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Mini Review

Biological properties of lemongrass: An overview

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Abstract

The use of herbal preparations remained the main approach of folk medicine to the treatment of ailments and debilitating diseases. Initial intensive researches conducted on Lemongrass extracts (tea) may have showed conflicting evidences, however the resurgence in claims of folk medicine practitioners necessitated further inquiry into the efficacy of the tea. Lemongrass tea contains several biocompounds in its decoction, infusion and essential oil extracts. Anti-oxidant, anti-inflammatory, anti-bacterial, anti-obesity, antinociceptive, anxiolytic and antihypertensive evidences of lemongrass tea were clearly elucidated to support initial pharmacological claims. Lemongrass tea was non-toxic, non-mutagenic and receives wide acceptance among alternative medicine practitioners in several developing countries. This review therefore presents previous research activities, technologies and information surrounding bioactivities of lemongrass tea. Areas of future researches which may elucidate mechanisms of the biological properties of lemongrass extracts were highlighted.

Introduction

The use of whole herbs and extractives has remained the main approach of folk medicine practitioners in the treatment of ailments and debilitating diseases. They usually claimed that such whole herbs and extractives are efficacious against several ailments and diseases without recourse to scientific proofs. Increased cases of opportunistic diseases emanating from side effects associated with synthetic drugs continue to necessitate incremental efforts in searching for effective biological substitutes with little or no side effects. Therefore, efforts are being directed towards elucidating potential sources such as ethno-medicinal plants (Patil, 2010). New, robust and less cumbersome extraction techniques assisted by recent developments in biotechnology have enhanced investigation of natural compounds faster with more precision than before leading to isolation of bioactive compounds with intense health benefits (Wang and Weller, 2006). According to folk medicine, several plants possess ethno medicinal benefits and *Cymbopogon citratus* Stapf, also known as lemongrass remained one of them.

Lemongrass is a perennial grass plant widely distributed worldwide and most especially in tropical and subtropical countries (Francisco *et al.*, 2011). Several reports have linked its origin to Asia (Indochina, Indonesia and Malaysia), Africa and the Americas. The plant could grow up to 6 inch high and its bulblike stems consist of terete and glabrous linearly venated sheathed leaves with narrow base and acute apex. The leaf height is about 100 cm in length and 2 cm in width. When squeezed, the leaves usually produce yellow or amber colored, aromatic, essential oil (Adejuwon and Esther, 2007). Its aqueous extract is commonly used as an aromatic drink while the whole plant is well incorporated into traditional food for its lemon flavour. It also enjoyed wide application in folk medicine (Figueirinha *et al.*, 2008). Traditionally, tea made from lemongrass leaves is popular among countries of South America, Asia and West Africa having been widely utilized as antiseptic, antifever, antidyspeptic, carminative and anti-inflammatory effects. Others are febrifuge, analgesic, spasmolytic, antipyretic, diuretic, tranquilizer and stomachic agent (Sawyerr, 1982, Viana *et al.*, 2000, Negrelle and Gomes, 2007; Adejuwon and Esther, 2007; Tatiana *et al*., 2011). In this review however, details about main medicinal properties of lemongrass tea will be clearly elucidated, while area of future researches will be well highlighted.

Lemongrass phytochemistry and technology

Lemongrass contains several important bioactive compounds which are useful in several health issues. These active compounds are normally found in the leaves and this is summarized in Table 1. The various methodologies used in extracting such bioactive compounds are also summarized in Figure 1.The root of lemongrass is also being used as chewing stick for mouth cleaning in several parts of the world

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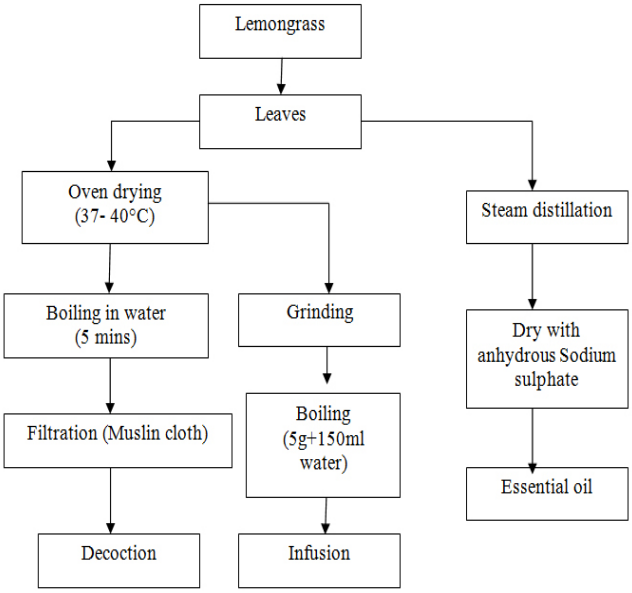

Figure 1. Methods of extracting bioactive compounds from lemongrass

(Sawyerr, 1982).

