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Review paper

Cymbopogon citratus (DC.) STAPH: CHEMICAL COMPOSITION, ANTIMICROBIAL AND ANTIOXIDANT ACTIVITIES, USE IN MEDICINAL AND COSMETIC PURPOSE

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ABSTRACT: The genus *Cymbopogon* (Greek words 'kymbe' meaning boat and 'pogon' meaning beard), commonly known as lemongrass, belongs to the Poaceae family. It comprises a large number species, but only two have economic importance as cultivated plants: *C. citratus* and *C. flexuosus*. However, *C. citratus* is more resistant to drought and low temperatures and because of that can be cultivated over large areas therefore it is commercially more important. *C. citratus* leaves are widely used as a lemon flavor ingredient in herbal teas, prepared either by decoction or infusion, or in finished herbal products such as capsules, tablets and creams. Even though essential oils are known for being used for fragrance and as an important ingredient in Asian cuisine, they are also used in other industries (pharmaceutical and cosmetic) due to their bioactive compounds that show various therapeutic effects. The chemical composition of *C. citratus* essential oil varies widely depending on genetic diversity, habitat and agronomic treatment of the culture, as well as on the part of the plant, maturity stage and extraction method. However, the essential oil of *C. citratus* mainly consists of the citral, which is a mixture of two isomeric acyclic monoterpene aldehides: geranial (*trans*-citral) and neral (*cis*-citral). *C. citratus* possesses good antibacterial activity, it could be used as alternative treatment for enteric fever, to cure infectious diseases related to the respiratory system, as well as for oral hygiene, it helps by removing bacteria from the oral cavity and prevents teeth and gum diseases such as peridontitis, plaque and gingivitis. Furthermore, *C. citratus* showed high contents of total phenolic and total flavonoids, as well as high free radical scavenging capacity with potential as an antioxidant. *C. citratus* shows good antiinflamatory, anti-diabetic, hypolipidemic, renoprotective and cardioprotective, as well as anticancer activities. Apart from this, *C. citratus* possesses vasorelaxant, sedative and antitusive potential. Furthermore, the compound citral is used in perfume industry as well as for cleaning wounds and treatment of skin diseases in forms of gels, or functional paper microencapsulated with essential oil, which can be used for hand hygiene.

Key words: *lemongrass, fragrance, essential oil, citral*

INTRODUCTION

The genus *Cymbopogon*, commonly known as lemongrass, belongs to the Poaceae family. It originates from southwest Asia (southern India and Sri Lanka), but nowadays it grows spontaneously all over the world, especially in the tropical and subtropical regions (Machraoui et al., 2018). It comprises a large number species, but only two have economic importance as cultivated plants: *C. citratus* and *C. flexuosus* (Avoseh et al., 2015). *C. flexuosus* or East Indian lemongrass is cultivated in Asia, while *C. citratus* or West Indian lemongrass is resistant to drought and low temperatures and because of that can be cultivated over large growth areas, therefore it is commercially more important (Prins et al., 2013). It has been cultivated for its medicinal properties, as well as for garden decoration and for its repelling effects on insects. It is tropical plant, grown as an ornamental plant in many temperate areas.

The name of genus *Cymbopogon* is derived from the Greek words kymbe (boat) and pogon (beard), referring to the flower spike arrangement, while *citratus* derives from the ancient Latin, meaning lemon-scented leaves. However, *Cymbopogon citratus* (DC.) Stapf. forms dense clumps of up to 3 m tall, with short rhizomes. The whole plant has a lemon like smell and bitter taste. Its leaves are erect, glabrous plane, more than 1 m long, 5-15 mm wide, whiter upper face and closed edge in the base, with rough margins and membranaceous or arid ligules 4-5 mm long. The upper surface side of leaves is dark green, while the lower surface is light green. Inflorescences are erect, usually in pairs of terminal spiciform racemes 30-60 cm long. Sessile small spikes, canaliculated ventral side, 4.5-5.0 mm long, 0.8-1.0 mm wide, ciliated margins (Negrelle and Gomes, 2007; Shah et al., 2012). Conversely, flowering has never been observed under cultivation due to rapid harvesting time (Tajidin et al., 2012).

CULTIVATION AND POSTHARVEST PROCESSING

Since the plant rarely flowers or sets seed, propagation is by root or by plant division of shoots from healthy plants that are cut to 12 cm, dead or extensive roots are trimmed and treated with fungicides. Planting is done mainly on the flat 10-15 cm deep, with spacing 50-90 cm × 50-60 cm. Good drainage is the most important soil requirement, usually of pH 5.5-7.5. Deep planting and earthing up are beneficial on sandy soils; but on heavy soils these practices are not advisable as the young plants are susceptible to root rot (Sonawane et al., 2008).

