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New York State Integrated Pest Management Program | Cornell Cooperative Extension

Thyme and Thyme Oil Profile

Active Ingredient Eligible for Minimum Risk Pesticide Use

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Label Display Names: Thyme, Thyme Oil

Active Components: Thymol, carvacrol, rosmarinic acid

CAS Registry #: 84292-51-1 (Thyme)
8007-46-3 (Thyme oil)

U.S. EPA PC Code: 128894 (Thyme herbs)
597800 (Thyme oil)

CA DPR Chem Code: 2330 (Thyme)
6014 (Thyme Oil)

Other Names: Creeping thyme, red thyme oil, thym oil, thyme absolute, thymian, *Thymus vulgaris* extract, white thyme oil

Other Codes: BRN: 1907135 (Thymol)
Caswell: 618F
FEMA : 3064, 3065
RTECS: XP2000000

Summary: Thyme is a commercially important herb cultivated in Mediterranean and temperate climates. The leaves, flowers, and oils extracted from the plant are widely used as food ingredients in a variety of cuisines, and therefore considered safe. For pesticidal purposes, thyme, thyme oil, and its main active constituent thymol have demonstrated anti-microbial, anti-fungal, and insecticidal properties.

Pesticidal Uses: Insects: ants, aphids, armyworms, billbugs, chinch bugs, clothes moths, earwigs, fleas, grasshoppers, ground beetles, leafhoppers, mealybugs; mosquitos, wireworms. Other arthropods: centipedes, millipedes, scorpions, spiders, ticks. Diseases: botrytis in grapes. Applied in ponds, fountains, aquaria as an arthropod repellent and to control mosquito larvae.

Formulations and Combinations: Combined with other herbs, including rosemary oil, lemongrass oil, mint oil, citronella oil, eugenol, wintergreen oil. Formulated with water, alcohol, lecithin, peanut shells, xanthan gum. Also mixed with botanical insecticides registered under §3 of FIFRA, including pyrethrins and neem.

This document profiles an active ingredient currently eligible for exemption from pesticide registration when used in a Minimum Risk Pesticide in accordance with the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) section 25b. The profile was developed by the New York State Integrated Pest Management Program at Cornell University, for the New York State Department of Environmental Conservation. The authors are solely responsible for its content. The Overview Document contains more information on the scope of the profiles, the purpose of each section, and the methods used to prepare them. Mention of specific uses are for informational purposes only, and are not to be construed as recommendations. Brand name products are referred to for identification purposes only, and are not endorsements.

Basic Manufacturers: Angene Chemicals; Ultra International, B.v.; Vdh Organics Pvt. Ltd.

Safety Overview: Thyme is a commonly consumed food with antifungal and insect repellent properties, and a long history of consumption as a food and safe use as a pesticide. It is permitted to be used as a pesticide on food crops.

Background

Thyme can refer to plants from the genus *Thymus,* which is in the family Labiatae, along with the genera *Rosmarinus, Lavendula* and *Salvia.* There are an estimated 215 species of *Thymus* (Morales 2003). The most widely used species, *Thymus vulgaris*, is known as common or garden thyme. Other commercially used species include *T. capitata,* known also as Spanish oregano or conehead thyme; *T. mastichina* sometimes called mastic thyme or Spanish marjoram; *T. serpyllum* creeping or wild thyme; and *T. zygis* or Spanish thyme. Thyme is believed to have originated on the Iberian Peninsula. Leading producers of thyme are Spain, Portugal and France, with smaller amounts coming from Albania, Algeria, Hungary, Israel, Morocco and the former Yugoslavia (Lawrence et al. 2002). Most thyme oil is produced by steam distillation of the flowering tops of *T. vulgaris* or *T. zygis* (Khan and Abourashed 2010). Other extraction methods involve the use of aromatic petroleum solvents, such as butane; alcohols, including methanol; acetone and supercritical fluid extraction with carbon dioxide (Venskutonis 2003). Thyme oil is rich in the phenolic compound thymol, which is believed to be the main biologically active component (Zarzuelo and Crespo 2003).

