New York State Integrated Pest Management Program | Cornell Cooperative Extension

Lemongrass Oil Profile

Active Ingredient Eligible for Minimum Risk Pesticide Use

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Active Ingredient Name: Lemongrass oil

Active Components: Citral (a- and b-); methylheptenone, citronellal, geraniol, geranial, neral, 2,6-Octadienal, 3,7-dimethyl; limonene, dipentene

CAS Registry #:
8007-02-1 (Lemongrass oil)
106-26-3 (Citral-b/Neral)

U.S. EPA PC Code: 040502

CA DPR Chem Code: 040502

Other Names: Oil of lemon grass; Indian oil of verbena; Indian melissa oil

Other Codes: FEMA: 2624; RTECS: OG8250000

Summary: Lemongrass oil is derived from three different species: *Cymbopogan flexuosus, C. citratus*, and *C. pendulus.* Its uses as a pesticide active ingredient are primarily as an anti-fungal agent in post-harvest handling and as an insect repellent. Lemongrass oil also has some herbicidal properties. The essential oil is high in citral, which is considered the principal biologically active agent. A common food ingredient in many cuisines, lemongrass oil is non-toxic to humans and most non-target species. Lemongrass has a non-toxic mode of action and is believed to pose a minimal risk to human health and the environment.

Pesticidal Uses: Antimicrobial, antifungal, insect repellent, vertebrate animal (dog and cat) repellent.

Formulations and Combinations: Other essential oils, including citronella. Vegetable oils, including castor, corn and soy oils.

Basic Manufacturers: Aromas Naturales; Ayuroma Centre; Dhopeshwar and Sons; Gramme Products; Ungerer and Co.

Safety Overview: The EPA concluded that lemongrass oil, along with other flower and vegetable oils, poses a minimal risk to human health and the environment (Matthews 2012).

Background

Lemongrass oil is derived from the perennial grasses *Cymbopogan flexuosus*, known widely as East Indian lemongrass, but also referred to as Cochin, Native, or British Indian lemongrass; and *C. citratus*, mainly known as West Indian lemongrass, but also called Madagascar or Guatemala lemongrass. A third species, *C. pendulus,* also known as North Indian lemongrass, is a minor source of commercial production. Although the species *C. nadrus* and *C. winterianus* are sometimes referred to as lemongrasses, they, along with their primary active constituent citronellal, are covered separately in a profile on citronella. The three species of lemongrass are cultivated in humid tropical climates. The two leading exporters of lemongrass oil to the US are India followed by Guatemala. Together they account for 96% of all US imports in 2013 (ITC 2014).

The oil from lemongrass is fractionally distilled. The main biologically active constituent of lemongrass oil is believed to be citral, a terpenoid, which is itself a pair or mixture of double-bound isomers. The E-isomer, or citral A, is also known as geranial (CAS 141-27-5). The Z-isomer is known as citral B or neral (CAS 106-26-3). Lemongrass oil tends to produce a racemic mixture of the two isomers (CAS 5392-40-5) at a 2:1 ratio of geranial and neral (Merck 2015). *C. flexosus* is higher in citral content than *C. citratus* (Khan and Abourashed 2010). Varieties of East and West Indian lemongrass oil typically contain 65-85% citral. Some varieties of East Indian lemongrass are reported to have higher concentrations of geraniol and methyl-eugenol than citral. There are additional processed variations where citral is derived from dehydrogenation of a geranial-neral mixture obtained from beta-pinene. Where data are unavailable for lemongrass oil, values for citral are included.

Chemical and Physical Properties

The physical and chemical properties of lemongrass oil and citral appear in Table 1. Values are for lemongrass oil unless otherwise specified.

Table 1

Physical and Chemical Properties of Lemongrass Oil and Citral

Property	Characteristic/Value	Source(s)
Molecular Formula (Citral):	$C_{10}H_{16}O$	(US NLM 2016)
Molecular Weight (Citral):	152.56	(US NLM 2016)
Percent Composition:	Citral: 75-85%. Other biologically active constituents include methylheptenone, citronellal, geraniol, limonene, dipentene.	(Merck 2015)
Physical state at 25°C/1 Atm.	Liquid	(Merck 2015)
Color	Reddish-yellow to reddish-brown	(Merck 2015)
Odor	Strong odor of verbena	(Merck 2015)
Density/Specific Gravity	0.895-0.908	(Merck 2015)
Melting point (Citral)	< -10°C	(US NLM 2016)
Boiling point (Citral)	229°C	(US NLM 2016)
Solubility	Slightly soluble in water; soluble in 70% alcohol; chloroform, ether.	(Merck 2015)