Essential oil is one of the important components of lemon grass extracts and its applications include co-ingredients for perfumes and cosmetics. Its high citral composition has made it important for several chemical syntheses (Negrelle and Gomes, 2007). Similarly, investigations carried out on different lemongrass extracts showed other important therapeutic potentials such as anti-cancer, anti-hypertensive and anti-mutagenicity. Others include non-toxic properties, anti-diabetic, anti-oxidant, anxiolytic, anti-nociceptive and anti-fungi (Shah *et al*., 2011).

Initially, the use of lemongrass extract in folk medicine for the treatment of certain ailment was disputed, but recent findings have confirmed its efficacy (Adejuwon and Esther, 2007; Celso *et al.*, 2011a). Despite this, lemongrass tea and its essential oils is becoming unpopular especially among developing nations. This might be due to lack of awareness of published results on the efficacy of the extracts on several health related issues. Hence, the focus of this review is to concisely document all reported biological properties of lemongrass extracts (infusion and decoction) and essential oils. Similarly, suggestions regarding future directions in this area of study were thoroughly prepared to ease the path towards elucidation of inherent medicinal properties of lemongrass.

Lemon grass extracts contained several medicinal chemical components which reside in its essential oil and aqueous extract as summarized in Table 1. Detail information on performance of all these compounds are concisely presented in next section.

Table 1. Bioactive compounds from lemon grass extract and essential oil

Component	Biological activities	References
Myrcene	Antibacterial activity	Grace *et al.*, 1984
Citral	Antibacterial activity	Grace *et al.*, 1984;
α-citral (geranial)	Antinociceptive activities	Viana *et al.*, 2000;
β-citral (neral)		Dharmendra *et al.*, 2001
Heptenone	Not available	Grace *et al.*, 1984
Dipentene	Not available	Grace *et al.*, 1984
Limonene	Not available	Berenice *et al.*, 1991; Grace *et al.*, 1984
Linalool	Not available	Berenice *et al.*, 1991; Grace *et al.*, 1984
Borneol	Not available	Grace *et al.*, 1984
Geranial	Antimicrobial action,	Mirghani *et al.*, 2012
Geraniol	Antiviral activity,	Celso *et al.*, 2011;
Limonene	Anti-oxidant activity	Bidinotto *et al.*, 2010;
β-myrcene	Anti-gout activity	Blanco *et al.*, 2009;
6-methyl-5-hepten-2-ona	Anti-diabetic activity Anxiolytic	Costa *et al.*, 2006;
undecan-2-one	properties	Viana *et al.*, 2000;
	Antinociceptive activity	Dharmendra *et al.*, 2001,
	Anti-fungal activity	Shigeharu *et al.*, 2001; Berenice *et al.*, 1991
Citronellol	Anti-fungal activity	Dharmendra *et al.*, 2001; Berenice *et al.*, 1991

Pharmacological properties of lemongrass

Anti-inflammatory properties

Tissue inflammation is one of the main health issues worldwide. The hike in its prevalence has been attributed to sophisticated lifestyles occasioned by technological advancement. Therefore, inflammation accounts for more cases of mortality among people. Importantly, it has been linked with other health problems like cancer, cardiovascular rheumatoid, neurodegenerative and diabetes (Jaswir and Monsur, 2011). Inflammation in animal tissue is usually triggered by physical stress or when chemical inducers (e.g. lipopolysaccharide) are present within the tissue composition. Mechanistically, inflammation will occur when lipopolysaccharide (LPS) is incubated with macrophages thereby leading to secretion of pro-inflammatory mediators such as nitric oxide (NO) and prostaglandin E2 (PGE2). Other inductive factors include reactive oxygen species (ROS), cytokines which includes tumor necrosis factor-TNF-α, interleukins and up-regulation of nuclear factor keppa-B cells proteins (NF-κB).

Inducible Nitric Oxide Synthase (iNOS) and Cyclo-oxygenase (COX-2) are responsible for the release of NO and PGE2 while TNF-α trigger NF-κB and mitogen-activated protein kinases (MAPK) pathways. To complete the list, the latter is responsible for p38-MAPK, c-Jun N-terminal kinases (JNK) and extracellular-signal-regulated kinases (ERK) (Kulinsky, 2007).

Solvent extracts, polyphenol rich extractants and citral isolate are the chief components of lemongrass exhibiting anti-inflammatory activities as reported by several investigators. Similarly, aqueous extracts

devoid of lipid and essential oil and polyphenol fractions (phenolic acids, flavonoids and tannins) of lemongrass leaves were investigated for their anti-inflammatory properties. Aqueous lemongrass extract inhibited secretion of NO, PGE2 and expression of iNOS, but not COX-2 in LPS induced RAW 264.7 macrophage cell lines and skin-derived dendritic cell line (FSDC) (Figueirinha *et al*., 2010; Francisco *et al*., 2011). Furthermore, same extract was also reported to inhibit LPS induced phosphorylation of p38MAPK and JNK 1/2 but no effect on ERK 1/2 activation. Degradation of IκBα by LPS induction was prevented by aqueous extract by inhibiting NF-κB activation (Francisco *et al*., 2011).

