Cymbopogon citratus (DC.) Stapf : chemical composition and biological activities

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RESUMO: *Cymbopogon citratus* (DC.) Stapf: composição química e atividades biológicas. *Cymbopogon citratus* (DC.) Stapf é uma graminea perene, amplamente distribuída no mundo, principalmente em regiões tropicais e savanas. As infusões das folhas são usadas na medicina popular como antimicrobiano, antinflamatório e sedativo. O óleo essencial da folha é usado em indústrias alimentícias, de perfumaria, cosmética e farmacêutica e de fabrico de inseticidas. Os principais constituientes do óleo essencial são citral (mistura dos aldeídos geranial + neral) e terpenos (mirceno - monoterpeno e geraniol - álcool terpênico). Esta revisão apresenta uma ampla descrição dos constituintes químicos e das atividades biológicas, visando ressaltar o potencial desta planta como recurso farmacêutico e agrícola.

Palavras-chave: *Cymbopogon*, fitoquímica, atividade antitumoral, efeito antinociceptivo, atividade antimicrobiana.

ABSTRACT: *Cymbopogon citratus* (DC.) Stapf is a perennial grass that grows spontaneously around the world, mainly in the tropical and savannah regions. Infusions of its leaves are used in traditional medicine as antimicrobial, anti-inflammatory and sedative. The leaf essential oil is used in the food, perfumery, soap, cosmetic, pharmaceutical and insecticide industries. The main constituents of the essential oil are citral (aldehydes geranial + neral) and terpenes (myrcene - monoterpene and geranial - terpenic alcohol). The comprehensive account of the chemical constituents and the biological activities are presented in this review to allow an evaluation of the potential use of this plant either in pharmaceutics or as an agricultural resource.

Key words: *Cymbopogon*, phytochemistry, antitumoral activity, antinociceptive effect, antimicrobial activity.

BOTANY

Cymbopogon citratus, formerly described as *Andropogon citratus* by De Candolle and re-classified by Otto Stapf, belongs to *Poaceae*, a very large plant family that comprises approximately 500 genus and 8,000 herb species, generically named as grasses (University, 2003). The genus *Cymbopogon* includes around 30 grass species, most of all native from the Old World (Tripplebrookfarm, 2003) The name *Cymbopogon* is derived from the Greek words kymbe (boat) and pogon (beard), referring to the flower spike arrangement (Plants, 2003). *Citratus* derives from the ancient Latin, meaning lemon-scented leaves.

C. citratus is native from the southwest Asia and, now, it grows spontaneously around the world, mainly in the tropical and savannah regions (Gupta & Jain, 1978). Perennial herb, it grows forming dense clumps of up to 3 m tall, with short rhizomes. Its leaves are erect, glabrous plane, more than 1m long, 5-15mm wide, whiter upper face and closed edge in the base, with rough margins and membranaceous or arid ligules 4-5mm long. Erect inflorescences, usually in pairs of terminal spiciform racemes 30-60cm long. Sessile small spikes, canaliculated ventral side, 4.5-5.0mm long, 0.8 -1.0mm wide, ciliated margins. Equal or sub equal glumes. The inferior glume is lance-shaped, bicarinated, with bilobulated apex and with acutely curved margins from the middle upwards. The superior glume is lanceolated, 4.3-4.5mm long, usually 1-nervate. Sterile lanceolated lemma, 3.5mm long, 2-nerved, ciliated. Lineal fertile lemma, 2.5mm long, bifid, 1-nerved ciliated (Reitz, 1982).

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Classification (Plants Classification, 2004)

Kingdom Plantae
Plants Subkingdom Tracheobionta (Vascular plants)
Superdivision Spermatophyta (Seed plants)
Division Magnoliophyta (Flowering plants)
Class Liliopsida (Monocotyledons)
Subclass Commelinidae
Order Cyperales
Family Poaceae (R.BR) Barnhart, 1895 (Grass family)
Genus *Cymbopogon* Sprengel, *1815*
Species *Cymbopogon citratus* (D. C. ex Nees) Stapf in Kew Bull. 1906, 322, 357.

Synonyms (Catalogue, 2003)
Andropogon ceriferus Hack
Andropogon citratus DC
Andropogon citratus DC ex Nees
Andropogon citriodorum Hort x Desf.
Andropogon nardus subsp. *ceriferus* (Hack) Hack
Andropodon roxburghii Nees ex Steud.
Andropogon schoenanthus L.
Cymbopogon nardus subvar. c*itratus* (DC.) Roberty

Common names (Seminário Tramil, 1991; Gernot, 2003)

