Traditional uses, bioactive compounds and pharmacological uses of *Vitex doniana* Sweet: A Review

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Review

Abstract

Background: Medicinal plants have been extensively utilized and esteemed since ancient times for their multifaceted benefits. Owing to their Ethnopharmacological attributes, they become a vital reservoir for managing and averting ailments such as inflammation, coronary disease and cancer. Recently, *Vitex doniana* has garnered considerable interest for its possible therapeutic properties. The aim of the study is to provide a thorough and up-to-date review of published collection regarding the therapeutic properties, phytochemical composition, and pharmacognosy of *V. doniana.*

Methods: Research articles were searched on Elsevier, Springer, Google Scholar, Taylor & Francis, PubMed, and Scopus using the keywords *V. doniana*, chemical composition, antioxidant, antibacterial, anti-diabetic, anticancer, and other relevant terms.

Results: *Vitex doniana* was used in traditional medicine as a remedy for several health conditions including hypertension, paralysis, epilepsy, convulsions, spasm, sleeplessness, depression, and leprosy. Bioactive study revealed the presence of 483 compounds including hydroxycinnamic acid, saponin, allicin, flavonoids, terpenoid, aldehydes, amino acids, alkynes, alkane, hydrocarbon, phenethylamines, alcohol, and others. Most of these bioactive studies have focused on leaves. The medicinal and pharmacological capabilities have been substantiated by a diverse array of investigations, particularly highlighting its antioxidant, anti-inflammatory, antimicrobial, antibacterial, anti-diabetic, anti-epileptic, blood pressure regulating, hepatoprotective, anticancer, and anesthetic actions.

Conclusions: It is crucial to ascertain its safe dosage and elucidate its mode of action. This offers potential for wider perceptions and advancement for a foundation for clinical investigations. This may garner attention for its efficacy as a supplement that promotes health and its potential for the development of novel herbal products.

Keywords: Antioxidant, Africa, fruits, medicinal, plants, malaria, diabetes, and intestinal aliments, wounds, skin diseases, toothache fever, diarrhea and respiratory illnesses

Background

Medicinal plants are a cornerstone in traditional healthcare systems around the world, providing natural cures for several diseases. From the earliest time of human existence, plants were used in the treating of diseases. Numerous studies have confirmed the possible pharmacological uses of different medicinal plant species (Agbafor *et al.* 2011). The failure of the modern synthetic drugs pointed out a much higher drug resistance and this led to the continued use of plant products (Ifeanacho *et al.* 2019). Furthermore, the safety and affordable nature remain the major driving force towards overall increased in the use of plant products. As a result of the foregoing, it is essential to develop new natural remedy that stems from plant origin (Abdulrahman *et al.* 2019).

V. doniana is commonly consumed and used in West Africa for food and medicinal purposes (Forcados Sallau et al., 2021), it is a deciduous tree with moderate sizes and belongs to the family Lamiaceae (Ifeanacho *et al.* 2019). *V. doniana* is popularly known as black plum which has socio-economic potentials due to its versatility in food, treatment, and tradition (Oumorou et al., 2010).

Traditionally, the leaves of *V. doniana* are used in treating malaria, diabetes, and gastro-intestinal aliments; and its leaves are used as a cooked vegetable (Owolabi *et al.* 2022; Odugbemi, 2008; Sofowora, 1993). Burkill (1985) reported the use of stem bark extracts to treat diseases like wounds, skin diseases and ailments, toothache and several other diseases. The cultural applications of roots were used to cure fever, diarrhea and respiratory illnesses (Schmelzer & Gurib-Fakim, 2008). Furthermore, in the management of anemia arising due to the presence of iron, the fruit is commonly used to support nutritional health (Ajiboye, 2015). For general wellbeing, several plants were used to treat inflammations in traditional remedies (Ishola *et al.* 2014; Sofowora, 1993). It has extensively been reported that several parts of V. *doniana* plant are used by traditional healers and medicinal practitioners to treat and manage certain diseases such as inflammatory diseases, cancer, hypertension and rheumatism (Agbafor *et al.* 2011; Emmanuel *et al.* 2015).

Despite numerous studies having been carried out on its traditional uses, chemical composition and pharmacological studies, yet no comprehensive studies have been documented on the species. Therefore, hindering further scientific investigation on *V. doniana* potentials. Recognizing the vast potential of *V. doniana* in conventional therapeutic applications, our study aims to compile data on its traditional practices, pharmacological applications and the significant of it bioactive compounds. Therefore, our review provides comprehensive analysis of the therapeutic applications of V. *doniana* all over the world.

Materials and Methods

The inclusion criteria for this study consist of the following databases: Elsevier, Scopus, Springer, Pubmed, Google Scholar, and Taylor & Francis database. Utilizing terms are "chemical composition," "*Vitex doniana*," "doniana," "Vitex," "antioxidant," "Lamiaceae," "antibacterial," "antidiabetic," "anticancer," “ethnobotany” “traditional” “cytotoxicity” “toxicity”. A comprehensive taxonomic and morphological analysis of *V. doniana* is provided. The information was sourced from Plants of the WorldOnline, which may be accessed at Kew Science's website (https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:865694). After conducting an extensive search of PubChem databases, the NIST Chemistry Webbook, and ChemSpider, the chemical structures of *V. doniana* were discovered based on documented search from the literature search. Some of these structures were then shown using ChemDraw (version 17.0.0). Exclusion criteria include conference proceedings, abstracts, and unpublished articles written in English. To make sure of the accuracy of scientific conclusions, these kinds of publications were excluded because they don't usually go through the strict peer review process that is needed to back up study findings.

Traditional uses of *V. doniana*

The genus Vitex is a member of the Lamiaceae family, which includes more than 250 species of shrubs and trees (Owolabi *et al.* 2022). Vitex, which is a generic name, is an ancient Latin name for the genus (Audu *et al.* 2022). The classification was adopted from https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:865694.

Kingdom: Plantae
Phylum: Equisetopsida
Class: Magnoliidae
Order: Lamiales
Family: Lamiaceae
Genus: Vitex

Species: *V. doniana* (Fig. 1).

The species is widely distributed across Nigeria, Niger, Uganda Angola, Somalia, Botswana, Sudan, Ethiopia, Lesotho, Kenya, Namibia, Senegal, South Africa, Tanzania and Zambia (Ajiboye, 2015; Ifeanacho *et al.* 2019; Dadjo *et al.* 2012).

Figure 1. *V. doniana* in the wild, was adopted from the website.
(https://www.africa.upenn.edu/faminefood/category3/cat3_Vitex_doniana.htm)

Traditional uses of *V. doniana*

Vitex doniana or the black bush or sacred lavender has many social and cultural uses and is found in West and Central Africa. Its uses trace their origins to ancient African traditional medicine where the leaves, the bark and roots of the plant are used to cure diseases such as fever, headache, digestive system complications, and skin diseases. There is also a strong traditional belief that it discharges a function of regulating menstruation cycle and improving fertility. Traditionally, *V. doniana* is of immense importance in the spiritual and healthcare aspects of people's lives. It is said to have some protective spiritual properties and the leaves, or the trunk may be used for burning as an incense during the rites. It is not a cultigen, but the fruit has been used for ages for its sweet somewhat astringent taste as a food, fresh or processed into juice or paste which can be drunk or used for making jams or porridge. *Vitex doniana* has been consumed as food or used as a folk medicine since prehistoric times.

The wood of *V. doniana* has been used traditionally for construction of huts, furniture, tools and musical instruments due to its duration nature. It has due to this versatility been deemed useful in rural areas. In agroforestry, the tree is used in checking soil erosion particularly along water channels; used in soil improvement on farmlands. Further, the leaves of the tree are locally used as an insecticide to guard crops and homes against insects as well as home-constructed insecticides.

Various research has studied the traditional utilization of *V. doniana* different parts for treating and controlling various ailments (Table 1). As a result of the cultural and significance of herbal remedies, its continue to be popular all over the globe. Both in the developed and developing countries, plants with medicinal potential played a crucial in meeting the populace health care requirements. Great potential has been demonstrated by *V. doniana* parts in providing less toxic, affordable and easily accessible therapeutic. If the traditional medication proven with pharmacological investigation. The plant parts will be source of medication for diverse ailment. The review study delves into the possible correlation of the traditional usage and pharmacological evaluation in collaboration to its chemical constituents. The review provides new direction for the development of pharmaceutical and herbal products.

Table 1. Traditional uses of *V. doniana*

Country	Parts	Preparation	Diseases	Reference
Nigeria	Stembark	Not available	Hypertension, hepatotoxic effect and treatment of stomachache, pains, disorders and indigestion	(Adejumo *et al.* 2013)
Ghana	Stem	Not available	Colds, cough, sterility	(Adejumo *et al.* 2013)
Benin	Leaves	Not available	Malaria, stomachache, painful menstruation, burns, sterility, diarrhea, sore eyes, hemorrhoids, ulcers, dermatosis	(Dadjo *et al.* 2012)
Benin	Pod, bark	Decoction	Amenorrhea, febrifuge, anti-dysenteric, smallpox and measles, malaria	(Lagnika *et al.* 2012)
Mali	Aerial parts	Not available	Diuretic, aphrodisiac, and bactericide	
Not available	Root, leaves, stem bark	Decoction	Stomach, rheumatic pains, inflammatory disorders	(Ochieng *et al.* 2013)
Nigeria	Stembark	Decoction	Gastroenteritis	(Ali *et al.* 2017; Kilani, 2006)
Angola	Leaves	Decoction	Fatigue, constipation, pain, bloody diarrhea, stomach pain, back pain	(Mawunu *et al.* 2023)
Nigeria	Stembark	Decoction and maceration	Malaria	(Zakariya *et al.* 2021)
Nigeria	Leaves	Decoction	Stomach pains, stooling with blood	(Osum *et al.* 2013)
Nigeria	Leaves, root	Not available	Gonorrhea, anemia	(Okoh et al., 2019)
Uganda	Stem, bark	Not available	Termites	(Okori *et al.* 2022)
Nigeria	Leaves, bark	Decoction	Stomach	(Amusa *et al.* 2010)
Benin	Leaves, bark, root	Not available	Malaria, headache, fever, stomachaches, tiredness, hemorrhoid	(Oumorou *et al.* 2010)
Benin	Root, bark, leaves	Not available	Sterility, hemorrhoids, snake and scorpion bites, intestine worms, ulcers, stomach-ache, diabetes, constipation, malaria, wounds, sexual impotence, eye pain, cough, amenorrhea, dysmenorrhea, strokes	(N'Danikou et al., 2015)
Nigeria	Stem bark	Decoction	Gastroenteritis, diarrhea and dysentery	(Adelodun *et al.* 2016)
Mali	Leaves		Diuretic, tonifiant, aphrodisiac and bactericide	(Adelodun *et al.* 2016)
Ivory Coast	Root	Decoction	Children with rickets	(Muhammad *et al.* 2015)
Nigeria	Bark	Decoction	Dysentery, diarrhoea	(Ladeji & Okoye, 1996)
Nigeria	Leaves	Infusion	Cold	(Suleiman *et al.* 2008)
Nigeria	Root	Decoction	Diarrhea	(Suleiman *et al.* 2008)
Nigeria	Stem bark	Decoction	Postpartum bleeding	(Ladeji *et al. 2005)*
Nigeria	Stem bark	Decoction	Blood pressure	(Ladeji *et al.* 1996)
Nigeria	Leaves	Decoction	stomach and rheumatic pains, inflammatory disorders, diarrhoea dysentery and diabetes	(Yakubu *et al.* 2013)
Burkina Faso	Aerial parts	Not available	inflammatory diseases and certains cancers	(Barry *et al.* 2022)
Tanzania	Fruits	Not available	High blood pressure, cancer	(Charles *et al.* 2021)

Bioactive compounds of *V. doniana*

Plants produce a wide range of chemicals, consisting of hundreds that serve various functions such as phytohormones, protein modifying agents, antioxidants, and others. Phylogenetically, these substances are involved in either defending the plant or attracting helpful creatures to it. It can also be said phytochemicals are plant compounds that are not nutritious but have qualities that guard against or prevent diseases. The investigation of chemical composition of *V. doniana* was covered extensively in the literature. One commonly embraced concept posits that plants acquired the capacity to produce novel chemicals through natural selection as time progressed. This happened as the organisms they interacted with, both beneficial and harmful, eventually evolved, causing the current plant substances to become ineffective. The phenomenon is commonly known as the 'coevolutionary arms race'. Four hundred and eight three (483) compounds are being documented (Table 2 and Appendix A). It may be categorized into many groups, including flavonoids, hydroxycinnamic acid, saponin, phenols, steroids, allicin, terpenoids, and other compounds. Table 3 provides a summary of the phytoconstituents levels found in *V. doniana.* Providing a comprehensive description of several key classes.

Hydroxycinnamic acid

Table 2 presents the identification of hydroxycinnamic acid as one of the components belonging to the class found in *V. doniana*. Several compounds, including p-coumaric acid, caffeic acid, o-coumaric acid, coumarin, cinnamic acid, and others, were detected. According to Ifeanacho *et al.* (2019), hydroxycinnamic acids have several physiological effects, such as antimelanogenic, antioxidant, anti-inflammatory, and anticollagenase effects. Hydroxycinnamic acid molecules have been found to induce various pharmacological responses, such as a 20% decrease in cell proliferation and immunomodulatory effects (Rajendra *et al.* 2011). The use of p-coumaric acid in diabetic treatment protocols has been suggested for hydroxycinnamic acids. This process involves the restoration of glycosylated hemoglobin, optimal glucose levels, glucose-6-phosphatase, hexokinase, and fructose-1,6-bisphosphatase while simultaneously reducing hemoglobin, total protein, insulin, c-peptide, and glycogen levels (Shairibha *et al.* 2014). These functions are attributed to the numerous hydroxyl groups present in their chemical structures.

Saponin

This review reported a significant quantity of saponins that have been discovered. Saponins have also been shown to be beneficial in the treatment of hypercholesterolemia. Saponins are known to possess a variety of pharmacological functions. Fruits that contain saponins are thought to possess anti-inflammatory, antioxidant, anticancer, and antiviral characteristics (Phillips *et al.* 2005). Saponins aid in combating harmful bacteria, increasing the effectiveness of specific vaccines, and eliminating some types of cancer cells, particularly those found in the blood and lungs. Saponins function as natural antibiotics that aid in combating infections and the infiltration of microorganisms into the body. These chemicals can also lower cholesterol and bile acid levels by creating complexes (Shereen, 2011). Sapogenins exhibit significant cholesterol-lowering effects by enhancing the elimination of biliary cholesterol (Ifeanacho *et al*. 2019). Adome *et al*. (Nweke *et al*., 2015) reported that saponins form complexes with bile salts and cholesterol in the gastrointestinal tract. The absorption of cholesterol is facilitated by bile salts that form tiny micelles. Saponin inhibits the reabsorption of blood cholesterol, leading to a decrease in cholesterol levels. Saponins hinder the outflow of sodium ions (Na^+) by obstructing the entry of the Na^+-Ca^{2+} antiporter in cardiac muscle, hence enhancing contraction of the heart muscle.

Flavonoids

Table 2 displays the specific amounts of the detected flavonoids. *V. doniana* contains a variety of chemicals, including vitexin, quercitrin, isovitexin, penduletin, tageretin, epicatechin, ellagic acid, myricetin, catechin, silymarin, hesperidine, baicalein, rutin, naringin, artemetin, epigallocatechin, and others. Flavonoids provide essential health-enhancing features such as antioxidant effects, protection against Parkinson's disease, prevention of high blood pressure, and a role in reducing the risk of dementia (Ifeanacho *et al.* 2019).

Terpenoids

Terpenoids are a group of chemicals that are present in all living creatures. Green plants, especially flowering plants, have a significantly greater abundance of terpenoids than *V. doniana* parts do. Examples include sabinene, 2-methyl butenoic acid, 2-methyl butanoic acid, 2-methyl butenoic acid ethyl ester, camphor, azulene, α-pinene, β-pinene, β-phellandrene, benzyl alcohol, myrcene, allo-Ocimene, cis-ocimene, pinene-2-ol, α-thujene, citral, Γ-terpinene, 2,6-dimethyl-5-heptanol, and many others.

Table 2. Bioactive compounds identified from different parts of *V. doniana.*

Plant Parts	Method of Identification	Class of compounds	Identified Compound	Molecular Formula	Reported Reference	Pharmacology of the identified compounds
Leaves	GC/MS	Hydroxycinnamic acid	Caffeic acid	$(HO)_2C_6H_3CH{=}CHCO_2H$	(Ifeanacho *et al.* 2019)	Antioxidant (Gülçin, 2006), hepatocarcinoma (Espíndola *et al.* 2019)
			P-coumaric acid	$HOC_6H_4CH{=}CHCO_2H$		Antioxidant and antimicrobial (Boz, 2015)
			o-coumaric acid	$C_9H_8O_3$		Anticarcinogenic (Sen *et al.* 2013)
			Cinnamic acid	$C_9H_8O_2$		Antioxidant and antimicrobial (Sova, 2012)
			Coumarin	$C_9H_6O_2$		Anticancer (Küpeli Akkol *et al.* 2020)
			Chlorogenic acid	$C_{16}H_{18}O_9$		Antibacterial (Lou *et al.* 2011)
			Sinapinic acid	$C_{11}H_{12}O_5$		Antioxidant and anti-aging(Chen, 2016)
			Cichoric acid	$C_{22}H_{18}O_{12}$		Antioxidant (Thygesen *et al.* 2007)
Leaves	GC/MS	Saponin	Sapogenin	$C_{27}H_{44}O$	(Ifeanacho *et al.* 2019)	Antidiabetic (Omoruyi, 2008)
			Gitogenin	$C_{27}H_{44}O_4$		Anticancer (Liu *et al*. 2022), anti-hypertension (Ul Haq *et al*., 2021)
			Tigogenin	$C_{27}H_{44}O_3$		Anticancer (Corbiere *et al.* 2003; Michalak *et al*., 2020)
			Diosgenin	$C_{27}H_{42}O_3$		Antidiabetic (Gan *et al.* 2020)
			Solagenin	No data		Not reported
			Neohecogenin	$C_{28}H_{44}O_4$		Not reported
			Hecogenin	$C_{27}H_{42}O_4$		Anticancer (Corbiere *et al.* 2003), anti-ulcer (Cerqueira *et al.* 2012)
			Euphol	$C_{30}H_{50}O$		Anticancer (Lin *et al.* 2012; Silva *et al*., 2018), anti-colitis(Dutra *et al.* 2011)
Fruits	GCMS		Platycodin D	$C_{33}H_{53}O_{18}$	(Ajiboye, 2015)	Anticancer (Khan *et al.* 2016), anti-atherosclerotic (Wu *et al.* 2012)
Leaves	GC/MS	Allicin	Methyl-allyl-thiosulphinate	$C_4H_8O_2S_2$	(Ifeanacho *et al.* 2019)	Not reported
			Diallyl-thiosulphinate	$C_4H_8O_2S_2$		Premature ejaculation (Cai *et al.* 2018)
			Allyl-methyl-thiosulphinate	$C_4H_8O_2S_2$		Premature ejaculation (Cai *et al.* 2018)
Leaves	GC/MS	Flavonoids	Kaempferol	$C_{15}H_{10}O_6$	(Ifeanacho *et al.* 2019)	Anti-inflammation (Devi *et al.* 2015; Rho *et al.* 2011)
			Quercetin	$C_{15}H_{10}O_7$	(Ifeanacho *et al.* 2019;	Anti-inflammation (Li *et al.* 2016), antioxidant (Li *et al.* 2016; Zhang *et al.* 2011)

		Muanda *et al.* 2019)	
Apigenin	$C_{15}H_{10}O_5$	(Ajiboye, 2015; Ifeanacho *et al*. 2019)	Anticancer (Imran *et al.* 2020; Yan *et al.* 2017)
Casticin	$C_{19}H_{18}O_8$		Anticancer (Shen *et al.* 2009)
Vitexin	$C_{21}H_{20}O_{10}$		Anticancer (Choi *et al.* 2006), Anti-depressant (Can *et al.* 2013)
Quercitrin	$C_{21}H_{20}O_{11}$		Antiinflammation (Comalada *et al.* 2005), hepatoprotective (Yin *et al.* 2013)
Isovitexin	$C_{21}H_{20}O_{10}$		Antidiabetic (Choo *et al.* 2012)
Penduletin	$C_{18}H_{16}O_7$		Antivirus (Zhu *et al.* 2011a)
Tageretin	$C_{20}H_{20}O_7$		Not reported
Epicatechin	$C_{15}H_{14}O_6$		Neuropsychological health (Bernatova, 2018)
Ellagic acid	$C_{14}H_6O_8$		Anticancer (Losso *et al*., 2004), anti-inflammatory (Corbett *et al.* 2010)
Myricetin	$C_{15}H_{10}O_8$		Antioxidant (Wang *et al.* 2010), anticancer (Jiang *et al.* 2019)
Catechin	$C_{15}H_{14}O_6$		Antioxidant (Katalinić *et al.* 2004; Zanwar *et al.* 2014)
Silymarin	$C_{25}H_{22}O_{10}$		Hepatoprotective (Saller *et al.* 2001)
Hesperidine	$C_{28}H_{34}O_{15}$		Antioxidant (Wilmsen *et al*., 2005)
Baicalein	$C_{15}H_{10}O_5$		Anti-inflammatory (Dinda *et al.* 2017), anticancer(Chen *et al.* 2013)
Rutin	$C_{27}H_{30}O_{16}$		Antioxidant (Yang *et al.* 2008), antidiabetic (Ghorbani, 2017)
Naringin	$C_{27}H_{32}O_{14}$		Not reported
Artemetin	$C_{20}H_{20}O_8$		Hypotensive (de Souza *et al.* 2011)
Epigallocatechin	$C_{15}H_{14}O_7$		Anticancer (Fujiki *et al.* 1992)
Kaempferol-3-arabinoside	$C_{20}H_{18}O_{10}$		Not reported
Baicalin	$C_{21}H_{18}O_{11}$		Anti-HIV (Kitamura *et al*., 1998)
Naringenin	$C_{15}H_{12}O_5$		Antibacterial (Celiz *et al.* 2011), antioxidant(Cavia-Saiz *et al.* 2010)
Biochanin	$C_{16}H_{12}O_5$		Anti-diabetic (Harini *et al.* 2012), Antioxidant (Sadri *et al.* 2017)
Gallocatachin	$C_{15}H_{14}O_7$		Antioxidant (Plumb *et al.* 2002)