The polyphenolic fractions of the extracts have been demonstrated to reduce secretion of NO and expression of iNOS in LPS stimulated skin-derived dendritic and RAW 264.7 cell lines. However, flavonoids and tannins fractions exhibited better anti-inflammatory potency due to presence of luteolin glycosides. Phenolic acids on the other hand exhibit satisfactory inhibition of PGE2 production in LPS induced RAW 264.7 macrophage. None of the lemongrass polyphenolic fractions inhibited COX-2 expression (Lee *et al*., 2008; Figueirinha *et al*., 2010; Francisco *et al*., 2011). The removal of the essential oil, which contains citral has been opined for such inactivity. Similarly, ethanolic lemongrass extract (50%) is efficacious against inflammation caused by LPS induced by murine alveolar macrophages. The mechanism of action is by inhibiting the secretion of NO and pro-inflammatory cytokine tumor necrosis factor TNF-α (Tiwari *et al.*, 2010).

Citral, and other monoterpenes from lemongrass, exhibits *in-vivo* anti-inflammatory using carrageenan induced paw edema and peritonitis in model rat. Paw edema was reportedly reduced by application of citral (100 and 200 mg/kg body weight) and peritonitis was also reduced as leukocyte conversion to peritoneal cavity was mitigated (Quintans-Júnior *et al*., 2010). In addition, citral is dose dependent in reducing COX-2 mRNA, protein expression and activated peroxisome proliferator-activated receptor (PPARα and γ) in LPS induced U937 human macrophage-like cells (Katsukawa *et al.*, 2010). PPARα and γ are group of nuclear receptor proteins that play essential role in regulation of cell development, differentiation and metabolism by functioning as transcription factor (Kulinsky, 2007).

Equally, Citral was reported to inhibit cytokine production by reducing IL-1β, IL-6 and IL-10 production before and after LPS introduction in animal and peritoneal macrophages, while aqueous methanolic (70%) extract of lemongrass only inhibited IL-6 production (Sforcin *et al.*, 2009; Bachiega and Sforcin, 2011). Water extract of lemongrass, containing linalool and epoxy-linalool oxides, was reported to inhibit IL-1β but induce IL-6 (Sforcin *et al.*, 2009).

Lemongrass tea has been proven to possess analgesic activity due to presence of terpenes (especially myrcene). Hyperalgesia induced by both carrageenan and PGE2, but not dibutyryl cyclic AMP in rat was reported to ameliorated by oral administration of lemongrass infusion in a dose dependent manner (Lorenzetti *et al.*, 1991; Sforcin *et al*., 2009). Oral application of decoction obtained from lemongrass also possess anti-inflammatory properties by reducing rat hind paw edema previously induced by a subplantar injection of carrageenan (Carbajal *et al*., 1989).

Anti-oxidant properties of lemongrass tea

Oxidation is a fundamental process in human cells, tissue and systems leading to formation of reactive oxygen species (ROSs) which include hydrogen peroxide (H_2O_2), superoxide anion (O^{2-}) and free radicals (Heo *et al*., 2003). Due to its reactivity, ROSs damage biochemical components like cell membrane, cellular lipids, proteins and DNA (Devasagayam *et al*., 2004). Additionally, ROS(s) function as major inducer of several health issues like atherosclerosis, rheumatoid arthritis and muscle destruction. Others are cataracts, certain neurological disorders, cancer and ageing. Antioxidants have to be present in the body to offer protective mechanism against damaging effects of oxidation process caused by these radicals (Finkel, 1998; Thannickal and Fanburg, 2000).

Researchers have identified antioxidant potentials of lemongrass extracts and documented their abilities to reduce ROSs. Such mechanism include inhibition of lipoperoxidation and decolorization of 2,2-diphenyl-1-picrylhydrazyl (DPPH) (Sharma and Bhat, 2009; Mirghani *et al.*, 2012). Infusions and decoctions prepared from lemongrass showed anti-oxidant properties by scavenging superoxide anion, inhibiting lipoperoxidation and decolorizing DPPH. These effects are higher in infusion than decoction (Cheel *et al*., 2005). Similarly, lemongrass infusion exhibited stronger antioxidant activities in relation to other extracts (methanolic, 80% aqueous ethanol and decoction). Further studies revealed that tannin and flavonoid fractions of oil-free infusion extract were most active anti-oxidative agents compared to phenolic acids fraction (Figueirinha *et al.*, 2008). Aqueous ethanol extract was reported to exhibit antioxidant properties by decreasing reactive oxygen species production and lipid peroxidation, as well

as, increasing superoxide dismutase activity and glutathione formation (Tiwari *et al.*, 2010). Recently, essential oil of lemongrass was also reported to show antioxidant property by DPPH scavenging test. The results showed that both leaves and stalk extracts possess radical scavenging ability in a dose dependent manner (Mirghani *et al*., 2012).