C. citratus leaves are usually harvested twice per year. Investigations show that for both harvest dates (April and September) plant quality is key criteria that has to be taken into account when selecting the material for human consumption, in order to obtain benefits that have been associated with phenolic compounds, namely those which are present in this plant (Costa et al., 2016).

After harvest, plant material can be dried naturally (in the sun or in shade) or artificially. In one study, the leaves of *C. citratus* were dried using three different drying methods (sun-drying for 36 h, shade-drying for 48 h and oven-drying at 45 °C for 7 h). Differences in the essential oil content of leaves dried by different drying methods are observed. Eighteen components were identified in the essential oil of fresh and dried *C. citratus* leaves obtained by different drying methods, including geranial, neral and myrcene as the main components. The drying methods had a marked effect on the proportion of the various components (Hanaa et al., 2012). Furthermore, convection drying is a commonly used drying method that could extend the shelf life of the product. In this study, a suitable kinetic model for the drying process was determined by fitting moisture data corresponding to four different temperature levels: 50, 55, 60 and 65 °C. In addition, the effect of drying temperature on the moisture removal rate, the effective diffusion coefficient and activation energy were also estimated. The results showed that the time for moisture removal increases proportionally with the air-drying temperature. The activation energy for lemongrass evaporation is relatively high, suggesting that more energy is required to separate moisture from the material by drying (Nguyen et al., 2019).

Dried *C. citratus* leaves are widely used as a lemon flavor ingredient in herbal teas, prepared either by decoction or infusion (Tilaye et al., 2018). *C. citratus* tea contains 4.79-13.03% ash, 10.00-13.85% moisture, 0.98-6.09% lipid, 0.16-0.44% protein and 78.16-84.35% crude fiber (Akande et al., 2012). *C. citratus* is widely used in functional food as well as in traditional medicines. Treatments with plant-based medicine appears to be an alternative approach due to the adverse effects associated with the use of synthetic drugs (Mirghani et al., 2012; Manvitha and Bdya, 2014).

Finished herbal products are presented in various dosage forms such as decoctions, herbal powders, alcoholic beverages, capsules, tablets, ointments and creams. The growing demand for herbal medicinal products across the world has resulted in the large scale manufacturing of these products (Kumadoh and Ofori-Kwakye, 2017). The granules can be prepared with methanolic extract of *C. citratus* leaves by wet granulation method using acacia or gelatin as a binder. The results of the phytochemical analysis showed that alkaloids, carbohydrates, saponins, reducing sugars, steroids, tannins, glycosides, proteins, flavonoids, resins, oils and terpenoids were present at different concentrations, while acid compounds were absent (Chime et al., 2012; Salome et al., 2012).

There is increased interest in natural products such as essential oils to be used for fragrance. It is widely used as an essential ingredient in Asian cuisines because of its sharp lemon flavor (Tadtong et al., 2014). The demand for essential oils in current industry has increased due to its bioactive compounds that show various therapeutic effects (Ranitha et al., 2014). The essential oil of *C. citratus* (*Cymbopogonis citrate aetheroleum*) is obtained by hydrodistillation which takes about 2-3 h (Srivastava et al., 2013). The obtained oil is mobile, pale yellow, with a powerful, fresh, lemon like odor that is quite prominent **(Ghosh 2013)**. The relative density of the oil is 0.893 g/cm^3, boiling point is 229 °C, and refractive index is between 1.484 and 1.490 (Shahzadi, 2017).

Wilting the herbage of lemon grass before distillation reduces moisture content, and has little effect on the oil yields, but increases the citral content (Sonawane et al., 2008). However, based on simultaneous evaporation and diffusion mechanism, the kinetics of lemongrass oil hydrodistillation process can be described mathematically using a two-parameter model. It was found that the parameter relating to the fast oil distillation period (evaporation coefficient) was larger than that of the slow oil distillation period (diffusion coefficient), thus, the evaporation stage was much faster than the diffusion stage. The gas chromatography-mass spectrometry analyses have proved that the material length did not influence the composition of lemongrass oils (Supardan et al., 2019).