Burma: Zabalin, Sabalin
China: Cang-Mao, Xiang Mao Cao, Heung mao tsu, Ching tong
Costa Rica: zacate, limón, té de limón, zacate té
Croatia: Vlaska
Cuba: caña santa
Czech Republic: Citrónová tráva
Denmark: Citrongræs
Dominican Republic & Venezuela: limoncillo
England & USA: Lemon grass, Citronella
Estonia: Harilik sidrunhein
France: Citronnelle, Verveine des Indes
Germany: Zitronengras, Citronella, Lemongras
Greece: Ëåìïíü÷ïñôï, Êéôñïíýëëá (*Cymbopogon nardus*) Lemonochorto; Kitronella (*Cymbopogon nardus*)
Guatemala: zacate, limón, té de limón, zacate té
Israel: סארג וומיל, תינחיר תינומיל, וומיל בשע Eshb limon, Limon gras, Limonit rihnit
India: Sera, Verveine
Honduras: zacate, limón, té de limón, zacate té
Hungary: Citromfû, Citronella
Iceland: Sítrónugras
Indonesia: Sereh
Italy: Cimbopogone
Laos: Si khai, Sing khai
Malasia: Serai, Serai dapur
Netherlands: Citroengras, Sereh
Poland: Palczatka cytrynowa; Palczatka pogiêta (Cymbopogon flexuosus)
Portugal: Capim-santo, Erva-cidreira, Erva-príncipe, Capim-cidrão
Romania: Iarbã de limon
Russia: Limonnoe sorgo, סאראגו וומיל
Singapore: Sera
Slovakia: Slovenian Limonska trava, וומיל גראס
Spain: Zacate de limón, Te de limón, Canã de limón, Citronella, Hierba de Limón
Sweden: Citrongräs
Thailand: Ta krai, Cha krai, Soet kroei
Turkey: Limon otu
Vietnam: Xa, Sa chanh; Sa diu
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Brazil: (Farmacopéia, 1959; Paviani, 1964; Silva & Bauer, 1971; Reitz, 1982; Correa, 1984; Farmacologia, 1985 ; Costa, 1986; Oliveira & Saito, 1991; Correa Junior et al., 1994; Silva Junior et al., 1995; Akisue et al., 1996 ; Brasil, 1998) : cana-cidreira, cana-cidreira-do-reino, cana-limão, caninha-limão, capim cidrão, capim-barata, capim-cheiroso, capim-cidreira, capim-cidrilho, capim-cidró, capim-jossá, capim-limão, capim-santo, chá-de-estrada, erva-cidreira, facapé, falso-patchuli, jaçapé, patchuli, verbena-da-Índia.

In Brazil, other species receive popular denomination identical of Cymbopogon *citratus*, as for example: *Melissa officinalis* L. (Labiatae) and *Lippia alba* N.E.Br (Verbenaceae) – both called capim-cidreira or erva-cidreira (Liberalli et al., 1946; Ferro et al., 1996; Gomes et al., 1997) and *Killinga odoratta* Vahl (Cyperaceae) - called capim-cheiroso, capim-santo and erva- cidreira (Liberalli et al., 1946; Silva et al., 1977; Correa, 1992; Chernovicz, 1996).

USES AND APPLICATIONS

The “tea” or “infusion” prepared with fresh or dry leaves of lemon grass is very used in the popular medicine in almost all the continents and it comprises a wide range of indications. Equally wide is the spectrum use of substances extracted from the lemon grass, especially of the essential oil.

In India, it is used for gastrointestinal problems (Alves & Souza, 1960) and, in China, as ansiolitic (Peigen, 1983) . In the Mauricio islands and in the Malay Peninsula, it is common to use the lemon grass tea against flu, fever, pneumonia, and to solve gastric and sudorific problems (Farmacologia, 1985). In Nigeria, it is used as antipyretic, and for its stimulating and antispasmodic effects (Olaniyi et al., 1975). In Indonesia, the plant is indicated to help the digestion, to promote diuresis, sweating and as

emmenagogue (Hirschorn, 1983). Still in Africa and Asia, it is considered as antitussive, antiseptic, sudorific, stomachis, anti-rheumatic and to treat backache, sprain and haemoptysis (Alves & Souza, 1960).

Lemon grass is also widely used in traditional medicine in Cuba and in many other countries of the Caribbean region. Among its attributable popular properties are those related to analgesic and anti-inflammatory actions (Ortiz et al., 2002). In Trinidad and Tobago it is used to combat diabetes (Mahabir & Gulliford, 1997).

In Suriname's traditional medicine, lemon grass is used against coughing, cuts, asthma, bladder disorders and as a diaphoretic and to relieve headaches. It is also used as an insect repellent and a carminative (Lemon Grass, 2003).