Property	Characteristic/Value	Source(s)
Vapor pressure (Citral)	$9.13X10^{-2}$ mm Hg@25°C	(EPI 2012)
pH (Citral)	5.0	(US NLM 2016)
Octonol/Water (K_{ow}) coefficient	17.06	(EPI 2012)
Viscosity	< 7×10^{-6} m^2/s at 40°C	(Moyler 2010)
Miscibility (Citral in the form of the racemic mixture of geranial and neral)	Miscible with alcohol, ether, benzyl benzoate, di-ethyl phthalate, glycerol, propylene glycol, mineral oil, essential oils.	(Merck 2015; (US NLM 2016)
Flammability	Flammable liquid; flash point 72.8°C	(Vigon International 2015)
Storage stability	Stable under recommended storage conditions	(Sigma-Aldrich 2015)
Corrosion characteristics	Not found	
Air half life	0.096 hr	(EPI 2012)
Soil half life	8,640 hrs	(EPI 2012)
Water half life	4,320 hrs	(EPI 2012)
Persistence	4,450 hrs	(EPI 2012)

Human Health Information

Acute Toxicity

The acute toxicity of lemongrass oil or citral appears in Table 2. Values are for lemongrass oil unless stated otherwise.

Table 2

Acute Toxicity of Lemongrass Oil and Citral

Study	Results	Source(s)
Acute oral toxicity	Rat: >5,000 mg/kg Rabbit: West Indian >5,000 mg/kg East Indian: 2,000 mg/kg	(Opdyke 1976b; HSDB 2015)
Acute dermal toxicity	East Indian: Rabbit LD_{50} >2,000 mg/kg	(Opdyke 1976b)
Acute inhalation (Citral)	Rabbit: <27 mg/ mL	(Moyler 2010)
Acute eye irritation (Citral)	Rabbit: Not irritating	(OECD SIDS 2001)
Acute dermal irritation	Rabbit: Moderately irritating	(Opdyke 1976b)
Skin sensitization	Rabbit: Negative Human: Weak	(Opdyke 1976a; Lalko and Api 2006)

Earlier studies of human skin sensitization to lemongrass oil were negative at a concentration of 4% (D. L. J. Opdyke 1976). Subsequent testing on human subjects resulted in a Maximum Tested No Observed Effect Level (MT NOEL) of 3,448 µg/cm^2, which makes lemongrass oil considered a weak irritant (Lalko and Api 2006). The Lowest Observed Effect Level (LOEL) for citral in petroleum is 2,759 µg/cm^2, with the safe threshold for human exposure thought to be 1,400 µg/cm^2 for consumer products directly applied to skin as fragrances and body care products (Lalko and Api 2008).

More tests have been conducted with citral because it is a common component in 'lemon-scented' dish detergents, fragrances and other household and personal care products. A cumulative irritation study carried out on eight volunteers over a period of 21 days found that an 8% concentration of citral was a marginal irritant (OECD SIDS 2001). In an outbreak of dermatitis following the introduction of a lemon-scented detergent, citral was shown by patch tests to be a strong primary irritant if applied in association with heat (Rothenborg et al. 1977). Using the European standard series, another group of 586 patients with hand eczema were patch-tested with a selection of fragrances including citral 2% petrolatum. Based on the results, the authors concluded that citral could be an allergen and/or an irritant worthy of further study (Heydorn et al. 2003).

Patches containing various personal care or household products formulated with citral were applied to the skin of human test subjects. The experiments applied 13,104 patches, including 10,660 with household products formulas and 2,098 with fragrance formulas. A total of 22 induced sensitizations occurred in 174 tests conducted at 1 to 5% concentrations of pure citral in ethanol, but no inductions occurred at 0.5% citral concentrations when tested on 82 subjects. The researchers concluded that citral itself was not a sensitizer (Steltenkamp et al. 1980).

Another study of the irritant effect of 19 oils and 20 synthetic perfumes used in cosmetics was conducted on skin of 50 male volunteers. Citral at a 32% concentration was the most irritating of the perfumes in human patch test (OECD SIDS 2001).

Sub-chronic Toxicity

The sub-chronic toxicity of Lemongrass oil or citral appears in Table 3.