CHEMICAL COMPOSITION OF ESSENTIAL OIL

The chemical composition of *C. citratus* essential oil varies widely depending on genetic diversity, habitat and agronomic treatment of the culture (Ranitha et al., 2014), as well as on the part of the plant (Olayemi, 2017), maturity stage (Tajidin et al., 2012) and extraction method (Bossou et al., 2015). The variability is especially related to the proportions of constituents and relatively to the presence of new compounds or the absence of particular ones. It has been suggested that the variation in essential oil yield and the composition could be due to the activity of enzymes responsible for the biosynthesis of volatile compounds (Olayemi, 2017). Furthermore, environmental conditions can influence essential oil biosynthesis, since it may alter hormonal balance. Thus, phytohormones may act as signals that can directly or indirectly induce secondary metabolites biosynthesis. Light availability and quality can be positively associated with essential oil production. The effect of cytokinin on essential oil production can be associated with an increase in photosynthetic activity, as a consequence of the higher number of chloroplasts or enhanced chlorophyll biosynthesis, biomass production, increased secretory storage formation and senescence delay, and interaction with exogenous signals such as light (Prins et al., 2013).

C. citratus essential oil mainly consists of the monoterpene fractions (Ganjewala, 2009). The dominant is citral, or 3,7-dimethyl-2,6-octadienal ($C_{10}H_{16}O$), which is a mixture of two isomeric acyclic monoterpene aldehides. The two compounds are double bond isomers. The *trans*-citral is known as geranial, while *cis*-citral is known as neral. Geranial has a strong lemon odor, while neral is less intense and sweeter with a floral-herbal odor (Ghosh, 2013). Apart from citral, which compromises from 23.6 to 91.8% in the aerial parts (leaves and stalks), myrcene (up to 16.2%), geraniol (up to 41.2%), geranyl acetate (up to 4.1%) are also registered (Table 1). However, citral is industrially important, because it is used as raw material for the production of ionone, vitamin A and β-carotene (Ranitha et al., 2014).

Table 1. Chemical composition of *C. citratus* essential oil according to literature

Origin	Plant part	Reference	Geranial (E-citral)	Neral (Z-citral)	Myrcene	Geraniol	Geranyl acetate
Benin	Leaves (fresh)	Adjou et al., 2017	41.3	33.0	10.4	6.6	2.4
Benin	Leaves (HD)	Bossou et al., 2015	44.3	33.1	12.4	1.0	0.8
Benin	Leaves (SDE)	Bossou et al., 2015	0	23.6	1.2	41.2	0.5
Benin	Leaves (SPME)	Bossou et al., 2015	23.9	19.7	1.2	2.0	0
Benin	Leaves	Degnon et al., 2019	41.3	33.0	10.4	6.6	2.4
Benin	Leaves	Sessou et al., 2012	44.5	31.2	9.6	7.9	2.2
Brazil	Leaves	Oliveira et al., 2017	46.6	34.1	6.8	1.1	-
Egypt	Leaves (fresh)	Hanaa et al., 2012	40.7	35.0	15.7	0.5	0.5

Egypt	Leaves (Sun-drying)	Hanaa et al., 2012	31.5	30.1	16.2	0.9	0.7
Egypt	Leaves (Shade-drying)	Hanaa et al., 2012	39.9	34.5	14.5	1.0	0.5
Egypt	Leaves (Oven-drying)	Hanaa et al., 2012	37.2	31.3	15.4	1.3	0.7
Egypt	Leaves (fresh)	Shaaban et al., 2013	37.7	33.2	11.41	0.7	0.2
Egypt	Stalk (Culms)	Soliman et al., 2017	42.9	39.8	8.1	3.2	
Iran	Aerial parts	Vazirian et al., 2012	33.3	39.0	0	0	4.1
Kenya	Whole plant	Matasyoh et al., 2011	39.5	33.3	11.4	3.1	0.2
Malaysia	Stalk (Culms)	Mirghani et al., 2012	32.1	22.4	2.2	5.4	
Malaysia	Leaves	Mirghani et al., 2012	29.6	21.7	2.3	5.8	
Morocco	Aerial parts	Fadli et al., 2016	46.3	35.2	-	5.4	-
Morocco	Aerial parts	Fouad et al., 2015	18.2	29.2	3.9	-	-
Morocco	Aerial parts	Salma et al., 2016	55.3	36.5	-	3.4	-
Nigeria	Root	Olayemi, 2017	4.3	4.4	3.5	3.1	-
Nigeria	Stalk (Culms)	Olayemi, 2017	14.9	12.9	10.7	6.0	1.0
Nigeria	Leaf	Olayemi, 2017	18.8	16.3	14.2	7.3	1.4
Sudan	Leaves	Ali et al., 2017	34.8	30.7	11.3	5.5	
Thailand	Leaves (fresh)	Tadtong et al., 2014	48.7	31.7	3.9		
Turkey	Leaves	Duran and Kaya, 2018	47.5	36.3	9.3	-	-
Vietnam (Phu Ninh)	Stalk (Culms)	Van et al., 2016	35.2	28.9	3.6	5.2	0.2
Vietnam (Phu Ninh)	Leaf	Van et al., 2016	42.0	34.3	7.6	3.7	0.6
Vietnam (Thanh Son)	Stalk (Culms)	Van et al., 2016	42.5	33.6	6.2	3.3	0.8
Vietnam (Thanh Son)	Leaf	Van et al., 2016	40.1	32.4	10.7	3.7	1.1

HD – hydrodistillation; SDE – simultaneous distillation extraction; SPME – solid phase microextraction, AERIAL PARTS – stalks (culms) and leaves.