Thyme is a culinary herb used in a wide range of cuisines. In French cuisine it is commonly used with meat dishes. Mediterranean and Asian cuisine also use fresh and dried thyme in sauces. The fastest growing market for thyme oil is cosmetics and in aromatherapy (Lawrence et al. 2002). It is also used as a topical treatment and in toothpastes (Zarzuelo and Crespo 2003). Various thyme species are also grown as ornamentals (Lawrence et al. 2002).

This review primarily focuses on *T. vulgaris* and the oil derived from both *T. vulgaris* and *T. zygis.* Thymol is present in most species and is consistently the most common active constituent in oil extracted from *T. vulgaris* (Stahl-Biskup 2003). While the levels vary widely by species, climate, production practices, and extraction methods, *T. vulgaris* oil consists of between 3% and 80% thymol (CAS #89-83-8), with most samples between 36% and 65% (Stahl-Biskup 2003; Imelouane et al. 2009). In cases where there is missing data for thyme oil, values for thymol will be used. The review of thyme oil was separated from other vegetable and flower oils (Harrigan-Ferrelly and McDavit 2010). However, thymol is not listed as an active ingredient eligible to be used in minimum-risk pesticides. (US EPA 2015).

Chemical and Physical Properties

The physical and chemical properties of thyme oil and thymol are summarized in Table 1.

Table 1

Physical and Chemical Properties of Thyme and Thyme Oil

Property	Characteristic/Value	Source
Molecular Formula:	Thyme absolute: $C_{50}H_{82}O_4$)	(US NLM 2016)
Molecular Weight:	Thyme absolute: 747.18368 g/mol	(US NLM 2016)
Percent Composition:	Thyme: 0.8 – 2.6% thyme oil; (Thyme oil from T. vulgaris) Thymol (3-80%) carvacrol; linalool, p-cymene, γ-terpinene, borneol, 1,8-cineole, geraniol, various other terpenoids, alcohols and esters.	(Stahl-Biskup 2003; Khan and Abourashed 2010; Imelouane et al. 2009)
Physical state at 25°C/1 Atm.	liquid	(Sigma-Aldrich 2014)
Color	Colorless to reddish brown	(Merck 2015)
Odor	Thyme smell, usually considered pleasant	(Merck 2015)
Density/Specific Gravity	0.916 g/cm3	(Sigma-Aldrich 2014)
Melting point	250˚C	(Royal Society of Chemistry 2014)
Boiling point	190˚C	(Sigma-Aldrich 2014)
Solubility	Very slightly sol in water; sol in 2 vols 80% alcohol, Thymol: soluble in glacial acetic acids, oils, fixed alkali hydroxides	(Andersen 2005; Merck 2015)
Vapor pressure	0.167 mm Hg at 25°C	(EPI 2012)
pH	Thymol: Solution neutral to litmus test	(HSDB 2015)
Octonol/Water (K_{ow}) coefficient	3.3 (Log K_{ow}: -1.77 to -1.69)	(Andersen 2005)
Viscosity	Not found	
Miscibility	Thymol: Miscible in water	(HSDB 2015)
Flammability	Flash point: 60˚C (closed cup)	(Sigma-Aldrich 2014)
Storage stability	Stable under recommended conditions. Avoid heat, flames, and sparks. Incompatible with strong oxidizing agents.	(Sigma-Aldrich 2014)
Corrosion characteristics	Rated as corrosive by the US Department of Transportation	(Sigma-Aldrich 2014)
Air half life	Thymol: 2.4 hrs	(EPI 2012)
Soil half life	Thymol: 720 hrs	(EPI 2012)
Water half life	Thymol: 360 hrs	(EPI 2012)
Persistence	Thymol: 470 hrs	(EPI 2012)

Human Health Information

The US EPA states there was no risk to human health from the use of a registered pesticide containing thyme for controlling aphids in ornamental aquatic settings (US EPA Office of Pesticides and Toxic Substances 2001). No human health incidents were reported to EPA for thyme oil as a sole active ingredient in a pesticide formulation as of February 19, 2010 (Matthews 2010).

Acute Toxicity

The acute toxicity of thyme oil and its active constituent thymol are summarized in Table 2.

