New York State Integrated Pest Management Program

Cornell Cooperative Extension

Citric Acid Profile

Active Ingredient Eligible for Minimum Risk Pesticide Use

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Active Ingredient Name: Citric acid

Active Components: Citric acid

CAS Registry #: 77-92-9

U.S. EPA PC Code: 021801

CA DPR Chem Code: 142

Other Names: 2-Hydroxy-1,2,3-propanetricarboxylic acid; 1,2,3-Propanetricarboxylic acid, 2-hydroxy- (9CI) β-hydroxytricarballylic acid; Ácido cítrico (Spanish); Zitronensäure (German); Acide citrique (French);

Other Codes: BRN: 782061; EINECS: 222-536-6; FEMA: 2306; INS: 330; RTECS: GE7350000;

Summary: Citric acid is a naturally occurring substance and a common food ingredient. It is a severe eye irritant and can cause other health problems to exposed people. Its pesticidal use is primarily as an antimicrobial. The EPA has affirmed that no additional data requirements need to be filled and on that basis determined that citric acid can be used as an active ingredient in minimum-risk pesticides.

Pesticidal Uses: The principal pesticidal use of citric acid is as a contact antimicrobial pesticide. It is used as both a food-contact and non-food-contact antimicrobial with many uses in food handling, residential, and public facilities. Citric acid is used as a disinfectant on fruits, vegetables, and food-contact surfaces. It is also used as a sanitizer, virucide, and germicide; and as an algicide in pools, hot tubs, and other places where unwanted algae grow.

Formulations and Combinations: As a pesticide active ingredient, it is often combined with acetic acid, vinegar, and malic acid. It is also combined with various essential oils, particularly mint oils. Citric acid is an ingredient in registered anti-microbial pesticides and as an inert ingredient in a wide range of pesticide formulations. It works as a pH adjuster and chelating agent, and as an adjuvant mixed with a broad range of pesticides as a pH adjuster and buffering agent in tank mixes.

Basic Manufacturers: ADM, Cargill, DSM, Haarman-Reimer, Huangshi Xinhua Biochem, Jiangsu Nobei Biochem, Jungbunzlauer, Schweizerhall, Tate & Lyle.

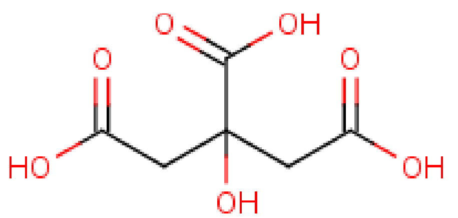
This document profiles an active ingredient currently eligible for exemption from pesticide registration when used in a Minimum Risk Pesticide in accordance with the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) section 25b. The profile was developed by the New York State Integrated Pest 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.

Safety Overview: Citric acid is characterized by low oral acute toxicity, biodegradability, and extensive presence in nature (Harrigan-Ferrelly 2009b). However, it can be an eye and respiratory irritant in higher concentration.

General Background

Citric acid is a Krebs cycle acid responsible for basic metabolic activity in all aerobic organisms, and is closely related to malic, tartaric, and fumaric acids. Citric acid is a naturally occurring carboxylic acid that is found in fruits, vegetables and other plants. It is the prevalent acid found in *Citrus* spp. fruit, such as lemons, oranges and grapefruit. Tomatoes (*Lycopersicon esculentum*) also have a significant amount of citric acid in their fruit. Among the other plants known to contain high amounts of citric acid are angelica (*Angelica archangelica*), cranberries (*Vaccinium macrocarpon*), *Gingko biloba,* stinging nettle (*Urtica dioica*), rose hips (*Rosa* spp.), hibiscus (*Hibiscus* spp.), and marigolds (*Tagetes* spp.) (Khan and Abourashed 2010). Originally isolated from lemon juice in 1784, commercial citric acid was produced by extraction from juice up until the 1940s. Virtually all commercial citric acid is now produced by fermentation. Citric acid has a broad range of food and non-food uses that far exceed its use as a pesticide. The EPA first registered citric acid as a pesticide in the 1970s (US EPA OPPTS 1992).

Chemical and Physical Properties



Source: (EMBL 2015)

The physical and chemical properties of citric acid are summarized in Table 1.