Anti-bacteria potential of lemongrass tea

Anti-bacterial activity in extracts of plant materials has been elucidated from various sources in recent times with promising results. This characteristic has also been investigated in the volatile oil portion of the aqueous extract of lemon grass (Grace *et al*., 1984). Among the major bioactive compounds identified in the oil were α-citral (geranial) and β-citral (neral) components. These components demonstrate their antibacterial activity by inhibiting the growth of both Gram positive and Gram negative bacteria. However the third component- myrcene possess no antibacterial activity individually but do enhance activity when combined with others (Grace *et al*., 1984).

Anti-obesity and antihypertensive activity of lemon tea

Several investigations have been carried out on the potentials of lemon grass extract as a source of hypolipidemic and hypoglycemic substances which may lower the risks of hypertension and obesity. Available reports showed that citratus aqueous extracts when fed to rats at 500 mg/kg/day led to significant reduction in hypoglycemic index in spite of counter-regulatory factors such as catecholamine, cortisol and glucagon. Hypolipidemic effect was recorded with noticeable reduction in low density lipids levels in the blood stream. The mechanism by which the tea effectively performs these effects remained elusive but several researchers have associated it with increased insulin synthesis and secretion (hyperinsulinemia) or increased peripheral glucose utilization (Adejuwon and Esther, 2007; Celso *et al*., 2011a).

The presence of anti-hypertensive compounds such as flavonoids and alkaloids has been reported to assist in the hypoglycemic properties exhibited by lemon grass aqueous extract since it contains essential oil and other extractants (Onabanjo *et al.*, 1993; Oladele *et al.*, 1995). Similarly, lemon grass extracts were efficacious in reducing cholesterol levels in the blood stream. Investigators opined that this could be due to the presence of an endogenous ligand of central-type benzodiazepine receptors known as endozepine octadecaneuropeptide (ODN), which are inhibitors of food intake in small animals (Do Rego *et al.*, 2007).

Anxiolytic properties of lemongrass tea

In order to elucidate its efficacy in curing anxiety related conditions, researchers have investigated anxiolytic properties of lemongrass tea (Liberalli *et al*., 1946; Alves *et al.*, 1960; Olaniyi *et al.*, 1975; Nogueira, 1983). Earlier investigations reported negative effects related to anxiolytic properties of the decoctions made from lemon tea (Carlini *et al*., 1986; Leite *et al.*, 1986). However, recent experimental results revealed that decoctions and infusion (lemon grass tea) made from lemon grass actually exhibit the potential to cause anxiolytic effects when they are fed to animals (Celso *et al.*, 2011a). This was evident from positive results recorded in Light/dark box test. In this particular test, a biphasic dose response (U-shaped) curve which was similar to the curves extensively studied by Calabrese and Baldwin (2003) was reported. Similarly, the anxiolytic effects of the extract appeared to follow a GABAergic system signaling behaviour with established anxiolytic drugs (Celso *et al.*, 2011b). These reports therefore buttressed the use of lemongrass extracts for treatment of ailments of central nervous system (CNS) in folk medicine. However, there are unanimous reports among researchers on the safety of lemon grass tea for domestic and other uses as opined by folk medicine practitioners (Souza Formigoni *et al*., 1986; Leite *et al*., 1986; Carlini *et al*., 1986; United States Environmental Protection Agency, 1997).

Antinociceptive properties of lemon tea

The possibility of lemon tea possessing antinociceptive effects has been well researched over the years. Earlier reports showed that lemon grass extracts has little or no positive actions thereby negating the claims in folk medicine (Carlini *et al*., 1986; Leite *et al*., 1986; Souza-Formigoni *et al.*, 1986). However, recent investigations presented contra reports. According to Viana *et al.* (2000), lemon grass tea possessed antinociceptive property which was evident in positive results from different nociceptive testes performed on the extract. Essential oil of lemon grass, which contained citral but no myrcene was investigated for their antinociceptive activities using three experimental models of nociception in mice. The hot plate test showed that response to stimulus by the mice was increased by essential oil administered intra-peritoneally (I.P.) while writhing by acetic acid induction showed that intra-peritoneal and oral administration of essential oil caused inhibition of abdominal contraction in a dose dependent manner. In the formalin test, licking time was drastically inhibited by essential oil administered I.P. at both first and second phase of the

experiment (Viana *et al.*, 2000). They reported that opioid receptors are involved in the antinociceptive action since antagonist naloxone blocked the effects of the tested essential oils present in the extract. Same group of investigators opined that the discrepancy noticed with regards to earlier reports could be due to differences in plant chemotypes used for analysis. Citral, obtained from lemongrass, has been reported to possess anti-nociception properties according to the findings of Quintans-Junior *et al.* (2011) using acetic acid induced writhing and nociception induced by formalin. It was concluded that citral is capable of exhibiting peripheral antinociceptive property by inhibiting writhing and nociception.