		Quercetin3,7,4-trimethyether	$C_{18}H_{16}O_7$		Not reported
		Robinetin	$C_{15}H_{10}O_7$		Anticancer (Birt *et al.* 1986)
		Nobiletin	$C_{21}H_{22}O_8$		Antioxidant (Li *et al.*2014)
		Kaemferol3,7,4-trimethylether	$C_{18}H_{16}O_6$		Not reported
		Butein	$C_{15}H_{12}O_5$		Antioxidant (Cheng *et al.* 1998)
		Luteolin	$C_{15}H_{10}O_6$		Anticancer (Seelinger Merfort Wölfle *et al.* 2008), Antioxidant, anti-inflammatory and anti-allergic activities (Seelinger Merfort, & Schempp, 2008)
		Quercetin3,7,3,4 tetramethylether	$C_{18}H_{16}O_7$		Not reported
		Isorhamnetin	$C_{16}H_{12}O_7$		Anti-obesity (González-Arceo *et al.* 2022), anti-inflammatory(Chirumbolo, 2014)
		Epigallocatechin-3-gallate	$C_{22}H_{18}O_{11}$		Neuroprotective (Singh *et al*. 2015), anticancer (Min *et al.* 2014)
Fruits	HPLC-DAD	Cinanimic acid	$C_9H_8O_2$	(Ajah *et al.* 2021)	Antioxidant and antimicrobial (Sova, 2012)
		Daidzein	$C_{15}H_{10}O_4$		Anti-inflammatory and antioxidant (Peng *et al.* 2017)
		Protocatechuic acid	$C_7H_6O_4$		Anticancer (Tanaka *et al.* 2011), antioxidant
		Genistein	$C_{15}H_{10}O_5$		Antibacterial (Hong *et al.* 2006), antioxidant (Record *et al.* 1995)
		Tectorigenin	$C_{15}H_{10}O_5$		Anti-inflammatory (Ha *et al.* 2013), antibacterial (Joung *et al.* 2014)
		5-O-Methylgenestein	$C_{16}H_{12}O_5$		Antibacterial (Bora *et al.* 2024), anti-inflammatory, antioxidant and antibacterial (Maria do Socorro *et al.* 2022)
		5-O-Methyltectorigenin	$C_{17}H_{14}O_5$		Antioxidant (Ajah *et al.* 2021)
		Methylmalvidin	$C_{15}H_{11}O_5$		Anticancer (Oliveira *et al*. 2016), antioxidant (Sun *et al.* 2020)
		5-Methylpeonidin	$C_{16}H_{13}O_7$		Antioxidant (Wang *et al.* 2007), antibacterial (Diep *et al.* 2021)
		Peonidin	$C_{15}H_{11}O_{6+}$		Antioxidant (Sun *et al.* 2018), anticancer (Chen *et al.* 2005)

			Kampferol-3-O [2-galloyl]-glucopyranoside	$C_{27}H_{22}O_{17}$		Antioxidant and antimicrobial (Abd Elkarim *et al.* 2021)
Leaves	LCMS		20 ′,30 ′-Diacetylcosmosiin	$C_{21}H_{20}O_{11}$	(Forcados Sallau *et al.* 2021)	Antimicrobial (Jay *et al.* 1984), antibacterial (de Almeida Júnior *et al.* 2015)
			40 ,5-Dihydroxy-7-methoxy-6-methylflavone	$C_{17}H_{14}O_5$		Anti-inflammatory and antioxidant (Forcados Sallau *et al.* 2021)
Fruits	GCMS		Chrysin	$C_{15}H_{10}O_4$	(Ajiboye, 2015)	Anticancer (Zheng *et al.* 2003), antimicrobial (Faize Beg *et al.* 2014)
			Abyssinone	$C_{15}H_{12}O_4$		Antioxidant (Rao *et al.*, 2009), anticancer (Zingue *et al.* 2020)
			Galangin	$C_{15}H_{11}O_5$		Antioxidant (Russo *et al.* 2002), anticancer (Heo *et al.* 2001)
Leaves	HPLC	Phenolic	Usrutin	$C_{27}H_{30}O_{16}$	(Muanda *et al.* 2019)	Antimicrobial (Bahri-Sahloul *et al.* 2014), antioxidant (Irkin *et al*. 2015)
			Gallic acid	$C_7H_6O_5$		Antioxidant (Badhani *et al.* 2015), anticancer (Subramanian *et al.* 2015)
			Homoorientin	$C_{27}H_{30}O_{15}$		Antioxidant (Lee *et al*. 2008), antimicrobial (Zhang *et al.* 2008)
Fruits	GCMS		Catechol	$C_6H_6O_2$	(Ajiboye, 2015)	Antimicrobial (Amato *et al.* 2018)
			4-Hydroxy-β-ionol	$C_{11}H_{16}O_2$	(Lasekan, 2017)	Antimicrobial (Hall *et al.* 2016)
			Guaiacol	$C_7H_8O_2$		Antioxidant and anti-inflammatory (Esatbeyoglu *et al.* 2015)
Leaves	GCMS	Terpenoid	Butanoic acid	$C_4H_8O_2$	(Ifeanacho *et al.*, 2019)	Antibacterial (Kennedy *et al.* 2019)
			Sabinene	$C_{10}H_{16}$	(Ifeanacho *et al.* 2019; Sonibare *et al.* 2009)	Antioxidant (Quiroga *et al.* 2015), antibacterial (Park *et al.* 2019)
			2-methyl Butenoic acid	C_5H8O_2	(Ifeanacho *et al.* 2019)	Not reported
			2-methyl Butanoic acid	$C_5H_{10}O_2$		Anticancer (Suzuki *et al.* 2015)
			2-methyl Butenoic acid ethyl ester	$C_7H_{12}O_2$		Not reported
			2-methyl Butanoic acid ethyl ester	$C_7H_{14}O_2$		Not reported

Azulene	$C_{10}H_8$		(Ajaiyeoba and Singh 2015)
α-Pinene	$C_{10}H_{16}$		Wound healing (Salas-Oropeza *et al.* 2021), anti-inflammatory (Rufino *et al.* 2014)
β-Phellandrene	$C_{10}H_{16}$		Not reported
β-Pinene	$C_{10}H_{16}$		Not reported
Benzyl alcohol	$C_6H_5CH_2OH$		Anesthetic (*Wilson et al.* 1999)
cis-Ocimene	$C_{10}H_{16}$		Not reported
Myrcene	$C_{10}H_{16}$		Analgesic activity (Lorenzetti *et al.* 1991)
Allo-Ocimene	$C_{10}H_{16}$		In secticide (Kishimoto *et al.* 2006)
Pinene-2-ol			Not reported
α-Thujene	$C_{10}H_{16}$		Not reported
Γ-Terpinene	$C_{10}H_{16}$		Anti-parasites (Baldissera *et al.* 2016), Antioxidant (Foti *et al.* 2003)
2,6-Dimethyl-5-heptanol	$C_9H_{16}O$		Not reported
Citral	$C_{10}H_{16}O$		Antimicrobial (Saddiq *et al.* 2010), antifungal (Silva *et al.* 2008)
Camphor	$C_{10}H_{16}O$		Hepatotoxicity (Uc *et al.* 2000)
Neral	$C_{10}H_{16}O$		Anti-inflammatory (Liao *et al.* 2015)
Geranial	$C_{10}H_{16}O$	(Ifeanacho *et al.* 2019; Lasekan, 2017)	Anti-inflammatory (Liao *et al.* 2015)
Valencene	$C_{15}H_{24}$	(Ifeanacho *et al.* 2019)	Antioxidant and antibacterial (Liu *et al.* 2012)
Caryophellene oxide	$C_{15}H_{24}O$		Analgesic and anti-inflammatory (Chavan *et al.*, 2010)
Humulene	$C_{15}H_{24}$		Anti-ulcer (Yeo *et al.* 2021)
Copane	$C_{15}H_{24}$		Not reported
β-Selinene	$C_{15}H_{24}$		Not reported
α-Gurjunene	$C_{15}H_{24}$		Not reported
Shogaol	$C_{17}H_{24}O_3$		Antiulcer (Hassan *et al.* 2018)
β-Elemene	$C_{15}H_{24}$		Anticancer (Zhai *et al.* 2018)
α-Caryophyllene	$C_{15}H_{24}$	(Ifeanacho *et al.* 2019; Sonibare *et al.* 2009)	Not reported

Bicyclogermacrene	$C_{15}H_{24}$	(Ifeanacho *et al*., 2019; Sonibare *et al*., 2009)	Antimalaria (Govindarajan *et al.* 2016)
β-Caryophyllene	$C_{15}H_{24}$	(Ifeanacho *et al.* 2019; Sonibare *et al.* 2009)	Anticancer and analgesic (Fidyt *et al.* 2016)
γ-Cadinene	$C_{15}H_{24}$		Not reported
β-Bisabolene	$C_{15}H_{24}$		Anticancer (Yeo *et al.* 2016)
Phytol	$C_{20}H_{40}O$	(Ifeanacho *et al.* 2019; Odoom *et al.* 2023; Owolabi *et al*. 2022; Sonibare *et al.* 2009)	Antinociceptive and antioxidant (Santos *et al.* 2013)
Germacrene D	$C_{15}H_{24}$		Antibacterial (Montanari *et al.* 2011)
Neryl acetate	$C_{12}H_{20}O_2$		Not reported
Geraanyl acetate	$C_{12}H_{20}O_2$		Insecticidal (Plata-Rueda *et al*., 2020)
Citronellol	$C_{10}H_{20}O$	(Odoom *et al.* 2023)	Nociceptive and inflammatory (Brito *et al.* 2012)
Borneol acetate	$C_{12}H_{20}O_2$		Antimicrobial (Tabanca *et al.* 2001)
Linalyl Acetate	$C_{12}H_{20}O_2$		Anti-inflammatory (*Peana et al.* 2002), anti-psoriatic (Rai *et al*., 2020)
Terpinen-4-ol	$C_{10}H_{18}O$		Antimicrobial (Budhiraja *et al.* 1999), antibacterial (Maquera-Huacho *et al.* 2018)
Ethyl cinnamate	$C_{11}H_{12}O_2$		Antimicrobial (Zhang *et al.* 2015)
α-Terpinenyl acetate	$C_{12}H_{20}O_2$		Antimicrobial (Sonboli *et al.* 2006)
α-Terpineol	$C_{10}H_{18}O$		Antimicrobial (Park *et al.* 2012), anticancer (Chen *et al.* 2023)
Nerol	$C_{10}H_{18}O$		Antibacterial (Yang *et al.* 2023), anticancer (Teixeira *et al.* 2019)
Taraeron	$C_{15}H_{24}O$		Not reported

			Citronellal	$C_{10}H_{18}O$		Antibacterial (Kankeaw *et al.* 2015), anti-inflammatory (Melo *et al.* 2011)
			Linalool	$C_{10}H_{18}O$		Antibacterial (Stević *et al.* 2006)
			Ascaridole	$C_{10}H_{16}O_2$		Anti-tumor (Bezerra *et al.* 2009), antimicrobial (Geroldinger *et al.* 2017)
			α-Selinine	$C_{15}H_{24}$		Not reported
			Lupeol	$C_{30}H_{50}O$		Antimicrobial (Gallo *et al.* 2009), anti-athritic (Chaturvedi *et al.* 2008)
			Borneol	$C_{10}H_{18}O$		Antimicrobial (Sokolova *et al.* 2017), antioxidant (Su *et al.*, 2012)
			1,8-Cineole	$C_{10}H_{18}O$		Antimicrobial (Cai *et al.* 2021), antibacterial (Villecco *et al.* 2008)
			Iso-Artemisia	No data		Antibacterial (Zhang *et al.* 2024), antimicrobial (Al-Gaby *et al.* 2000)
			Aristolone	$C_{15}H_{22}O$		Antidiabetic (Lerma-Herrera *et al.*, 2022)
			Aromadendrene	$C_{15}H_{24}$		Antimicrobial (Mulyaningsih *et al.* 2010)
			Viridiflorol	$C_{15}H_{26}O$		Anti-inflammatory, antioxidant and anti-mycobacterium (Trevizan *et al.* 2016)
			γ-muurolene	$C_{15}H_{24}$		Antimicrobial (Marinas *et al.* 2021), anticancer (Essa *et al.* 2021)
			Menth-2-en-1-ol	$C_{10}H_{18}O$		Antibacterial (Padalia *et al.* 2018), antimicrobial (Al-Rehaily *et al.* 2014)
			5-Methylene-1,3a,4,5,6,6a-hexahydropentalen-1-ol	$C_{10}H_{14}O$		Not reported
			Scytalon	$C_{14}H_{18}O$	(Muanda *et al.* 2019)	Antimicrobial (Rassabina *et al.* 2021)
Fruits			Geraniol	$C_{10}H_{18}O$	(Lasekan, 2017)	Antioxidant and anti-inflammatory (Mączka *et al.* 2020)
			3-Oxo-α-ionol	$C_{11}H_{16}O_2$		Antibacterial (Oelschlaegel *et al.* 2012), antimicrobial (Suzuki *et al.* 2019)
			4-Oxo-β-ionol	$C_{13}H_{18}O$		Antibacterial (Elchaghaby *et al.* 2022), antioxidant and anti-inflammatory (Lockwood *et al.* 2005)
Fruits	GCMS	Monoterpenoids	Linalool	$C_{10}H_{18}O$		Anti-inflammatory (Suzuki *et al.* 2019)

			α-Terpineol	$C_{10}H_{18}O$	(Lasekan, 2017)	Antimicrobial (Park *et al.* 2012), antibacterial (Li *et al.* 2014)
			L-à-terpineol	$C_{10}H_{18}O$	(Odoom *et al.* 2023)	Antibacterial. Antifungal, insecticidal and antioxidative (Abdullah *et al.* 2022)
			β-Citral	$C_{10}H_{16}O$		Antimicrobial (Oliveira *et al.*, 2017), antioxidant (Lee *et al.* 2021)
			α-Citral	$C_{10}H_{16}O$		Antimicrobial (Oliveira *et al.* 2017), antifungal (Tyagi *et al.* 2010)
			Fenchol, exo-	$C_{10}H_{18}O$	(Chinyere *et al.* 2021)	Antimicrobial and antioxidant (Mothana *et al.* 2013)
Fruits	HPLC	Triterpenoid	Oleanolic acid	$C_{30}H_{48}O_3$	(Adjei *et al.* 2021)	Antimicrobial (Paszel-Jaworska *et al.* 2014)
	GCMS		Kalopanaxsaponin A	$C_{34}H_{54}O_{10}$		Antitumor (Park *et al.* 2001), anti-rheumatoidal (Choi *et al.* 2002)
			Saikosaponin	$C_{34}H_{54}O_{10}$		Anti-inflammatory (Benito *et al.* 1998), antitumor (Zhou *et al*., 2021)
Seed	GCMS	Amino acid	dl — Alanyl-l-phenylalanine	$C_{12}H_{16}N_2O_3$	(Adomè *et al.* 2023)	Antimicrobial (Kenig & Abraham, 1976), antibacterial (Kenig Vandamme *et al.* 1976)
Seed	GCMS	Alkynes	7-Pentadecyne	$C_{15}H_{28}$		Antimicrobial (Sianipar *et al.* 2018)
Leaves		Alkynes	1-Tridecyne	$C_{13}H_{24}$	(Nweke *et al.* 2015)	Antidiabetic (Numonov *et al.* 2019), antibacterial (Carballeira *et al*., 2017)
Seed	GCMS	Alkenes	Eicosene	$C_{20}H_{40}$	(Adomè *et al.* 2023)	Antimicrobial (Naragani *et al.* 2016)
Seed	GCMS	Hydrocarbon	Cycloheptane, methyl-	C_8H_{16}		Not reported
Seed	GCMS	Phenethylamines	Metaraminol	$C_9H_{13}O_2$		Antimicrobial (Albertson *et al.* 1970)
Seed	GCMS	Fatty alcohol	Hexadecanol	$C_{16}H_{34}O$		Antimicrobial (Silvey, 1960), anticancer (Marrufo *et al.* 2013)
Leaves		Fatty alcohol	1-Octadecanol	$C_{18}H_{38}O$	(Odoom *et al.* 2023)	Antimicrobial (Servi *et al.* 2020), antibacterial (Togashi *et al.* 2007)
Seed	GCMS	Alcohol	2- Methyl-Z, Z-3,13-octadecadienol	$C_{19}H_{36}O$	(Adomè *et al.* 2023)	Antimicrobial (Aguoru *et al.* 2017), antibacterial (Mehranian *et al.* 2017)
			Ethanol, 2-phenoxy-	$C_2H_5C_6H_4OH$		Not reported
Fruits			Phenylethyl alcohol	$C_6H_5CH_2CH_2OH$	(Odoom *et al.* 2023)	Antimicrobial (Zhang *et al.* 2014)
			1-Hexanol	$C_6H_{14}O$		Antibacterial (Kyoui *et al.* 2023), antimicrobial (Motelica *et al.* 2022)
			Cis, cis-4,6-octadienol	$C_8H_{14}O$		Antimicrobial (Debi *et al.* 2020)

			Cyclohexa-2,4-dienylmethanol	$C_7H_{10}O$		Not reported
			3-Phenylpropanol	$C_9H_{12}O$		Antifungal (Hameed *et al*. 2016), antimicrobial (Ikazaki *et al.*2023)
			3-Methyl-but-3-en-1-ol	$C_5H_{10}O$	(Lasekan, 2017)	Antimicrobial (Frezza *et al*., 2022)
Leaves			Octylether	$C_8H_{18}O$	(Nweke *et al.* 2015)	Antiplasmodial and antitrypanasomal (Weis *et al*., 2006)
Fruits			Terpinene-4-ol	$C_{10}H_{16}O$	(Chinyere *et al.* 2021)	Antibacterial (Merghni *et al*., 2022), antigastrointestinal cancer (Shapira *et al*., 2016)
Leaves			Linalool	$C_{10}H_{18}O$	(Odoom *et al.* 2023)	Antimicrobial (Stević *et al*., 2006)
			4-Cyclooctene-1-methanol	$C_9H_{16}O$		Not reported
			1-Heptatriacotanol	$C_{37}H_{76}O$		Antibacterial (Moni *et al*., 2021), antibacterial and antiviral (Boulechfar *et al*., 2023)
			Hexadecen-1-ol, trans-9-	$C_{16}H_{32}O$		Not reported
Fruits			2/3-Methyl-butanol	$C_5H_{12}O$	(Lasekan, 2017)	Antibacterial and antioxidant (Kakumyan *et al*., 2019)
			(Z)-3-Hexen-1-ol	$C_6H_{12}O$		Antimicrobial and antibacterial (Kim *et al*., 2005)
			Hexan-1-ol	$C_6H_{14}O$		Antimalarial (Sato *et al*., 2011), antimicrobial (Ampadu *et al*., 2022)
			2,6-Dimethylcyclohexanol	$C_8H_{16}O$		Antioxidant and antibacterial (Gashaw *et al*., 2024)
			1-Octen-3-ol	$C_8H_{16}O$		Antimicrobial (Xiong *et al.* 2017), antifungal (Wang *et al.* 2022)
Seed	GCMS	Triterpenol	alpha.-Amyrin	$C_{30}H_{50}O$	(Adomè *et al.* 2023)	Analgesic and anti-inflammatory (Aragao *et al.* 2008)
Seed	GCMS	Vitamin E	delta.-Tocopherol, O-methyl -	$C_{29}H_{50}O_2$		Antimicrobial (Nazareno, 2014)
Seed	GCMS	Phytosterol	Campesterol	$C_{28}H_{48}O$	(Adomè *et al.* 2023)	Antiangiogenic (Choi *et al.* 2007), antibacterial (Freitas da Silva *et al.* 2023)
Fruits			β-Sitosterol	$C_{27}H_{49}O$	(Ajiboye, 2015)	Anti-inflammatory (Villaseñor *et al.* 2002)

			Campesterol	$C_{27}H_{49}O$		Antiangiogenic (Choi *et al.* 2007), anti-inflammatory (Nazir *et al.* 2023)
Seed	GCMS	Diterpene alcohol	Pseudophytol	$C_{20}H_{42}O$	(Adomè *et al.* 2023)	Antimicrobial (Hasan *et al.* 2023)
Leaves			Isophytol	$C_{20}H_{40}O$	(Owolabi *et al*., 2022)	Antimicrobial (Ames *et al.* 1963)
Seed	GCMS	Sterols	Stigmasta-5,24(28)-dien-3-ol, (3.beta.,24Z)	$C_{29}H_{48}O$	(Adomè *et al.* 2023)	Anticancer (Sureshkumar *et al.* 2012), antimicrobial (Azizah *et al.* 2019)
			Stigmasterol	$C_{29}H_{48}O$		Antimicrobial (Mailafiya *et al.* 2018), anti-arthritic (Gabay *et al.* 2010)
			Stigmastan-3,5-diene	$C_{29}H_{48}$		Antifungal (Bai *et al*., 2012), antimicrobial (Tabassum *et al*., 2022)
Stembark	Chromatographic and spectroscopic	Phytoecdysteroids	21-hydroxyshidasterone (1)	$C_{29}H_{48}O_6$	(Ochieng *et al.* 2013)	Antimicrobial (Kamal *et al*., 2022)
			11β-hydroxy-20-deoxyshidasterone (2)	$C_{29}H_{46}O_6$		Antimicrobial (Ishola *et al.* 2014)
			2,3-acetonide-24-hydroxyecdysone (3)	$C_{27}H_{44}O_7$		Anti-inflammatory (Ochieng *et al*., 2013), antimicrobial (Das *et al*., 2021)
			Shi-dasterone (4)	$C_{29}H_{48}O6$		Not reported
			Ajugasterone C (5)	$C_{28}H_{44}O_6$		Anti-proliferative, antioxidant and antimicrobial (Mamadalieva *et al.* 2013)
			24-hydroxyec-dysone (6)	$C_{27}H_{44}O_7$		Anti-inflammatory (Ochieng *et al.* 2013), antimicrobial (Arif *et al*. 2022)
			11β,24-hydroxyecdysone (7)	$C_{27}H_{44}O_8$		Antidepression (Ishola *et al.* 2014)
	Chromatography		Ajugasterone	$C_{27}H_{44}O$	(Bunu *et al.* 2021)	Antioxidant and antimicrobial (Aliouche *et al.* 2018)
Leaves	GCMS	Monoterpene	α-Pinene	$C_{10}H_{16}$	(Sonibare *et al.* 2009)	Antimicrobial (da Silva Rivas *et al*., 2012), antibacterial (de Sousa Eduardo *et al.* 2018)
			β-Pinene	$C_{10}H_{16}$		Antimicrobial (Feng *et al*., 2021), antibacterial (de Sousa Eduardo *et al.* 2018)
			β-Myrcene	$C_{10}H_{16}$		Anti-ulcer (Bonamin *et al.* 2014), antioxidant (Xanthis *et al.* 2021)
			α-Phellandrene	$C_{10}H_{16}$		Antimicrobial (İşcan *et al*., 2012), antifungal (Zhang *et al.* 2017)