Table 2

Acute Toxicity of Thyme Oil and Thymol

Study	Results	Source
Acute oral toxicity	LD_{50} (rat): 2,840 mg/kg, mouse: 1,250mg/kg, rabbit: >5000mg/kg Thymol: LD_{50}: (rat) 980 mg/kg bw, (mouse) 1050-2000 mg/kg bw, (guinea pig) 880 mg/kg bw	(Gwynn 2014; HSDB 2015)
Acute dermal toxicity	Thymol: LD_{50} (rabbit): >5000 mg/kg	(Sigma-Aldrich 2014)
Acute inhalation	Not found	
Acute eye irritation	Not found	
Acute dermal irritation	Not found	
Skin sensitization	Thymol: Guinea pig: No sensitization reaction	(HSDB 2015)

Other than oral toxicity, the acute toxicity of thyme and thyme oil is estimated by thymol.

Sub-chronic Toxicity

No data was found on the subchronic toxicity of thyme or thyme oil; the subchronic toxicity of thymol is summarized in Table 3.

Table 3

Sub-chronic Toxicity of Thymol

Study	Results	Source
Repeated Dose 28-day Oral Toxicity Study in Rodents	Not found	
90 day oral toxicity in rodents	Not found	
90 day oral toxicity in non-rodents	No effect	(Hagan et al. 1967)
90 Day dermal toxicity	Not found	
90 Day inhalation toxicity	Not found	
Reproduction/development toxicity screening test	Not found	
Combined repeated dose toxicity with reproduction/development toxicity screening test	Not found	
Prenatal developmental toxicity study	Possible teratogen	(Verrett et al. 1980)
Reproduction and fertility effects	Not found	

A 19 week subchronic toxicity study performed on Osborne-Mendel rats determined thymol to have a no–observable-effect level of 1,000 mg/kg of body weight (Hagan et al. 1967). Thymol caused developmental abnormalities in chicken embryos, but the effects were not significant enough to classify it as a known teratogen (Verrett et al. 1980). However, thymol exhibited genotoxic and potent mutagenic activity against *Drosophila melanogaster* fruit flies (Karpouhtsis et al. 1998).

Chronic Toxicity

No studies on the chronic toxicity of thyme or thyme oil were found. The chronic toxicity of thymol is summarized in Table 4.

Table 4

Chronic Toxicity of Thymol

Study	Results	Source
Chronic toxicity	Ames test: Mildly positive to negative.	(Stammati et al. 1999; Azizan and Blevins 1995)
Carcinogenicity	Negative	(Andersen 2005; Stoner et al. 1973)
Combined chronic toxicity & carcinogenicity	Not Found	

Thymol (1.2 and 6.0 g/kg) was negative for promoting lung tumors in mice (Stoner et al. 1973). Anti-tumor effects were observed for thymol (Andersen 2005).

Human Health Incidents

The National Pesticide Information Center had reports of 11 human health related incidents involving thyme between April 1, 1996 and March 30, 2016 (NPIC 2016). Those incidents involved either additional active ingredients, or use of a pesticide applied to thyme as a crop plant. Several of these incidents involved EPA-registered pesticides.

Environmental Effects Information

Effects on Non-target Organisms

The effects of thyme and thyme oil on non-target organisms are estimated by the effects of the principle component, thymol, which may be up to 80% of thyme oil and regarded as the primary active constituent. The results are summarized in Table 5.

Table 5

Effects of Thymol on Non-target Organisms

Study	Results	Source
Avian Oral, Tier I	>10,000 mg/kg (non-toxic)	(Gwynn 2014)
Non-target plant studies	No effects	(Gwynn 2014)
Non-target insect studies	Honeybee (*Apis mellifera*) LC_{50}: 24 hr: 21.89 µl/dish 48 hr: 11.9 µl/dish 72 hr: 8.05 µl/dish	(Damiani et al. 2009)
Aquatic vertebrates	Rainbow trout: 3.0 mg/l (Thymol, 96 hr) Coho Salmon: 20.5 mg/mL LD50 thyme oil (96 hr)	(Gwynn 2014, Stroh et al. 1998))
Aquatic invertebrates	*Daphnia magna* LC_{50} 4.9 mg/l (48 h)	(Gwynn 2014)

Thymol has been tested against Varroa mites (*Varroa destructor*) on honeybees, and found to be tolerated by bees (Imdorf et al. 1999), although, as reported in Table 5, prolonged exposure could be toxic (Damiani et al. 2009). Researchers have also noted high variability of honeybee susceptibility to thymol among hives (Calderone et al. 1997) and greater sensitivity by queens than by workers (Whittington et al. 2000). Thyme oil was found to be non-toxic to the rove beetle (*Atheta coriaria*), a beneficial predator used mainly in greenhouses to control fungus gnats (*Bradysia* spp.) (Echegaray and Cloyd 2012).