In several states of Brazil, the lemon grass is equally evidenced as popular medicinal plant (see Ramakers et al., 1994 (Ceara State); Deus, 1981 (Pernambuco State); Estudo, 1976 (Rio Grande do Norte State); Agra, 1977 and Alencar et al., 1994 (Paraíba State); Vandenberg, 1980 (Mato Grosso State); Mattos & Graças, 1980 (Brasília); Stellmann & Brandão, 1994 (Minas Gerais State); Nogueira, 1983 (Sao Paulo State) and Paviani, 1964 (Rio Grande do Sul State), among others). Its popular use range is considerably wide, such as: restorative, digestive, anti-tussis, effective against colds, analgesic, anti-hermetic, anti-cardiopatic, antithermic, anti-inflammatory of urinary ducts, diuretic, antispasmodic, diaphoretic and antiallergic. According to Nogueira (1983), the lemon grass was indicated as medicine for "psychoneurological diseases" by 201 out of 479 women that attend health centers in Sao Paulo, being the most used plant for this purpose. In the State of Parana, the lemon grass also stands out in several ethnobotanical studies, being preferentially used as sedative (Perozin, 1989; Jacomassi & Piedade, 1994; Laus, 1994; Gomes et al., 1997).

Besides the medicinal use, the lemon grass essential oil is also used in the food (flavouring), perfume and cosmetics industries (Bhattacharyya, 1970; Thapa et al., 1971; Lawrence, 1978, Lorenzetti et al., 1991, Oliveira et al., 1997a e 1997b), being this use of reasonable economical importance.

CHEMICAL COMPOSITION OF THE ESSENTIAL OIL

Several *Cymbopogon* species supply essential oil that is applied in the industry of soap, toilet-soap, perfumery and related products as well as other with medicinal purposes. Especially, *C. citratus* and *C. flexuosus* have been cultivated in several countries given the high citral content in its essential oil (70-80%) (Robbins, 1983). Several research works have been done aiming at enlarging the knowledge of the chemical composition of the essential oil of these species leaves (Chisowa et al., 1998). These studies have been revealing that although the chemical composition of the essential oil of *C. citratus* varies according to the geographical origin, the compounds as hydrocarbon terpenes, alcohols, ketones, esters and mainly aldehydes, have constantly been registered (Costa, 1986; Cicogna et al., 1986-1987; Matouschek & Stahl, 1991; Trease, 1996; Silva Jr. et al., 1995). Among the several isolated and identified substances from the leaves and roots of lemon grass, there are alkaloids, saponin, (â-sistosterol, terpenes, alcohols, ketone, flavonoids, cholorogenic acid, caffeic acid, p-coumaric acid and sugars (Alves & Souza, 1960; Olaniyi et al., 1975; Hanson et al., 1976; Gunasingh & Nagarajan, 1981; Matouschek & Stahl, 1991; Chisowa et al., 1998).

The total amount of essential oil obtained from the leaves is quite variable - among 0.28 to 1.4% (see Silva & Bauer, 1971; Cicogna Junior et al., 1986-1987; Sargenti & Lancas, 1997; Chalchat et al., 1997; Sidibë et al., 2001, Kasali et al., 2001 and Cimanga et al., 2002a). The maximum registered value was 3.0% obtained by hydrodistillation of the dry leaves (Chisowa et al.,1998).

Mono, Di and Sesquiterpenes

A wide number of terpenes have been identified in the essential oil of *C. citratus,* using analyses by GC or GC-MS. In spite of current variations of the origin of the analyzed plants, there is consistence that myrcene is a characteristic compound of this species (Miyasaki et al., 1970) (Figure 1). The amounts of this compound are highly variables (2 to 25.3%) (Cicogna Junior et al., 1986-1987; Chalchat et al., 1997; Chisowa et al., 1998; Menut et al., 2000; Dudai et al., 2001; Kasali et al., 2001; Sidibe et al., 2001; Cimanga et al., 2002a). Mancini (1972); Faruq et al., (1994) and Torres & Ragadio (1996) also mention the myrcene presence although they do not indicate its percentage.

Limonene, one of the most frequent monoterpenes in essential oils, is also found in the lemon grass oil (Figure 1). This was isolated in concentrations between 0.3 and 5% (Cicogna Junior et al., 1986-1987; Zheng et al., 1993; Faruq et al., 1994; Torres & Ragadio, 1996; Chalchat et al., 1997; Chisowa et al., 1998; Menut et al., 2000; Cimanga et al., 2002a and Schaneberg & Khan, 2002).

The terpenes á and â- ocimene were obtained in smaller quantities (Faruq et al., 1994; Chalchat et al., 1997 and Kasali et al., 2001). The terpene á-pinene was isolated by Faruq et al. (1994); Torres & Ragadio (1996); Chisowa et al. (1998) and Menut et al. (2000). Also, the â- caryophyllene, another hydrocarbon sesquiterpene found in many essential oils, was obtained from lemon grass leaves by hidrodistillation (Torres & Ragadio, 1996). Rozzi

(2002), also found â- caryophyllene in the essential oil, using the supercritical fluid extracting method.