			β-Phellandrene	$C_{10}H_{16}$		Antimicrobial and antioxidant (Petrović *et al*. 2017)
Fruits			Loliolide	$C_{10}H_{14}O_2$	(Ajiboye, 2015)	Anticancer, antifungal, antibacterial and antioxidant (Grabarczyk *et al.* 2015)
Leaves	GCMS	Sesquiterpene	β-Caryophyllene	$C_{15}H_{24}$	(Sonibare *et al.* 2009)	Anticancer, antioxidant and antimicrobial (Dahham *et al.* 2015)
			D-Germacrene	$C_{15}H_{24}$		Anti-insecticidal and antimicrobial (Aziz *et al.* 2021)
			Caryophyllene oxide	$C_{15}H_{24}O$		Anticancer (Fidyt *et al.* 2016), antiparasitic (Bettarini *et al.* 1993)
Fruits			(E)-α-Bergamotene	$C_{15}H_{24}$	(Lasekan, 2017)	Antimicrobial (Xing *et al.* 2019)
Leaves			Calarene epoxide	$C_{15}H_{24}O$	(Odoom *et al.* 2023)	Antimicrobial (Sushma *et al.* 2017), antimicrobial and antifungal (Alonso-Hernández *et al.* 2023)
			Selina-4(15),7(11)-diene	$C_{15}H_{22}$	(Odoom *et al.* 2023)	Antibacterial (Turri, 2020), antimicrobial (Zhao *et al.* 2022)
			α-Nerolidol	$C_{15}H_{26}O$		Antibacterial (Li *et al.* 2022)
			Patchouli alcohol	$C_{15}H_{26}O$		Antimicrobial (Hu *et al.* 2017), anti-tumorigenic (Jeong *et al.* 2013), antibacterial (Wan *et al.* 2021)
			α-Copaene	$C_{15}H_{24}$	(Owolabi *et al.* 2022)	Antioxidant (Turkez *et al.* 2014), antimicrobial (Norouzi-Arasi *et al*. 2006)
			(*E*)-β-Caryophyllene	$C_{15}H_{24}$		Anticancer, antioxidant and antimicrobial (Dahham *et al.* 2015)
			ar-Curcumene	$C_{15}H_{24}$		Antimalaria (AlShebly *et al.* 2017), antibacterial (Zhang *et al.* 2017)
			(*E*)-Nerolidol	$C_{15}H_{26}O$		Antioxidant and antibacterial (de Moura *et al*. 2021)
			α-Humulene	$C_{15}H_{24}$		Anti-inflammatory (Fernandes *et al.* 2007)
			Caryophyllene oxide	$C_{15}H_{24}O$		Anticancer (Fidyt *et al.* 2016), antiparasitic (Bettarini *et al*., 1993)
			Humulene epoxide II	$C_{15}H_{24}O_2$		Antimicrobial (Abd-ElGawad *et al.* 2022), antifungal (Maccioni *et al*., 2021)

			Serratol	$C_{15}H_{26}O$		Antiprotozoal (Schmidt *et al.* 2011), anti-inflammatory (Pollastro *et al*., 2016)
Fruits	GCMS	Aldehyde	Benzaldehyde	C_6H_5CHO	(Odoom *et al.* 2023)	Antimicrobial (Eno *et al.* 2022), insecticidal, antimicrobial and antioxidant (Ullah *et al.* 2015)
	GCMS		2-Propenal, 3-phenyl-	C_9H_8O		Antimicrobial (Kaushik *et al.* 2016), antibacterial (Ellboudy *et al.* 2023)
Leaves	GCMS		2,6-Nonadienal, (E,Z)-	$C_9H_{14}O$		Antimicrobial (Cho *et al.* 2004)
	GCMS		2-Hexyl-(*E*)-cinnamaldehyde	$C_{15}H_{20}O$		Antifungal and antibacterial (Atiphasaworn *et al.* 2017)
Fruits	GCMS		Benzaldehyde	C_7H_6O	(Chinyere *et al.* 2021)	Insecticidal, antimicrobial and antioxidant (Ullah *et al*. 2015)
	GCMS		Lilac aldehyde B	$C_{10}H_{12}O$		Antibacterial (Felicioli *et al.* 2019)
Seed	GCMS		2- Octenal (E)-	$C_8H_{14}O$	(Adomè *et al.* 2023)	Antibacterial (Bisignano *et al.* 2001), antioxidative (Alaiz *et al.* 1995)
	GCMS		2.4-Decadienal (E, E)	$C_{10}H_{16}O$		Antioxidant (Tiji *et al*., 2021)
Fruits	GCMS	Terpene alcohol	Linalool	$C_{10}H_{18}O$	(Odoom *et al.* 2023)	Anti-inflammatory (Peana *et al.* 2002)
Fruits	GCMS	Benzene	Benzeneacetaldehyde	C_8H_8O	(Odoom *et al.* 2023)	Antimicrobial (Farag *et al.* 2013), antinematicidal (Tadigiri *et al.* 2020)
			Benzenepropanal	$C_9H_{10}O$		Antimicrobial (Hameed *et al.* 2016), antibacterial (Chang *et al.* 2008)
			1-Methylene indene	$C_{10}H_8$		Antimicrobial (Hwang *et al.* 2011), antibacterial (Adurosakin *et al.* 2023)
Seed	GCMS	Ketones	Cyclopentadecanone, 2-hydroxy-	$C_{15}H_{28}O$	(Adomè *et al*., 2023)	Antimicrobial (Kayat *et al.* 2016), antidepressant (Rahman *et al.* 2020)
Fruits			3-Octanone	$C_8H_{16}O$	(Odoom *et al*., 2023)	Antibacterial (Beltran-Garcia *et al.* 1997), antifungal and antimicrobial (Shirazi *et al.* 2022)
			Acetophenone	C_8H_8O		Antifungal (Gul *et al.* 2001), antimicrobial (Chauhan *et al.* 2011)
			2-Nonanone	$C_9H_{18}O$		Antibacterial (Melkina *et al.* 2017), antimicrobial (Veselova *et al.* 2019)
			3-Nonen-2-one	$C_9H_{16}O$		Antibacterial (Smith *et al.* 1995)

			1H-2-Indenone,2,4,5,6,7,7a-hexahydro-3-(1-methylethyl)-7a-methyl	$C_{15}H_{20}O$		Not reported
			1,8(2H,5H)-Naphthalenedione, hexahydro-8a-methyl-, cis-	$C_{11}H_{14}O_2$		Antimicrobial (Suleimen *et al.* 2018)
Leaves			1,3-Cyclohexanedione, 5,5-dimethyl-2-propyl-	$C_{11}H_{18}O_2$		Not reported
			2-(3-Isopropyl-4-methyl-pent-3-en-1-ynyl)-2-methyl-cyclobutanone	$C_{15}H_{22}O$		Antimicrobial (Chauiyakh *et al.* 2023)
			2-Pentadecanone, 6,10,14-trimethyl-	$C_{18}H_{36}O$		Insecticidal (Sanyaolu *et al.* 2019), antimicrobial (Essien *et al.* 2011)
			p-Menth-4-en-3-one	$C_{10}H_{16}O$		Antibacterial (Ghasemifar *et al.* 2020), antioxidant and antimicrobial (Odoom *et al.* 2023)
			Geranyl acetone	$C_{12}H_{20}O$	(Owolabi *et al.* 2022)	Antimicrobial (Bonikowski *et al.* 2015), antibacterial and antioxidant (He *et al.* 2020)
Fruits			Acetophenone	C_8H_8O	(Lasekan, 2017)	Antifungal (Gul *et al.* 2001), antimicrobial (Chauhan *et al.*, 2011)
			β-Ionone	$C_{13}H_{20}O$		Anticancer (Ansari *et al.* 2016), antimicrobial (Grabarczyk *et al.* 2016)
			p-Hydroxyacetophenone	$C_8H_8O_2$	(Chinyere *et al.* 2021)	Trypanocidal and antifungal (do Nascimento *et al.* 2004)
Fruits	GCMS	Aziridine	Cyclooctylidene-(2-phenylaziridin-1-yl) amine	$C_{16}H_{22}N_2$	(Odoom *et al.* 2023)	Not reported
Fruits	GCMS	Cinnamates	Isobutyl cinnamate	$C_{13}H_{16}O_2$	(Odoom *et al.* 2023)	Antimicrobial (Meilawati *et al.* 2023), antibacterial (Begum *et al.* 2023)
Fruits	GCMS	Dihydroisocoumarins	Mellein	$C_9H_6O_3$	(Odoom *et al.* 2023)	Antibacterial and fungicidal (Kendagor *et al.* 2013)
Fruits	GCMS	Dioxole derivatives	Spirio-10-(2,11-dioxabicyclo[4.4.1]undec	$C_{14}H_{20}O_3$	(Odoom *et al.* 2023)	Antibacterial (Payum, 2020), antimicrobial (Kumari *et al.* 2017)

			a-3,5-diene)-2′-(oxirane), 1,3,7,7-tetramethyl-			
Fruits	GCMS	Fatty acid	Hexanoic acid	$CH_3(CH_2)_4COOH$	(Odoom *et al.* 2023)	Antimicrobial (Huang *et al.* 2011)
			3-Decenoic acid, (E)	$C_{10}H_{18}O_2$		Antimicrobial (Ma *et al*., 1980)
			n-Hexadecanoic acid	$C_{16}H_{32}O_2$		Anti-inflammatory (Aparna *et al.* 2012), antibacterial (Ganesan *et al*., 2022)
			cis-vaccenic acid	$C_{18}H_{32}O_2$		Antioxidant and antimicrobial (Shawer *et al*., 2022)
			Octanoic acid	$C_8H_{16}O_2$		Antimicrobial (Huang *et al.* 2011), insecticidal (Rani *et al*., 2010)
			Hexadecanoic acid, ethyl ester	$C_{18}H_{36}O_2$		Antimicrobial (Musa *et al.* 2015), antibacterial (Igwe *et al.* 2013b)
Leaves			Tetradecanoic acid	$C_{14}H_{28}O_2$		Antioxidant (Sokmen *et al.* 2014), larvicidal (Sivakumar *et al*. 2011)
			Palmitoleic acid	$C_{16}H_{30}O_2$		Anti-inflammatory (Weimann *et al.* 2018), antimicrobial (Huang *et al.* 2010)
			n-Hexadecanoic acid	$C_{16}H_{32}O_2$		Antioxidant and antibacterial (Ganesan *et al.* 2022)
			Oleic acid	$C_{18}H_{34}O_2$		Antimicrobial (Fontana *et al*., 2013), anti-tumor (Carrillo Pérez *et al*., 2012)
			Octadecanoic acid	$C_{18}H_{36}O_2$		Antibacterial (Pu *et al.* 2010), antioxidant (Keawsa-Ard *et al.* 2012)
			Margaric acid	$CH_3(CH_2)_{15}COOH$	(Muanda *et al.* 2019)	Antimicrobial (Dong *et al.* 2018)
			Myristic alcohol	$C_{14}H_{30}O$	(Muanda *et al.* 2019)	Antibacterial (Abhyankar *et al.* 2021), anti-toxic (Bradley, 1976)
			14 methylpentadecanoic acid	$C_{16}H_{32}O_2$	(Nweke *et al.* 2015)	Antimicrobial (Saikarthik *et al.* 2017), antibacterial (Ismail *et al.* 2013)
			Hexadecanoic acid	$C_{16}H_{32}O_2$		Anti-inflammatory (Aparna *et al.* 2012)
			9,12-Octadecadienoic acid	$C_{18}H_{32}O_2$		Antibacterial (Igwe *et al.* 2013a; Krishnaveni *et al.* 2014)
			6-Octadecenoic acid	$C_{18}H_{34}O_2$		Antimicrobial and antibacterial (Chelliah *et al*. 2017)
			Octadecanoic acid	$C_{18}H_{36}O_2$		Antivirus (Linton *et al.* 2013), anti-inflammatory (Manivannan *et al.* 2017)

			Oleic acid	$C_{18}H_{34}O_2$		Antitumor (Fontana *et al.* 2013), antimicrobial (Hashimoto *et al.* 2003)
	LCMS		Zeanic acid	$C_{17}H_{26}O_4$	(Forcados *et al.* 2021)	Antimicrobial (Matsushima *et al.* 1973)
Seed	GCMS		18 6- Octadecenoic acid	$C_{18}H_{34}O_2$	(Adomè *et al.* 2023)	Not reported
			9.12-Octadecadienoic acid (Z, Z)-	$C_{18}H_{32}O_2$		Antimicrobial (Dafalla, 2018), antioxidant (Agustini *et al*. 2022)
			Hexadecanoic acid	$C_{16}H_{32}O_2$		Anti-inflammatory (Aparna *et al.* 2012), antibacterial (Musa *et al.* 2015)
Fruits	GCMS	Lipid	1-Monolinoleoylglycerol trimethylsilyl ether	$C_{27}H_{52}O_4Si_3$	(Odoom *et al.* 2023)	Antibacterial (Kumar *et al*., 2018), anti-inflammatory and antimicrobial (Vijayashalini *et al.* 2016)
Fruits	GCMS	Triterpene	Squalene	$C_{30}H_{50}$		Antimicrobial (Bhat *et al.* 2023)
Leaves	GCMS	Polycyclic aromatic	Naphthalene	$C_{10}H_8$		Antimicrobial (Makar *et al.* 2019)
Leaves	GCMS	Vitamin B	Folic acid	$C_{19}H_{19}N_7O_6$		Antimicrobial (Kasprzak *et al.* 2018)
Leaves	GCMS	Phenylpropanoids	Trans-isoeugenol	$C_{10}H_{12}O_2$		Antimicrobial and antioxidant (Singh *et al.* 2005)
Leaves	GCMS	Ionones	Trans-á-ionone	$C_{13}H_{20}O$		Antiproliferative and antiviral (Herath *et al.* 2017)
Leaves	GCMS	Dihydroisocoumarin	Mellein	$C_9H_6O_4$		Antimicrobial (Hussain *et al*., 2015), fungicidal and antibacterial (Kendagor *et al.* 2013)
Leaves	GCMS	Phenylpropanoid	Phenol, 2,6-dimethoxy-4-(2-propenyl)-	$C_{12}H_{14}O_3$		Antioxidant (Paudel *et al.* 2019), antimicrobial (Setyati *et al.* 2024)
Seed	GCMS	Alkane	n-Decane	$C_{10}H_{22}$	(Adomè *et al.* 2023)	Antibacterial (Mohebat *et al.* 2018), antimicrobial (Fathollahi *et al.* 2018)
Fruits			Hentriacontane	$C_{31}H_{64}$	(Odoom *et al.* 2023)	Antibacterial (Rabah *et al.* 2020), anti-inflammatory (Khajuria *et al.* 2017)
			Cyclohexane, 1,2,4,5-tetraethyl-	$C_{14}H_{28}$		Not reported
Leaves			Tetradecane	$C_{14}H_{30}$		Antioxidant and antimicrobial (Adedoyin *et al.* 2013)
			Heneicosane	$C_{21}H_{44}$		Microbicidal (Vanitha *et al.* 2020), antioxidant and antimicrobial (Rhetso *et al.* 2020)

			Heptacosane	$C_{27}H_{56}$		Antibacterial (Luna *et al.* 2020), antimicrobial (Köse *et al.* 2016)
			Pentacosane	$C_{25}H_{52}$		Antibacterial (Matloub *et al.*, 2020), antimicrobial (Carev *et al.*, 2023)
			Octacosane	$C_{28}H_{58}$		Antimicrobial (Kim *et al.* 2012)
			Eicosane	$C_{20}H_{42}$		Antifungal (Ahsan *et al.* 2017), antimicrobial (Kumaresan *et al.*, 2015)
			Hexadecane	$C_{16}H_{34}$		Antimicrobial (Solyanikova *et al.* 2019)
			Octadecane	$C_{18}H_{38}$		Antimicrobial (Kalsum *et al.* 2016)
Leaves	GCMS	Esters	Benzoic acid, tridecyl ester	$C_{20}H_{30}O_2$	(Odoom *et al.* 2023)	Anticancer and antimicrobial (Sophia *et al.* 2022)
			Benzoic acid, tetradecyl ester	$C_{21}H_{34}O_2$		Antibiotic and antimicrobial (Koilybayeva Shynykul Ustenova Waleron Mustafina *et al.* 2023)
			1,2-Benzenedicarboxylic acid, dinonyl ester	$C_{28}H_{46}O_4$		Antimicrobial, antibacterial and antifungal (Ramalakshmi *et al.* 2011)
			Benzyl benzoate	$C_{14}H_{12}O_2$		Insecticidal (Abdel-Baki *et al.*, 2024), antimicrobial (Farias *et al*. 2020)
			Benzoic acid, tetradecyl ester	$C_{21}H_{34}O_2$		Antidiabetic (Reddy *et al.* 2020), antimicrobial (Nithyadevi *et al.* 2015)
			Formic acid, 3,7,11-trimethyl-1,6,10-dodecatrien-3-yl ester	$C_{17}H_{26}O_2$		Antimicrobial (Fahem *et al.*, 2020), antibacterial (Hameed *et al.* 2018)
			1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	$C_{16}H_{22}O_4$		Antibacterial (Sivakumar, 2014), antioxidant and anti-inflammatory (Hamid *et al.* 2018)
			Pentafluoropropionic acid, 4-hexadecyl ester	$C_{19}H_{33}F_5O_2$		Antimicrobial (Nasir *et al.* 2020)
			2-Methoxy-4-vinylphenol	$C_9H_{10}O_2$		Anticancer (Kim *et al.*, 2019), anti-inflammatory (Asami *et al.* 2023)
			Chloroacetic acid, 2-tetradecyl ester	$C_{16}H_{31}ClO_2$		Antioxidant and antimicrobial (Odoom *et al.* 2023)
Fruits			n-Propyl 9,12-octadecadienoate	$C_{21}H_{38}O_2$		Antioxidant and antimicrobial (Adebayo-Tayo *et al.* 2021)

Octadecane, 1,1′-[1,3-propanediyl bis(oxy)]bis-	$C_{39}H_{80}O_2$		Not reported
Methyl cinnamate	$C_{10}H_{10}O_2$		Antifungal (Lima *et al*., 2018), antimicrobial (Padalia *et al.* 2017)
1,4-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester	$C_{24}H_{38}O_4$		Antibacterial and antimicrobial (Vasumathi *et al.* 2023)
Acetic acid and hexyl ester	$C_8H_{16}O_2$		Antimicrobial (El-Hawary *et al.* 2018)
γ-Caprolactone	$C_6H_{10}O_2$		Antimicrobial (Inchagova *et al.* 2023)
Ethyl cinnamate	$C_{11}H_{12}O_2$		Antimicrobial and acaricidal (Zhang *et al.* 2015)
3-Phenyl-1-propanol acetate	$C_{11}H_{14}O_2$		Antimicrobial (Le Thi *et al*., 2008), antifungal (Velascob *et al.* 2010)
1-Cyclohexen-1-ol, 2,6-dimethylacetate	$C_{10}H_{16}O_2$		Not reported
Ethyl-2-methylpropionate	$C_7H_{14}O_2$	(Lasekan, 2017)	Anticonvulsant and antimicrobial (Karakurt *et al.* 2010)
Methylbutanoate	$C_5H_{10}O_2$		Antimicrobial (TI *et al*., 2001)
Ethylbutanoate	$C_6H_{12}O_2$		Antibacterial and antifungal (Alkhalidi *et al.* 2024)
1-Pentyl acetate	$C_7H_{14}O_2$		Antibacterial (Warren *et al.* 1962)
Methyl hexanoate	$C_7H_{14}O_2$		Mosquitocidal (Demiray *et al.* 2017), antimicrobial (Jiang *et al.* 2021)
Butyl butanoate	$C_8H_{16}O_2$		Nematicidal and antimicrobial (Sun *et al*., 2023)
2-Heptyl acetate	$C_9H_{18}O_2$		Antimicrobial (Nguyen *et al.* 2016), antibacterial (Ritzmann *et al.* 2019)
Hexyl acetate	$C_8H_{16}O_2$		Antimicrobial (El-Hawary *et al.* 2018)
(Z)-3-Hexenyl acetate	$C_8H_{14}O_2$		Antimicrobial (Chakravorty *et al.* 2012)
Methyl octanoate	$C_9H_{18}O_2$		Anti-inflammatory (Samarakoon *et al.* 2022), antimicrobial (Brophy *et al.* 2008)
Ɣ-Jasmolactone	$C_{11}H_{16}O_2$		Not reported
Ethyl cinnamate	$C_{11}H_{12}O_2$		Antimicrobial (Jiang *et al.* 2021)

Leaves	GCMS	Terpenes	Squalene	$C_{30}H_{50}$	(Odoom *et al.* 2023)	Antimicrobial (Huang *et al.* 2009)
Fruits			Limonene	$C_{10}H_{16}$	(Lasekan, 2017)	Antimicrobial (Vuuren *et al.* 2007), therapeutic (Anandakumar *et al.* 2021)
			(E)-β-Ocimene	$C_{10}H_{16}$		Anti-toxic and antileishmanial (Sousa *et al.* 2023)
			Borneol	$C_{10}H_{18}O$		
			(Z)-Rose oxide	$C_{10}H_{18}O$		Antidepressant (Maia *et al*., 2021), anti-inflammatory (Nonato *et al.* 2012)
Leaves			Linalool	$C_{10}H_{18}O$	(Muanda *et al.* 2019)	
Leaves	GCMS	Phenylpropenes	Asarone	$C_{12}H_{16}O_3$	(Muanda *et al.* 2019)	Antibacterial and anthelmintic (McGaw *et al.* 2002)
Leaves	GCMS	Phloroglucinols	Hyperforin	$C_{35}H_{52}O_4$	(Muanda *et al.* 2019)	Anticancer and antibacterial (Immacolata Pia Schiavone *et al.* 2014)
Fruits	GCMS	Aromatic	2-Phenylethanal	C_8H_8O	(Lasekan, 2017)	Antibacterial (Fons *et al.* 2010; Zhu *et al*., 2011b), antifungal (Lawson *et al.* 2020)
Fruits			Benzaldehyde	C_7H_6O		Insecticidal, antimicrobial and antioxidant (Ullah *et al*. 2015)
Fruits	GCMS	Carboxylic Acid	2-Ethyl hexanoic acid	$C_8H_{16}O_2$		Antibacterial and antibiotic (Koilybayeva Shynykul Ustenova Waleron Jońca *et al.* 2023)
Fruits	GCMS		Acetic acid	CH_3COOH		Antibacterial and antibiotic (Koilybayeva Shynykul Ustenova Waleron Jońca *et al.* 2023)
Fruits	GCMS	Furanone	4-Hydroxy-2,5-dimethyl-3(2H)-furanone	$C_6H_8O_3$		Antioxidant (Koga *et al.* 1998), antimicrobial (Sung *et al.* 2007)
Fruits	GCMS	Norisoprenoids	Theaspirane isomer I	$C_{13}H_{22}O$		Antioxidant (Yong *et al.* 2019), antimicrobial (Zhang *et al.* 2021)
			Theaspirane isomer II	$C_{13}H_{22}O$		Not reported
			β-Damascenone	$C_{13}H_{18}O$		Antioxidant, antibacterial and anti-inflammatory (Palariya *et al.* 2019)
Leaves	GCMS	Vinyl ethers	*p*-Vinylanisole	$C_9H_{10}O$	(Owolabi *et al.* 2022)	Antimicrobial and antioxidant (Alade *et al.* 2021)

