, T-chol and LDL levels. This same treatment induced body weight reduction. The EO showed hypocholesterolemic effect mediated by the regulatory enzyme, HMG-CoA reductase in post-transcriptional down- regulation (Middleton and Hui, 1983). This way, the EO inhibits the hepatic 3-hydroxy-3- methyl-glutaryl-coenzyme A (HMG-CoA) reductase that plays an important role in cholesterol synthesis (Elson et *al.*, 1989).

10. Toxicity of *C.citratus* EO

Applied at doses generally higher than 1500 mg/kg body weight, the oils caused significant functional damages to stomach and liver of Wistar rats for consecutive 14 days (Fandohan et *al.*, 2008). The herbal tea made out of dried leaves of *C. citratus* caused slight elevations of direct bilirubin and amylase on humans but without clinical manifestation (Leite et *al.*, 1986). At an elevated dose of 2000mg/Kg of *C. citratus* EO tested on Wistar mices, symptoms like torpor, nose and eyelid bleeding were observed. These symptoms were due to stomach mucosa atrophy and hepatocytes necrosis (Costa et *al.*, 2011). Concerning the plants, the aqueous extracts of *C. citratus* on *Allium cepa* bulb (onion) at doses going from 1 to 20% induced cytotoxic and genotoxic effects (Akinboro and Bakare, 2007). Aqueous extract tested on *Lactuca sativa* at a concentration of 30mg/ml caused chromosomal abnormalities and root cell death (Sousa et *al.*, 2010).). The major components causing toxicity in *C. citratus* are citral and β-myrcen. Limonen showed low toxicity on humans with a dose of 100 mg/Kg causing nausea, vomiting and diarrhea (Vigushin et *al.*, 1998). At doses going from 125 mg/kg up to 1200 mg/kg, citral and β-myrcen become toxic on embryos. Growth is delayed and skeletal abnormalities is observed with an increase in the fetal spleen weight (Nogueira et *al.*, 1995).

11. Conclusion

Scientific research conducted on *Cymbopogon citratus* helped understanding the beneficial effects on human, animals and plants. Its pharmacological properties explained the different uses of this plant in medicine as a digestive and cardiovascular regulator but also against infectious diseases and psychiatric disorders. The chemical composition of the EO, phenolic compounds and aqueous extracts showed the major compounds which are responsible of the antifungal, antimicrobial, antioxidant and anticancer activities. The different information detailed in this review on the benefits and uses of *C. citratus* make it a good candidate for further scientific experiments in other fields such as agronomy and pharmaceuticals.

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