ANTIMICROBIAL ACTIVITY

The use of essential oils as antimicrobial agents is gaining attention in the couple of last decades. Multi-drug resistant microbial infections as well as negative effect of synthetic antimicrobial therapy, lead to the increase of natural herbal preparations. Literature reviews show that *C. citratus* possesses good antibacterial activity (Table 2). However, it could be used as an alternative treatment for enteric fever (Zige and Ohimain, 2017), to cure infectious diseases related to the respiratory system (Suma and Tanuja, 2016), as well as for oral hygiene, it helps by removing bacteria from the oral cavity and prevents teeth and gum diseases such as peridontitis, plaque and gingivitis (Kukkamalla et al., 2012; Satthanakul et al., 2014; Ambade and Bhadbhade, 2015; Tofiño-Rivera et al., 2016; Oliveira et al., 2017; Ortega-Cuadros et al., 2018; Mitrakul et al., 2018; Kumar and Gurunathan, 2019; Ambade and Deshpande, 2019).

Furthermore, *C. citratus* can be a good candidate for the development of new chemosensitizer drugs able to restore antibiotic activity of some drug-resistant Gram-negative bacteria (Jafari et al., 2012; Fadli et al., 2016). Apart from this, *C. citratus* possesses inhibitory effect against herpes viruses (HSV-1) (Duran and Kaya, 2018).

Table 2. Literature review of *C. citratus* antimicrobial activity (results are expressed as zone of inhibition in mm)

Microorganism	Reference	Essential oil	Ethanol extract	Ethyl acetate extract	Hexane extract	Methanol extract	Water extract
Actinomyces howellii	Ambade and Bhadbhade, 2015	16.00	9.00	12.00	9.00		
Actinomyces naeslundii	Oliveira et al., 2017	16.00					
Bacillus cereus	Jafari et al., 2012					18.00	
Bacillus subtilis	Kigigha et al., 2018		10.67				9.67
Candida albicans	Ambade and Bhadbhade, 2015	20.00	11.00	15.00	6.00		
Escherichia coli	Kigigha et al., 2018		12.00				9.33
Escherichia coli	Jafari et al., 2012					12.00	
Lactobacillus acidophilus	Ambade and Bhadbhade, 2015	12.00	6.50	7.00	6.00		
Lactobacillus acidophilus	Oliveira et al., 2017	8.00					
Lactobacillus rhamnosuss	Ambade and Bhadbhade, 2015	18.00	8.00	12.00	6.50		
Pseudomonas aeruginosa	Kigigha et al., 2018		11.33				9.33
Pseudomonas aeruginosa	Suma and Tanuja, 2016					18.00	
Salmonella paratyphi	Zige and Ohimain, 2017		22.33				
Salmonella typhi	Zige and Ohimain, 2017		22.67				
Salmonella typhimurium	Zige and Ohimain, 2017		21.17				
Staphylococcus aureus	Kigigha et al., 2018		12.33				11.33
Staphylococcus aureus	Suma and Tanuja, 2016					19.00	
Staphylococcus aureus	Jafari et al., 2012					18.00	
Staphylococcus pyogenes	Suma and Tanuja, 2016					20.00	
Streptococcus	Ambade and	13.00	11.00	12.00	10.00		

salivarious	Bhadbhade, 2015				
Streptococcus gordonii	Oliveira et al., 2017	10.00			
Streptococcus mitis	Oliveira et al., 2017	19.00			
Streptococcus mitis	Ambade and Bhadbhade, 2015	14.00	10.00	12.00	9.00
Streptococcus mutans	Ambade and Bhadbhade, 2015	14.00	7.00	8.00	7.00
Streptococcus mutans	Oliveira et al., 2017	11.00			
Streptococcus oralis	Ambade and Bhadbhade, 2015	16.00	10.00	12.00	12.00
Streptococcus sanguinis	Oliveira et al., 2017	10.00			
Streptococcus sobrinus	Oliveira et al., 2017	11.00			