From April 1, 1996 to March 30, 2016, 10 animal-related incidents involving thyme were reported to NPIC (NPIC 2016). All involved other active ingredients in addition to thyme, and some involved mixes of multiple pesticide formulations. Several of the incidents involved companion animals' adverse reactions to products specifically designed to repel cats and dogs. Others involved flea repellents labeled for use on dogs and cats.

Between 2006 and 2008, The American Society for the Prevention of Cruelty to Animals' Animal Poison Control Center reported 38 incidents involving the exposure of cats, and eight involving dogs. The incidents were due to use of flea products containing thyme oil and other active ingredients that are eligible for EPA exemption from registration (Genovese et al. 2012). Two formulated products, sprays and spot-on treatments accounted for all incidents. Symptoms included skin erythema, vomiting, diarrhea, lethargy, edema, seizures, weakness, recumbent tachycardia, agitation, anorexia, hyperactivity, hypersalivation, panting, retching, tremors, and vocalization. One 7-week old kitten died from inappropriate use of the product.

Environmental Fate, Ecological Exposure, and Environmental Expression

No data was found for thyme or thyme oil's environmental fate, ecological exposure or environmental expression. When re-reviewing thymol's eligibility to be re-registered, the EPA waived its data requirements for hydrolysis; photodegradation in water and soil; aerobic and anaerobic soil degradation; anaerobic water degradation; leaching, adsorption, and desorption; terrestrial field dissipation; and accumulation in confined rotational crops (US EPA OPPTS 1993). Thyme and its active constituent, thymol, are considered readily biodegradable in air, soil, and water (Gwynn 2014). The EPA found that no environmental incidents were reported for thyme oil as a sole active ingredient as of February 19, 2010 (Matthews 2010).

Environmental Incidents

From April 1, 1996 to March 30, 2016, NPIC received 24 reported incidents involving thyme or thyme oil (NPIC 2016). All involved active ingredients in addition to thyme. While most incidents did not have a narrative, those with detailed descriptions involved other active ingredients and were either inquiries about how to clean up multiple pesticide formulations or complaints about the pesticide's unpleasant odor.

Efficacy

Insecticidal Activity

Of the four essential oils tested against the mosquito *Culex pipiens*, thyme oil was the most potent repellent, providing 91% protection for a period of over an hour (Choi et al. 2002). The larvae of the mosquito *Culex quinquefasciatus* were left in treated water for five hours, and the 24 hour LC_{50} was extrapolated for doses ranging from 14 to 117 mg/l (Pavela et al. 2009). Mortality increased significantly in relation to time of exposure, and total mortality of the larvae at the end of their development was about 90% with a 48-hour exposure at the highest dose. The LC_{50} levels were 32.9 mg/l for the third instar and 14.2 mg/l for the fourth instar. A concentration of 0.2% was 100% effective at inhibiting oviposition when applied to ovipositing sites.

When used against the Asian citrus psyllid (*Diaphorina citri*) thyme oil (obtained from a fragrance company and having over 95% purity) attained the greatest repellency effect when compared to lavender, coriander, and rose oils (Mann et al. 2012). Out of 34 different monoterpenoids screened, thymol—the main active substance in thyme oil—was found to be the most lethal against the common house fly (*Musca domestica*) (Lee et al. 1997). The LD_{50} was 29 µg per adult fly. Thymol was also found to be lethal against the larvae of *Drosophila melanogaster* fruit flies, with an LD_{50} of 2.6 µl per larva (Karpouhtsis et al. 1998). Isolated thymol is not eligible for use as an active ingredient in a minimum risk pesticide, and the equivalent efficacy cannot be directly inferred because of thyme oil's variable thymol content.