Table 1

Physical and Chemical Properties of Citric Acid

Property	Characteristic/Value	Source
Molecular Formula:	$C_6H_8O_7$	(Merck 2015)
Molecular Weight:	192.12	(Merck 2015)
Percent Composition:	C 37.51%, H 4.20%, O 58.29%	(Merck 2015)
Physical state at 25°C/1 Atm.	Solid: Granulated Powder of translucent crystals to fine crystalline powder. Crystals are monoclinic holohedra. (Anhydrous)	(Gowda 2009)
Color	Colorless translucent to white	(Gowda 2009)
Odor	Odorless with strongly acid taste	(Gowda 2009)
Density/Specific Gravity	1.665 g/cu cm at 20°C	(US NLM 2016)
Melting point	153°C.	(Merck 2015)
Boiling point	175°C	(Gowda 2009)
Solubility	Water: 59.2% at 20 deg C; 70.9% at 50°C; 84.0% at 100°C; Very soluble in ethanol; soluble in ether, ethyl acetate; insoluble in benzene, chloroform	(US NLM 2016)
Vapor pressure	$1.7X10^{-8}$ mm Hg at 25°C	(US NLM 2016)

Property	Characteristic/Value	Source
pH	0.8 for a 50% solution; 2.8 for a 10% solution	(Gowda 2009)
Octonol/Water (K_{ow}) coefficient	-1.67	(EPI 2012)
Viscosity	2.549 cP 30% aqueous solution at 20°C	(US NLM 2016)
Miscibility	Miscible with alcohol	(US NLM 2016)
Flammability	Flammable as dust at levels of 0.28-2.29 Kg/Cu M	(HSDB 2015)
Storage stability	Stable. Incompatible with bases, strong oxidizing agents, reducing agents, metal nitrates.	(Royal Society of Chemistry 2015)
Corrosion characteristics	Corrosive to copper, zinc, aluminum, nickel and their alloys. Aqueous solutions of citric acid are mildly corrosive of carbon steel. Generally non-corrosive to glass and plastic.	(Gowda 2009)
Air half life	36.6 hrs	(US EPA 2012)
Soil half life	416 hrs	(US EPA 2012)
Water half life	208 hrs	(US EPA 2012)
Persistence	387 hrs	(US EPA 2012)

Human Health Information

Acute Toxicity

The acute toxicity of citric acid is summarized in Table 2.

Table 2

Acute Toxicity of Citric Acid

Study	Results	Source
Background	Not found	
Acute oral toxicity	Rat LD_{50}: 3 g/kg (3,000 mg/kg	(Mottl 2009)
Acute dermal toxicity	Rabbit: 4 hr exposure caused erythema and edema	(Weinberg Group 2003)
Acute inhalation	Not found	
Acute eye irritation	Severe	(Mottl 2009)
Acute dermal irritation	Moderate	(Mottl 2009)
Skin sensitization	Not found	

Inhalation of citric acid causes airway constriction and coughing (HSDB 2015). A number of registered pesticides with citric acid as the only active ingredient have had additional acute toxicity tests performed for the entire formulation and the data reviewed by the EPA (Blackwell 1998, 2001). These formulations were categorized as Level IV, Signal Word “Caution”, which is the lowest risk among registered pesticides. The EPA evaluated the acute toxicity data of citric acid and concluded that no additional data is required for EPA registered pesticides (Harrigan-Ferrelly 2009a).

Sub-chronic Toxicity

The sub-chronic toxicity of citric acid is summarized in Table 3. The EPA concluded that no additional sub-chronic toxicity data is needed to continue the use of citric acid as an active ingredient in registered pesticides (Harrigan-Ferrelly 2009a).

Table 3

Sub-chronic Toxicity of Citric Acid

Study	Results	Source
Repeated Dose 28-day Oral Toxicity Study in Rodents	Rat (6 week): NOEL: 2,260 mg/kg LOAEL: 4,670 mg/kg:	(Weinberg Group 2003)
90-day oral toxicity in rodents	No effect	(Mottl 2009)
90-day oral toxicity in non-rodents	Rabbit (150 Day) some effects on growth and survival, but no histopathologic changes.	(Mottl 2009)
90-Day dermal toxicity	Not found	
90-Day inhalation toxicity	Not found	
Reproduction/development toxicity screening test	No indication of adverse effects	(US EPA 2015a)
Combined repeated dose toxicity with reproduction/development toxicity screening test	No adverse effects observed	(Mottl 2009)
Prenatal developmental toxicity study	No effects observed	(Weinberg Group 2003)
Reproduction and fertility effects	No reproductive or fertility effects detected	(US EPA 2015)

Chronic Toxicity

The chronic toxicity of citric acid is summarized in Table 4. Citric acid is not identified as a carcinogen by the International Agency for Research on Cancer (IARC 2014), 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).