Other isolated terpenes were phellandrene (Torres & Ragadio, 1996) and á- oxobisabolene, the latter being the second most abundant compound in the essential oil (12%) evaluated by Abegaz & Yohannes (1983).

Triterpenoids

During investigations into the constituents of the leaf wax of *C. citratus* leaves, Hanson et al. (1976) isolated and identified two triterpenoids- the former being a ketone, denominated cimbopogone and previously isolated and reported by Crawford & Menezes (1963) and, the latter was a new compound, an alcohol denominated cimbopogonol. According to Hanson et al. (1976), the structural relationship verified between the cimbopogonol and the cimbopogone suggests the possibility that the cimbopogone is not a natural product, but an artefact formed during the isolation of the cimbopogonol.

Ketones

Ionones were obtained of the lemon gras essential oil by Faruq et al. (1994). The ketone methylheptenone was isolated by Torres & Ragadio (1996); Mancini, (1972) (0.5%) and Chalchat et al. (1997) (0.8%). This ketona, according to Cicogna Junior et al. (1986-1987), can be equal to more than 25% of the total composition, depending on the extraction time during the hydrodistillation.

Aldehydes (Citral)

Independently of the origin place (Brazil, Zambia, Mali, United States, China, Sri Lanka, Philippines, Somalia, India and Congo, among others), the predominant compound (30 to 93.74%) of the lemon grass essential oil obtained is the citral (mixture of the aldehydes neral and geranial, with general predominance of this last one) (Farmacopéia, 1959; Trease, 1966; Silva & Bauer, 1971; Mancini, 1972; Olaniyi et al., 1975; Oliveros - Belardo & Aureus, 1979; Rabha et al., 1980; Liu et al., 1981; Abegaz & Yohannes, 1983; Costa, 1986; Cicogna Junior et al., 1986-1987; Ming et al. (1996), SeminarioTramil , 1991; Il Idrissi et al., 1993; Torres, 1993; Faruq et al., 1994; Akisue et al., 1996; Torres & Ragadio, 1996; Chalchat et al., 1997; Sargenti & Lancas, 1997; Chisowa et al., 1998; Lecherq et al., 2000, Menut et al., 2000; *Cymbopogon*, 1999-2000; Dudai et al.; 2001; Kasali et al., 2001; Sidibe et al., 2001; Cimanga et al., 2002a, 2002b; Rozzi et al., 2002; Schaneberg & Khan, 2002). (Figure 1)

This high citral content justifies the commercial cultivation of lemon grass in wide scale in several countries (Robbins, 1983), and it is responsible for the lemon smell that characterizes the species (Saito & Scramin, 2000).

As an exception, the essential oil from the Ethiopian lemon grass presents the geraniol (40%) as main compound, followed by citral (13%) and (á - oxobisabolene (12%) (Abegaz & Yohannes, 1983).

Experiments carried out in environmental conditions in Philippines revealed that in drought season (March to June) there was a better yield of the oil and citral content (Oliveros-Belardo & Aureus, 1979). The extraction of the essential oil with hexano also supplied a larger citral income (86.83%), when compared with the extraction by other solvents (Schaneberg & Khan, 2002). The synthetic citral can be obtained from the coal and petroleum (Bricout & Koziet, 1978).

Other aldehydes

The aldehydes isocitral, decinal, valeric and citronelal (Figure 1) were isolated from the lemon grass essential oil by hydrodistillation (Mancini, 1972). Cicogna Junior et al. (1986-1987); Torres & Ragadio (1996); Cimanga et al. (2002b); Schaneberg & Khan (2002) also obtained the citronelal. Faruq et al. (1994) isolated anisaldehyde, cinnamonaldehyde and salicyaldehyde, among others compounds. Also, Cicogna Junior et al. (1986-1987) isolated the aldehydes C-9 and C-10.

Phenolic Compounds

Among the flavanoids isolated by Cagiotti et al. (2001), luteolin was considered one of the plant marker compounds. Gunasingh & Nagarajan (1981); Matouschek & Stahl (1991) also obtained this compound and its 6-C and 7-O -glycosides, respectively. Matouschek & Stahl (1991) also isolated the homoorintine flavanoides and its 2–O rhamnosil–limborientino. Miean & Mohamed (2001) described the isolation of the flavanoids myrcene, quercetin, kaempferol and apigenine and Faruq et al. (1994) obtained the phenolic compounds elemicin, catecol and hydroquinone.

Alcohols and esters

Among the several alcohols and esters obtained from the essential oil of lemon grass, the geraniol is the most frequently compound found, regardless the plant origin (Figure 1). The oil contents can vary from 1.5 to 10.4% (see Mancini, 1972; Cicogna Junior et al., 1986-1987; Zheng et al., 1993; Faruq et al., 1994; Torres & Ragadio, 1996; Chalchat et al., 1997; Chisowa et al., 1998; Lecherq et al., 2000; Dudai et al., 2001; Sidibe et al., 2001; Cimanga et al., 2002b; Schaneberg & Khan, 2002).