Anti-fungi properties of lemon tea

The action of essential oils extracted from lemon grass decoction against both pathogenic and edible fungi is of immense contribution as investigated by researchers. Lemon grass oil showed a promising prospect among several essential oils by inhibiting the growth of fungi cells which are implicated in secreting mycotoxins during storage of grains and other food products (Fandohan *et al.*, 2008; Nguefacka *et al.*, 2012). Here, the synergistic effects of oil fractions showed both synergistic and antagonistic effects among different portion of characterized oils (Viana *et al*., 2000; Nguefacka *et al.*, 2012). Essential oil fraction of lemon tea has been reported to exhibit anti-fungal effects against filamentous fungi of different classes thereby showing its broad spectrum of activity against both disease causing and non pathogenic fungi. Similarly, the oil is capable of inactivating disease causing yeast cells (*Candida* spp.) by inhibiting their growth (Dharmendra *et al.*, 2001).

Cytotoxicity and anti-mutagenicity

Several studies (both *in-vivo* and *in-vitro*) have been conducted to investigate cytotoxicity and mutagenicity effects of lemongrass extract in order to confirm the safety of lemongrass tea. All phenolic compounds isolated from methanolic extract of lemongrass were nontoxic to human lung fibroblasts even at high concentration (1 mM) (Cheel *et al*., 2005). In another study, adult rats subjected to oral consumption of lemongrass tea for 2 months did not cause any toxicity effect on both the rat and their resulting offspring (Lucia *et al.*, 1986). Rat repeatedly feed with lemongrass myrene did not develop tolerance unlike analgestic drug morphine (Sforcin *et al*., 2009). Protection of mitochondria membrane integrity in stressed murine alveolar macrophages was reportedly restored by 5% ethanol extract of lemongrass therefore exhibiting cytoprotective property (Tiwari *et al*., 2010). Lemongrass extract obtained using 80% ethanol did not show any matagenic properties in *Salmonella* mutation test. Even, the extract was able to counter chemical mutation in *Salmonella typhimurium* strains TA98 and TA100 (Vinitketkumnuen *et al.*, 1994). Also, damage to chromosome induced by mitomycin C in human lymphocytes was inhibited by lemongrass (Meevatee *et al*., 1993). Bidinotto *et al*. (2011) investigated protective effect of essential oil from lemongrass in N-methyl-N-nitrosurea (MNU) induced leukocyte DNA female Balb/C mice. It was reported that lemongrass essential oil exhibited protective action against MNU-induced DNA damage.

Consumption of lemongrass infusion preparation was tested for toxicity effect on human. The toxicology effect was reported to be negative as there were no differences in serum biochemical assays, urine analysis and physical examination after 6 and 14 days of drinking lemongrass tea. Although, slight increase in bilirubin and amylase in some of the volunteers observed, such increase did not exhibit any medical implication. Furthermore, lemongrass tea did not show any hypnotic and anxiolytic properties (Leite *et al*., 1986).

Toxicity and gastric tolerance of three essential oils, including that of lemongrass, were tested in adult rat. Lemongrass essential oil did not show any acute (1 day) and sub-acute (14 days) toxicity when dosed at 5-1500 mg/Kg body weight, but at higher dose, 2000 and 3000 mg/Kg body weight, abnormalities were recorded. LD50 is >3500 mg/Kg body weight. Also, low dosage of oil did not show change in morphological structural of rat stomach and liver, however, higher dosage of oil result into hepatocytes necrosis and leukocytes infestation of liver parenchyma alongside with alteration of stomach structure. Therefore, essential oil from lemongrass is safe for human consumption and can be used for maize storage at prescribe concentration (Fandohan *et al*., 2008).

Future trends

Most studies on lemongrass tea and extracts are prepared through infusion, decoction or organic solvent extraction without considering effects of other factors, such as method of cultivation, harvesting time, controlled oxidation/fermentation, roasting/ frying and withering conditions. Previous works have reported that these factors affect composition, physicochemical and biological properties of tea from other sources (Dix *et al*., 1981). There are possibilities that properties of lemongrass tea

might also be affected if studies consider the above mentioned factors.

Also, conventional solvent extraction techniques form majority of the works on lemongrass. Other extraction aiding method like microwave aided extraction, ultrasonic aided extraction, enzymatic aided extraction, high pressure processing, sub-critical water extraction and supercritical fluid extraction have not been well explored, if studied at all. These novel techniques have been reported to give improve yield and biological properties of products (Wang and Weller, 2006). Supercritical fluid extraction of essential oil from lemongrass was reported to give higher yield compared to hydro-distillation method (Marongiu *et al.*, 2006). Efforts have also been made to investigate the effects of ultrasound processing during the production of lemongrass essential oil-alginate nanoemulsions. This will eventually enhance incorporation of lemongrass essential oil in food matrix and increase its bioavailability (Salvia-Truijillo *et al.*, 2012).

Furthermore, it has been reported that clarification of beverage improve appearance and beverage qualities, no study of such on lemongrass tea has been reported. All these areas that have been identified should form the focus of future researchers working on lemongrass.

References

Adejuwon, A. A. and Esther, O. A. 2007. Hypoglycemic and hypolipidemic effects of fresh leaf aqueous extract of *Cymbopogon citratus* Stapf in rats. Journal of Ethnopharmacology 112: 440–444.