Table 4

Chronic Toxicity of Citric Acid

Study	Results	Source
Chronic toxicity	Negative	(Mottl 2009)
Carcinogenicity	Not identified as a carcinogen	(Mottl 2009)
Combined chronic toxicity & carcinogenicity	No adverse effects at the highest dosage	(Mottl 2009)

Human Health Incidents

EPA received reports of 105 adverse human incidents related to citric acid pesticide use that were found during a search of the OPP Incident Data System (IDS) (Harrigan-Ferrelly 2009a). The EPA determined that the symptoms involved in human incidents were minimal with no residual disability involved. Reported symptoms included rash, blisters, shortness of breath, congestion, abdominal pain, cough, fatigue, runny nose, body aches, swollen eyes, and corneal abrasion when exposed via the inhalation, dermal and ocular routes. The California Pesticide Illness Surveillance Program received four incident case reports identified as citric acid exposure. When inhaled, citric acid caused shortness of breath, throat irritation, chest tightness, wheezing, coughing, headache, nausea and vomiting. Citric acid also caused eye irritation. The same EPA report indicated that there were no citric acid specific incidents reported in the Poison Control Center data. Between April 1, 1996 and March 30, 2016, the National Pesticide Information Center—one of several sources used in the IDS—received six reported human health incidents with citric acid (NPIC 2016). All of these involved formulated products with other active ingredients, including three that were EPA registered.

Environmental Effects Information

Effects on Non-Target Organisms

The effects of citric acid on non-target organisms are summarized in Table 5.

Table 5

Effects of Citric Acid on Non-target Organisms

Study	Results	Source
Avian Oral, Tier I	Not found	
Non-target plant studies	8 day growth inhibition level: 640 mg/L	(Weinberg Group 2003)
Non-target insect studies	Not found	
Aquatic vertebrates	*Lepomis macrochirus* 96 hr LC_{50}: 1,516 mg/L	(Gowda 2009)
Aquatic invertebrates	*Daphnia magna* 72 hr EC_{50}: 240 mg/L	(Weinberg Group 2003)

As noted below, citric acid has some herbicidal properties and can result in non-target plant damage and phytotoxicity when applied at higher concentrations to foliage.

The EPA OPP Incident Data System reported 75 pet incidents with formulated citric acid prior to the 2009 registration review (Harrigan-Ferrelly 2009a). Symptoms included hair loss, difficulty breathing and rashes. The NPIC received three incident reports involving animals exposed to citric acid between April 1, 1996 and March 30, 2016 (NPIC 2016). A study examined potential citric acid exposure and toxicity to Hawaiian hoary bats (*Lasiurus cinereus semotus*) associated with the control of invasive non-native frog species. The study concluded that the bats were not likely to be harmed based on the low toxicity, application method and application rate (Pitt et al. 2014).

Based on its low toxicity, widespread natural occurrence and the minor nature of the adverse effects on non-target organisms, the EPA concluded that citric acid has a favorable ecological profile and that no additional data are needed for its use as an active ingredient in EPA registered pesticide products (Gowda 2009).

Environmental Fate, Ecological Exposure, and Environmental Expression

EPA has waived all environmental fate data for citric acid (Gowda 2009). There is no plan to require those data gaps to be filled (Harrigan-Ferrelly 2009a). The decision was based on its natural occurrence, common use as a food item, lack of significant toxicity and reported adverse incidents. Estimated values for environmental fate, ecological exposure and environmental expression based on the chemical and physical properties are reported in Table 6.

Table 6

Environmental Fate, Ecological Exposure, and Environmental Expression of Citric Acid

Study	Results	Source
Leaching series	Not found	
Photodegradation in water	Not found	
Photodegradation in air	18.273 hrs	(EPI 2012)
Photodegradation in soil	Not found	
Ready biodegradability	Biodegradable	(EPI 2012)

Citric acid can be used to decontaminate soils. Soil samples contaminated with heavy metals were treated with citric acid, malic acid, or humic acid to enhance the ability of plants to take up elemental pollutants and thereby decontaminate soils. All treatments showed a significant increase in uptake of lead, cadmium and chromium by canola (*Brassica rapae*) grown in the control soil (Ebrahimian and Bybordi 2014). Trials with 11 different plant species used to draw lead from contaminated soil showed mixed results with lead translocation from soils treated with citric acid (Shahid et al. 2012).

Leymus chinensis plants—a grass native to arid and alkali conditions—were observed to have lower stress grown in alkali or saline soils following exogenous application of citric acid (Sun and Hong 2011).

Fine dust dispersed in air may ignite. Risk of ignition followed by flame propagation or secondary explosions should be prevented by avoiding accumulation of dust (ADM 2012).

Environmental Incidents

Four incidents that were not human health or animal related were reported to NPIC between April 1, 1996 and March 30, 2016 (NPIC 2016). The specifics of the incidents were not known.

Efficacy

Anti-microbial and Fungicidal Activity

Most efficacy studies of citric acid involve formulations with other active ingredients. Some are exempt formulated products, some are EPA registered, some are not subject to EPA regulation (e.g., used outside the US) and some have an unknown registration status.