Exceptionally, according to Abegaz & Yohannes (1983), the geraniol was the main compound of African origin plants, corresponding to 40% of the total of the essential oil composition,

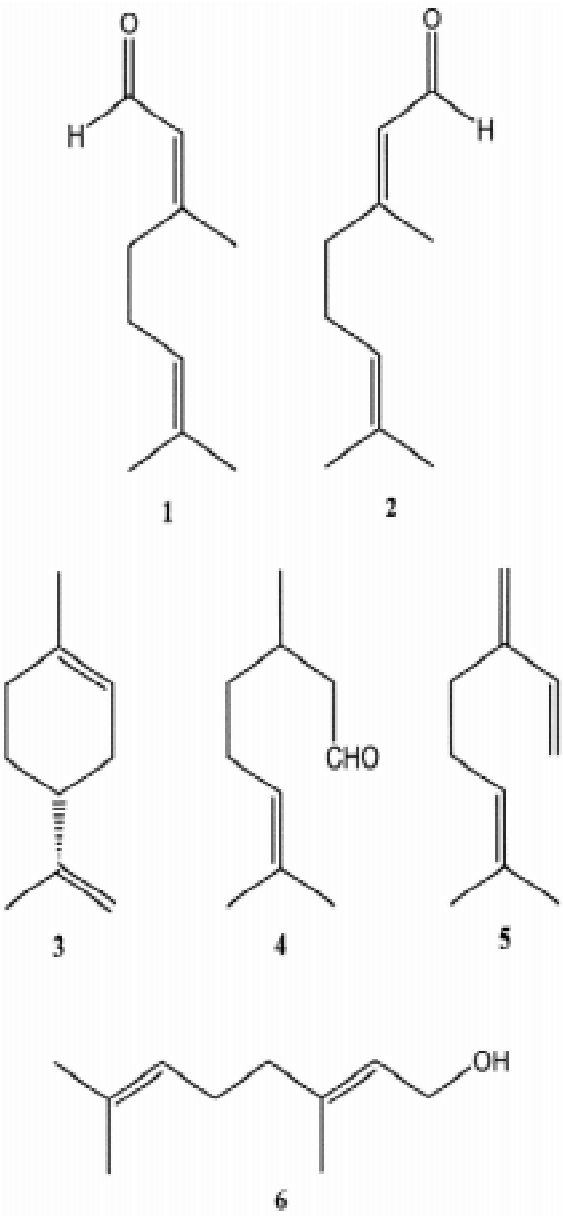

FIGURE 1. Structures of the main marker compounds in the essential oil of lemon grass: 1. neral; 2. geranial; 3. limonene; 4. citronelal; 5. myrcene; and 6. geraniol (Based on Schanenberg & Khan, 2002).

surpassing even the marker compound - citral.

Faruq et al. (1994); Torres & Ragadio (1996) and Chalchat et al. (1997) isolated the linalol and citronelol alcohols. According to Chalchat et al. (1997), in the percentages of 1.2% and 0.1%, respectively. Chisowa et al. (1998) and Mancini (1972) obtained only the linalol. Methaheptanol was obtained by Faruq et al. (1994), 1.8–cineole and menthol by Torres & Ragadio (1996) and neomenthol and terpineol by Kasali et al. (2001). Nerol was isolated by Dudai et al., (2001) and farnesol by Mancini, (1972). Besides the already mentioned alcohols found in the lemon grass essential oil, it was evidenced the presence of octacosanol, dotriacontanol and triacontanol in leaf lipophilic extract (Matouschek & Stahl, 1991). Olaniyi et al. (1975) besides triacontanol also isolated hexacosanol.

The esters geranil formate, citronelil acetate, terpinil acetate and linalil formate were isolated by Faruq et al., (1994). Besides these, in the essential oil of this plant, also were isolated: linalil acetate (Kasali et al.(2001) – 2.3%); ester laurate (Torres & Ragadio, 1996); geranil acetate (Dudai et al., 2001; Chalchat et al., 1997 – 0.2%) and geraniol caproate (Mancini, 1972).

Other compounds

Among the non-volatile compounds present in the lemon grass leaves, we can mention chlorogenic, caffeic and p-coumaric acids (Matouschek & Stahl, 1991). Also, according to Sargenti and Lancas (1997), the nerolic and geranic acids (Dudai et al., 2001) are present in the essential

oil. The analytic study of this plant additionally revealed the presence of tannins, phosphates, nitrates and chlorets (Vasconcelos et al., 2000).