ANTIOXIDANT ACTIVITY

Oxidative stress plays a key role in the pathogenesis of aging and can be caused by various negative impacts such as gamma or UV radiations, environmental factors, polluted and poor-quality food, stress, some medications or treatments, smoking, alcoholism, etc. Prolonged oxidative stress inevitably leads to dangerous diseases such as cancer, cardiovascular diseases, or diabetes and premature aging. Oxidative stress can be reduced by antioxidant therapy, i.e., by consumption of certain amounts of natural antioxidants (Chaturvedi et al., 2017). Antioxidants are substances which delay or prevent the oxidation of an oxidizable substrate and they can either be natural or synthetic. Natural antioxidants are produced by biological systems. *C. citratus* showed high contents of total phenolic and total flavonoids, as well as high free radical scavenging capacity (Soliman et al., 2017). Ethanol extract of *C. citratus* leaves show the high total phenol content with potential as an antioxidant, because it acts inhibitory against free radical DPPH, and oxidative stability by Rancimat experiment with soybean oil (Hasim et al, 2015). Furthermore, *C. citratus* ethanol extract have hydrogen peroxide and hydroxyl radical scavenging activity, and chelating effect of ferrous iron activity. Apart of that *C. citratus* leaves extract have anti-glycation activity (Sari et al., 2017).

ANTIINFLAMATORY

C. citratus extract and its polyphenols inhibited the cytokine production on human macrophages. This supports the anti-inflammatory activity of *C. citratus* polyphenols in physiologically relevant cells. Concerning the effect on the activation of nuclear factor (NF)-kB pathway, the results pointed to an inhibition of LPS-induced NF-kB activation by *C. citratus* and polyphenol-rich fractions. Chlorogenic acid was identified, as the main phenolic acid of the *C. citratus* infusion, and it demonstrated to be, at least in part, responsible for that effect. Additionally, it was verified for the first time, that *C. citratus* and polyphenol-rich fractions inhibited the proteasome activity, a complex that controls NF-kB activation, having CGA a strong contribution (Francisco et al., 2013).

The evaluation of the anti-inflammatory activity of *C. citratus* leaves infusion and its flavonoid-rich and tannin-rich fractions was performed in the carrageenan-induced rat paw oedema model. Both central and peripheral analgesic activities were evaluated in mice through the hot plate test and the acetic acid-induced writhing test, respectively. In the acute inflammation model, the statistically significant results obtained in percentage of oedema inhibition. For the peripheral pain evaluation, statistically significant results showed a pain reduction. This demonstrates that *C. citratus* infusion compounds are able to reduce inflammation and peripheral pain *in vivo*, with polyphenols showing a significant contribution for these activities (Garcia et al., 2015).

ANTIDIABETIC ACTIVITY

Investigations show that *C. citratus* essential oil from stalks possesses high antioxidant activity by DPPH scavenging test. Furthermore, β-glucosidase inhibition assay was carried out using *in vitro* model for anti diabetic test, while anti-gout test was examined by xanthine oxidase inhibition assay. Results show that β-glucosidase activities tend to deceases as the concentration of *C. citratus* essential oil decreases. As the β-glucosidase inhibition increases, it indicated that the rate of carbohydrate digestion is higher and this scenario could help in reducing the level of blood sugar in human body thus decreases the risks of diabetes. In addition it can be concluded that lemongrass essential oil has great potential to be an alternative source of anti gout drugs as it has compounds containing xanthine oxidase inhibitor (Mirghani et al., 2012).

Evaluating the antidiabetic activities of essential oil from leaf sheath of *C. citratus* in poloxamer-407 induced type 2 diabetic Wistar rats in comparison to diabetic control rats showed that the *C. citratus* essential oil treated diabetic rats had significant amelioration of glycaemia, insulinamia and lipid dysmetabolism, accompanied by increased glucagon-like peptide-1 content in cecum and remarkable reduction of oxidative markers. Histopatholgical analysis of pancreas showed increase in β-cell mass, islet number and quality of insulitis. The results provided a pharmacological evidence of *C. citratus* essential oil as antidiabetic mediated by interaction of various phytoconstituents with multiple targets operating in diabetes mellitus (Bharti et al., 2013).

HYPOLIPIDEMIC ACTIVITY

Furthermore, it is concluded that *C. citratus* powder attenuated the serum lipid parameters dose dependently; hence, it can be considered as an arsenal for fighting against the health problems that have risen from elevated levels of lipid markers (Waheed et al., 2019).