Leaves	GCMS	Damascones	(*E*)-β-Damascenone	$C_{13}H_{18}O$		Antimicrobial (Brahmi *et al*., 2012), antibacterial (Benmeddour *et al*., 2015)
Leaves	GCMS	Ionones	(*E*)-β-Ionone	$C_{13}H_{20}O$		Anticancer (Ansari *et al.* 2016)
Leaves	GCMS	Salicylic acid esters	Hexyl salicylate	$C_{13}H_{18}O_3$		Antibacterial (Coburn *et al.* 1981), anti-inflammatory (Mancuso *et al.* 2019)
Leaves			Benzyl salicylate	$C_{14}H_{12}O_3$		Anti-inflammatory (Lee *et al.* 2021), antifungal (Jantan *et al*., 2008)
Leaves	GCMS	Acyclic diterpene	Neophytadiene	$C_{20}H_{36}$		Antioxidant (Luhata *et al.* 2023), anti-inflammatory (Banni *et al.* 2023)
Leaves	GCMS	Lipids	Phytone	No data		Anti-tumor and antibiotic (Hirano *et al*., 2001)
Leaves	GCMS	Acetate ester	Incensyl acetate	$C_{14}H_{20}O_2$		Antimicrobial (Owolabi *et al*., 2022)
Leaves	GC/MS	Alkyl chlorides	1-chloro-3-methyl-butane	$C_5H_{11}Cl$	(Nweke *et al.* 2015)	Not reported
Stembark	Chromatography	Ecdysteroids	20-hydroxyecdysone	$C_{27}H_{44}O_{7.\ 20}$	(Bunu *et al.* 2021)	Antimicrobial (Roussel *et al.* 1997)
			Turkesterone	$C_{27}H_{44}O_7$	(Bunu *et al.* 2021)	Antiproliferative, antimicrobial and antioxidant (Mamadalieva *et al.* 2013)
Fruits	GCMS		Ecdysterone	$C_{21}H_{31}O_3$	(Ajiboye, 2015)	Antimicrobial (Kim *et al.* 1983), antitumor (Konovalova *et al.* 2002)
Fruits	GCMS	Ether	Acetylfuran	$C_6H_6O_2$	(Chinyere *et al.* 2021)	Antiamoebic (Abid *et al.* 2005), antiviral (Bailey *et al.*1996)
Fruits	GCMS		Lilac alcohol formate C	$C_{10}H_{18}O$		Antimicrobial (Chinyere *et al.* 2020), antioxidant and antibacterial (Kosakowska *et al.* 2018)
Leaves	GC/MS		2,2,4-Trimethylpentylvinyl ether	$C_{11}H_{24}O$	(Nweke *et al.* 2015)	Antimicrobial (Mukherjee *et al.* 2012), antibacterial (Nweke *et al.* 2015)
Fruits	GCMS	Carboxylic Acid	Heptanoic acid	$C_7H_{14}O_2$	(Chinyere *et al.* 2021)	Antimicrobial (Jeong *et al.* 2005)
Fruits	GCMS	Terpene	Linalool	$C_{10}H_{18}O$		Anti-inflammatory [99]
Leaves			Linalool	$C_{10}H_{18}O$	(Owolabi *et al.* 2022)	Anti-inflammatory [99]

Fruits			Alpha-Thujene	$C_{10}H_{16}$	(Chinyere *et al.* 2021)	Antidermatophytic (Jain *et al*., 2017), antioxidant (Mohammadi *et al.* 2015)
Fruits			Eucalyptol	$C_{10}H_{18}O$		Anti-inflammatory and antioxidant (Seol *et al*., 2016)
Leaves	LCMS	Organic Acid	L-Tartaric acid	$C_4H_6O_6$	(Forcados *et al.* 2021)	Antimicrobial (Khiati *et al.* 2012), antifungal (Mabkhot *et al.* 2016)
Leaves		Aromatic Amine	Vanillylamine	$C_8H_{11}NO_2$		Antiherpetic (Chanquia *et al.* 2017)
Fruits	GCMS	Lignan	4-Keto pinoresinol	$C_{18}H_{18}O_3$	(Ajiboye, 2015)	Antioxidant and antimutagens (Namiki, 1990)
Stembark	TLC	Steroids	21-hydroxyshidasterone	$C_{21}H_{34}O_3$	(Ishola *et al.* 2014)	Antidepressant (Ishola *et al.* 2014), antimicrobial (Kamal *et al.* 2022)
Stembark			11β-hydroxy-20-deoxyshidasterone	$C_{21}H_{33}O_3$		Antidepressant (Ishola *et al*., 2014), antimicrobial (Jean *et al*., 2019)
Stembark			ajugasterone and 24-hydroxyecdysone	$C_{21}H_{33}O_3$		Anti-inflammatory (Ochieng *et al.* 2013), antiathritis and rheumatoid
Seed	GCMS		Pregn-5-en-3-ol, 20-amino-, (3.beta.,20S)-	$C_{22}H_{38}N_2O$	(Adomè *et al.* 2023)	Not reported
	Column chromatography	Naphthoquinolinone derivative	3-ethyl-3,4,4a,5,6,6a,10a,11,12,12a-decahydro-1H-naphtho[2,3, g]quinolin-2-one	$C_{18}H_{19}N_1O$	(Mudi, 2011)	Antiplasmodial (Mudi, 2011), antifungal (Garba *et al.* 1998)
Stembark		Piperidine	2,2,6,6-tetramethyl-4-oxo-piperidinium nitrate	$C_9H_{18}N_2O_4$	(Bunu *et al.* 2024)	Antimicrobial (Bunu *et al*., 2024)

Phenol

Some phenol compounds were identified from *V. doniana* parts, some of which are quercetin, gallic acid and homoorientin. Phenols are among the main chemical components that function as antioxidants by scavenging free radicals or acting as chelating agents. The compounds were discovered to hinder the activity of neuraminidase and were also observed to possess antioxidant capabilities in the free radical scavenging assay 1,1-diphenyl-2-picrylhydrazyl (DPHH) (Kashiwada *et al.* 2012). Phenolic chemicals have gained popularity among scientists and consumers because of their health-enhancing qualities, particularly their antioxidant activity.

Volatile compounds

V. doniana has a variety of volatile compounds that are classified and distributed on the basis of diverse chemical classes, including ether, aldehyde, carboxylic acid, acetate ester, sesquiterpene, and monoterpene.

Pharmacological uses

This review discusses the numerous biological activities of *V. doniana* parts, specifically with respect to their antimicrobial, anti-inflammatory, antidiarrheal, antimalarial, antidiabetic, antiulcer, antiepilepsy, hepatoprotective and cytotoxic properties, when different extracts are used in numerous models (Table 3).

Anti-inflammatory effects

Inflammation has been shown to be a significant consideration in the progression of several diseases. There are several drawbacks and side effects associated with conventional anti-inflammatory drug usage, highlighting the need for a potent treatment for inflammation. The following study compiles earlier published results concerning the potential of *V. doniana* extract to treat inflammation.

The aqueous extract of leaves significantly inhibited the growth of paw edema caused by agar in the rats ($P<0.05$). The dose of the aqueous leaf extracts also controlled the duration of thermal pain in the mice. The degree of ulceration of the stomach mucosa in the rats significantly increased with increasing aqueous leaf extract. Moreover, the effect of the extract was dose dependent, which has the ability to prevent hemolysis of red blood cells induced by hypo tonicity (Iwueke *et al.* 2006). There were significant differences among the tested leaf extracts in terms of their ability to inhibit swelling of the carrageenan-induced paw in rats; the methanol fraction of the leaves presented the highest potency, with an ED_{50} value of 16.52 mg/kg. The next most potent fraction was the ethyl acetate leaf fraction (ED_{50} = 19.17 mg/kg), followed by the petroleum ether leaf fraction. The reference drugs dexamethasone and diclofenac had ED_{50} values of 7.19 mg/kg and 7.55 mg/kg, respectively (Adjei *et al.* 2021). The data obtained from the four methods indicate that the various fractions play an equally important role in anti-inflammatory activities. Most importantly, the ethyl acetate leaf fraction exhibited the ultimate potency, with denaturation inhibition of 70.12 ± 1.02%, proteinase inhibition of 69.93 ± 2.00%, A5-LOX inhibition of 70.60%, and xanthine oxidase inhibition of 72.12%. On the other hand, the n-hexane soluble fraction (n-HF) exhibited the lowest activity in these assays (Barry *et al*., 2022).

According to the literature on *V. doniana*, the leaves clearly have anti-inflammatory properties in animal models. Further research should include the identification of individual compounds that act as anti-inflammatory agents and the determination of their safety and mechanism of action.

Antibacterial

Efforts to develop new antibiotics are hampered because clinically resistant bacteria are now common and can morph themselves to resist several antibiotics. This resistance is dangerous, especially for people with weakened immune systems, who are likely to develop severe problems. Consequently, natural plant products are considered promising sources for further exploration and identification of bioactive antibacterial compounds with low toxicity, wide-spectrum activity and acceptable pharmacokinetic profiles that can be used directly in the clinic without chemical modifications. Several scientists have evaluated the antibacterial efficacy of several *V. doniana* extracts against pathogenic microorganisms. The studies that have been presented all show some degree of efficacy against the targeted bacteria (Table 3).

Nwachukwu *et al.* (2010) reported that acetone leaf extracts had a 19.71 mm inhibitory effect on *Salmonella typhi*, whereas methanol extracts had a 14.61 mm inhibitory effect on *Escherichia coli*. The ethanol extracts exhibited moderate efficacy against S. typhi, resulting in a zone of 13.66 mm. In comparison, gentamicin exhibited enhanced antibacterial activity, with inhibition zones of 23.04 mm against *E. coli*, 26.18 mm against *Staphylococcus aureus*, 5.84 mm against *Pseudomonas aeruginosa*, 24.30 mm against *Bacillus subtilis,* and 27.15 mm against *S. typhi* when 100 µg/mL gentamicin was used. *Shilgella* *dysentarae* exhibited the greatest sensitivity, measuring 22 mm, followed by *E. coli,* with a sensitivity of 16 mm. *S. typhi* displayed the lowest sensitivity, measuring 11 mm, as determined by the disc diffusion method (Kilani, 2006). The MIC varied between 0.039 and 2.5 mg/mL. Notably, the dichloromethane leaf extract showed potential for combatting *S. aureus*, with an MIC value of 39 µg/mL. Moreover, both ethanol and methanol leaf extracts were effective against *S. aureus* at 78 µg/mL (Lagnika *et al.* 2012). On the other hand, the ethanol extract of the leaves, via the agar well diffusion method, yielded inhibition zones of 14, 11, 11, and 5.7 mm for *E. coli, S. aureus, S. typhi,* and *P. aeruginosa,* respectively (Osuagwu *et al*., 2013). Additionally, the ethanolic leaf extract had a promising effect, with a 93.75 µg/mL MIC against *B. subtilis*, whereas nystatin had an MIC of 3.9 µg/mL. *E. coli, P. aeruginosa*, *S. aureus,* and *S. typhi* (Osuagwu *et al.* 2013).

Philizary reported that the average zone of inhibition for both aqueous and methanol extracts from the leaves of *H. suffruticosa* against the *S. typhi* strain, as revealed by the agar well diffusion method, was 20.63 mm, whereas for ciprofloxacin, the average zone of inhibition was 13 mm at 100 mg/mL (Philizary and alsol, 2017). In the agar well diffusion method, stem bark saponin at a concentration of 50 mg/ml inhibited the following clinical strains of *E. coli*, *P. aeruginosa* and *E. coli* ATCC 11775: 20.0 ± 1.41 mm, 18.5 ± 0.71 mm, 17.0 ± 0 mm and 13.0 ± 1.41 mm, respectively. On the other hand, the effect observed in this study was highly potent at 100 mg/mL ciprofloxacin against every strain that was analyzed. At 1000, 500, and 250 mg/mL, the methanol extract had an inhibition zone ranging from 10.50 mm to 21.00 mm, but the acetone extracts inhibited *Escherichia coli* growth to a maximum of 7.50 mm at 1000 mg/mL (Aiwonegbe *et al.* 2018). Both the tested pathogenic organisms, *S. aureus, S. typhi, P. aeruginosa* and *E. coli,* were susceptible to the extract, and the inhibition zones varied between 4 and 20 mm (Salihu *et al.* 2011). The average MIC is 1000 µg/cm3, and the maximum MIC is 2000 µg/cm3 (Salihu *et al.* 2011). The methanol seed extract experiment via the agar well diffusion method yielded an inhibition zone of 17.7 mm against *Bacillus subtilis*, 16 mm against *Staphylococcus aureus*, 21.3 mm against *Enterococcus faecalis* and 10.6 mm against *Pseudomonas aeruginosa* and Salmonella typhi. However, an inhibition zone of 36.3 mm was observed for ciprofloxacin against *B. subtilis and S. typhi*, 32.7 mm against *S. aureus*, 28 mm against *E. faecalis* and 26 mm against *P. aeruginosa* (Udeani *et al.* 2021). Furthermore, by employing the broth dilution assay, the plant fruit and leaf extracts were also tested. The fruit essential oils presented minimum inhibitory concentrations ranging from 6.25 mg/mL to 25.00 mg/mL, and the concentrations of the leaf essential oils ranged from 19.75 mg/mL to 79.00 mg/mL. The MICs for ciprofloxacin were lower, varying from 0.31–5.00 µg/mL. In addition, the highest activity of the fruit essential oils was against *E. coli,* with an average zone of inhibition of 21.5 mm, followed by *S. pyogenes* (17.5 mm) and *S. typhi* (14.5 mm) (Odoom *et al.* 2023).

The ethanolic extract from fruits recorded an inhibition zone of 80% against the bacterial strains as compared to 60% recorded by the extract from the leave of the plant. The fruit extract showed zone of inhibition against *M. luteus* with the diameter of 12.75 mm after 24 h and against *E. coli* with a diameter of 4.0 mm after 48 h. The extract obtained from the leaves reduced the growth of *S. epidermidis* by 12.5 mm after 24 h and *E. coli* by 6.5 mm after 24 h (Dah-Nouvlessounon *et al.* 2023). The disc diffusion assay displayed the inhibition zone of may be 11 mm and 4 mm *Pseudomonas mirabilis* and *Bacillus subtilis* respectively, when the essential oil extracted from the leaves was used while gentamicin displayed an inhibition zone of 31–40 mm, which shows minimal oil action (Sonibare et al. 2009).

In addition, the oils extracted from the leaves also exhibited moderate activity against *B. cereus, S. epidermidis*, *C. neoformans*, and *M. canis* with MIC = 312.5 µg/mL (Owolabi *et al.* 2022). Furthermore, the antibacterial activity of the acetonic and ethanolic extracts from the leaves, stem barks and root of the plant against *S.typhi* was tested using agar well diffusion method. The next criterion as inhibition zone was comparatively equal with 2.66mm for acetonic extract and 3.33mm for the ethanolic one using 50 mg/mL of the leaf extracts.

The inhibitory effects of the stem bark extracts were as follows: 3.66 mm (acetonic) and 4.33 ± 0.33 mm (ethanolic). Similarly, the inhibitory effects of the root extracts were 4.33 mm (acetonic) and 4 mm (ethanolic), whereas a significant increase in the inhibition zone was shown by the standard ciprofloxacin as follows: 32.66 mm at 5 mg/mL (Kuta *et al.* 2016).

Thus, at 300 mg of ethanolic acetone extract of the leaves, bark, and roots per body weight of the mice injected with the strain of *S. typhi*, the mice seemed to consciously recover full strength. Also, Kuta *et al.* (2016) observed that all the non-treated mice controls (the infected mice) died within 48 hours after being infected by *S. typhi*.

Based on the extracts, the moderate to full antimicrobial activity on *S. aureus*, *S. typhi P. aerogenosa* and *E.coli* inhibition zone was found ranging from 2.38mm to 19.71 mm (Emmanuel *et al.* 2015). The growth of *S. aureus* was highly reduced by the leaf extract with MIC value within 0.4µg/mL – 0.8µg/mL. Furthermore, the extract was more effective against *K. pneumoniae* with MIC of 0.6–1.4 µg/mL (HZ *et al.* 2022).

Compared to Ofloxacin with inhibition zone of 38mm when agar well diffusion method was used, the tannins from the leaf extract at the dosage of 0.3125 mg/ml had the best inhibitory against *Salmonella typhi* with inhibition zone of 7.1mm (Njokuocha, 2020). The diameter of the inhibition zones for *P. aeruginosa*, *E. coli*, and *S. aureus* by the methanol leaf extract was found to be 14 mm, 16 mm, and 15 mm respectively as determined by the disc diffusion assay. While tetracycline showed relatively smaller zones of inhibition for *B. subtilis* (8mm, *P. vulgaris* (9mm), and *K. pneumoniae* (9mm), it produced relatively larger zones of inhibition for S. aureus (19mm), *P. aeruginosa* (16mm), and *E. coli* (20mm) as described by Umar *et al*. 2015). Both the ethanol and water extracts of the leaves and bark did not show inhibition to the growth of the strains tested using the disc diffusion method (Raji *et al.* 2003).

The MIC values for the extracts ranged from 150 to 300 µg/mL. At varying dosages, it demonstrated significant efficacy against Salmonella strains, with zones of inhibition measuring 20 mm and 18 mm. In contrast, a larger inhibited zone of 22 mm was observed with chloramphenicol (Noel *et al*., 2022). The 70% ethanolic, methanolic, and ethyl acetate extracts of stem bark had inhibitory effects on different strains ranging from 11 to 26 mm in diameter. With a 17 mm inhibitory diameter, the aqueous stembark extract was solely effective against *S. aureus* Meti-S. With minimum bactericidal concentrations (MBCs) of 3.12 mg/mL for *S. aureus* Meti-R, 0.39 mg/mL for *S. aureus* Meti-S, and 3.12 mg/mL for *S. aureus*, the ethyl acetate extract showed the best overall activity among all the extracts tested (Ouattara *et al.* 2013). The *E. coli* strain ESBL demonstrated inhibition diameters of 13 mm with the methanolic extract and 19 mm with the ethyl acetate extract via the agar well diffusion approach. An inhibition diameter of 11 mm was observed for *K. pneumoniae* in the methanolic extract, and an inhibition diameter of 15 mm was observed in the ethyl acetate extract. Interestingly, neither cefoxitin (30 µg) nor oxacillin (5 µg) inhibited the tested bacteria (Abou *et al.* 2017). The recorded antibacterial efficacy of different parts of *V. doniana* might be the result of the diverse active compounds present in the plant. The activity might be due to a single compound or the synergistic action of many compounds present in the extract. Different classes of compounds, ranging from amino acids to hydroxycinnamic acids, phenethylamines, and flavonoids, have been reported to be present in plants. The crude extract exhibited a synergistic effect that resulted in DNA damage. This effect also led to the initiation of oxidative stress, specifically reactive oxygen species (ROS), which in turn disrupted the metabolic pathway. Additionally, the crude extract induced disruption of the cellular membrane, resulting in the leakage of cellular components.

Antidiarrheal

Diarrhea, which is characterized by more than three stools per day and may be either loose or watery in nature, is a major contributor to morbidity and mortality in children. Diarrhea is known to cause the death of one child out of every ten in children below the age of five years (Dogara, 2023). Like the positive control drug loperamide at 5 mg/kg, the aqueous fruit extract, when given to mice at doses of 150, 350, and 650 mg/kg, significantly protected against castor oil-induced diarrhea ($P < 0.05$) (Suleiman *et al*., 2008). The aqueous extract of stem bark had a substantial effect ($P < 0.05$) on decreasing the total stool frequency (TSF). The lowest TSF was recorded at a concentration of 100 mg/kg bw, which was 4.80, whereas the TSF of the standard medication loperamide was 2.5 mg/kg, which was 5.75. Compared with the benchmark reference medication, the concentrations of 100 mg/kg bw and 400 mg/kg bw resulted in the suppression of defecation (Aliyu *et al.* 2020).

