New York State Integrated Pest Management Program
Cornell Cooperative Extension

Rosemary & Rosemary Oil Profile

Active Ingredient Eligible for Minimum Risk Pesticide Use

Brian P. Baker and Jennifer A. Grant
New York State Integrated Pest Management, Cornell University, Geneva NY

Label Display Names: Rosemary, Rosemary Oil

Active Components: Carnosic and labiatic acids, caffeic acid, rosmarinic acid, chlorogenic acid, rosmanol, carnosol, α- and ß-pinene, diterpenes, terpenes (1,8 cineole), and other natural antioxidants

CAS Registry #: 8000-25-7 (Rosemary Oil)

U.S. EPA PC Codes: 128893 (Rosemary)

597700 (Rosemary Oil)

CA DPR Chem Codes: 2331 (Rosemary)

5450 (Rosemary Oil)

Other Names: Rosemary absolute, Rosemary leaf oil

Other Codes: FEMA: 2992
Beilstein: 0-01-00-00462

Summary: Rosemary, a widely used culinary herb, and rosemary oil are derived from the evergreen shrub *Rosmarinus officinalis.* Most rosemary oil is produced by steam distillation of the flowering tops, and is primarily composed of a mixture of monoterpenes including alpha-pinene, 1,8 cineole, and camphene as well as ketones including camphor, and the alcohol borneol. Compounds found in rosemary include carnosic acid, carnosol, and rosmarinic acid. As a pesticide, it is primarily used as an insect repellent. Due to its use as a food, there is no notable concern as to its safety.

Pesticidal Uses: Anti-microbial, insect repellent of clothes moths, fruit flies, lice, mosquitoes, and other insects.

Formulations and Combinations: Clove oil, cinnamon oil, thyme oil, eugenol, wintergreen oil, cinnamon oil, and alcohol have all been combined in rosemary pesticide products.

Basic Manufacturers: Biolandes; Destilaciones Bordas Chinchurreta S.A; Carbonnel; Herbes del Moli.

Safety Overview: Rosemary and rosemary oil are common food and cosmetic ingredients with a long history of safe use.

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.

Background

Rosemary (*Rosmarinus officinalis*) is an evergreen native to the Mediterranean region, with a wide cultivation area. The rosemary crop is harvested at the flowering top stage (Başer and Demirci 2012). Most rosemary oil is made from steam distillation of the fresh flowering tops (Khan and Abourashed 2010), although extraction time can be reduced, yield increased, and certain quality parameters can be improved by extraction in water superheated under pressure to between 125°C and 175°C (Basile et al. 1998). Rosemary oil and various extracts contained in it can also be derived by use of the solvents acetone, supercritical carbon dioxide, or hexane (EFSA 2008). These extracts were not explicitly included in the December 2015 clarification of the active ingredients eligible for use in minimum risk pesticides (US EPA 2015b).

The primary use of rosemary is as an herb and flavoring. Rosemary has a distinct flavor and aroma that is rich in pinene and various terpenoids. The leaves are used in cooking in a variety of cuisines. Extracts have been used as herbal remedies in traditional folk medicine (Merck 2015). Rosemary oil is noted to have several health benefits, including for the prevention of bronchial asthma, atherosclerosis, and ischaemic heart disease; for treatment of peptic ulcer; as a protectant for hepatotoxicity; and as an anti-spasmodic, anti-inflammatory, and anti-carcinogen (Inoue et al. 2006; al-Sereiti et al. 1999).

Chemical and Physical Properties

The physical and chemical properties of rosemary oil and some of its terpene constituents are summarized in Table 1.

Table 1

Physical and Chemical Properties of Rosemary Oil and Selected Terpenes

Property	Characteristic/Value	Source
Molecular Formula:	Rosemary oil $C_{10}H_{18}O_1$ (Carnosol $C_{20}H_{26}O_4$, Carnosic Acid $C_{20}H_{28}O_4$, Rosmarinic acid $C_{18}H_{16}O_8$)	(US NLM 2016)
Molecular Weight:	Rosemary Oil Terpenes: 154.25 g/mol (Carnosol: 330.41804 g/mol, Carnosic Acid: 332.43392 g/mol , Rosmarinic acid: 360.31484 g/mol)	(US NLM 2016)
Percent Composition:	(Rosemary essential oil) Monoterpenes: α-pinene 20.14%, camphene 11.38%, 1.8 cineole 26.54%, Ketones: Camphor 12.88%.	(Khan and Abourashed 2010)
Physical state at 25°C/1 Atm.	Extract and essential oil: Liquid Plant: solid	(Merck 2015)
Color	Colorless or pale yellow liquid	(Merck 2015)
Odor	Characteristic rosemary odor	(Merck 2015)
Density/Specific Gravity	Relative density (Water=1): 0.908	(ChemWatch 2015)
Melting point	Mean MP: 35.37˚C	(Merck 2015)
Boiling point	176˚C (349˚F)	(Sigma-Aldrich 2015)
Solubility	Insoluble in water. Sol in 10 vols 80% alcohol, soluble in methanol	(Merck 2015)
Vapor pressure	>1	(ChemWatch 2015)
pH	N/A	
Octonol/Water (K_{ow}) coefficient	logK_{ow}: 2.8515	(EPI 2012)
Viscosity	Not found	