Table 3

Sub-chronic Toxicity of Lemongrass Oil and Citral

Study	Results	Source(s)
Repeated Dose 28-day Oral Toxicity Study in Rodents	Rat: No differences between treatment and control (8 weeks)	(Formigoni et al. 1986)
90 day oral toxicity in rodents (Citral)	Rat: No adverse effects at 50 mg/kg	(HSDB 2015)
90 day oral toxicity in non-rodents	Not found	
90 Day dermal toxicity	Not found	
90 Day inhalation toxicity	Not found	
Reproduction/development toxicity screening test	Rat: No differences between treatment and control (8 weeks)	(Formigoni et al. 1986)
Combined repeated dose toxicity with reproduction/development toxicity screening test	Rat: No differences between treatment and control (8 weeks)	(Formigoni et al. 1986)
Prenatal developmental toxicity study	Rat: No differences between treatment and control (8 weeks)	(Formigoni et al. 1986)
Reproduction and fertility effects	Rat: No differences between treatment and control (8 weeks)	(Formigoni et al. 1986)

Rats and mice exposed to high doses of lemongrass tea showed no effects—either positive or negative—suggesting that water soluble lemongrass constituents are non-toxic, and pharmacologically ineffective (Carlini et al. 1986). Similarly, tests on volunteer human subjects showed that lemongrass tea did not

have hypnotic or anxiolytic effects (Leite et al. 1986). Rats subjected to high doses of lemongrass tea for two months showed no differences in reproductive cycle, mating, weight gain, teratogenicity, post-natal weight gain or other growth parameters (Formigoni et al. 1986).

Chronic Toxicity

The chronic toxicity of lemongrass oil or citral appears in Table 4.

Table 4

Chronic Toxicity of Lemongrass Oil and Citral

Study	Results	Source(s)
Chronic toxicity (Citral)	Ames Test: Negative	(Gomes-Carneiro et al. 1998)
Carcinogenicity (Citral)	Rat: Non-carcinogen in males; equivocal carcinogen in females	(HSDB 2015)
Combined chronic toxicity & carcinogenicity	Not found	

Lemongrass oil is not identified as a carcinogen by the International Agency for Research on Cancer (IARC 2014). Lemongrass oil is not on the California Proposition 65 list of known carcinogens (Cal-EPA 1997) and does not appear on the Toxics Release Inventory (TRI) Basis of OSHA Carcinogens (US EPA Toxics Release Inventory Program 2015). Male rats fed up to 260 mg/kg body weight had no significant difference in lymphoma from the control. However, female rats had significantly higher lymphoma (HSDB 2015).

Human Health Incidents

The EPA's human health risk assessment for oil of lemongrass stated that "[t]here are no incident reports on file with the agency for Oil of Lemongrass" (Matthews 2010).

For the period from April 1, 1996 to March 30, 2016, the National Pesticide Information Center (NPIC) received reports of five human health incidents involving lemongrass oil as an active ingredient (NPIC 2016). The three incidents resulting in medical treatment, all involved active ingredients in addition to lemongrass. One incident was with a registered pesticide product having deltamethrin as another active ingredient. The other two were eye irritation incidents that also had multiple active ingredients (NPIC 2016), in formulations that were apparently exempt from registration.

Environmental Information

Effects on Non-target Organisms

No relevant studies were found of the eco-toxic effects of lemongrass oil. The effects of citral on non-target organisms are summarized in Table 5. NPIC received nine incident reports that were animal related (NPIC 2016). All of these involved products formulated with other active ingredients.

Table 5

Effects of Citral on Non-target Organisms

Study	Results	Source(s)
Avian Oral, Tier I	Not found	
Non-target plant studies	Not found	
Non-target insect studies	Not found	
Aquatic vertebrates	*Oryzias latipes* LC_{50} 96 hr: 4.1 g/L *Leuciscus idus*: LC_{50} 96 hr 4.6-10 mg/L	(OECD SIDS 2001)
Aquatic invertebrates	*Daphia magna* EC_{50}: 27.0 mg/L	(Moyler 2010)

Between 2006 and 2008, the American Society for the Prevention of Cruelty to Animals' Animal Poison Control Center reported multiple flea product incidents—39 involving exposure of cats and nine incidents involving dogs. The products contained lemongrass oil and other active ingredients that are eligible to be EPA exempt from registration (Genovese et al. 2012). Three formulated products (sprays, shampoos and spot-on treatments) accounted for the incidents and their symptoms included skin erythema, vomiting, diarrhea, lethargy, edema, ataxia, seizures, weakness, recumbent tachycardia, agitation, anorexia, hyperactivity, hypersalivation, panting, retching, tremors, vocalization, and renal failure. Three incidents had particularly poor outcomes: a 7-month-old kitten died with inappropriate use, a 3-year-old dog was euthanized 6 days after appropriate use, and a 13-year-old cat was euthanized 72 hours after appropriate use. All the formulations included lemongrass oil as one of multiple active ingredients.