The major component of the non-saponifiable fraction of the light petroleum extract was found to be â-sistosterol, according to Olaniyi et al. (1975). These authors also isolated a steroidal saponin, closely related to fucosterol, from the defatted plant material.

Alves & Souza (1960) had detected alkaloids in the rhizomes of this plant. Matouschek & Stahl (1991) did not identify alkaloids or saponines in the lemon grass leaves.

BIOLOGICAL ACTIVITY

Central nervous system (CNS) - Ansiolitic and other activities

The results of a neurobehavioral study of the myrcene effect in rodents, suggest that it does not possess ansiolitic activity as the benzodiazepine compounds do and that its activity is unlikely on CNS - as much anti-depressive as antipsychotical (Silva et al., 1991). The lemon grass dry leaf tea, administered to healthy volunteers also did not also show any hypnotic or ansiolitic effect (Leite et al., 1986).

The studies accomplished by Seth et al. (1976) revealed that the lemon grass essential oil produced marked depression on the CNS of mice. The general effect of the dose of 150 mg Kg^{-1} of essential oil was comparable to the dose of chloropromazine hydrochloride (5 mg Kg^{-1}). Also, in agreement with Ferreira & Fonteles (1985), the lemon grass essential oil was capable to strongly prolong the mice sleepness time, about 3 times more potent than the medicine sodic thiopental. On the other hand, studies accomplished in mice and rats using tea obtained from fresh and dry leaves did not confirm the sedative effect of this plant (Carlini et al., 1986).

According to Rao et al. (1990) the myrcene extracted from the species essential oil presented antinociceptive[1] effect in mice. This antinociceptive activity of the essential oil of *C. citratus* was confirmed by Viana et al. (2000).

The peripheral analgesic effect of the myrcene was confirmed in mice and rats by Lorenzetti et al. (1991). In these experiments the myrcene did not cause tolerance in repeated doses, opposed result to that of central effect analgesics such as morphine. According to these authors, this breaks a path for researches with the use of myrcene to develop new peripherical analgesics, whose action profile differs from drugs like aspirin. However, Moron Rodriguez et al. (1996) report the absence of analgesic effect in the extract fluid to 30% of lemon grass orally administered to rodents.

Antitumoral and Anticancerigen Activity

Several studies have aimed at explaining the antitumoral and anticancerigen activities of the lemon grass extract. According to Kauderer et al. (1991), the â-myrcene presented antimutagenic activity in mammary cells. These plant compounds, ä-limonene and geraniol, presented inhibition of the liver and intestinal mucous membrane cancer in mice (Zheng et al., 1993). Vinitketkumnuen et al. (1994) obtained data on antimutagenic activities of the ethanolic extract of *C. Citratus.* Murakami et al. (1994) also registered antitumoral properties of the edible lemon grass plant. Balboa & Lim (1995) explained that juices derived from this plant leaves contain inhibitors of the development phase of cutaneous tumors. According to Murakami et al. (1997), the methanolic extract of the Thailand cultivated plant, exhibited antitumoral "in vitro" activity. According to Suaeyun et al. (1997), the ethanolic extract to 80% of lemon grass cultivated in Thailand promoted inhibition of colorectal neoplasia in mice. Dubey et al. (1997) evidenced the isolated citral action against P388 leukemic cells.

Puatanachokchai et al.(2002) evidenced inhibitory effects of lemon grass extract on the early phase hepatocarcinogenesis in rats after initiation with diethylnitrosamine.

Antimicrobian Activities

The essential oils abundant in citral are very well known by their bactericidal and fungicidal properties (Guenther, 1950; Pattnaik et al. 1995). According to Onawunmi et al. (1984), the geranial and neral compounds existent in the essential lemon grass oil also present positive antimicrobian effect, and the myrcene reinforces this effect when mixed to one of these compounds.

Several species of the *Cymbopogon* are referred to as antifungic against rice-pathogens, especially against *Rhizoctonia solani* and *Sclerotium oryzae* (Naidu & John, 1981; Shimoni et al., 1993).

The oil obtained from the *C. citratus* leaves exhibited antimicrobian activity when tested against 42 microorganisms (20 bacteria, 7 yeasts and 15 fungi). The isolated bacteria presented a superior susceptibility compared to the fungi (Ibrahim, 1992). Likewise, Syed et al. (1991), Baratta et al. (1998) and Cimanga et al. (2002a, 2002b) reported the antimicrobian effective activity of this oil species against a series of microorganisms.