Property	Characteristic/Value	Source
Miscibility	Partly miscible in water.	(Sigma-Aldrich 2015)
Flammability	Oxidizer; may intensify fire. Flammable liquid and vapor.	(Sigma-Aldrich 2015)
Storage stability	Stable. Store in airtight container in well ventilated place away from clothing, organic, or combustible materials, and away from extreme heat and strong oxidizers	(Science Lab 2013; Sigma-Aldrich 2015)
Corrosion characteristics	Non-Corrosive in presence of glass	(Science Lab 2013)
Air half life	Rosemary oil: 22.5 hrs	(EPI 2012)
Soil half life	Rosemary oil: 1,800 hrs	(EPI 2012)
Water half life	Rosemary oil: 900 hrs	(EPI 2012)
Persistence	Rosemary oil: 833 hrs	(EPI 2012)

Human Health Information

Acute Toxicity

Rosemary oil's acute toxicity is summarized in Table 2.

Table 2

Acute Toxicity of Rosemary Oil

Study	Results	Source
Acute oral toxicity	5ml/kg (rats)	(Opdyke 1974)
Acute dermal toxicity	>10ml/kg (rabbits)	(Opdyke 1974)
Acute inhalation	Not found	
Acute eye irritation	Not found	
Acute dermal irritation	24h moderate	(Opdyke 1974)
Skin sensitization	Negative	(Opdyke 1974)

An expert panel of the European Food Safety Authority determined that rosemary derivatives extracted by acetone, supercritical carbon dioxide, ethanol, or hexane, as well as carnosol and carnosic acid concentrated from rosemary oil are of low acute and subacute toxicity, and their use as food additives are "not of toxicological concern" (EFSA 2008).

Sub-chronic Toxicity

Sub-chronic toxicity data for rosemary and rosemary oil were not found.

Human Health Incidents

The National Pesticide Information Center (NPIC) had 13 human health related incidents involving rosemary or rosemary oil between April 1, 1996 and March 30, 2016 (NPIC 2016). Reviewing the narratives where available, all involved other active ingredients in addition to rosemary or rosemary oil. Several of these incidents involved EPA-registered pesticides.

Environmental Effects Information

Effects on Non-target Organisms

A formulated 25(b) exempt insecticide product—Dr. Earth Fruit and Vegetable spray—with the active ingredients rosemary, cinnamon, clove oil, and garlic extract was found to be phytotoxic to the Transvaal daisy (*Gerbera jamesonii*) (Cloyd et al. 2009).

A formulation composed of rosemary oil and soybean oil (Pharm Solutions' Indoor Pharm) was found to be non-lethal to the rove beetle (*Atheta coriaria*) (Echegaray and Cloyd 2012). The article did not say whether the formulation was exempt or registered.

Two incidents involving a plant-derived flea shampoo were reported to the American Society for the Prevention of Cruelty to Animal's Animal Poison Control Center. The product was exempt from registration and contained 1.0% rosemary oil, and the reactions included skin erythema, vomiting, diarrhea, lethargy, edema, ataxia, seizures and renal failure. 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 (Genovese, et al. 2012). The formulation also contained several other 25(b) eligible active ingredients: peppermint oil, clove oil, sodium lauryl sulfate, cinnamon oil, and cedarwood oil.

From April 1, 1996 to March 30, 2016, NPIC learned of 4 animal-related incidents involving rosemary or rosemary oil (NPIC 2016). The one event having a narrative description involved a dog being soaked after running through a misting system.

Environmental Fate, Ecological Exposure, and Environmental Expression

No studies were found on the environmental fate, ecological exposure, or environmental expression of rosemary and rosemary oil. The EPA waived environmental fate studies for rosemary and rosemary oil. Computer modeling suggests rosemary oil—non-volatile in water—to have high mobility in the soil (HSDB 2015), and to be susceptible to rapid degradation through exposure to sunlight and biological activity. Such modeling was used as there are no data for photodegradation or biodegradability of rosemary and its various extracts (HSDB 2015).