Alves, A. C., Prista, L. N. and Souza, A. F. 1960. A preliminary note on the phytochemical study of *Cymbopogon citratus.* Garcia de Orta 8: 629-638.

Amit, K. T. and Anushree, M. 2010. Liquid and vapour-phase antifungal activities of selected essential oils against candida albicans: microscopic observations and chemical characterization of *Cymbopogon citratus.* Complementary and Alternative Medicine 10: 1-11.

Bachiega, T. F. and Sforcin, J. M. 2011. Lemongrass and citral effect on cytokines production by murine macrophages. Journal of Ethnopharmacology 137: 909– 913.

Bidinotto, L. T., Costa, C. A. R. A., Salvadori, D. M. F., Costa, M., Rodrigues, M. A. M. and Barbisan, L. F. 2011. Protective effects of lemongrass (*Cymbopogon citratus* StapF) essential oil on DNA damage and carcinogenesis in female Balb/C mice. Journal of Applied Toxicology 31: 536–544.

Blanco, M. M., Costa, C. A. R. A., Freire, A. O., Santos Jr., J. G. and Costa, M., 2009. Neurobehavioral effect of essential oil of *Cymbopogon citratus* in mice. Phytomedicine 16: 265–270.

Calabrese, E. J. and Baldwin, L. A. 2003. Hormesis: the dose–response revolution. Annual Review of Pharmacology and Toxicology 43: 175–197.

Carbajal, D., Casaco, A., Arruzazabala, L., Gonzalez, R. and Tolon, Z. 1989. Pharmacological study of *Cymbopogon citratus* leaves. Journal of Ethnopharmacology 25: 103-107.

Carlini, E. A., Contar, J. D. P., Silva, -F. A. R., Da Silvera, -F. N. G., Frochtengarte, M. L. and Bueno, O. F. A. 1986. Pharmacology of lemongrass (*Cymbopogon citrates* Stapf.). I. Effects of teas prepared from leaves on laboratory animals. Journal of Ethnopharmacology 17: 37–64.

Cheel, J., Theoduloz, C., Rodrguez, J. and Schmeda, -H. G. 2005. Free radical scavengers and antioxidants from lemongrass (*Cymbopogon citratus* (DC.) Stapf.). Journal of Agricultural and Food Chemistry 53: 2511–2517.

Costa C. A., Kohn D. O., de Lima V. M., Gargano A. C., Flório J. C. and Costa, M. 2011. The GABAergic system contributes to the anxiolytic-like effect of essential oil from *Cymbopogon citratus* (lemongrass). Journal of Ethnopharmacology 137: 828–836.

Costa, C. A. R. A., Gargano, A. C. and Costa, M. (2006). Anxiolytic-like effect of the essential oil from *Cymbopogon citratus* in experimental procedures in mice. European Neuro psychopharmacology 16: S475–S1475.

Costa, C. A., Bidinotto, L. T., Takahira, R. K., Salvadori, D. M., Barbisan, L. F. and Costa, M. 2011. Cholesterol reduction and lack of genotoxic or toxic effects in mice after repeated 21-day oral intake of lemongrass (*Cymbopogon citratus*) essential oil. Food and Chemical Toxicology 49: 2268–2272.

Devasagayam, T. P. A., Tilak, J. C., Boloor. K. K., Sane, Ketaki, S., Ghaskadbi, Saroj, S. and Lele, R. D. 2004. Free Radicals and Antioxidants in Human Health: Current Status and Future Prospects. Journal of Association of Physicians of India 52: 794-804.

Dharmendra, S., Suman, P. S. K., Atul, P. K., Subhash, C. G. and Sushil, K. 2001. Comparative antifungal activity of essential oils and constituents from three distinct genotypes of *Cymbopogon* spp. Current Science 80: 1264-1266.

Dix, M. A., Fairley, C. J., Millin, D. J. and Swaine, D. 1981. Fermentation of tea in aqueous suspension. Influence of tea peroxidase. Journal of the Science of Food and Agriculture 32: 920–932.

do Rego, J. C., Orta, M. H., Leprince, J., Tonon, M. C., Vaudry, H. and Costentin, J. 2007. Pharmacological characterization of the receptor mediating the anorexigenic action of the octadecaneuropeptide: evidence for an endozepinergic tone regulating food intake. Neuropsychopharmacology 32: 1641–1648.

Fandohan, P., Gnonlonfin, B., Laleye, A., Gbenou, J. D., Darboux, R. and Moudachirou, M. 2008. Toxicity and gastric tolerance of essential oils from *Cymbopogon citratus*, *Ocimum gratissimum* and *Ocimum basilicum* in Wistar rats. Food and Chemical Toxicology 46: 2493–2497.

Figueirinha, A., Cruz, M. T., Francisco, V., Lopes, M. C. and Batista, M. T. 2010. Anti-inflammatory activity of *Cymbopogon citratus* leaf infusion in lipopolysaccharide-stimulated dendritic cells: contribution of the polyphenols. Journal of Medicinal Food 13: 681-90.