The essential oil also presented significant antifungic activity against *Candida albicans* (Syed et al., 1995; Chalchat et al., 1997; Hamer et al., 1998); *Candida pseudotropicalis* and *Mycosporum gypseum* (Onawunmi, 1988), *Aspergillus niger* (Joarder & Khatun, 1982) and *Beauveria bassiana* (Raghavaiah

[1] relief of pain with no loss of conscience or anesthesia. (Medical Dictionary Online, 2004)

& Jayaramaiah, 1987). Likewise, it inhibited the *Aspergillus flavus* growth, a fungus that is a common originator of alimentary deterioration (Mishra & Dubey, 1994) and it totally inhibited the mycelial growth and the germination of the *Didymella bryoniae* spores (Fiori et al., 2000) - exclusive fungus of *Cucurbitaceae*, which jeopardizes the fruit quality and can lead the plant to death (Ferreira & Boley, 2003).

The leaves aqueous extract of the plant inhibited "in vitro" and "in vivo" the vegetal pathogenic fungi: *Macrophomina phaseolina*, *Fusarium moniliforme*, *F. solani, Bothryochiploidia theobromae* (Bankole & Adebanjo, 1995) and it inhibited "in vitro": *Ustilago maydis, Ustilaginoidea vikens, Curvularia lunata, Rhizopus sp.* (Awuah, 1989). During an experiment accomplished by Valarini et al. (1996), the oil fully inhibited the mycelial growth of *Fusarium solani f. sp. phaseoli, Sclerotinia sclerotiorum* and *Rhizoctonia solani,* fungi that affect bean, soy and potato cultures, among many others (Fronza, 2003; Rios, 2003; Lees, 2003).

The plant (oil) was also active against several dermatophyt fungi (Lima et al., 1993), among them *Trichophyton rubrum, Microsporum gypseum*, *Aspergillus fumigatus* and *Cladosporium trichoides* (Kishore et al., 1993.); *Trichophyton mentagrophytes, Epidermophyton floccosum* (Wannisorn et al., 1996) and against other pathogenic fungi as *Botrytis cinerea* and *Aspergillus nidulans* (Torres et al., 1989; Shimoni et al., 1993; Ruiz et al., 1996).

This plant oil presented inhibition activity of the fungi growth also associated to cereals storage as *Aspergillus flavus*, *A. fumigatus, Microphomina phaseoli* and *Penicilum chrysogenum* (Adegoke & Odesola, 1996).

This plant extracts and/or essential oil, especially the oil for its citral content, presented positive antibacterian activity for *Escherichia coli* (Ogulana et al., 1987), *Staphilococcus aureus*, *Bacillus subtilis*, *Pseudomonas aeruginosa*, *Streptococcus pneumoniae*, *S. pyogenes, Neisseria gonorhoeae, Clostridium perfrigens* (Onawunmi et al., 1984; Onawunmi et al., 1988; Syed et al., 1995; Sá et al., 1995-1996; El-Kamali et al., 1998; Ahn et al., 1998); *Pseudomonas fluorescens* (Adegoke & Odesola, 1996); *Acinetobacter baumanii, Aeromonas veronii biogroup sober, Enterobacter faecalis, Klebsiella pneumoniae, Salmonella enterica subsp. Enterica sorotipo typhimurium, Serratia marcenscens* (Hamer et al., 1998); *Proteus mirabilis, Shigella flexneri* and *Salmonella typhy* (Syed et al., 1995; Chalchat et al., 1997).

The combination of plant essential oil to the fenoxiethanol, in "in vivo" studies, increased the action spectrum of fenoxiethanol against *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and reduced the necessary therapeutic dosage (Onawunmi, 1988).

The essential oil inhibited the growth of eight stumps of the *Paenibacillus larvae* bacteria, causal agent of the disease "american foulbrood" that affects bees colonies (Allipi et al., 1996).

The methanolic extracts of the plant inhibited *Meloydogyne javanica* - quite common nematoid in horticultures (Sweelan, 1989), however it demonstrated weak antinematoidal activity against *Bursaphellenchus xylophilus*, a parasite that attacks especially *Pinus* species causing serious wood losses (Mackeen et al., 1997).

Insects repellent and insecticide activity

The plant oil and powder showed efficiency in protecting stored seeds against *Callosobruchus maculatus* – bean woodworm, resulting in reduction or inhibition of eggs laid and its emergency (Gbolade & Adebayo, 1993; Adebayo & Gbolade, 1994; Ketoh et al. (2000). This insecticide activity was also confirmed by Rajapake & Vamemden (1997) including *Callosobruchus chinensis* and *C. rhodesianus.*

The essential oil of *Cymbopogon* species (*C. citratus, C. nardus, C. martini*) were very effective against anopheline mosquitos, *Anopheles culicifacies* and *Anopheles quinquefasciatus* (Ansari & Razdan, 1995), and it also inhibited certain development phases of the mosquito *Aedes aegypti* – host vector of the yellow fever and dengue (Osmani & Sighamony, 1980). The citral, obtained from the oil, was effective "in vivo" against *Musca domestica L*. (Rani & Osmani, 1980).