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Table 3. Profile of the documented pharmacological activity of *V. doniana*

Activity	Method of evaluation	Experimental model	Compound/extract	Part of the plant	Concentration of the administration	Positive control	Negative control	Reference
Antimicrobial	MIC, MBC, agar well diffusion	*Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus, Salmonella typhi and Bacillus substilis*	Ethanol, methanol, acetone	Leaves	100 mg/mL	Gentamycin (100 µg/mL)	DMSO	(Nwachukwu *et al.* 2010)
	MIC, Disc diffusion	*S. typhi*, *Shigella dysentarae* and *E. coli*	Methanol	Stembark	0.2 to 2.5 mg/mL	NA	NA	(Kilani, 2006)
	MIC	*E. coli* CIP 53126, *S. aureus* ATCC 6538, *Enterococcus faecalis* ATCC 29212, *P. aeruginosa* CIP82118, *S. abony* CIP 8039, *S. aureus* Methicillin Resistant (SARM) and *S. epidermidis*	Methanol, ethanol	Leaves	10 mg/mL	NA	Dichlorometha ne	(Lagnika *et al.* 2012)
	Ager well diffusion	*E. coli*, *S. aureus*, *S. typhi* and *P. aeruginosa*	Ethanol	Leaves	5, 15, 20 and 25 mg/mL			(Osuagwu *et al.* 2013)
	Ager well diffusion	S. typhi	Aqueous, methanol	Stembark, leaves	50, 100, 150 200 mg/mL	Ciprofloxaci n (100 mg/mL)	NA	(Ali *et al.* 2017)
	Ager well diffusion	*E. coli* ATCC 11775, *P. aeruginosa* ATCC 10145, and *S. aureus* ATCC 12600	Saponin, ethanol	Stembark, leaves	50, 25, 12.5, and 6.25 mg/mL	Ciprofloxaci n (100 mg/mL)	NA	(Akaniro-Ejim *et al.* 2016)
	Ager well diffusion	*E. coli*, *S. aureues, P. areuginosa and K. pnuemoniae*	Methanol, acetone	Fruits	1000, 500 and 250 mg/mL	NA	NA	(Aiwonegbe *et al.* 2018)

Ager well diffusion	*S. aureus*, *S. typhi*, *P. aeruginosa* and *E. coli*	Petroleum Ether, chloroform and methanol	Leaves, stembark, root	2000, 1000, 500 and 250 µg/cm3	NA	NA	(Salihu *et al.* 2011)
Ager well diffusion	*S. aureus*, *P. aeruginosa*, *B. subtilis*, *E. faecalis*, *S. typhi*, *A. nigger*.	Methanol	Seed	100.0, 50.0, 25.0, 12.5, and 6.25 mg/mL	Ciprofloxacin and ketoconazole (10-0.3125 mg/ml)	DMSO	(Udeani *et al.* 2021)
Broth dilution assay	*S. aureus* ATCC 29213, *B. subtilis* NTCC 10073, *E. feacalis,* and *S. pneumoniae* ATCC 49619, *P. aeruginosa* ATCC 27853 and *E.coli* ATCC 25922.	Essential oil	Leaves, fruit	Not available	Gentamicin	NA	(Odoom *et al.* 2023)
Ager well method	*S. aureus* ATCC 29213, *S. epidermidis* T22695, *Micrococcus luteus* ATCC 10240, *S. oralis*, *Enterococcus faecalis* ATCC 29212), *E. coli* ATCC 25922, *Proteus mirabilis* A24974, *P. vulgaris* A25015, *P. aeruginosa* ATCC 27853)	Ethanol, ethyl acetate and dichloromethane	Leaves, fruit	Not available	NA	NA	(Dah-Nouvlessounon *et al.* 2023)
Disc diffusion	*B. subtilis* ATTC 33923, *S. aureus* ATTC 6538, *P. aeruginosa* ATTC 27856, *B. cereus* ATTC 14579 and *P. mirabilis* ATTC 21784	Essential oil	Leaves	10, 100, 1000, 10000 ppm	Gentamicin (0.01 ml)	Dimethyl sulfoxide	(Sonibare *et al.* 2009)
Microbroth dilution	*B. cereus*, *S. aureus*, *S. epidermidis*, and *S. pyogenes*	Essential oil	Leaves	Not available	NA	NA	(Owolabi *et al.* 2022)

	Ager well diffusion	*S. typhi*	Acetone, ethanol, aqueous	Root, stembark and leaves	10, 50, 100 and 150 mg/mL	Ciprofloxacin	uninoculated media	(Kuta *et al.* 2016)
	In vivo (Mice)	Mice	Acetone, ethanol, aqueous	Root, stembark and leaves	300 mg/body		Control (not treated)	(Kuta *et al.* 2016)
	Not available	*S. aureus, S. typhi, P. aeruginosa and E. coli*	Aqueous, ethanol, acetone and methanol	Stem bark	Not available	NA	NA	(Emmanuel *et al.* 2015)
	MIC	*S. aureus*	Not available	Leaves	Not available	NA	NA	(HZ *et al.* 2022)
	Agar well diffusion	*P. aeruginosa, S. aureus*, *S. typhi* and *E. coli*	Tannin	Leaves	5, 2.5, 1.25, 0.625 and 0.3125 mg/mL	Ofloxacin	DMSO	(Njokuocha, 2020)
	Disc diffusion	*S. aureus, P. aeruginosa and E. coli.*	Ethanol, aqueous	Leaves	30,60,90,120 and 150 mg/mL	Tetracycline	DMSO	(Umar *et al.* 2015)
	Disc diffusion		Ethanol, aqueous	Bark, leaves	2-200 mg/mL			(Raji *et al*., 2003)
	Agar well diffusion		Ethyl acetate, methanol	Not available	100, 200 mg/mL	Chloramphenicol	DMSO	(Noel *et al.* 2022)
	Agar well diffusion	*E. coli* and *K. pneumoniae*	Methanol, ethyl acetate	Bark	200 mg/mL	Oxacillin (5 µg) and Cefoxitin (30 µg)	DMSO/sterile distilled	(Abou *et al.* 2017)
	Agar well diffusion, macrodilution method	*S. aureus* Meti-S, *S. aureus* Meti-R and *S. aureus* ATCC 25923	Ethanol, aqueous	Stem bark	NA	NA	NA	(Ouattara *et al.* 2013)
Antidiarrheal	In vivo (Mice)	Mice	Aqueous	Fruits	150, 350, 650 mg/kg	Loperami(5 mg/kg)	Saline (5 mL/kg)	(Suleiman *et al.* 2008)
	In vivo	Wister rat	Aqueous	Stem bark	100, 200, 400 mg/kg	Loperamide (2.5 mg/kg)	Normal saline	(Aliyu *et al.* 2020)
Anti-inflammation	In vivo	Albino rat	Aqueous	Leaves	0.5 and 1.0 mg/kg	NA	NA	(Iwueke *et al.* 2006)
	In vivo	Chickens	Methanol	Fruits	30, 100 and 300 mg/kg	Diclofenac	Untreated	(Adjei *et al.* 2021)

	Protein denaturation, protienase, A5-LOX and xanthine oxidase	Arachidonate 5-lipoxygenase	Acetone	Leaves	50, 100 and 200 mg/kg	NA	NA	(Barry *et al.* 2022)
Anti-Testicular torsion	In vivo (Wistar rats)		Aqueous	Leaves	50, 100 and 200 mg/kg	Not available	Not available	(Adelodun *et al.* 2016)
Postpartum bleeding	In vivo (Rat)		Aqueous	Stembark	1 g/mL		Not available	(Ladeji *et al.* 2005)
Anti-Malaria	In vivo	Anopheles mosquitoes (larvae)	Ethanol	Leaves	5.0, 7.5, 10.0 and 12.5 mL	NA	Untreated	(Nnamani *et al.* 2008)
	In vitro	*Plasmodium falciparum*	Ethanol	Stem bark	250, 500 and 1000 µg/mL	NA	Untreated	(Mudi, 2011)
	In vivo (Albino rat)	Albino rat	Ethanol	Leaves	5, 7, 10 and 12.5 mL	NA	Untreated	(Sweet *et al.* 2008)
	In vivo	*P. falciparum*	n-hexane, ethyl acetate.	Stem bark	10, 5, 2.5 and 1.25 mg/mL		Untreated	(Imam *et al.*, 2017)
	In vivo	Mice	Ethanol	Leaves	200, 400, 600 µg/mL	NA	Untreated	(Okpe *et al.* 2023)
Anti-depression	In vivo	Albino mice	21-hydroxyshidasterone, 11β-hydroxy-20-deoxyshidasterone, ajugasterone and 24-hydroxyecdysone	Stembark	10 mg/kg	Imipramine and fluoxetine	Untreated	(Ishola *et al.* 2014)
	In vivo	Albino rats	Ethanol	Stembark, leaves	100, 200 and 400 mg/kg	Xylocaine	Untreated	(Tijjani *et al.* 2012)
Ant- diabetic	In vivo	Albino rats	Aqueous, ethanol	Leaves	100 and 200 mg/kg	Metformin (250 mg/kg)	Untreated	(Oche *et al.* 2014)

In vivo		Aqueous	Leaves	50 and 100 mg/kg	Glibenclamide (0.3 mg/kg)	Untreated	(Ezekwesili *et al.* 2012)
In vitro	α-glucosidase, α-amylase	Aqueous, ethanol, methanol	Leaves	1.25-10 mg/mL	Acarbose	Untreated	(Nnenna *et al.* 2020)
In vivo	Albino Wistar	Aqueous, ethanol, methanol	Leaves	120 mg/kg	Glibenclamide (5 mg/kg)	Untreated	(Nnenna *et al.*, 2020)
In vivo	Albino rat	Aqueous, ethanol and n-hexane	Leaves	100 mg/kg	Glibenclamide	Untreated	(Yakubu *et al.* 2013)
In vivo	Wistar rats	Methanol	Leaves	100, 200 and 400 mg/kg	Glibenclamide (0.5 mg/kg)	Untreated	(Ujowundu *et al.* 2022)
In vivo	Albino rats (male)	Alkaloid extracts	Leaves	200, 400 mg/kg	NA	Untreated	(Njoku *et al.* 2019)
In vivo	Wister albino rats	Phenolic aqueous	Leaves	100, 200 and 400 mg/kg	Dimethylguanide (500 mg/kg)	Untreated	(Obasi *et al.* 2019)
In vivo (Rat)	Rat (Male)	Ethanol	Leaves, stem	300 mg/kg	Glibenclamide (300 mg/kg)	Untreated	(Atanu *et al.* 2021)
In vivo	Wistar rat	Aqueous	Leaves, Stem Bark and Root Bark	100 mg/kg	NA	Untreated	(James *et al.* 2013)
In vivo	Wistar rats	Phenolic	Leaves	100, 200, 400 mg/kg	Glibenclamide (0.50 mg/kg)	Untreated	(Onyema *et al.* 2023)
In vivo	Wistar rats	Aqueous	Leaves	100 mg/kg	Glibenclamide (2.5 mg/kg)	Untreated	(Yakubu *et al.* 2012)
In vivo	Wistar albino	Ethanol	Leaves, stem and root bark	20, 30, 100 mg/kg	Atorvastatin	Untreated	(Sheneni *et al.* 2018)
In vivo	Albino rats	Aqueous, methanol	Leaves	250, 500 and 750 mg/kg	Glibenclamid (5 mg/kg)	Untreated	(Obasi *et al.* 2013)

	In vivo	Male wistar rats	Ethanol, N-hexane and aqueous	Leaves	200 mg/kg	Glibenclamide	Untreated	(Nwaneri-Chidozie *et al.* 2014)
	In vivo	Wistar rats	Ethanol, aqueous	Leaves	50, 100, 200 mg/kg	NA	Untreated	(Yakubu *et al.* 2016)
	In vivo	Wistar rats	Ethanol, aqueous	Leaves	100, 200 mg/kg	Metformin (250 mg/kg)	Untreated	(Oche *et al.* 2012)
Anti-epilepsy	In vivo	Mice	Aqueous	Leaves	250, 500, and 1000 mg/kg	Diazapam (5 mg/kg)	Untreated	(Imoru *et al.* 2020)
Blood pressure	In vivo	Wistar rats	Aqueous	Stem bark	200-800 mg/kg	NA	Untreated	(Ladeji Okoye *et al.* 1996)
Wound healing	In vivo	Mice	NA	Stembark	10 mg/mL	Betadine 10%	Untreated	(Amégbor *et al.* 2012)
Anti-HIV	Cell viability assays	ARV-resistant HIV-1	Methanol	Root	Not available	NA	NA	(Tietjen *et al.* 2016)
Anti-ulcer	In vivo	Male Albino Wistar rats	Methanol, Aqueous	Leaves	200 and 400 mg/kg	100 mg/kg cimetidine	10 mL/kg of saline	(Steven *et al.* 2016)
	In vivo	Albino rat	Methanol, aqueous	Leaves	100-400 mg/kg	Cimetidine	Untreated	(Onwukwe *et al.* 2018)
Anti-Anesthesia	In vivo	Rabbit	Aqueous	Stem bark	400, 600, 800 and 1200 mg/kg	NA	NA	(Sanni *et al.* 2005)
	In vivo	Sprague dawley rat	Aqueous	Root-bark	400, 600, 1000, 1200, 1600 mg/kg	NA	Not infected	(Abdulrahman *et al.* 2007)
Hepatoprotective	In vivo	Albino rats	Aqueous, ethanol	Leaves	250 mg/kg	Infected	Not infected	(Agbafor *et al.* 2011)
	In vivo	Wistar rats	Methanol	Leaves	200 and 400 mg/kg	Infected	Not infected	(Olajide *et al.* 2018)
	In vivo	Albino rats	Aqueous	Stembark	200–1000 mg/kg	Infected	Not infected	(Ladeji & Okoye, 1996)
	In vivo	Mice	Methanol	Fruit	100, 200 and 400 mg/kg	Infected	Not infected	(Ajiboye, 2015)
	In vivo	Mice	Aqueous	Root bark, stem bark, leaves	100 mg/kg	Infected	Not infected	(Bolanle *et al.* 2014)

	In vivo	Albino rat	Aqueous	Leaves, stem	100 and 200 mg/kg	Infected	Not infected	(James *et al.* 2010)
	In vivo	Albino rat	Aqueous	Leaves, stem bark and root bark	1000, 20, 100, 100 and 30 mg/kg	Infected	Not infected	(Sheneni *et al.* 2014)
	In vivo	Wistar rats	Ethanol	Leaves	100 mg/kg	Infected	Not infected	(Yakubu Nwodo Imo *et al.* 2016)
	In vivo	Albino rats	Alkaloid fraction	Leaves	400, 600 mg/kg	Infected	Not infected	(Ayoka *et al.* 2023)
	In vivo	Wistar rats	Phenolic	Leaves	100, 200, 400 mg/kg	Infected	Not infected	(Onyema *et al.* 2023)
			Alkaloid	Leaves	200 and 400 mg/kg	Infected	Not infected	(Njoku *et al.* 2021)
	In vivo	Wistar rats	Methanol	Leaves	200 and 400 mg/kg	Infected	Not infected	(Umar *et al.* 2023)
	In vivo		Aqueous	Root-bark	50,100 and 200 mg/kg	Infected	Not infected	(Akan *et al*., 2012)
	In vivo	Wistar rats	Aqueous	Leaves	200 mg/kg	Infected	Not infected	(Mafulul *et al*., 2018)
	In vivo	Wistar rats	Methanol	Stem bark	100, 200 and 400 mg/kg	Infected	Not infected	(Amuzat *et al*., 2020)
Anticancer	In vivo	Wistar rats	Ethanol	Leaves	50, 100, 200 mg/kg	NA	Un treated	(Forcados *et al.* 2021)
	MTT	mcf-7 breast cancer cells	Ethanol	Leaves	12.5, 25, 50 and 100 µg/mL	NA	Un treated	(Forcados James *et al.* 2021)
	In vivo	Wistar rats	Aqueous	Leaves	250, 500 mg/kg	Cyclophosph amide (100 mg/kg)	Un treated	(Abireh *et al.* 2020)
	In vivo	Wistar rats	Aqueous, methanol	Leaves	100 mg/kg	NA	Untreated	(Ukaejiofo *et al.* 2015)
	Brine Shrimps Lethality Assay	Zoological organism-brine shrimp	Methanol	Stem bark, leaves	5 , 10, 25, 50, 100 and 200 and 300 µg/mL.	NA	Untreated	(Gunda *et al.* 2023)

	Brine Shrimps Lethality Assay	Zoological organism-brine shrimp	n-hexane, chloroform, ethyl acetate, acetone, ethanol and aqueous	Stem bark	1000, 100, 10µg/mL	NA	Untreated	(Mudi, 2010)
	In vivo	Wistar rats	Aqueous, methanol	Leaves	200, 300 mg/kg	Cyclopho sphamide (3 mg/kg)	Saline (5 mL/kg)	(Ufelle *et al.* 2011)
Toxicity	In vivo	Wistar rats	Ethanol	Leaves	50, 100 and 200 mg/kg	NA	Untreated	(Forcados James *et al.* 2021)
	In vivo	Albino rats	Aqueous	Bark	100, 150 and 200 mg/kg	NA	Untreated	(Muhammad *et al*. 2015)
	In vivo	Albino rats	Ethanol	Stembark	1600, 2900 and 5000 mg/kg	NA	Untreated	(Tijjani *et al.* 2012)
	In vivo	Albino rats	Aqueous	Leaves	10, 100 and 1000, 1500, 2000, 2500 and 3000 mg/kg	NA	Untreated	(Iwueke *et al.* 2006)
	In vivo	Sprague–Dawley rats	Methanol	Fruits	100, 300, 1000 and 3000 mg/kg	NA	Untreated	(Adjei *et al.* 2021)
	In vivo	Rat	Ethanol	Leaves	1000, 1500, 3000 mg/kg	NA	Untreated	(Njoku *et al.* 2019)
	In vivo	Albino wister	Acetone	Leaves	600, 1000, 2000, 5000 mg/kg	NA	Untreated	(Barry *et al.* 2022)
	In vivo	(Albino rat)	Methanol	Steam bark	1000, 2000, 3000, 4000 and 5000 mg/kg	NA	Untreated	(Ukwuani-Kwaja *et al.* 2021)
	In vivo	Albino Wistar rats	Aqueous, methanol	Leaves	1 500, 2 500 and 3 500 mg/kg	NA	Untreated	(Steven *et al.* 2016)
	In vivo	Mice	Acetone, ethanol, aqueous	Root, stem-bark and leaves	5000 mg/kg	NA	Untreated	(Kuta *et al.* 2016)
	In vivo	Mice	Ethyl Acetate	Leaves	10, 100 and 1000 mg/kg	NA	Untreated	(Dawang, 2015)

In vivo	Mice	Butanol fraction, ethylacetate fraction	Fruits	2000, 3000, 4000 and 5000 mg/kg	NA	Untreated	(Ajah *et al.* 2021)
In vivo	Wister rat	Ethanol	Leaves		NA	Untreated	(Okpala *et al.* 2021)
In vivo	Wister rat	Methanol	Leaves	150 mg/kg and 300 mg/kg	NA	Untreated	(Onwukwe *et al.* 2020)
In vivo	Wister rat	Aqueous	Root-bark	400, 600, 1000, 1200 and 1600 mg/kg	NA	Untreated	(Akan *et al.* 2012)
In vivo	Wister rat	Aqueous, methanol	Leaves	250, 500 and 750 mg/kg	NA	Untreated	(Obasi Kalu Okorie *et al.* 2013)
In vivo	Albino Wister rat	Aqueous	Leaves	100, 150 200 mg kg	NA	Untreated	(Ahmad *et al.* 2013)

Note: NA = Not available

Anti-Malaria

Malaria is one of the major global health issues to date, as it impacts millions of people every year and is a key factor in morbidity and mortality worldwide. The emerging immunity of malaria parasites to conventional antimalarial drugs justifies the search for more effective therapeutic compounds. Owing to their high density of phytochemicals, plants such as *V. doniana* have become potential sources for identifying novel antimalarial agents.

The MIC of the ethanol leaf extract against Anopheles mosquito larvae was 10 mL per 20 mL. With a mortality rate of 70.11%, the lowest concentration of 5 mL per 20 mL resulted in the highest death rate (Nnamani *et al.* 2008). After 72 hours of incubation with the stembark extract at 500 µg/mL, the ethanol and methanol stembark extracts exhibited mortality rates of 68.0% and 78.0%, respectively, against *Plasmodium falciparum* (Mudi, 2011). The results also revealed that when *D. aborea* and *V. doniana* leaf extracts were combined at a ratio of 5 mL/20 mL, they had a synergistic effect on these organisms. However, when the *V. doniana* ethanol leaf extracts were used alone, their effectiveness was diminished. Statistical analysis of variance revealed no significant difference (P = 0.01) between the combined treatment with leaf extracts and the separate treatments for these organisms (Sweet *et al.* 2008). The hexane extract eradicated 81% of the parasites at a concentration of 10 mg/cm3, 72% at 5 mg/cm3, 68% at 2.5 mg/cm3, and 64% at 1.25 mg/cm3 after 72 hours of incubation. The ethyl acetate stembark extract exhibited a 71% reduction at a concentration of 10 mg/cm3, a 67% reduction at 5 mg/cm3, a 61% reduction at 2.5 mg/cm3, and a 56% reduction at 1.25 mg/cm3 after 72 hours of incubation (Imam *et al.* 2017). At 200, 400, and 600 µg/mL, the extract dramatically decreased erythrocyte hemolysis, with decreases of 91.29%, 80.52%, and 75.68%, respectively. Compared with disease control, which has a parasitaemia level of 7.93 ± 1.61%, chloroquine reduces parasitaemia levels by 4.25 ± 0.25% and 4.65 ± 0.28%, respectively (Okpe *et al*., 2023).

There were also differences in the extent of the extract from different parts of the plant exhibiting malaria parasites, possibly because of the phytochemical differences in various parts of *V. doniana*. Further investigations are needed to identify the particular bioactive compounds present in *V. doniana* that possess antimalarial properties, in addition to how these compounds can function and/or interact with other natural compounds or compounds in a complementary way to combat the parasite

Anti-diabetic effects

According to data from the International Diabetes Federation, more than 41 million people in the world currently suffer from this disease. This number is expected to rise to 70 million by 2025, largely because of the diabetes mellitus epidemic at the global level (Dogara *et al.* 2023). Notably, the potential hypoglycemic properties of *V. doniana* parts in several models have been reviewed and documented (Table 3).

In the in vitro assay, the extracts clearly inhibited the enzymes in a dose-dependent manner. For both α-amylase and α-glucosidase, the half-maximal inhibitory concentrations (IC50 values) were 3.09 mg/mL and 17.12 mg/mL, respectively. Notably, α-glucosidase inhibition was strongest in the aqueous leaf extract of *V. doniana,* while acarbose displayed low inhibition, with IC_{50} values of 9.0 mg/mL for α-glucosidase and 4.07 mg/mL for α-galactosidase (Nnenna *et al.* 2020). Ethanol and aqueous leaf extract significantly decreased (P<0.05) the activities of alanine aminotransferase, aspartate aminotransferase, and alkaline phosphatase in diabetic rats. A slight increase (P>0.01) in the serum marker enzyme activity of nondiabetic rats was also observed during treatment (Oche *et al.* 2014).

A significant decrease in the blood glucose levels of the rats at concentrations of 50 and 100 mg/kg, with P < 0.001, was recorded from the aqueous extract leaves. A decrease in blood sugar levels after four consecutive days to 84.5±3.2 mg/dl or 82.9% of 492.8±12.1 mg/dl was detected. Unlike leaf extract, glibenclamide was not significantly different at 0.3 mg/kg body weight (Ezekwesili *et al.* 2012). Administering leaf extracts in aqueous, ethanolic, and n-hexane solutions dramatically reduces the activities of catalase (CAT) and superoxide dismutase (SOD) (Yakubu *et al.* 2011). The extracts increased CAT and SOD activity at P < 0.05 but decreased the bilirubin, fasting blood sugar (FBS), alanine aminotransferase (ALT), alkaline phosphatase (ALP), and aspartate aminotransferase (AST) levels in contrast to those in all the untreated and glibenclamide-treated control groups. As a byproduct of lipid peroxidation, malondialdehyde was significantly reduced in alloxan-induced diabetic mice treated with phenolic leaf extract. Furthermore, the concentrations of reduced glutathione and ascorbic vitamin C also increased. Observation of the untreated diabetic group and the extract-treated group via microscopy revealed that the extract played a role in the repair of diabetes-induced damage to the structure of the pancreas. Among all the extracts tested, only the alkaloid extracts from the leaves of the plants under study effectively reduced the blood glucose levels of the male albino rats compared with those of the diabetic control group at P <0.05.