The EPA reviewed efficacy data and public health claims for EPA registered (non-exempt) pesticide formulations with citric acid as an active ingredient. A combination of 10% citric acid, 5% malic acid, and 2% sodium lauryl sulfate impregnated in a facial tissue effectively deactivated human rhinovirus in a contact time of 1 minute (Guse 1983). A subsequent study with a reduced dose of 3.2% citric acid, 1.6% malic acid and 0.5% sodium lauryl sulfate showed sufficient efficacy to reduce not only rhinovirus, but also parainfluenza and herpes simplex viruses as well (Guse 1986). Tissues impregnated with 7.53% citric acid and 2.02% sodium lauryl sulfate demonstrated sufficient efficacy to support a claim of controlling Rhinovirus 2 (Whyte 2004). That determination followed a previous review of another formulation that showed efficacy but was insufficient to support a public health claim (Mitchell 2002b).

EPA registered a product formulated with 3.5% citric acid as its only active ingredient as a surface disinfectant for hospital use. The product showed sufficient efficacy against the human pathogens *Staphylococcus aureus, Salmonella enterica,* and *Pseudomona aeruginosa* to have its label approved for making public health claims (Blackburn 2009). On the other hand, another product formulated with citric acid as its only active ingredient failed to provide acceptable data supporting efficacy against gram-negative bacteria (Barsoum 1999). A similar conclusion of lack of efficacy was reached with a dishwasher detergent that made bactericidal claims based on 25% citric acid as its active ingredient (Mitchell 2002a).

Citric and malic acid are claimed in a patent to enhance the efficacy of copper-based fungicides (Tate 1996).

Herbicidal Activity

In one trial comparing various natural product herbicides, Groundforce, consisting of citric acid (10%) and garlic oil (0.2%) had the greatest efficacy against broadleaf weeds of all the commercial products tested (Abouziena et al. 2009). Stranglervine (*Morrenia odorata*), black nightshade (*Solanum nigrum*), and velvetleaf (*Abutilon theophrasti*) were reduced by 95% or more at 4 weeks after treatment compared to a no-treatment control. Other products and active ingredients in the trial that were less effective included Matran II (45.6% clove oil), Alldown (5% citric acid and 0.2% garlic oil), corn gluten meal, and acetic acid.

Citric acid is also effective as a synergist. Citric acid increased the activity of herbicidal treatments of 70% caprylic acid on giant foxtail (*Setaria faberi*) and common lambsquarters (*Chenopodium album*) when formulated with 15% glycerol and 15% proprietary emulsifier. Caprylic acid formulated with 80% caprylic acid, 15% emulsifier and 5% lactic acid was significantly more effective in killing velvetleaf (*Abutilon theophrasti*), lambsquarters, and giant foxtail when citric acid was used as a synergist (Penner et al. 2011).

Another study looked at various complexing agents that increased the efficacy of the herbicides dichlorprop and glyphosate on common bean (*Phaseolus vulgaris*), quackgrass (*Agropyron repens*), and chickweed (*Stellaria media*). Citric acid enhanced herbicidal activity more than acetic, succinic, propionic, sulfuric, or formic acids (Turner and Loader 1978). However, orthophosphoric acid was the most effective acid at enhancing herbicidal effects, and malic, oxalic, tartaric, and glycolic acid all were similar to citric in their efficacy.

Insecticidal Activity

For control of the migratory grasshopper (*Melanoplus sanguinipes*), citric acid is comparable in its efficacy to *Beauvaria bassiana*. Grasshoppers treated with citric acid alone had an LT_{50} of 7.25 days; those treated with *Beauvaria bassiana alone* had an LT_{50} of 7.33 days. Citric acid and *B. bassiana* combined reduced the LT_{50} to 3.88 days (Bidochka and Khachatourians 1991).

Vertebrate Pest Activity

Citric acid is also used to control amphibians. The coqui frog (*Eleutherodactylus coqui*), native to Puerto Rico but invasive to Hawaii, was reduced 3-fold by a 16% treatment of citric acid (Tuttle et al. 2008). Citric acid is the only pesticide approved for frog control in Hawaii (Pitt 2012). The mode of action is not entirely explained.

Standards and Regulations

EPA Requirements

Citric acid is explicitly exempt from the requirement of a tolerance [40 CFR 180.950(e)]. As a food additive, citric acid is exempt from pesticide tolerances and subject to FDA requirements [40 CFR 180.4]**.**

FDA Requirements

Citric acid is Generally Recognized As Safe (GRAS) by the FDA when used as a food ingredient [21 CFR 184.1033].

Other Regulatory Requirements

Citric acid is allowed for organic production provided it comes from a non-synthetic source. Prohibited sources of citric acid include those that are synthetically produced [7 CFR 205.105(a)] and produced by genetically modified organisms or 'excluded methods' [7 CFR 205.105(e)].

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