CARDIOPROTECTIVE ACTIVITY

Diabetic dyslipidemia is a recognized risk factor for coronary heart disease. The aim of this study was to investigate the effect of *C. citratus* leaf extract on the atherogenic index of plasma in diabetic dyslipidemic rats. The extract, which tested positive for tannins, saponins, alkaloids, flavonoids, etc. lowered fasting blood glucose and glycosylated hemoglobin levels, and dose dependently decreased the serum levels of total cholesterol, LDL, VLDL, and HMG-CoA reductase, while simultaneously increasing HDL levels. The atherogenic index of plasma was lowered in a dose dependent manner in groups treated with *C. citratus* extract. The results indicate that the *C. citratus* extract had an ameliorative effect on hyperglycemia, hyperlipidemia, obesity, and atherogenic index of plasma (Ekpenyong et al., 2014).

Methanolic extracts of leaves and roots from *C. citratus* elicited relaxation on vascular smooth muscle. The present study demonstrated that citral from essential oil is able to produce vasorelaxation in rat aorta, which appeared to be through NO pathway and blockade of calcium channels. Meanwhile, the methanolic extracts from leaves and roots were observed to exert vasorelaxation via blockade of calcium channels. The leaf extract may also cause relaxation of vascular smooth muscle through PGI2 since inhibition of its synthesis by indomethacin resulted in contraction. However, the exact mode of action on the vasorelaxant effect caused by these test materials remains to be investigated. The findings from this study provide a scientific basis for the use of this plant in traditional medicine and merits further investigations (Devi et al., 2012).

RENOPROTECTIVE ACTIVITY

Renal injury is the most common side effect of aminoglycosides (bactericidal drugs, which are obtained from different species of *Streptomyces*). These antimicrobial drugs are particularly effective against Gram-negative microorganisms. The present study was conducted to investigate the renal protective activity of *C. citratus* in gentamicin induced nephrotoxicity. Biochemical kidney functioning parameters in male rabbits, urinary enzymes and histopathological examination were performed. The results of the this study showed that simultaneous administration of *C. citratus* and gentamicin significantly protected alteration in body weight, blood urea nitrogen, serum creatinine, creatinine clearance, serum uric acid, serum electrolytes, urinary volume, urinary protein, urinary lactate dehydrogenase and urinary alkaline phosphatase induced by gentamicin. Histological examination of the kidney also suggested the same. It is concluded from the current study that co administration of *C. citratus* with gentamicin for 3 weeks successfully prevented renal damage associated with aminoglycosides (Ullah et al., 2013).

SEDATIVE

Depression is a common serious psychiatric disorder and the available anti-depressant treatments are associated with many unwanted side-effects. Thus, various herbal products have been tried. The advantages of herbal treatments would include its complementary nature to the conventional treatment, thus making the latter a safer and cheaper option for depressive disorders. The objective of the present study was to evaluate the anti-depressant activity of *C. citratus* in albino mice and compare it with Imipramine. *C. citratus* significantly reduced the immobility time in both the tests compared with the control. The reduction in the duration of immobility at the dose of 10 mg/kg was comparable to imipramine. The essential oil of *C. citratus* has significant antidepressant activity comparable to imipramine (Dudhgaonkar et al., 2014). Significant anxiolytic effect was observed of the aqueous extract at different dose levels in mice. This clearly justified its folkloric application in the treatment of anxiety disorders (Arome et al., 2014). Furthermore, the Methanolic extract of *C. citratus* leaves at the dose of 200 mg/kg increased the percentage of time-spent and the percentage of arm entries in the open arms of the elevated plus-maze (EPM) and decreased the percentage of time-spent in the closed arms of EPM. Moreover, it prolonged the ketamine-induced latency to sleep but had no significant effects on total sleeping time induced by ketamine. Also, the locomotor activity was affected but not to the same extent as observed for diazepam. The anxiolytic effects of methanol extract *Cymbopogon citratus* leaves may be related to their content of flavonoids. This study validates the traditional use of the plant in management of anxiety (Shah et al., 2010).

After the inhalation, the *C. citratus* essential oil enhanced their cognitive performance for the domains of the continuity of attention and the quality of memory, whereas the mood in terms of alertness and calmness was also increased. However, no significant change in the blood pressure and heart rate was observed. The *C. citratus* essential oil inhalation could improve the cognitive function and modulate mood of healthy women with no effect on the physiological status. However, the underlying mechanisms of these positive effects still require further studies (Sriraksa et al., 2018).