Environmental Fate, Ecological Exposure, and Environmental Expression

As a plant derived essential oil, lemongrass oil is considered biodegradable. Citral is readily biodegradable, with a 92% biological oxygen demand (BOD) (OECD SIDS 2001). No data on photodegradation of lemongrass oil were found. Citral contains chromophores that absorb at wavelengths >290 nm and models suggest it may be susceptible to direct photolysis by sunlight (HSDB 2015). Between April 1, 1996 and March 30, 2016, NPIC received 21 incident reports that were not human or animal related (NPIC 2016). Most incidents did not have a narrative, and involved spills, misapplications, and staining of the surfaces to which the formulated products were applied. The reports that included a narrative involved lemongrass oil and additional active ingredients and could not be attributed solely to any one active ingredient.

Environmental Incidents

The EPA's review of flower oils included no reports of environmental incidents involving lemongrass oil. (Matthews 2012).

Efficacy

Insecticidal Activity

A mosquito study conducted in Thailand found lemongrass and citronella oils had comparable insecticidal activity against adult *Aedes aegypti*, *Culex quinquefasciatus* and *Anopheles dirus*. Lemongrass essential oil at 10% concentration killed 100% of these three species of mosquitoes within 24 hours of exposure, while citronella oil at 10% also killed 100% of *C. quinquefasciatus* and *An. dirus* and 97.6% of *Ae. aegypti* adults in 24 hours post exposure (Phasomkusolsil and Soonwera 2011). In another study on *Ae. Aegypti*, various

essential oils were examined by Thai scientists for repellency and knockdown efficacy. Lemongrass oil was one of the strongest repellents and had the second greatest knockdown effect, with an LC_{50} of 6.7% (Boonyuan et al. 2014).

Terminix® ALLCLEAR® Sidekick, a blend of 2.6% lemongrass oil, with geranium oil, cinnamon oil, eugenol, and peppermint as other active ingredients reduced *Aedes albopictus* attacks by over 95% and *Culex pipiens* attacks by over 92% (Revay et al. 2013). The article did not identify whether the formulation was either EPA registered or exempt.

Lemongrass oil repelled stable flies (*Stomoxys calcitrans*) (Baldacchino et al. 2013). Researchers concluded that the neral and citral in the atmosphere were detected through the flies' antennal olfactory receptor cells, causing them to be repelled. Stable flies given access to two blood-soaked sanitary pads, one of which was treated with lemongrass oil, spent significantly more time in the untreated zone than in the lemongrass oil-treated zone, and none fed on the treated pads.

In a Canadian study that compared 17 different plant-derived insecticides, lemongrass oil from EcoSmart was relatively effective against the obliquebanded leafroller (*Choristoneura rosaceana*) and cabbage looper (*Trichoplusia ni*) (Machial et al. 2010). The insecticides were blended with either polysorbate 80 or acetone. The study did not mention which solvent or emulsifier was specifically used with lemongrass oil and it was not clear if the formulation meets the 25(b) requirements in the US.

Various commercial essential oils, including lemongrass oil, were mixed with the attractant bait acetic acid and 2-methyl-1-butanol to test their repellency to the vespid wasps yellowjackets (mainly *Vespula pensylvanica*) and paper wasps (mainly *Polistes dominulus*) (Zhang et al. 2013). Lemongrass oil was found to be the most effective repellent for both genuses of wasps. The study confirmed the repellency of isolated citral. Blends of lemongrass oil, clove oil, and geranium oil were more effective than any one essential oil and were shown to repel vespid wasps when heptyl butyrate and bacon were used as other attractants.

In one study, sand was treated with Citral, an active constituent of lemongrass oil. At a dose of 10 µL/g, the treated sand proved 100% effective at controlling Formosan subterranean termites (*Coptotermes formosanus*) (Cornelius et al. 1997).

Commercial traps with known stink bug pheromone attractants were used to test the potential repellency of essential oils to the brown marmorated stink bug (*Halyomorpha halys*). Lemongrass oil repelled over 95% of the insects when the trap was deployed (Zhang et al. 2014). It was not clear from the article whether these formulations met the EPA minimum-risk requirements, registered, or were experimental use only.