An experiment comparing the efficacy of 92 essential oils for the control of sweet potato whitefly (*Bemisia tabaci*) found thyme oil to be one of the more effective, with an LC_{50} of 0.45 mL/cm^3 for red thyme, 0.46 mL/cm^3 for white thyme and 100% mortality at a rate of 2.4 mL/cm^3 for the oil from both species (Kim et al. 2011).

Steam-distilled thyme oil inhibited reproduction in the bruchid beetle (*Anathoscelides obtectus*), a post-harvest pest of beans (Regnault-Roger and Hamraoui 1994). On the other hand, isolated thymol was found not only to be ineffective against the Western corn rootworm (*Diabrotica vergifera vergifera*), it was 100% phytotoxic to corn (*Zea mays*) at a dosage of 500 ppm (Lee et al. 1997).

Acaricidal Activity

Thyme oil is an effective acaricide, and is used to manage parasitic mites of honeybees. Tests of *T. vulgaris* oil compared with laurel oil (*Lauris nobilis*) and lavender oil (*Lavendula officinalis*) showed that *T. vulgaris* had the lowest LC_{50} for the parasitic mite *Varroa destructor,* (Damiani et al. 2009). The LC_{50} values were 4.65 µl/dish for 24 hours, 3.02 µl/dish for 48 hours, and 2.93 µl/dish for 72 hours.

T. vulgaris oil was also effective against the two-spotted spider mite (*Tetranychus urtica*), reducing egg laying and resulting in 100% mortality at a 1% concentration (El-Gengaihi et al. 1996). However, isolated thymol was more effective at lower doses. When compared with 53 different essential oils, white and red thyme oil at concentrations of 14 x 10^3 l/ml of active ingredient had mortality rates of 93% and 90% respectively (Choi et al. 2004). Caraway, geranium, lemon eucalyptus, lemongrass, oregano, peppermint, spearmint, and sage were all more effective, with 100% mortality at the highest dose of 19 x 10^{-3} µl/ml air. An efficacy comparison study of 34 essential oils found that thyme oil was the most effective, and the only oil able to achieve 100% mortality of *T. urticae* at a rate of 5 µl/L at a temperature of 25°C (Lim et al. 2011).

Red thyme oil with a 54% thymol content was shown to be effective against the American household dust mite (*Dermatophagoides farina*) (Kim and Sharma 2011). When applied as microcapsules to fabric at saturation levels, the red thyme oil resulted in almost 84% mortality—though not as effective as clove oil's 94% mortality.

Antimicrobial and Fungicidal Activity

The antimicrobial properties of thyme were first observed in 1887 (Zarzuelo and Crespo 2003). Two different literature reviews documented various microorganism efficacy tests showing that thyme oil is effective against gram-negative and –positive bacteria, fungi, and yeast (Zarzuelo and Crespo 2003; Pauli and Schilcher 2009). Thyme oil inhibited methicillin resistant *Staphylococcus aureus* (MRSA) at a minimum concentration of 4 µl/ml (Shukr and Metwally 2014), but there was no mention of testing on antibiotic susceptible strains. Putting thyme oil in a polymer gel made it more spreadable and increased the zone of inhibition.

Thyme oil obtained by steam distillation was relatively effective at inhibiting the entomopathogenic bacteria *Paenibacillus larvae,* the organism responsible for American foulbrood in honey bees. The minimum inhibitory rate ranged between 100 and 150 µg/l (Alippi et al. 1996).

Standards and Regulations

EPA Requirements

Thyme and thyme oil are eligible for use as an active ingredient in minimum risk pesticides. Thyme is exempt from the requirement of a tolerance and can be used for food uses [40 CFR 180.950(a)].

FDA Requirements

T. vulgaris and *T. serphyllum* are considered to be Generally Recognized As Safe (GRAS) by FDA [21 CFR 182.10] The oils of *T. vulgaris, T. serphyllum* and the variety Gracilis of *T. zygis* are also considered GRAS [21 CFR 182.20].

Other Regulatory Requirements

Natural thyme and thyme oil are allowed for organic production under the National Organic Program standards [7 CFR 205].

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