On the other hand, liver function biomarkers are strongly associated with diabetes. Many studies have shown that *V. doniana* may help reduce serum lipid levels and liver function parameters, which can have positive effects on diabetes management and overall metabolic health. The extracts positively altered the lipid profile of the animals (Njoku *et al.* 2019). A significant decrease in the amount of MDA but an increase in the amount of serum SOD, CAT activity, GSH, and ascorbic acid ($P < 0.05$) was detected in albino rats treated with aqueous phenolic extract with increasing concentrations of the extract compared with those in the control group that received dimethylguanide (500 mg/kg) (Obasi *et al.* 2019). The influence of the ethanolic stem and leaf extracts on high-density lipoprotein cholesterol (HDL-C), total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C) and triglycerides (TAGs) was also observed. Compared with normal control rats, diabetic rats treated with alloxan presented greater ($P<0.05$) increases in TC, LDL, and TAG but reduced HDL. Compared with conventional antidiabetic drugs, ethanol extracts are more effective at decreasing TC and LDL levels ($P<0.05$) (Atanu *et al.* 2021). Acute and chronic administration of the root bark and stem bark extracts to Wistar rats at a dose of 100 mg/kg body weight daily for 21 days resulted in decreased total serum cholesterol and LDL-cholesterol concentrations in the treatment group ($P<0.05$) (James *et al*., 2013).

Compared with glibenclamide, the phenolic extract from leaves decreased the serum protein and bilirubin contents and improved the lipid profile and atherogenic and cardiac indices, depending on the concentration of the phenolic leaf extract (Onyema *et al.* 2023). Yakubu *et al.* (2012) reported that biochemical changes in Wistar rats were significantly positive after the administration of aqueous leaf extract. The superoxide dismutase (SOD) and catalase (CAT) activities and alanine aminotransferase (ALT), thiobarbituric acid reactive substances (TBARS), alkaline phosphatase (ALP), aspartate aminotransferase (AST), and bilirubin concentrations were significantly different ($p<0.05$) from those in the standard treatment with glibenclamide (2.5 mg/kg). The levels of liver enzymes (AST, ALT, and ALP) were significantly elevated in the hyperlipidemic control group compared with those in the normal control and treated groups. Notably, after treatment with the aqueous extracts from the leaves, stem and root bark enzymes decreased significantly in both the hyperlipidemic model and the normal treatment groups, although there were no significant changes in the normal treatment groups. Additionally, in the hyperlipidemic group, the total protein (TP) and direct bilirubin (DB) levels were significantly lower than those in the normal control and treated groups, whereas the total bilirubin (TB) and indirect bilirubin (ID) levels were significantly elevated (Sheneni *et al.* 2018).

Compared with those in the normal and diabetic control groups (5 mg/kg glibenclamide), the total cholesterol, triacylglyceride, LDL, alkaline phosphatase, AST and ALT levels in the reference and diabetic groups ($P<0.05$) were reduced in a dose-dependent manner. Additionally, an increase in high-density lipoprotein (HDL) was observed in the abovementioned treatment groups ($P<0.05$) (Obasi *et al.* 2013). The findings revealed that ethanol, N-hexane and aqueous leaf extracts were capable of reversing the impairments in blood glucose levels and lipid peroxidation. The extracts caused reductions of 45.7%, 51.8%, and 63.3% in total cholesterol, triglyceride and LDL-C, respectively, compared with those in the diabetic control group (Nwaneri-Chidozie *et al.* 2014). The ethanol and aqueous leaf extracts at an oral dose of 100 mg/kg body weight did not affect the biochemical variables, including TBARS, in the liver or testes of the experimental groups. However, aspartate aminotransferase (AST), alkaline phosphatase (ALP) and alanine aminotransferase (ALT) significantly increased in the AlCl3 control and AlCl3 + 100 mg groups ($P<0.05$), whereas ALP did not significantly increase compared with those in the control group (Yakubu *et al.* 2016). The amount of fasting blood glucose (FBG) in the rats decreased with the administration of the aqueous leaf extract at concentrations of 100 and 200 mg/kg, with values of 23.01% and 21.9%, respectively. The ethanol content of leaves extracted at 100 mg/kg and 200 mg/kg decreased by 19.31% and 20.19%, respectively (Oche *et al.* 2012).

V. doniana maintains blood glucose levels by increasing insulin sensitivity after decreasing oxidative stress and cell damage in diabetic subjects, confirming the antioxidant activity and anti-inflammatory role of *V. doniana*. In addition, it reduces the activity of α-amylase and α-glucosidase, two enzymes that largely control insulin function. This multifactorial action not only optimizes glucose storage but also optimizes the general 'glucose story,' highlighting the potential of *V. doniana* as a therapeutic strategy for the management of diabetes.

Antiulcer

Steven *et al.* (2016) reported that the percentages of the ulcer prevention index estimated for albino rats that received leaf extracts II, II, IV, IV, and VI were 97%, 53%, 82%, 82%, and 22%, respectively. The tested leaf extracts revealed varying degrees of gastric mucosa protection against ulcers induced by indomethacin. This finding is in accordance with Onwukwe *et al.* (2018), who revealed that a high dose of methanol leaf extract (400 mg/kg body weight) provided approximately 70% protection and that the water extract provided 59% protection.

Anti-epilepsy

As described by Imoru *et al.* (2020), aqueous leaf extract administered to mice elicited reduced CNS activity during the open field test. While the 250 mg/kg extract had an anxiolytic effect, the 500 and 1000 mg/kg extracts had sedative effects. The effect of sodium valproate significantly reduced hind limb tonic extension to approximately 50% at a dose of 75 mg/kg when it was injected intraperitoneally. Similarly, different concentrations of the extract provided protection against HLTE. Interestingly, 100 mg/kg sodium valproate offered protection of approximately 50%, and notably, this decreased the time to recover from HLTE compared with that of the vehicle-treated group.

Anti-depression

In the work of Ishola *et al.* (2014), the oral administration of 21-hydroxyshidasterone, 11β-hydroxy-20-deoxyshidasterone, ajugasterone, and 24-hydroxyecdysone to the mice significantly reduced motionlessness time, with the strongest effect observed at 10 mg/kg, compared with standard antidepressants (imipramine and fluoxetine). The in vivo studies revealed that the ethanol stembark extracts significantly decreased the immobility time compared with that of the control group (xylocaine) ($P > 0.002$), although lower doses (25 and 50 mg/kg) were less effective. Additionally, Tijjani *et al.* (2012) reported that combining an ethanolic stem bark extract with pentobarbitone significantly increased sleep duration from 72.3±3.07 minutes at a 100 mg/kg dose of the extract and 35 mg/kg of pentobarbitone to 181±0.35 minutes at a 400 mg/kg dose of the extract and 35 mg/kg of pentobarbitone.

Anti-anesthesia

Central nervous system depression was related to a decrease in all measures, whereas the presence of reducing sugars in the extract was associated with an increase in respiration rates and analeptic/toxic effects. Compared with ketamine alone, administering the extract before ketamine reduced the respiratory rate and heart rate more significantly ($P<0.05$) but had no significant effect on temperature ($P>0.05$) (Sanni *et al.* 2005). The aqueous root bark extract caused a sleep duration of 108.8 minutes at 15 mg/kg, whereas 400 mg/kg enhanced sleeping time more than did a lower dose. This extract also exhibited potent muscle relaxant activity ($P < 0.05$). In addition, it offered 80/100% protection against pentylenetetrazole/strychnine-induced convulsions, respectively (Abdulrahman *et al.* 2007).

Anticancer

According to the International Agency for Research on Cancer (IARC), there were 14.1 million new cases of cancer worldwide in 2012, and the number of deaths from cancer in the same year was 8.2 million, while the number of people living with cancer globally was 32.6 million. There is a forecast that by 2030, the number of deaths from cancer will increase to 17 million, and the number of new cases of cancer will reach 26 million worldwide (Dogara, 2023). Consequently, the search for new anticancer drugs that are efficient and cost effective is a constant necessity. In this context, studies on the anticancer activities of *V. doniana* were reviewed to explore the possibility of *V. doniana* as a resourceful natural source in the effort to discover new anticancer drugs as a current global health issue.

In the in vitro study, there was a significant decrease in the proliferation of MCF-7 cells with increasing concentrations of the ethanol leaf extract. Ethanol leaf extracts also inhibited the growth of melanoma cells (Forcados *et al.* 2021). The n-hexane and ethanol extracts of the stem bark exhibited a significant degree of toxicity, with LC_{50} values of 6.7674 µg/mL and 5.3421 µg/mL, respectively (Mudi, 2010). The ethanol leaf extract, when administered to the rats, significantly decreased ($P < 0.05$) the estrogen receptor-a, malondialdehyde, IL-1b, and TNF-a levels. Moreover, there was a notable increase ($P < 0.05$) in glutathione and catalase activity. Compared with those in the control group, there was a reduction in malignant epithelial hyperplasia and mild COX-2 expression (Forcados *et al.* 2021). Compared with those in the negative control group, a reduced packed cell volume, white blood cell count and multinucleated cells in the bone marrow ($P<0.05$) were observed in albino rats treated with aqueous leaf extracts. However, in animals treated with aqueous leaf extracts, the packed cell volume, white blood cell count and number of multinucleated cells in the bone marrow are greater than those in those treated with cyclophosphamide (100 mg/kg) ($P<0.05$) (Abireh *et al.* 2020). Compared with those of the untreated group, the white blood cell count and neutrophil percentage of all the albino rats that received methanol or aqueous leaf extract were significantly greater (Ukaejiofo *et al.* 2015). Compared with the negative control, the stem and leaf extracts that were administered to the rats had significant effects on the extract of stem bark, with an LC_{50} value of 175, and the leaf extract had an LC50 value of 260 µg/mL (Gunda *et al*., 2023). A significant increase in the amount of bone marrow cellularity at a concentration of 200 mg/kg leaf extract was recorded compared with that in the untreated group (Ufelle *et al.* 2011). Several studies have investigated the effects of *V. doniana* extracts on the growth of several cancerous cultures. Leaf extract has the most potent effect on MCF-7 cells, as it increases the levels of glutathione and catalase and decreases the levels of IL-1β, TNF-α, estrogen receptor-α, and malondialdehyde. Further studies should focus on numerous cancerous cells to affirm its effectiveness and possible mechanism of action.

Hepatoprotective

Owing to the increasing incidence of liver-related diseases and the limitations associated with conventional medicinal approaches in liver therapy, natural sources that offer the liver strong defense and efficient physiological functionality are needed. This review provides information on diverse extracts of *V. doniana* for their hepatoprotective actions and ability to reduce hepatotoxicity (Table 3).

The administration of leaf extracts to albino rats successfully neutralized the effects of CCl_4. Compared with the untreated group, the treatment groups presented a significant decrease ($P<0.05$) in the malondialdehyde concentration. Additionally, the pretreated groups presented significantly greater levels of superoxide dismutase and catalase activity ($P<.05$) than did the positive control group (Agbafor *et al.* 2011). The administration of all the doses of the leaf extract to the albino rats effectively improved and reversed the cadmium-induced changes in the biochemical parameters to normal levels, as indicated by the significant ($P <0.05$) results. The improvement at a dosage of 200 mg/kg body weight of the extract was comparable to that of the control (Olajide *et al.* 2018). Treatment of albino rats with aqueous bark extract at doses ranging from 200 to 1000 mg/kg body weight significantly reduced the levels of alanine transaminase (ALT), aspartate transaminase (AST), alkaline phosphatase (ALP), and bilirubin in the blood following CCl_4 treatment ($P < 0.01$). However, the total protein level remained unchanged in both the test and untreated rats. The efficacy of the anti-hepatotoxic effect seems to be contingent upon the dosage and duration of treatment (Ladeji & Okoye, 1996).

The fruit extract reduced the levels of ALP, ALT, AST, albumin, and total bilirubin in the blood of the mice given acetaminophen. According to Ajiboye (2015), the activities of these liver enzymes in mice—superoxide dismutase, catalase, glutathione peroxidase, glutathione reductase, and glucose 6-phosphate dehydrogenase—were significantly ($P<0.05$) diminished by acetaminophen. There was a significant improvement in the liver marker enzymes ALT, AST, and ALP in the bloodstream, with $P <.05$ after the administration of root bark, stem bark or leaf extracts to the mice. Moreover, the experimental group presented a highly statistically significant ($P<0.05$) increase in the albumin level among all the treatment groups (Bolanle *et al.* 2014). The haematologic profile and biochemical parameters also showed that the rats that received CCl_4 exposed higher hepatic, renal and lymphatic toxicity than those in the aqueous extract group (James et al., 2010). However, the hyperlipidemic control group showed higher serum liver enzymes (AST, ALT, and ALP) compared to the normal control and other treated groups with aqueous leaves or stem extracts ($P < 0.05$) (James, *et al.* 2010).

In the same regard, hyperlipidemic albino rats treated with leaf stem or root extracts recorded a statistically significant ($P<0.05$) reduction in the levels of these marker enzymes when compared with hyperlipidemic control rats. Also, there was no significant difference ($P>0.05$) in the levels of the marker enzymes in the normal treatment groups and the normal control group (Sheneni *et al.* 2014). The oral administration of 100 mg/kg bw ethanol leaf extract did not result in any notable alterations in the TBARS levels of the liver and testes in the experimental groups. However, the levels of AST, ALT, and ALP in the $AlCl_3$ control group and the $AlCl_3$ + 100 mg *V. doniana* group significantly increased ($P<0.05$), whereas those in the control group did not significantly increase (except for ALT, which increased significantly). The PCV and Hb levels did not significantly differ ($P>0.05$) from those of the control group. Similarly, there was no significant variation in bilirubin levels among the four experimental groups (Yakubu *et al.* 2016).

Compared with those of the untreated plants, the alkaloid fraction of the leaves significantly increased the total protein, serum albumin, and HDL contents of the albino rats ($P< 0.05$). Compared with untreated rats, alkaloid-treated rats presented significantly lower blood levels of CHOL, TAG, LDL, BUN, and creatinine ($P<0.05$) (Ayoka *et al.* 2023). Compared with the control, the phenolic leaf extract administered to albino rats had hepatoprotective effects on total protein, serum albumin, and high-density lipoprotein (HDL) levels ($P< 0.05$) (Onyema *et al.* 2023). The findings revealed that all the rats that received the limit dose of the leaf extracts (3000 mg kg-1) were hyposensitive to external stimuli, such as touch, within 30 minutes after administration and were later observed to be active and responsive for the remaining 7 days of observation (Njoku *et al.* 2021). When the methanolic leaf extract was administered to the rats, there was virtually no alteration in the liver topology of the treated rats compared with the untreated rats. However, the liver architecture of group 2 rats that were given the extract at 10 mg/kg body weight was mildly improved (Umar *et al.* 2023). The results of the consumed aqueous root bark extract indicated that RBC, HB and PCV were significantly greater in the treated group ($P<0.05$) than in the control group. Moreover, the treated rats exhibited leucocytosis, which may be associated with an increase in the lymphocyte count (Akan *et al.* 2012).

The results of this study revealed that pretreatment with aqueous leaf extract offered protection against cadmium (Cd)-induced membrane lipid peroxidation and nonenzymatic antioxidants such as glutathione. It also activated the antioxidant enzymes catalase and superoxide dismutase in liver and kidney tissues. Additionally, the extract shielded against cadmium buildup and liver tissue damage. Interestingly, the kidney appeared to exhibit greater protection than did the hepatic tissue (Mafulul *et al.* 2018). The present study also revealed a significant ($P < 0.05$) increase in the serum creatinine and urea levels after the use of the aqueous stem bark extract. Furthermore, rats orally administered 100 or 400 mg/kg bw aqueous stem bark extract presented significant ($P < 0.05$) increases in blood sodium and chloride ion concentrations compared with those of the control group (Amuzat *et al.* 2020).

Therefore, it could be concluded that the hepato-protective effect of *V. doniana* specifically the leaves might be due to its inherent antioxidant effect that minimized cell damage and peroxidation in the liver. It constructed that leaves contain biologically active compounds that can enhance the activity of liver enzymes as well as facilitate regeneration of liver tissue due to the absence of the damage done by chemical influence. The major bioactive compounds existing in the leaves with hepato-protective potential should be isolated and studied as to the type of activity, toxicity, and the optimal dose before the prospective therapy trials. The synergistic mechanism of action of the combined bioactive compounds should also be determined.

Other Diseases

Wound healing: The results of this study revealed that the application of stem bark extract at 5% and 2.5% promoted the healing of skin wounds. Our assessment revealed a fair degree of closure of the wound area in the animals that received the extract treatment in comparison to the control (51.15%) (Amégbor *et al.* 2012). Anti-HIV: The methanol root extracts inhibited HIV-1NL4.3 replication in a dose-dependent manner without causing any harmful effects. The extracts demonstrated 50% inhibition of HIV-1 replication at a concentration of 25 µg/mL (Tietjen *et al.* 2016). Anti-testicular torsion: Compared with that in the control group, the diameter of the seminiferous tubules in group B (untreated) decreased dramatically. However, the luminal size was significantly greater in group B than in both the control group and the groups treated with the leaf extract at doses of 50, 100, and 200 mg/kg. Compared with those in Group B, the germinal epithelium in Group B was markedly lower (Adelodun *et al.* 2016). Postpartum bleeding: At a concentration of 1 mg/mL, the extract increased the contractility of the uterine muscle. Uterine muscle contraction was intensified by aqueous bark extract, which increased the contractile effects of ergometrine. The normal rat uterus experiences uterine muscular contractions as a result of the administration of oxytocin and ergometrine (Ladeji *et al.* 2005). Blood pressure: When the stem bark aqueous extract was given to the rat at a dose of 200 mg/kg, the blood pressure decreased to 10 mmHg within 2 hours, and the mean arterial pressure decreased by 16.5 mmHg within the same period when 800 mg/kg was administered. This finding indicates that the depressant effect of the extract is positively related to the dose (Ladeji *et al.* 1996).

Toxicity

The in vivo subacute toxicity studies of the ethanol leaf extract revealed no statistically significant difference ($P>0.05$) in the levels of serum alanine aminotransferase, gamma glutamyl transferase, urea, and creatinine between the treatment groups and the control group. Additionally, histopathological examination revealed that liver, kidney, and mammary tissues presented normal architecture across all groups (Forcados *et al.* 2021). The aqueous leaf extract administered to the rat was found to have an oral LD_{50} of more than 3,000 mg/kg (Iwueke *et al.* 2006). The study findings also revealed that, at the onset of high-dose treatment, slow and steady weight loss of 13.71% to 16.84% was observed after 7 days of oral administration. They noted that all the rats treated with the maximum dose of 3000 mg/kg leaf extract became less sensitive to touch sensation from 30 min to one hour after administration. Nevertheless, during the consecutive 7-day study period, the animals retained their usual activity and exhibited normal behavior (Njoku *et al.* 2019). The leaf extract at 5000 mg/kg did not cause any signs of toxicity or mortality in the rats that were administered the extracts orally, as would have been expected under normal circumstances. This manifestation of toxicity effects or death symptoms prevailed during the extra 14 days of the observation period. Therefore, the LD_{50} of the extract was greater than 5000 mg/kg body weight (Barry *et al.* 2022).

Oral acute studies performed on the tested mice revealed that the LD_{50} of both aqueous and methanol leaf extracts was greater than 3500 mg per kilogram of body weight, as observed in the studied animals. The animals did not show any clinical symptoms of suffering after dosing (Steven *et al*. 2016). In this study, the LD50 of the ethyl acetate leaf extract was greater than 5000 mg/kg in terms of body weight. No statistically significant increase was detected in the body weight or organ weight of the tested mice ($P \geq 0.05$) (Dawang, 2015). It has been predicted that the LD50 after oral consumption of aqueous and methanol leaf extracts would surpass 3000 mg/kg. There were no indications of excitation or depression in the autonomic or central nervous system. Sub-acute examinations demonstrated an increase in hematological indicators, including red blood cells (RBCs), hemoglobin (HB), and packed cell volume (PCV), as well as an increase in lymphocyte counts (Ufelle *et al.* 2011). The LD_{50} of the leaf extract was reported to be greater than 5000 mg/kg body weight (Okpala *et al.* 2021). The methanol fraction of the leaf extract did not negatively affect the body weight, rate of weight gain, or overall physical appearance of the tissues. Compared with those of the control group, the hematological and biochemical indices of the treated animals did not show any notable alterations (Onwukwe *et al.* 2020). Lethal dose (LD_{50}) results for aqueous and methanol leaf extracts greater than 5000 mg/kg were obtained from acute toxicity tests (Obasi Kalu Okorie *et al*. 2013).

The study proposed that, at stages 100 and 200 mg/kg, the use of bark extract may be risky. Acidosis may occur when the dose exceeds 100 mg/kg because it significantly increases the concentration of potassium ions, excluding increasing other electrolytes (Muhammad *et al.* 2015). The LD_{50} in rats, which was established with a 95% probability level, was 2154.06 mg/kg. No death was observed after the oral administration of 5000 mg/kg ethanol stem bark extract (Tijjani *et al.* 2012). The estimated LD_{50} was 5107.45 mg/kg for the methanol stem bark extract, and observations revealed that no signs of toxicity or death occurred for up to 14 days post administration. The results of the sub chronic toxicity trials revealed an increase in the mean hematology value over the basal hematology value, with a significant ($P<0.05$) tendency to increase from week 2 to week 4. In addition, sub chronic toxicity evaluation revealed that the elevated serum AST and ALT levels in most of the extract treatment groups were significantly ($P<0.05$) lower than those in the control group (Ukwuani-Kwaja *et al.* 2021).

The LD_{50} of the aqueous root bark extract, as established via i.p. injection, was 980 mg/kg, indicating low toxicity. However, prolonged oral treatment with the extract at greater concentrations may be harmful (Akan *et al.* 2012).

There were no indications of either stimulation or depression in the autonomic or central nervous system after the administration of the methanol fruit extract to the Sprague–Dawley rats. The LD_{50} after oral administration was determined to exceed 3000 mg/kg. Subacute analyses revealed increases in red blood cell counts and lymphocyte counts (Adjei *et al*., 2021). At every dose of the butanol fraction, the ethyl acetate fraction of the fruit extract that was given to the rat, there were no cases of fatalities or severe reactions in the oral acute toxicity study. The LD_{50} fraction value suggests a much higher value than 5000 mg/kg (Ajah *et al.* 2021). In the utilized model, the fruit showed a remarkable level of safety in mice because no deaths occurred within 24 hours after oral administration. Furthermore, in contrast to humans, the model developed a robust ability to predict outcomes accurately. The black plum fruit LD_{50} value was established to exceed 5000 mg/kg (Imoisi *et al.* 2021).

The mice were injected with the root, stem bark or leaf crude extracts of acetone, ethanol or aqueous solution via oral administration at a given dose of 5000 mg/kg body weight, and no deaths occurred in the mice (Kuta *et al*. 2016). There were no deaths recorded when oral doses of up to 5,000 mg/kg of body weight from the aqueous extracts of the leaves, stem bark, and root bark were administered in acute toxicity testing (James *et al.* 2013). Because of these findings, no deaths or acute toxicity related to the administration of the leaf stem bark, root or fruit extract up to 5000 mg/kg has been reported. Thus, *V. doniana* is essentially nontoxic.