Figueirinha, A., Paranhos, A., Pe´rez-Alonso, J. J., Santos-Buelga, C. and Batista, M. T. 2008. *Cymbopogon citratus* leaves: Characterisation of flavonoids by HPLC–PDA–ESI/MS/MS and an approach to their potential as a source of bioactive polyphenols. Food Chemistry 110: 718–728.

Finkel, T. 1998. Oxygen radicals and signalling. Current Opinion in Cell Biology 10: 248–253.

Francisco, V., Figueirinha, A., Neves, B. M., García-Rodríguez, C., Lopes, M. C., Cruz, M. T. and Batista, M. T. 2011. Cymbopogon citratus as source of new and safe anti-inflammatory drugs: bio-guided assay using lipopolysaccharide-stimulated macrophages. Journal of Ethnopharmacology 133: 818–827.

Heo, S. J., Lee, K. W., Song, C. B. and Jeon, Y. J. 2003. Antioxidant activity of enzymatic extracts from brown seaweeds. Algae 18: 71-81.

Jaswir, I. and Monsur, A. H. 2011. Anti-inflammatory compounds of macro algae origin: A review. Journal of Medicinal Plants Research 5: 7146-7154.

Katsukawa, M., Nakata, R., Takizawa, Y., Hori, K., Takahashi, S. and Inoue, H. 2010. Citral, a component of lemongrass oil, activates PPARα and γ and suppresses COX-2 expression. Biochimica et Biophysica Acta (BBA) - Molecular and Cell Biology of Lipids 1801: 1214-1220.

Kulinsky, V. I. 2007. Biochemical aspects of inflammation. Biochemistry 72: 595-607.

Lee, H. J., Jeong, H. S., Kim, D. J., Noh, Y. H., Yuk, D. Y. and Hong, J. T. 2008. Inhibitory effect of citral on NO production by suppression of iNOS expression and NF-kappa B activation in RAW264.7 cells. Archives of Pharmacal Research 31: 342-349.

Leite, J. R., Seabra, M. L., Maluf, E., Assolant, K., Suchecki, D., Tufik, S., Klepacz, S., Calil, H. M. and Carlini, E. A. 1986. Pharmacology of lemongrass (*Cymbopogon citratus* Stapf). III. Assessment of eventual toxic, hypnotic and anxiolytic effects on humans. Journal of Ethnopharmacology 17: 75–83.

Liberalli, C. H., Helou, J. H. and Franca, A. A. 1946. Contribuicao ao estudo das gramineas aromaticas. O capim-cidrao: *Cymbopogon citratus* DC.) Stapf. Reuista Brasileira de Farmacia 4: 189-209.

Lorenzetti, B. B., Souza, G. E. P., Sarti, S. J., Filho, D. S. and Ferreira S. H. 1991. Myrcene mimics the peripheral analgesic activity of lemongrass tea. Journal of Ethnopharmacology 34: 43-48.

Lorenzetti, B. B., Souza, G. E., Sarti, S. J., Santos, F. D. and Ferreira, S. H. 1991. Myrcene mimics the peripheral analgesic activity of lemongrass tea. Journal of Ethnopharmacology 34: 43-48.

Lucia, M. O., Formigoni, S., Lodder, H. M., Filho, O. G., Ferreira, T. M. S. and Carlini, E. A. 1986. Pharmacology of lemongrass (*Cymbopogon citratus* Stapf). II. Effects of daily two month administration in male and female rats and in offspring exposed "in utero". Journal of Ethnopharmacology 17: 65-74.

Marongiu, B., Piras, A., Porcedda, S. and Tuveri, E. 2006. Comparative analysis of the oil and supercritical CO_2 extract of *Cymbopogon citratus* Stapf. Natural Product Research 20: 455–459.

Meevatee, U., Boontim S., Keereeta, O., Vinitketkumnuen, U. and Oariyakul, N. 1993. Antimutagenic activity of lemon grass, in: Boot-in S. (Ed.), Man and Environment, Chiang Mai University Press p. 346.

Mirghani, M. E. S., Liyana, Y. and Parveen, J. 2012. Bioactivity analysis of lemongrass (*Cymbopogan citratus*) essential oil. International Food Research Journal 19: 569-575.

Negrelle, R. R. B. and Gomes, E. C. 2007. Cymbopogon citratus (DC.) Stapf: chemical composition and biological activities. Revista Brasileira de Plantas Medicinais 9: 80-92.

Nguefack, J., Tamgue, O., Dongmo, J. B. L., Dakolea, C. D., Leth, V., Vismer, H. F., Zollo, P. H. A. and Nkengfack, A. E. 2012. Synergistic action between fractions of essential oils from *Cymbopogon citratus*, *Ocimum gratissimum* and *Thymus vulgaris* against *Penicillium expansum*. Food Control 23: 377-383.