Environmental Incidents

The NPIC received 20 reported incidents involving rosemary or rosemary oil from April 1, 1996 to March 30, 2016 (NPIC 2016). Most of these incidents did not have a narrative, and the few that did all involved other active ingredients, including EPA-registered formulations.

Efficacy

Insecticidal and Acaricidal Activity

When compared with 11 other essential oils derived from plants grown in Argentina, rosemary oil had the longest repellent effect on the mosquito *Aedes aegypti,* with 100% repellence for 90 minutes at concentrations as low as 12.5% (Gillij et al. 2008). When compared with other essential oils, rosemary oil did not warrant further investigation because it was not sufficiently toxic to the larvae of *Anopheles stephensi* and *Culex quinquefasciatus* (Amer and Mehlhorn 2006). In another laboratory study, rosemary oil was found to be highly toxic to first instar larvae of *A. aegypti,* with an LC_{50} of 40.8 mg/L^2, but was non-toxic to the later instars at the higher doses of up to 500 40.8 mg/L^2 (Waliwitiya et al. 2009). The same study showed that rosemary oil reduced oviposition by nearly 50% at a rate of 20 mg/L^2 applied to oviposition sites.

When used to treat the myiasis vector fly, *Lucilia sericata*, rosemary oil had a mean LC_{50} of 6.77% concentration for males. Female survival at the lower doses was four times greater than male survival (Khater et al. 2011). Rosemary oil was found to be an effective contact toxicant against two-spotted spider mites (*Tetranychus urticae*). Pure rosemary oil had an LC_{50} of 13.19 ml/L on *T. urticae* in laboratory studies (Miresmailli and Isman 2006). Efficacy decreased rapidly after 24 hours. In plant studies, the LC_{100} for rosemary oil as a treatment against mites was 20 ml/L when used on beans and 40 ml/L for tomatoes (Miresmailli et al. 2006).

A laboratory and screenhouse study showed that pure rosemary oil at a rate of 1 μl/300mm^2 sheet of filter paper repelled the green peach aphid (Hori 1998). A commercial blend of 0.10% rosemary oil, 0.10% cinnamon oil and 1.5% cottonseed oil (Pharm Solutions Flower Pharm) in a ready-to-use formulation achieved over 90% mortality of citrus mealybug (*Planococcus citri*) when applied at a rate of 5.2 ml/plant (Cloyd et al. 2009). The product is 25b exempt. However, the treatment also resulted in significant damage to the test plants. Another commercial formulation (Dr. Earth Fruit & Vegetable Insect Spray) is exempt from registration. Its composition of 0.30% cinnamon, 0.40% rosemary, 0.30% clove oil and 0.30% garlic extract was relatively ineffective against western flower thrips (*Frankliniella occidentalis*), sweetpotato whitefly (*Bemisia tabaci*), and green peach aphid (*Myzus persicae*) (Cloyd et al. 2009).

Of essential oils screened for toxicity to wireworm (*Agriotes obscurus*), rosemary oil—with an LC_{50} of 15.9 μg/cm^3—was the second-most effective larvicide, after citronellal (Waliwitiya et al. 2005). Rosemary oil was also the most effective of 28 essential oils tested on the coleopteran storage pest *Rhyzopertha dominica* with 100% mortality at a concentration of 15 μl/L (Shaaya et al. 1991). Rosemary oil had less than 100% mortality against *Oryzaephilus surinamensis*, *Tribolium castaneum*, and *Sitophilus oryzae* at that concentration.

A patent for the blend of rosemary oil and wintergreen oil (Bessette and Lindsay 2014) sold under the brand name Hexacide™ makes broad efficacy claims for a wide range of pests and diseases hosted on a variety of crops.

Hexacide achieved 96.6% lethal control of strawberry aphid (*Chaetosiphos fragaefoliion*) on strawberries (*Fragaria* × *ananassa*) at a rate of 1 qt/acre. Applications of 2 qt/A and 4 qt/A were not significantly different from the 1 qt/A application. At all rates, the control was slightly lower, but not significantly different from the spinosad-based insecticide Conserve (Bessette and Lindsay 2014). At 2 qt/A, Hexacide reduced melon aphids (*Aphis gossypii*) on squash by over 96%, which was better than a formulated pesticide with azadirachtin as the active ingredient, and comparable to a formulated product with pyrethrin (Pyganic), but not consistently as effective as imidacloprid (Admire), methomyl (Lannate), pymetrozine (Fulfill), or thiamethoxam (Actara and Platinum) at six days after treatment (Bessette and Lindsay 2014).