ANTITUSIVE ACTIVITY

Antitussive activity of *C. citratus* ethanolic leaf extract was studied by inducing cough with citric acid in guinea pigs. The number of violent coughing fits was measured, while codeine phosphate was used as reference control. Both doses of *C. citratus* (100 and 200 mg/kg) significantly reduced the violent coughing fits in a dose dependent manner. Actually, the number of violent coughing fits observed with 100 and 200 mg/kg of *C. citratus* extract after citric acid administration was significantly reduced, by 65.36% and 85.43%, respectively. The antitussive effect produced by the *C. citratus* ethanolic leaf extract at 200 mg/kg was equipotent as that of the reference control codeine phosphate. According to the obtained results, the present study validates the traditional claims of *C. citratus* ethanolic leaf extract in the treatment of cough (Mani et al., 2017).

ANTICANCER ACTIVITY

Several natural products are nowadays employed as effective anticancer agents. In the last two decades the search for novel anticancer agents from natural sources has witnessed an impressive increase of interest. *C. citratus* essential oil initiate the cancer cell death by decreasing cell proliferation, increasing intracellular ROS, altering mitochondrial membrane potential and initiating apoptosis in human cervical adenocarcinoma (HeLa) and highly invasive squamous (ME-180) cell lines. The present findings of this study clearly demonstrate the involvement of oxidative mechanism for the anti-proliferative effect in HeLa and ME-180 cell lines (Ghosh, 2013). Furthermore, *C. citratus* essential oil showed potent activity against human lung carcinoma (A549) cell line but exhibited moderate effects on the HeLa cells. However, they are inactive against the human hepatocellular carcinoma (Hep3B) cell line. The results indicated that the essential oil of *C. citratus* could be considered as a promising candidate for the natural source of anticancer agents (Van et al., 2016).

Antigentoxic potential of *C. citratus* leaf aqueous extract against the cisplatin-induced gentoxicity in human peripheral leukocytes was investigated *in vitro*. Firstly, the antioxidant activity of plant extract was investigated by DPPH method which proved that *C. citratus* extract has good antioxidant potential. It enhanced the proliferation and increased cell count when compared to the control group. Furthermore, the expression of nucler protein Ki-67 as a marker of cell proliferation was tested immunocytochemically and the results supported the ameliorative effect of *C. citratus* against the gentoxic effect of cisplatin induced gentoxicity. The reduction of total genomic DNA fragmentation on agarose gel was noted among *C. citratus* treated group (El-Garawani, 2015).

The study aimed to explore the anticancer properties of *C. citratus* polysaccharide fractions β-d-xylofuranonose, by evaluating antiinflammatory and anticancer activities against cancer cells *in vitro* and the mechanism of action of the polysaccharides in inducing apoptosis in cancer cells via intrinsic pathway was also proposed. Two different human cancer cells such as cervical cancer (Siha) and prostate cancer (LNCap) were employed for *in vitro* studies on cytotoxicity. Induction of apoptosis and apoptotic DNA fragmentation, changes in mitochondrial membrane potential, and profiles of gene and protein expression in response to treatment of cells by polysaccharide fractions were also examined. It was established that these polysaccharide fractions exhibited potential cytotoxic and apoptotic effects on carcinoma cells, and they induced apoptosis in these cells through the events of up-regulation of caspase 3, down-regulation of bcl-2 family genes followed by cytochrome c relase (Thangam et al., 2014).

The antiproliferative potential of aqueous and ethanolic *C. citratus* extracts were tested on five different cancer cells: human colon carcinoma (HCT-116), breast carcinoma (MCF-7 and MDA-MB 231), ovarian carcinoma (SKOV-3 and COAV), and a normal liver cell line (WRL 68), while the antioxidant activity was investigated by DPPH radical scavenging assay. Both extracts showed appreciative metal chelating activity that revealed a concentration dependent trend. However, ethanolic extract proved to be more potent on breast cancer MCF-7 cell line and showed a moderate potency on the ovarian cancer (COAV) and MCF-7 cells. These results suggested antiproliferative efficacy of *C. citratus* ethanolic extract against human cancer cell lines (Halabi and Sheikh, 2014). Furthermore, the study describes the phytochemical and anticancer activity of *C. citratus* extracts on lung cancer (CALU6) cell line (Shanthala et al., 2018).