Fungicidal Activity

Lemongrass oil has been reported in a secondary source to have antimicrobial and fungicidal activity (Khan and Abourashed 2010). Growth media cultured with the fungi *Colletotrichum coccodes*, *Botrytis cinerea*, *Cladosporium herbarum*, *Rhizopus stolonifer* and *Aspergillus niger* were independently inoculated on growth plates treated with lemongrass oil at doses of 25, 50, 100 and 500 mg. All doses had significantly fewer spores for each pathogen than the no-treatment control. At 25 mg, spore production was depressed by 70% for *B. cinerea*, 58% for *C. coccodes*, 41% for *A. niger*, 40% for *C. herbarum*, and 35% for *R. stolonifer*. Doses of 50 mg and 100 mg achieved marginal reductions in most cases, but not complete

control of any species. At a dose of 500 mg there was no sporulation of any of the species (Tzortzakis and Economakis 2007).

In another study of diseases affecting peanuts, citral was the most effective of seven essential oil treatments for the control of spore germination of *Cercospora arachidicola, Phaeoisariopsis personata,* and *Puccinia arachidis* (Kishore et al. 2007). In the same study, citral completely inhibited the growth of *Alternaria alternata, Aspergillus flavus, Curvularia lunata, Fusarium moniliforme, F. pallidoroseum,* and *Phoma sorghina.* However, citral was relatively ineffective against *F. oxysporum* and *R. bataticola.*

Citral and lemongrass oil were effective treatments of the post-harvest decay pathogen *Collectotrichum gloeosporioides* in papaya (Palhano et al. 2004). The use of pressurized water to treat fruit for pathogens—known as high hydrostatic pressure (HHP)—increased the efficacy of the lemongrass oil.

In screening essential oils for efficacy against *Escherichia coli, Listeria innocua* and *Salmonella enteritidis*, researchers found lemongrass oil to be one of the top three essential oils, along with geraniol and cinnamon oil (Raybaudi-Massilia et al. 2006). At a concentration of 5 µl/ml, lemongrass oil reduced the populations of all three pathogens to below the limit of detection.

Of eight essential oils, lemongrass oil was the most effective in inhibiting the entomopathogenic bacteria *Paenibacillus larvae*, the organism responsible for American foulbrood in honey bees. The minimum inhibitory concentration (MIC) was 50 µg / l (Alippi et al. 1996).

Herbicidal Activity

Citral and other monoterpenes present in lemongrass oil were reported to have phytotoxic properties when used as a foliar bio-herbicide spray applied to barnyardgrass (*Echinochloa crus-galli*), redroot pigweed (*Amaranthus retroflexus*), buckhorn plantain (*Plantago lanceolata*) and thale cress (*Arabidopsis thaliana*) (Graña et al. 2013). In the same study, citral delayed germination and reduced the germination rate of barnyardgrass, wild oat (*Avena fatua*), redroot pigweed, and buckhorn plantain. Germination of corn (*Zea mays*) was accelerated, while wheat (*Triticum aestivum*) was slightly delayed, but citral did not affect germination rate.

Barnyardgrass was controlled by foliar application of citral (Poonpaiboonpipat et al. 2013), in tests that measured membrane disruption, lipid peroxidation and disruption of photosynthetic processes. Drench treatments were also shown to be effective in inhibiting seed germination and seedling growth. Rates of 1.25, 2.5, 5, and 10% were all more effective than the no-treatment control in causing phytotoxic effects.

Nematicidal Activity

When tested on root-knot nematodes (*Meloidogyne incognita*), citral reduced egg hatch to less than 50% at a concentration of 250 mg/L, and to under 8% at 500 mg/L. Citral also reduced juvenile mobility by over 80% at a concentration of 60 mg/L (Echeverrigaray et al. 2010). At a concentration of 250 mg/L, citral completely inhibited gall development on tomato plants. Concentrations of 500 mg/L provided nearly 100% control.

Protozoacidal Activity

Citral diluted with dimethyl sulfoxide (DMSO) was added at various doses to a culture with the parasitic flagellate responsible for Chagas disease, *Trypanosoma cruzi*. Metamorphosis and viability were both

adversely affected. Concentrations of citral higher than 60 µg/mL led to 100% cell death in both the epimastigote and trypomastigote forms (Cardoso and Soares 2010).

Standards and Regulations

EPA Requirements

Lemongrass oil is recognized as a food by the EPA in the category of herbs, and as such is implicitly exempted from the requirement of a tolerance [40 CFR 180].

FDA Requirements

Lemongrass oil is Generally Recognized As Safe (GRAS) as a food ingredient [21 CFR 182.20].

Other Regulatory Requirements

Naturally extracted lemongrass oil is allowed by the USDA's National Organic Program (NOP) [7 CFR 205].

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