Conclusion

This study provides a detailed summary of the pharmacological and traditional uses and details the bioactive compounds of *V. doniana,* reinforcing the pressing need for additional research to validate the specific beneficial effects of *V. doniana* on humans. *Vitex doniana* is a valuable tree that has extensive nutritional and medicinal potential. It is a very adaptable plant with numerous uses that possesses various arrays of phytochemicals and significant quantities of minerals and vitamins, which play crucial roles in promoting well-being. Owing to its vast array of medicinal traits, such as its anti-inflammatory, antioxidant, antitumor, antibacterial, diarrheal, hepatoprotective, antidiabetic, and anticancer effects, it has attracted significant interest. It has remarkable biological and pharmacological tendencies that may not be directly related to the traditional uses of plants; nevertheless, it holds potential for significant perceptions and further advancements. As reported in this review, *V. doniana* is an available, cost-effective, and easily accessible source of proteins and minerals. Therefore, it is not only used as a source of food but also for medicinal purposes for the control and treatment of many diseases. Therefore, progress in the use of multiple treatment methods incorporating *V. doniana* and other medications to increase the effectiveness of pharmaceuticals can potentially reshape the treatment of various diseases. *V. doniana* has significant value in both the medicinal and the food sectors and has the potential to provide socioeconomic advantages. On the other hand, the limitless use of *V. doniana* without cultivation or protection negatively impacts the plant and its population structure in Africa; this topic needs urgent attention. As a result, this study strongly emphasized the need for the cultivation and dispersal of *V. doniana* seedlings to promote natural regrowth and to study vegetative propagation and species status. These findings highlight the underutilized economic potential of *V. doniana* and the nutritional benefits of its fruits, which calls for urgent attention and action. Furthermore, our findings underscore the need for more thorough research to assess the biological impacts of the discovered compounds, suggesting the need for in vitro and in vivo studies to verify their safety and dosage. Although *V. doniana* has been extensively studied and utilized for its medicinal properties, additional research is necessary to investigate the therapeutic potential and other potential advantages of its phytochemicals. Furthermore, addressing the remaining challenges in terms of scientific examination of its medicinal applications is important. For example:

(1) To asses and compare the therapeutic effects of plant phytochemicals, it is necessary to conduct pharmacokinetic and pharmacodynamic investigations and analyze the toxicity of isolated compounds *in vivo* model with adequate control groups. Analyzing the dosages and comparing them to established benchmarks can aids in the identification and isolation of potent chemicals.
(2) It is crucial and pressing to examine the mechanisms of these extracts or isolates in suitable animal models.
(3) To the best of our knowledge, there are no recorded data from clinical trials of *V. doniana*. Therefore, future research should prioritize the simultaneous investigation of the pharmacological properties, mechanisms of action, and therapeutic uses of *V. doniana*.
(4) Determining the species' status according to IUCN recommendations.
(5) Forestry officials should produce and distribute *V. doniana* seedlings to nearby communities to improve the protection and sustainable management of the species.
(6) A thorough and comprehensive analysis of the many pharmacological and phytochemical activities, as well as traditional medicinal uses, of *V. doniana is necessary*. This will enable a rigorous scientific examination of the effectiveness of the documented literature, providing more justification.

Declarations

List of abbreviations: AA: ascorbic acid, ABTS: 2,2- azino-bis-3-ethylbenzothiazoline-6-sulfonic acid, AlC13: aluminium chloride, ALP: alkaline phosphatase, ALT: alanine aminotransferase, AST: aspartate aminotransferase, ATCC: 25923 American type culture collection, BHT: butylated hydroxytoluene, BMC: Bone marrow cellularity, BUN: blood urea nitrogen, CAT: catalase, CC14: tetrachloromethane, CHOL: cholesterol, CNS: Central nervous system, CP: ceruloplasmin, DMBA: 7, 12-dimethylben-z[a]anthracene, DPPH: 1,1-diphenyl-2-picrylhydrazyl, ED: effective dose, FBG: Fasting blood glucose, FBS: fasting blood sugar, FRAP: Ferric Reducing Antioxidant Power, GAE: gallic acid equivalence, GGT: γ-glutamyl transpeptidase, GR: glutathione reductase, HB: haemoglobin, HDL: high-density lipoprotein cholesterol, HIV: human immune virus, HLTE: hind limb tonic extension, IUCN: international union for conservation of nature, LD: lethal dose, LDL: low-density lipoprotein cholesterol, LPO: lipid peroxidation, MBC: minimum bactericidal concentration, MF: Methanol fraction, MDA: malondialdehyde, MIC: minimum inhibitory concentration, PCV: packed cell volume, PTZ: pentylenetetrazole, RBC: Red blood cell, RDA: recommended daily allowance, ROS: reactive oxygen species, SOD: superoxide dismutase, TAG: triglycerides, TAS: total antioxidant status, TBARS: thiobarbituric acid reactive substances, TC: total cholesterol, TSF: total stool frequency

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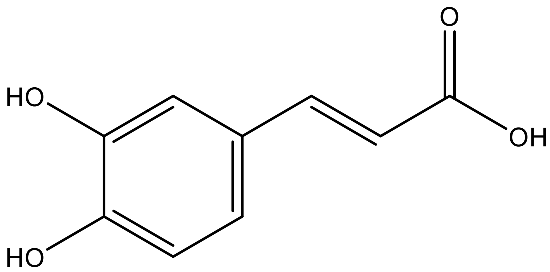
Appendix A. Chemical structures of the compounds obtained from different parts of *V. doniana* using different techniques



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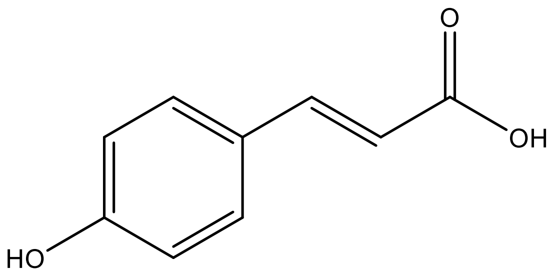
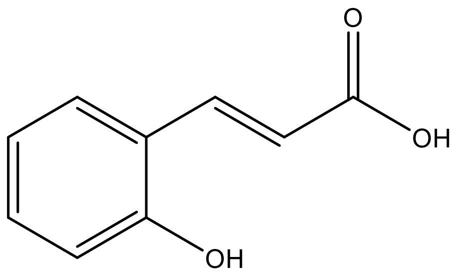


P-coumaric acid



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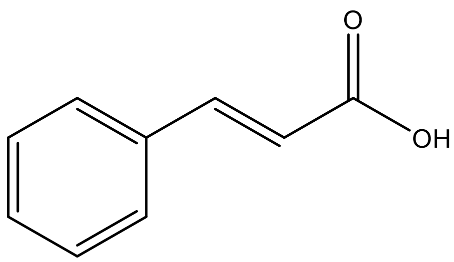
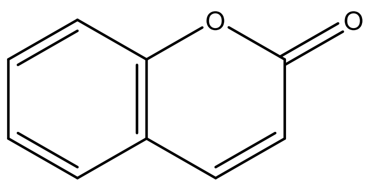
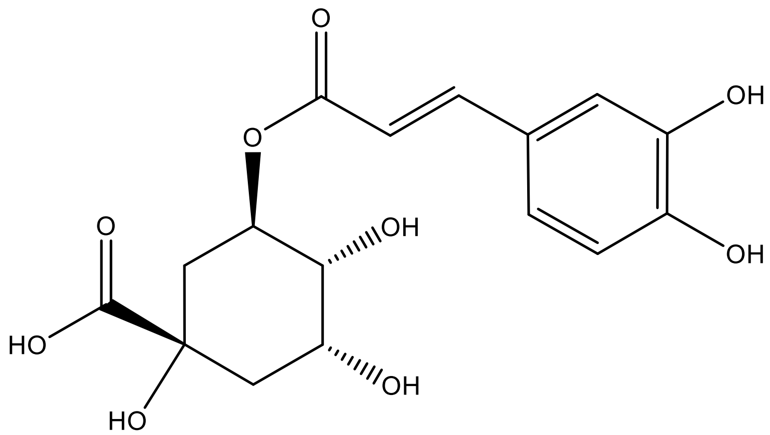


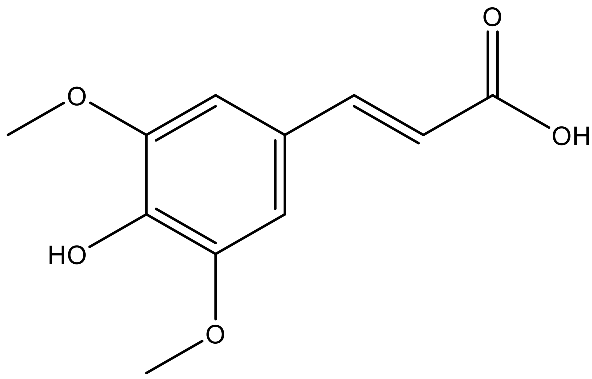
Cinnamic acid



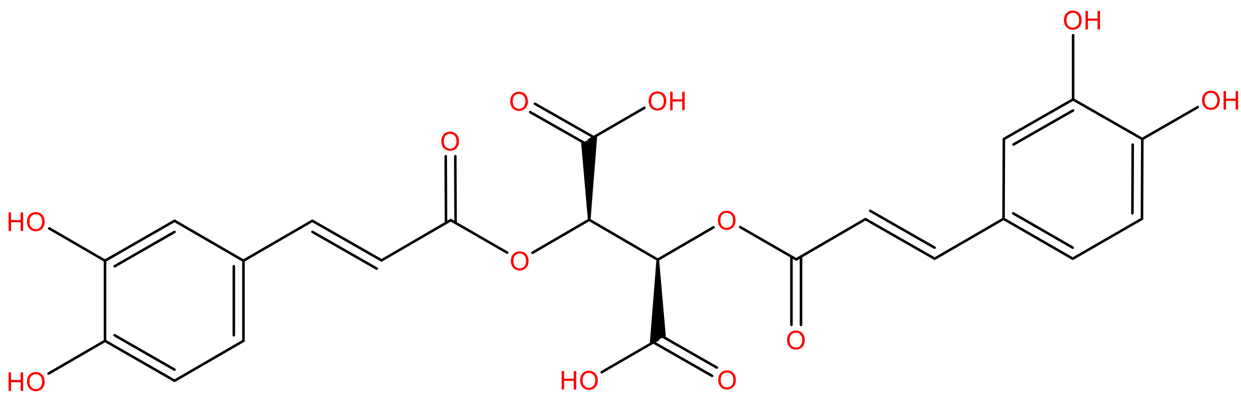
Coumarin



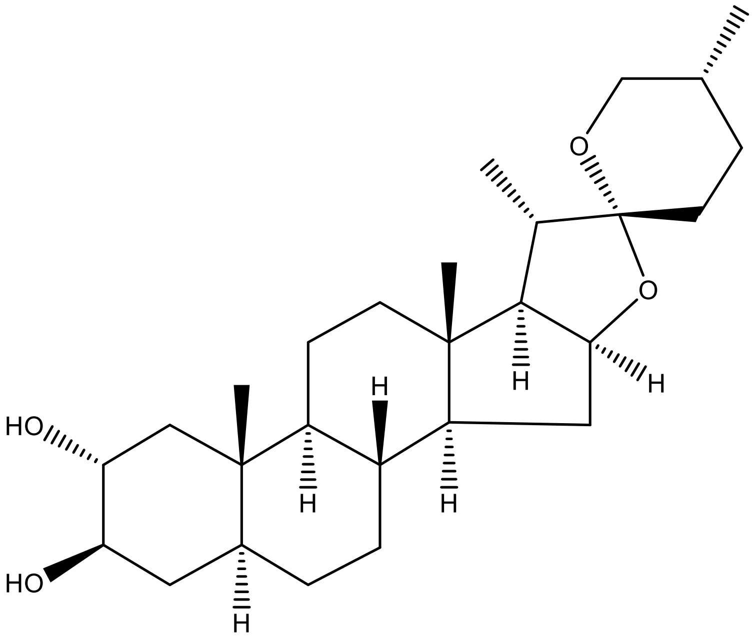
Chlorogenic acid



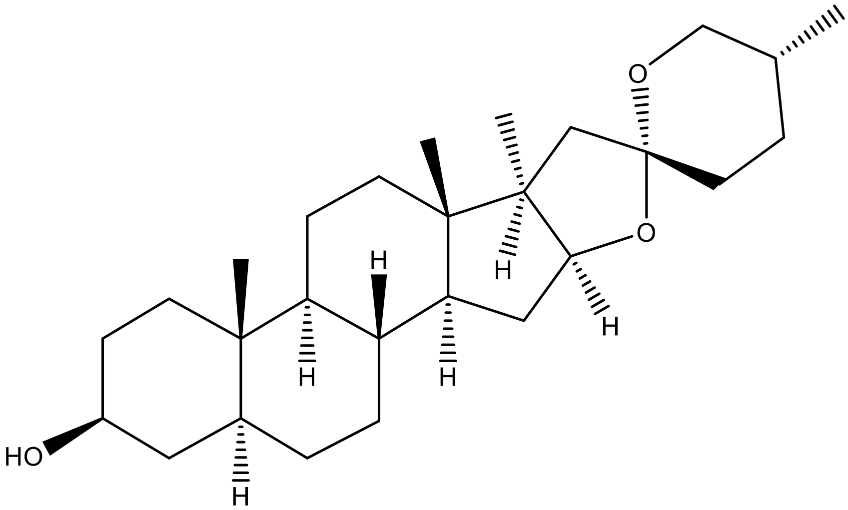
Sinapinic acid



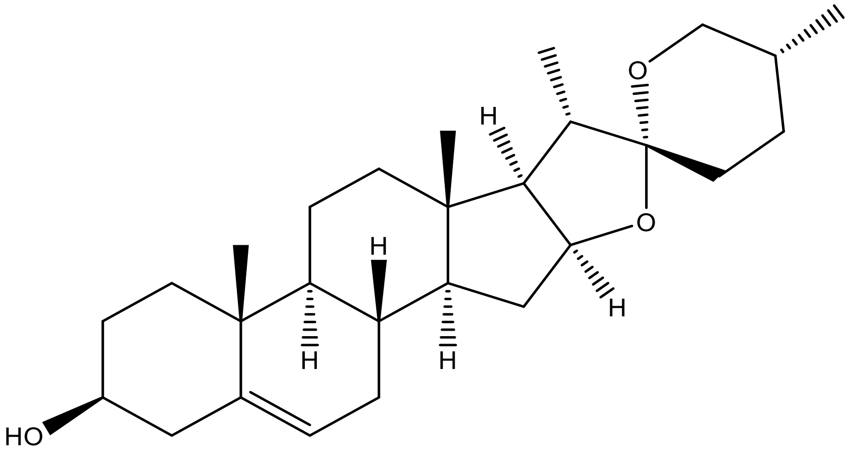
Cichoric acid andf Hydroxycinnamic acid



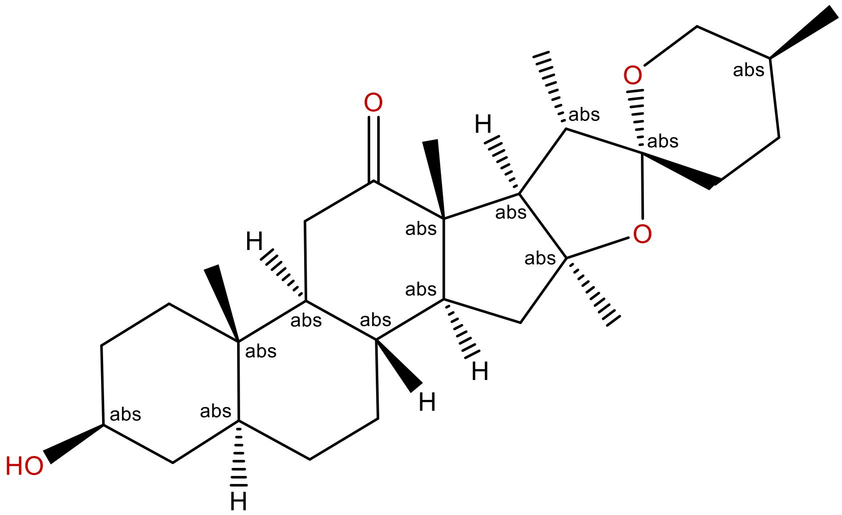
Gitogenin



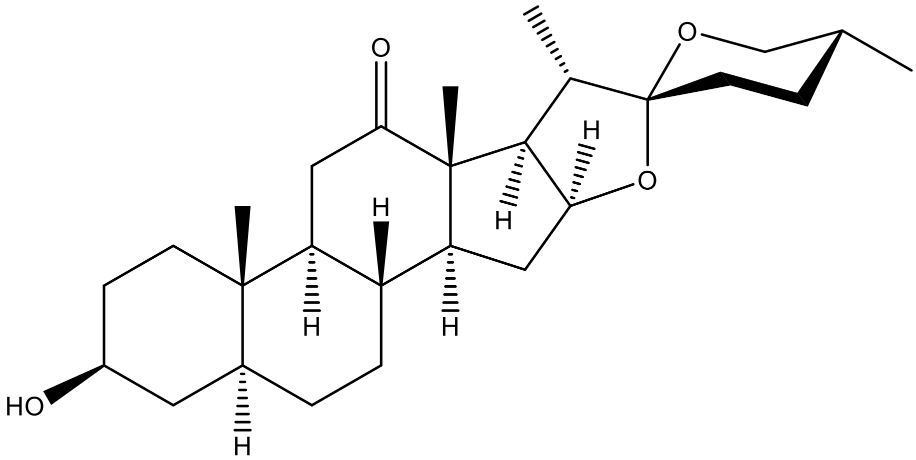
Tigogenin



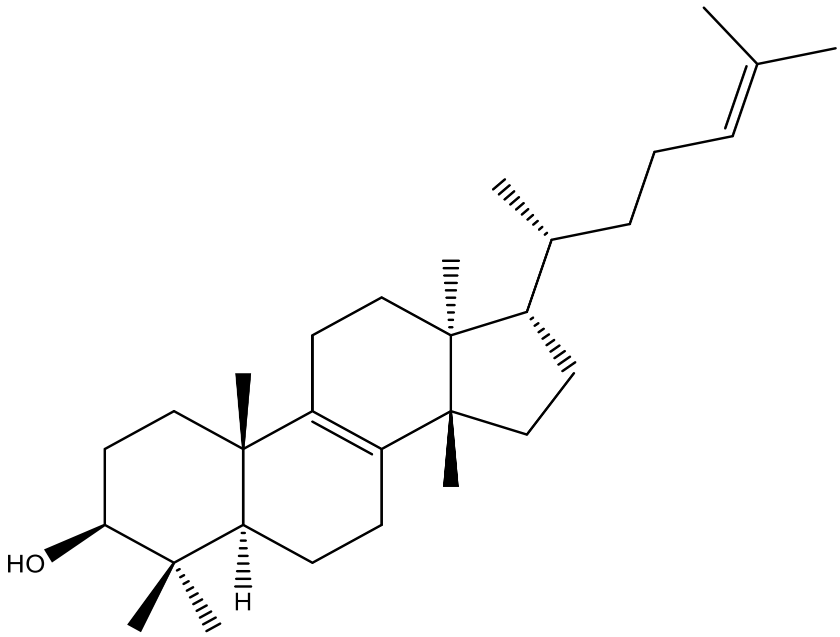
Diosgenin



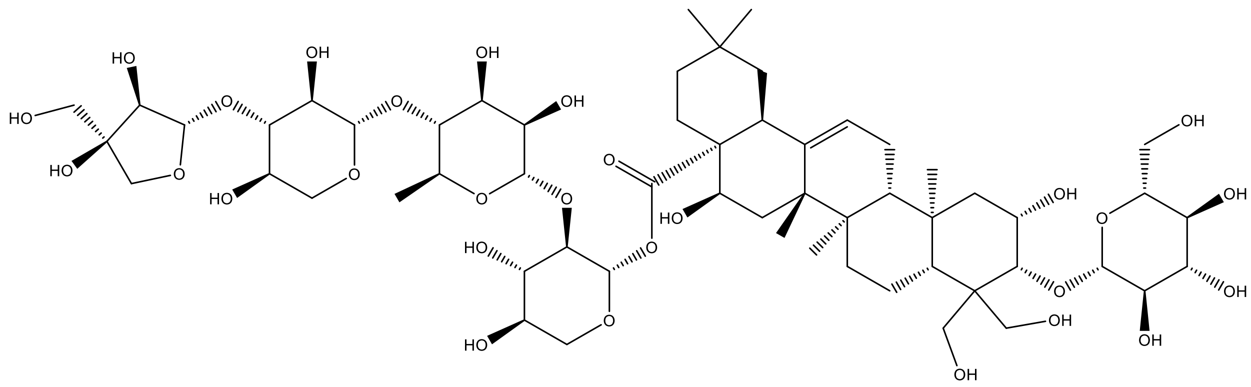
Neohecogenin



Hecogenin

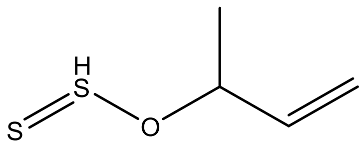


Euphol

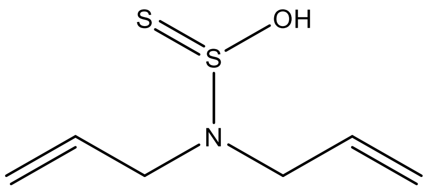


Platycodin D

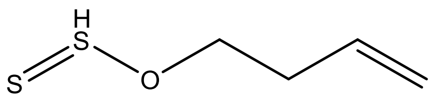
Appendix A2. Saponin



Methy -allyl –thiosulphinate

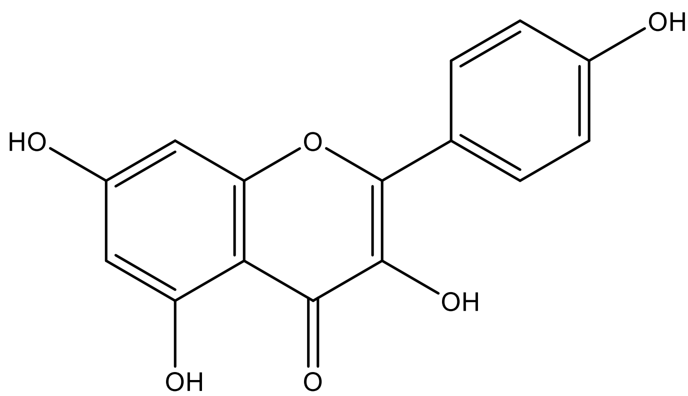


Diallyl –thiosulphinate

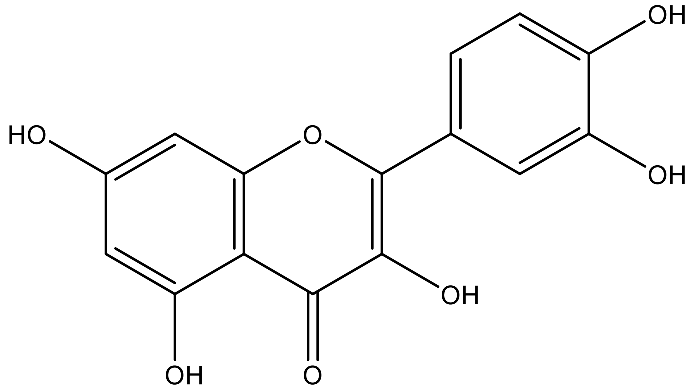


Allyl -methyl – thiosulphinate

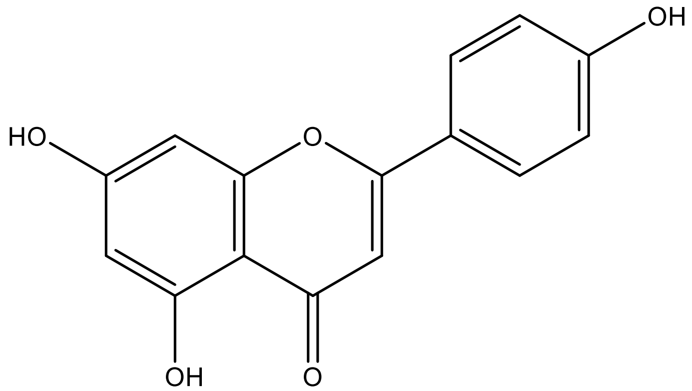
Appendix A3. Allicin



Kaempferol



Quercetin



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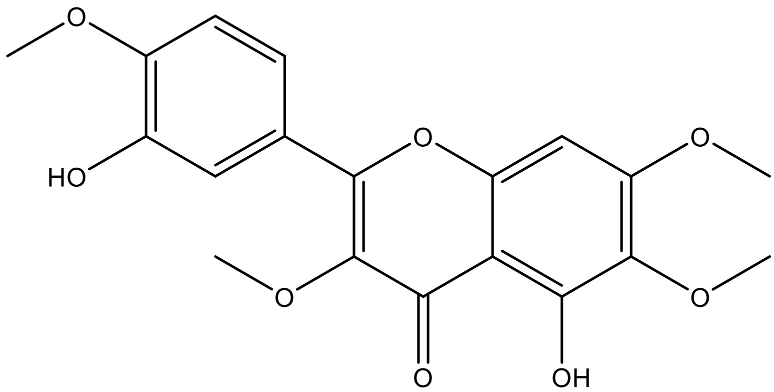