Nogueira, M. J. C. 1983. Fitoterapia popular e enfermagem comunitária. São Paulo, Tese (Livre-Docência) - Escola de Enfermagem, Universidade de São Paulo 12: 8-11.

Oladele, S. B., Ayo, J. O. and Adaudi, A. O. 1995. Medicinal and physiological properties of flavonoids, coumarin derivatives and anthraquinones of plant origin. West African Journal of Pharmacology and Drug Research 11: 134–144.

Olaniyi, A. A., Sofowora, E. A. and Oguntimehin, B. O. 1975. Phytochemical investigation of some Nigerian plants used against fevers. II. *Cymbopogon citratus.* Planta Medica 28: 186-189.

Onabanjo, A. O., Agbaje, E. O. and Odusote, O. O. 1993. Effects of Aqueous Extracts of *Cymbopogon citratus* in Malaria. Journal of Protozoological Research 3: 40–45.

Onawunmi, G. O., Yisak, W. A. and Ogunlana, E. O. 1984. Antibacterial constituents in the essential oil of *Cymbopugon citratus* (dc.) Stapf. Journal of Ethnopharmacology 12: 274-286.

Patil, A. S. 2010. Exploring Passiflora incarnata (L.): A medicinal plants secondary metabolites as antibacterial agent. Journal of Medicinal Plants Research 4: 1496-1501.

Quintans-Júnior, L. J., Guimarães, A. G., Santana, M. T., Araújo, B. E. S., Moreira, F. V., Bonjardim, L. R., Araújo, A. A. S., Siqueira, J. S., Antoniolli, A. R., Botelho, M. A., Almeida, J. R. G. S. and Santos, M. R. V. 2011. Citral reduces nociceptive and inflammatory response in rodents. Brazilian Journal of Pharmacognosy 21: 497-502.

Salvia-Truijillo, L., Rojas-Grau, A., Soliva-Fortuny, R. and Martin-Belloso, O. 2012. Physicochemical Characterization of Lemongrass Essential Oil-Alginate

Nanoemulsions: Effect of Ultrasound Processing Parameters. Food and Bioprocess Technology 6: 2439-2446.

Sawyerr, E. 1982 Traditional medicine in Sierra Leone - a critical appraisal. Nigerian Journal of Pharmacy 13: 28-33.

Sforcin, J. M., Amaral, J. T., Fernandes Jr., A., Sousa, J. P. B. and Bastos, J. K., 2009. LG effects on IL-1 and IL-6 production by macrophages. Natural Product Research 23: 1151–1159.

Shah, G., Shri, R., Panchal, V., Sharma, N., Singh, B. and Mann A. S. 2011. Scientific basis for the therapeutic use of *Cymbopogon citratus*, stapf (Lemon grass). Journal of Advanced Pharmaceutical Technology and Research 2: 3–8.

Sharma, O. P. and Bhat, T. K. 2009. DPPH antioxidant assay revisited. Food Chemistry 113: 1202–1205.

Shigeharu, I., Toshio, T. and Hideyo, Y. 2001. Antibacterial activity of essential oils and their major constituents against respiratory tract pathogens by gaseous contact. Journal of Antimicrobial Chemotherapy 47: 565-573.

Souza, F. M. L., Lodder, H. M., Gianotti, F., O., Ferreira, T. M. and Carlini, T. A. 1986. Pharmacology of Lemon grass (*Cymbopogon citratus* Stapf.). II. Effects of daily two month administration in male and female rats and in offspring exposed "in utero". Journal of Ethnopharmacology 17: 65–74.

Tatiana, F. B. and José, M. S. 2011. Lemongrass and citral effect on cytokines production by murine macrophages. Journal of Ethnopharmacology 137: 909– 913.

Thannickal, V. J. and Fanburg, B. L. 2000. Reactive oxygen species in cell signalling. American Journal of Physiology Lung Cellular and Molecular Physiology 279: 1005–1028.

Tiwari, M., Dwivedi, U. N. and Kakkar, P. 2010. Suppression of oxidative stress and pro-inflammatory mediators by *Cymbopogon citratus* D. Stapf extract in lipopolysaccharide stimulated murine alveolar macrophages. Food and Chemical Toxicology 48: 2913-2919.

United States Environmental Protection Agency, 1997. EPA REDS Fact sheet Oil of *Citronella* (*Cymbopogon citratus*) no: EPA-738-F-97-002.

Viana, G. S. B., Vale, T. G., Pinho, R. S. N. and Matos, F. J. A. 2000. Antinociceptive effect of the essential oil from *Cymbopogon citratus* in mice. Journal of Ethnopharmacology 70: 323–327.

Vinitketkumnuen, U., Puatanachokchai, R., Kongtawelert, P., Lertprasertsuke, N. and Matsushima, T. 1994. Antimutagenicity of lemon grass (*Cymbopogon citratus* Stapf) to various known mutagens in *Salmonella* mutation assay. Mutation Research 341: 71–75.

Wang, L. and Weller, C. L. 2006. Recent advances in extraction of nutraceuticals from plants. Trends in Food Science and Technology 17: 300–312.