Hexacide at 1 qt/A achieved 64.0% lethal control of two-spotted spider mites (*Tetranychus urticae*) on strawberries, with 89.7% control at 2 qt/A and 91.4% control at 4 qt/A. The control was comparable to abamectin (Agri-Mek®). Pacific Mite (*Tetranychus pacificus*) on grapes (*Vitis vinifera*) showed 100% mortality at a rate of 3 qt/A after 14 days. The result was comparable to the acaricide dicofol (Kelthane®). On the other hand, Dr. Earth Fruit & Vegetable Insect Spray was the least effective of 10 commercial products in controlling two-spotted spider mite. The other commercial pesticide products had garlic extract, soybean oil, canola oil, thyme oil, and mint oil, pyrethrins, and sodium lauryl sulfate as active ingredients. The EPA registration status was not given in all cases. However, Dr. Earth Fruit & Vegetable Insect Spray was significantly more effective than the no treatment control, with mortalities of 60-80% compared with less than 10% for the no treatment control.

Rosemary oil at a 100% concentration and a rate of 3.7 g/cap achieved 100% mortality of the American cockroach (*Periplaneta americana*) (Bessette and Lindsay 2014). Rosemary oil is also claimed to be an effective synergist that increases efficacy of both boric acid and pyrethrum against a broad range of insects, particularly cockroaches (Granirer and Nelson 1988).

Anti-microbial and Fungicidal Activity

A literature review documented that rosemary oil had an inhibition zone of greater than 0 mm for a broad range of gram-negative and gram-positive bacteria, fungi, and yeast by the agar diffusion test (Pauli and Schilcher 2009). Their results were replicated using a set of methods known as 'broth dilution' against six microbial species, including gram-positive bacteria (*Staphylococcus aureus* and *Bacillus subtilis*), gram-negative bacteria (*Escherichia coli* and *Pseudomonas aeruginosa*), a yeast (*Candida albicans*), and a fungus (*Aspergillus niger*) (Santoyo et al. 2005). That study identified camphor, borneol, and verbenone as the most active constituents against the different target organisms. Another study found significant antimicrobial activity by rosemary oil against *E. coli, S. typhi, S. enteritidis, and Shigella sonei* (Bozin et al. 2007). Minimum inhibitory concentrations (MIC) ranged from 15 to 30 μL/plate, and minimum fungicidal concentrations (MFC) were 30 μL/plate for all organisms except *C. albans*, which had an MFC of slightly over 60 μL/plate.

A combination of rosemary oil and wintergreen oil with a surfactant at 0.5 lb/A reduced the severity of controlled infections of powdery mildew (*Uncinula necator*) on grapes by over 21% (Bessette and Lindsay 2014). However, the treatment was not as effective as tebuconazole (Elite), fenarimol (Rubigan), or trifloxystrobin (Flint). The same formulation was applied to treat brown patch (*Rhizoctonia solani*) and dollar spot (*Sclerotinia homoeocarpa*) on turf at a rate of 2 oz./A (Bessette and Lindsay 2014). After four weeks, the disease severity index for brown patch was significantly better than the control, comparable to chlorothalonil (Daconil), but not as good as the turf treated with propiconazole (Banner Maxx). With dollar spot, the severity index at four weeks after treatment with rosemary oil and wintergreen oil was more effective than myclobutanil (Eagle) and propiconazole, and comparable to chlorothalinil.

In addition, the combination of rosemary oil and clove oil (*Syzygium aromaticum*) had a slight but significant synergistic effect against the pathogenic microorganisms *Staphylococcus epidermidis*, *Escherichia coli*, and *Candida albicans*, with a reduced kill-time response at various concentrations (Fu et al. 2007).

Standards and Regulations

EPA Requirements

Rosemary and rosemary oil are exempt from the requirement of a tolerance (40 CFR 180.950(a)(1)(iii)). Rosemary is also considered a minimal risk inert ingredient [40 CFR 152.25(f)(2)(i)].

FDA Requirements

Rosemary and rosemary oil are considered to be Generally Recognized As Safe (GRAS) by FDA [21 CFR 182.10 and 21 CFR 182.20].

Other Regulatory Requirements

Rosemary and rosemary oil are allowed by the USDA's National Organic Program (NOP) [7 CFR 205.105].

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