Doxorubicin is a chemotherapy drug used for the treatment of wide variety of cancers and the most effective antitumor agents, soon proved to be hampered by such serious problems as the development of cardiotoxicity and heart damage by producing free radicals and oxidative stress along the period of treatment. Doxorubicin induced significant increase in serum lactate dehydrogenase, CK-MB; alanine aminotransferase activities, urea, creatinine, malondialdehyde levels, reactive oxygen species contents. However, significant reduction in total antioxidant capacity and total proteins were observed. *C. citratus* pretreatment caused significant decrease in serum LDH and CK-MB levels, ALT, AST, urea, creatinine in serum, significant decrease in cardiac malondialdehyde, whereas, significant elevation in cardiac total antioxidant capacity and total protein, compared to doxorubicin-treated group. Histopathological examination of cardiac heart, liver and kidney tissues confirmed with the previous biochemical results, also, genomic DNA of cardiac heart tissues confirmed with the previous biochemical results. Chronic doxorubicin administration caused cardio toxicity and DNA damage. *C. citratus* pretreated exerted significant protection against Doxorubicin-induced cardiac damage (Ahmed and Ibrahim, 2018).

COSMETIC INDUSTRY

Citral is an aroma compound used in perfume industry for its citrus effect. Citral is also used for flavoring lemon oil (Ghosh, 2013). Perfume extraction refers to the extraction of aromatic compounds from lemongrass, using methods such as distillation, solvent extraction, expression or effleurage. The extracts are essential oils, absolutes, concretes, or butters, depending on the amount of waxes in the extracted product. Heat, chemical solvents, or exposure to oxygen in the extraction process modifies the aromatic compounds, either changing their odor, character or rendering them odorless. Three methods, solvent extraction, hydro distillation and enfleurage methods were used to extract essential oil from *C. citratus*. The extracted essential oil was formulated into perfume using a fixative and carrier solvent (Mane et al., 2015). *C. citratus* leaves that contain essential oils can be utilized in the production of perfumes that can mask body odors. *C. citratus* extracts obtained using Soxhlet extraction and solvent extraction (maceration) were utilized in the formulation of perfume using methanol and ethanol as solvent media. Physicochemical properties of the two formulations revealed that the essential oil has saponification value of 21.04 mg KOH/g and the densities of the two formulations in methanol and ethanol were 0.768 g/cm^3 and 0.82 g/cm^3 at 60 °C while the boiling point for both formulations was 85 °C. The essential oil can be profitably used for cosmetic grade and perfume formulations (Alhassan et al., 2018).

Antimicrobial properties make *C. citratus* essential oil effective drug for bacterial and fungal infections. It can be used for cleaning wounds and treating skin diseases such as ringworm (Singh et al., 2011). Results indicate that *C. citratus* essential oil has a noteworthy potential for the development of drugs for the treatment of fungal infections and skin inflammation that should be explored in future studies (Boukhatem et al., 2014). The objective of this study was to produce two antiseptic gels incorporating into each of them, individually, *C. citratus* essential oil, subsequently evaluating antimicrobial activity by minimum inhibitory concentration (MIC) test. Oils and gels were tested in parallel and showed a similar profile that can be observed in the inhibition concentration. This was a preliminary study that merits further investigation, which may include stability testing and evaluation of lower concentrations of oils incorporated into the gel base (Rohr et al., 2017). *C. citratus* essential oil was microencapsulated and applied in pressure – sensitive antimicrobial functional coatings on paper for secondary packaging. The results showed that microencapsulation methods were successful and resulted in container type single-core microcapsules. *In situ* microcapsule suspensions had better paper coating properties and were selected for industrial settings. The product enabled a prolonged use with the gradual release of citronella oil at multiple exposures of functional paper to pressure, e.g., by a human hand during product handling (Šumiga et al., 2019).

TOXICITY

The study aimed to examine the genotoxic effects of aqueous extract of *C. citratus*, prepared in 2%, 4% and 8% in the animal test system - *Mus musculus* L. The results showed that the bend the concentration of the aqueous extract of fresh leaves of lemon grass, bent also genotoxic effects on bone marrow *M. musculus*, inducing an increased frequency of micronucleus. This way, the consumption of *C. citratus* tea should be done with moderation and under health professionals monitoring (Abreu et al., 2019).

CONCLUSIONS

Cymbopogon citratus possesses good antibacterial activity, it could be used as alternative treatment for enteric fever, to cure infectious diseases related to the respiratory system, as well as for oral hygiene, it helps by removing bacteria from the oral cavity and prevents teeth and gum diseases such as peridontitis, plaque and gingivitis. Furthermore, *C. citratus* showed high contents of total phenolic and total flavonoids, as well as high free radical scavenging capacity with potential as an antioxidant. *C. citratus* shows good antiinflamatory, anti-diabetic, hypolipidemic, renoprotective and cardioprotective, as well as anticancer activities. Apart from this, *C. citratus* possesses vasorelaxant, sedative and antitusive potential. Furthermore, the compound citral is used in perfume industry as well as for cleaning wounds and treatment of skin diseases in forms of gels, or functional paper microencapsulated with essential oil, which can be used for hand hygiene.

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