The lemon grass oil acted as ovicide and larvicide of *Spodoptera exigua* (Sharaby, 1988). This insect is a serious pest in horticulture and in some trees, affecting mainly the foliage and the fruit, as the tomato (Sodoptera, 2003). However, it was ineffective against four insects of great occurrence in the fields of Nigeria: *Acraea eponina*, *Ryrrhocorid dysdercus*, *Ootheca mutabilis*, *Rintortus dentipus* (Olaifa et al., 1987). It also presented repellent activity against *Periplaneta americana* - the domestic cockroach (Ahmad et al., 1995).

This plant oil showed excellent results both in direct and indirect application, against the *Diptera* species that cause cutaneous mycosis (Subramanian & Mohanan, 1980).

The extract of this species was effective as biological insecticide against *Mysus persicae* "in vitro" (Stein & Klingauf, 1990) and *Crocidolomia binotalis* (Facknath & Kawol, 1993), important pests that affect the cruciferae cultures (Facknath, 2003; Brasil, 2003b).

The aketonic extract of *C. citratus* caused significant activity against *Aphis craccivora* (Ofuya & Okuku, 1994) – greenfly considered pest in pea and bean cultures (Brasil, 2003a).

In Brazil, the Far-Manguinhos (Oswaldo Cruz Foundation), a pharmaceutical division of the Brazilian Health Ministry, develops products of natural repellent

and insecticide action using lemon grass, among other species (Gilbert et al., 1999).

Diurethic and anti-inflammatory activity

Carbajal et al. (1989) registered weak diurethic and anti-inflammatory action of the leaf deccoction orally administered in mice. Cairo Martinez et al. (1996), for instance, reported the absence of diurethic effect of the leaf deccoction when administered to animals. The results of Moron Rodriguez et al.(1996) also evidenced absence of anti-inflammatory effect in the fluid extract to 30% of lemon grass orally administered to rodents.

Several pharmacological results

There is a possible sealing action of extract on the tin ions, considering that crude extract of lemon grass caused reduction effect of the tin chloride in the survival of *Escherichia coli* (Melo et al., 2001). Also, there is indication of the action of tea of lemon grass dry leaves ("Achara") cultivated in Nigeria, on the inhibition of the aluminum plasmatic absorption, in healthy adults that ingested this metal (Orisakwe et al., 1998).

Baratta et al. (1998) registered that the lemon grass oil presented anti-oxidizer capacity comparable to á- -tocopherol and butylate hydroxitoluene (BHT). Cheah et al. (2001) reported that the dichloromethanic and methanolic extracts of this plant showed powerful antioxidant activity.

Carbajal et al. (1989) registered the considerable hypotensor effect of leaves from the Cuban plants, when intravenously administered in mice.

According to Onabanjo et al. (1993), the aqueous extract of the plant of Nigerian origin was effective when fighting malaria caused in mice by *Plasmodium yolii nigeriensis*.

One of the *C.citratus* compounds, the â-myrcene, presented inhibitor reversible effect "in vitro" of the mono-oxygenases hepatic enzymes, suggesting the interference of this plant with the biotransformation of drugs and toxicant substances (Oliveira et al., 1997a). â- myrcene also presented induction effect of hepatic isoenzymes belonging to the CYP2B subfamily (Oliveira et al., 1997b).

Rajeshwari et al. (2000) indicates the use of *C. citratus* in veterinary medicinal composition for scabies treatment in rabbits.

Toxicity and adverse effects

Studies on the lemon grass oil toxicity in mammals demonstrated that this natural oil is innocuous (Dubey et al., 2000). Additionally, the tea of this plant dry leaves was administered to healthy volunteers not causing hypnotic (Leite et al., 1986), or even toxicant effects (Farmacologia, 1985; Formigoni et al., 1986).

Equally, according to Misrha et al. (2001), the extract administered to mice did not present adverse effects, considering that morphometric and histological alterations were not observed in vital organs, or biochemical alterations in the blood and urine.

According to Silva et al. (1991) and Zamith et al. (1993), the lemon grass does not present genotoxical[2] action. According to Kauderer et al. (1991), it is not mutagenical either.

However, according to Martinez Guerra et al. (2000), the plant fluid extracts to 30% and 80% demonstrated hepatotoxic and nephrotoxic effects in animals. Equally, the results presented by Paiva (1997) demonstrated that the â- myrcene and the limonene were capable to cause sex– specific hyaline tubular nephropathy in male mice.

Alellopathy

The lemon grass oil at 10% in aqueous suspension inhibited completely the germination of *Digitaria horizontalis*, *Sorghum halepense*, *Bidens pilosa*, *Euphorbia heterophylla* and *Raphanus raphanistrum* (Valarini et al., 1996). Dudai et al. (1999) positively clarifies the allelopathic properties of the lemon grass, discussing the possible use of this essential oil, among others, as herbicide.

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