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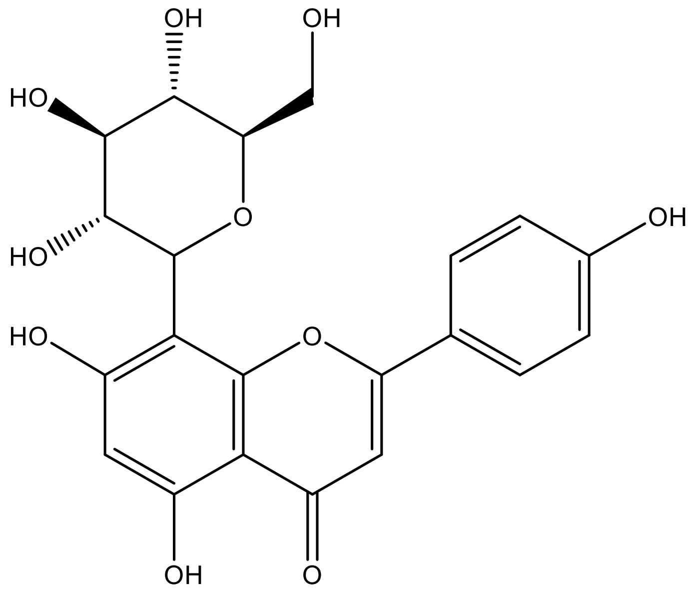
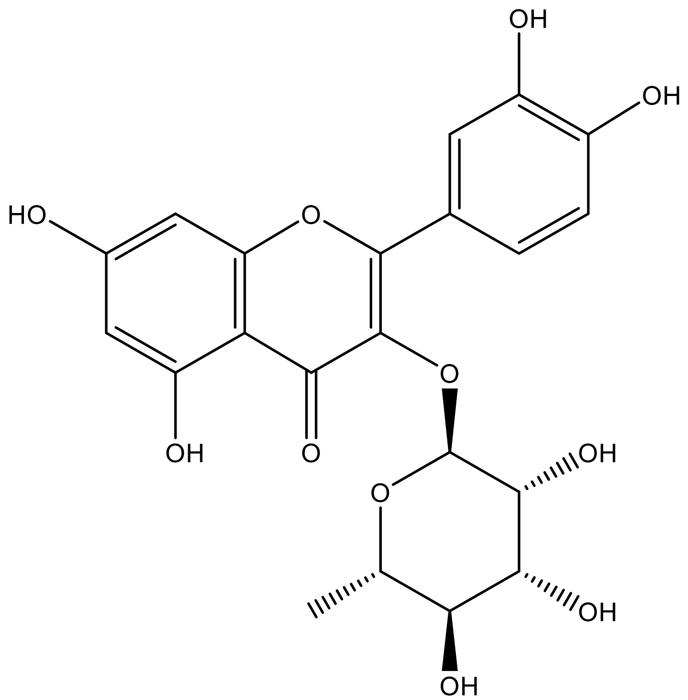
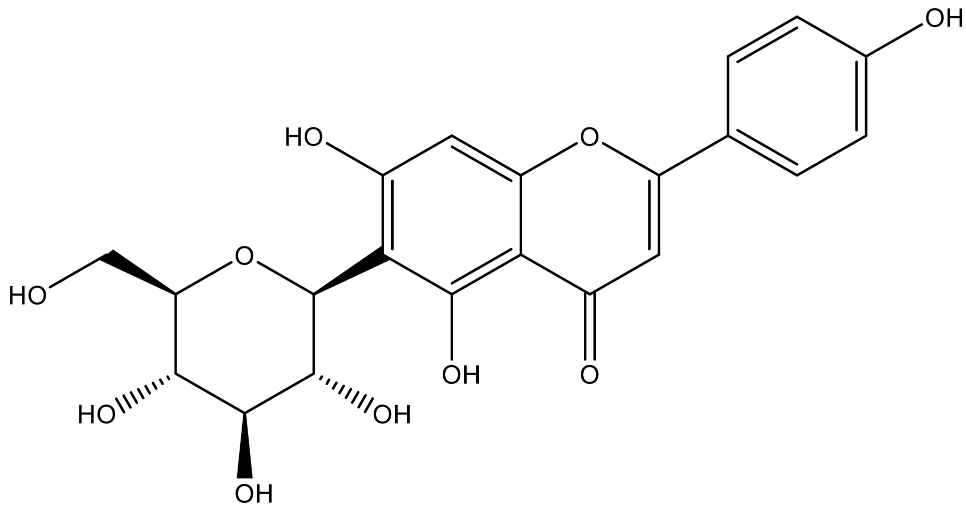


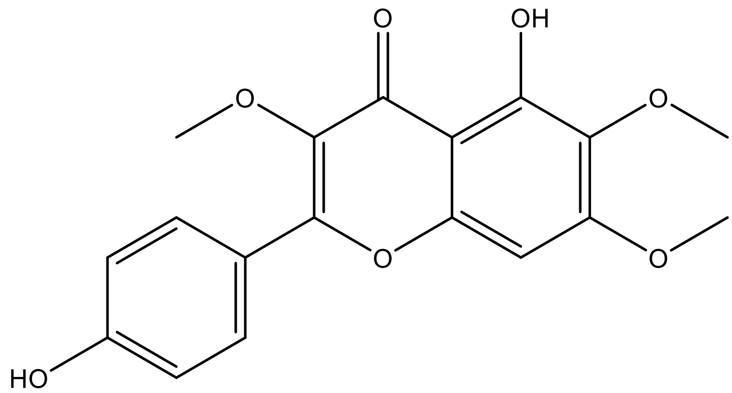
Vitexin



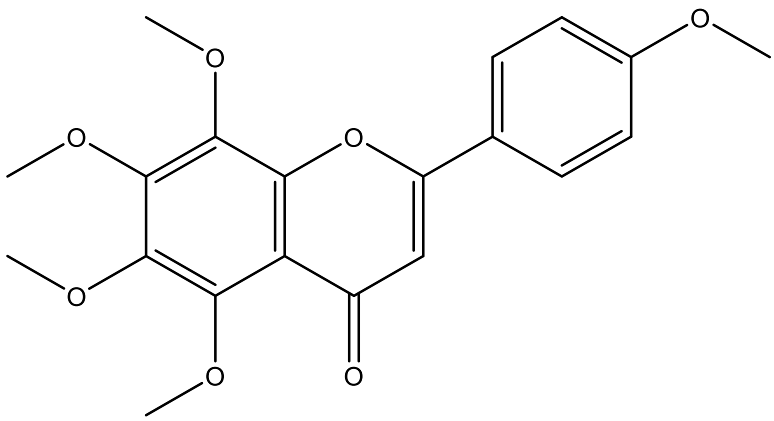
Quercitrin



Isovitexin



Penduletin



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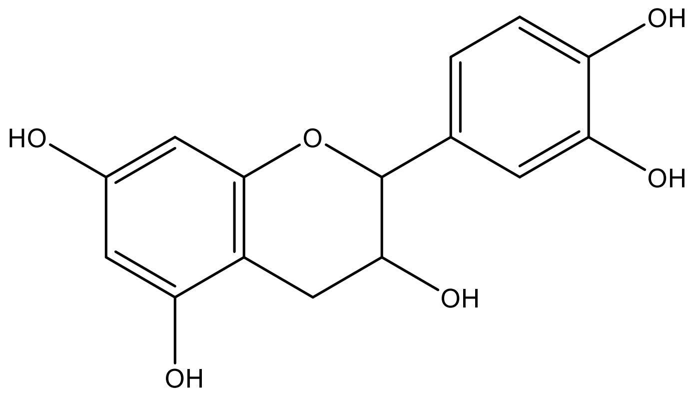
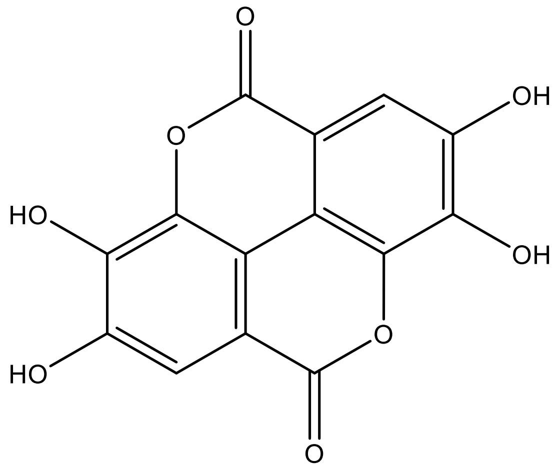
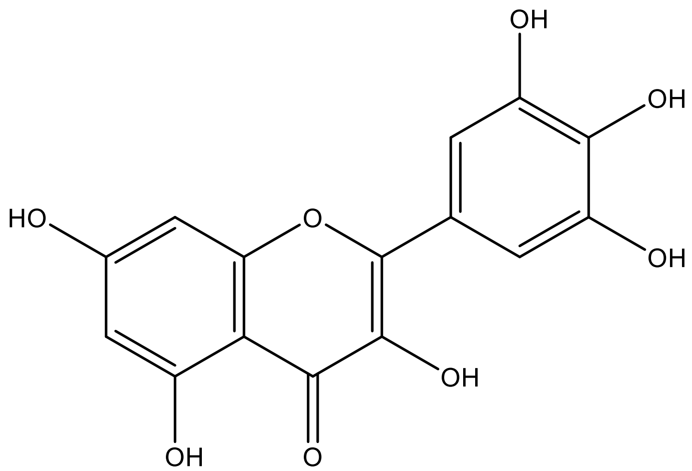


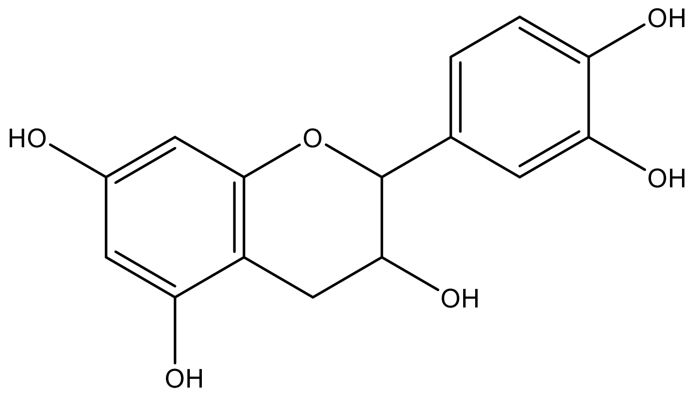
Epicatechin



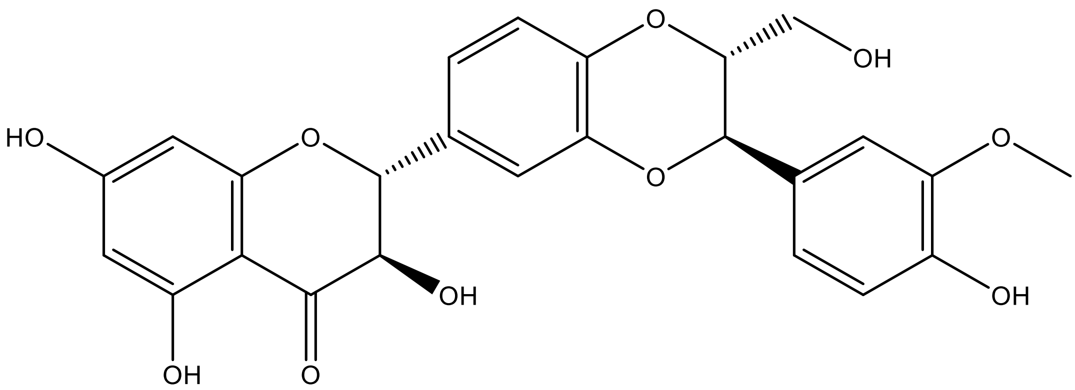
Ellagic acid



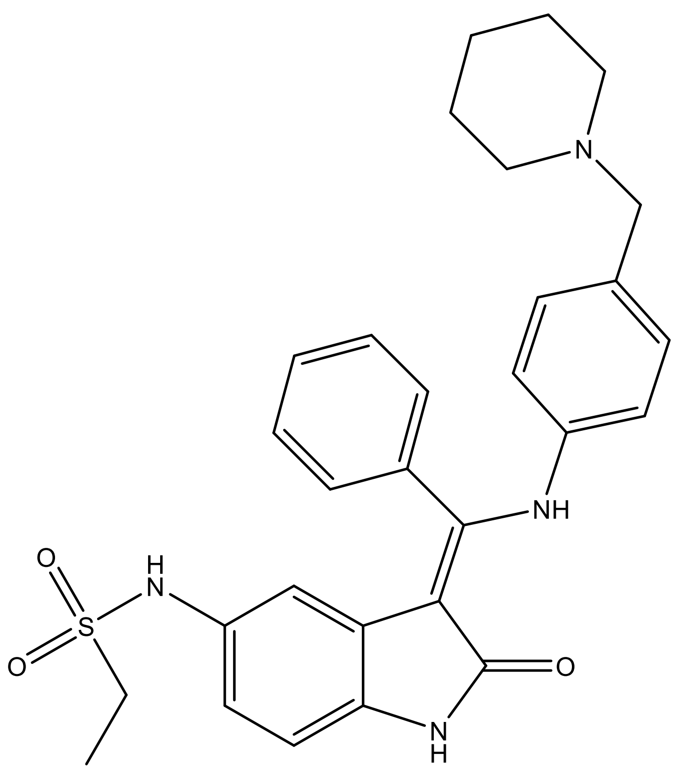
Myricetin



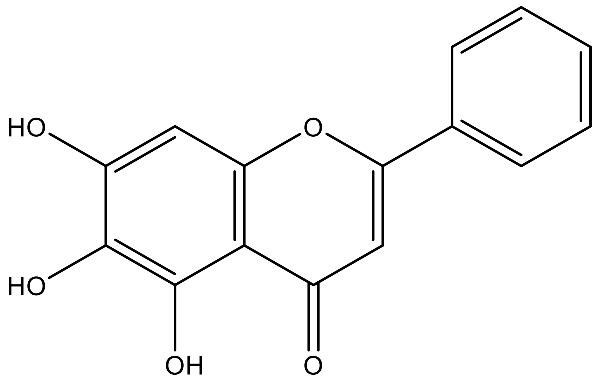
Catechin



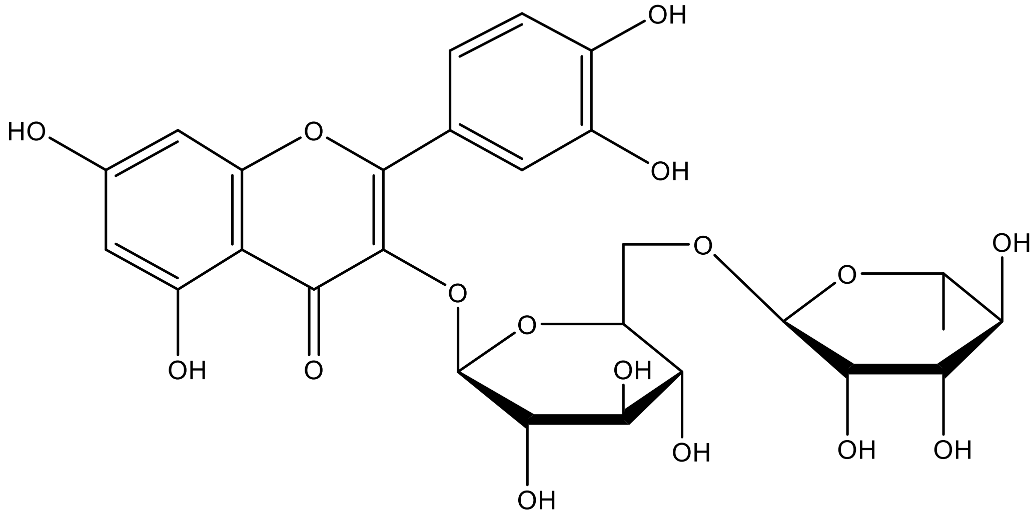
Silymarin



Hesperidine



Baicalein



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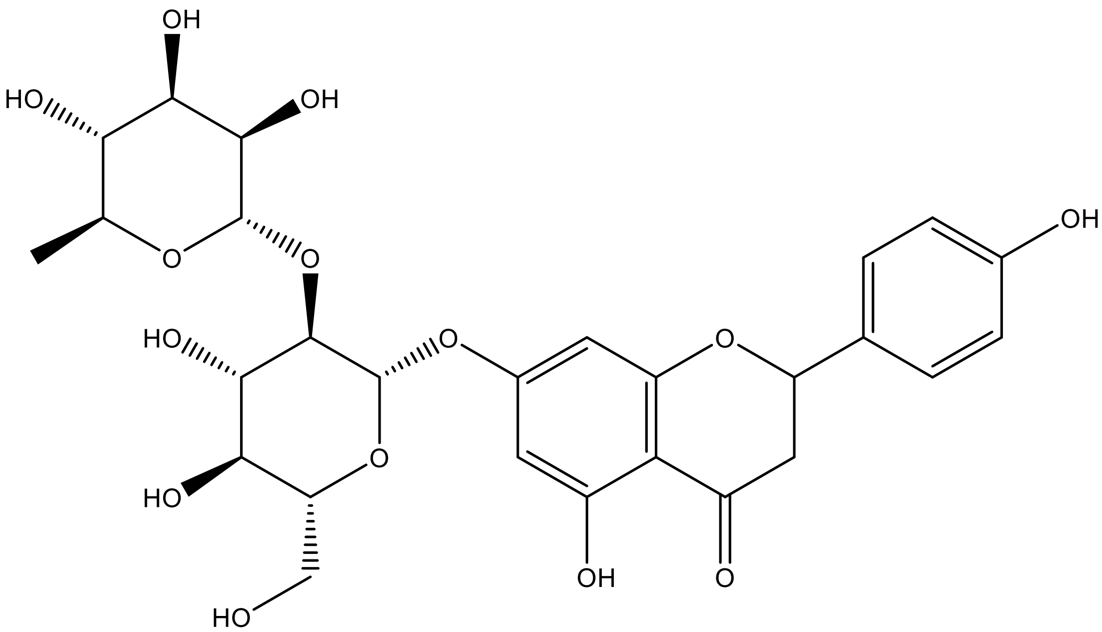

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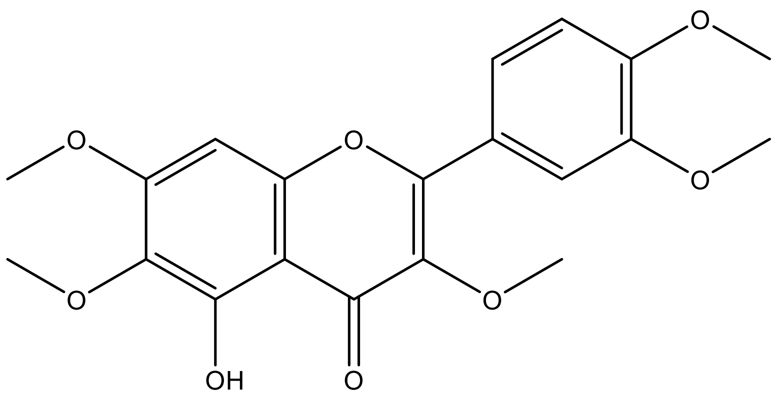
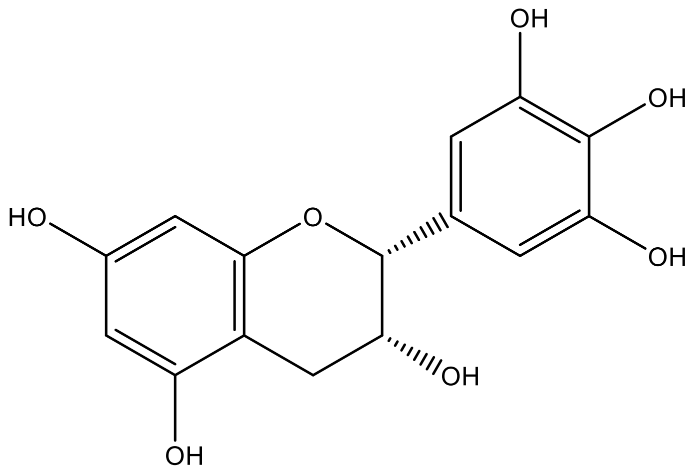
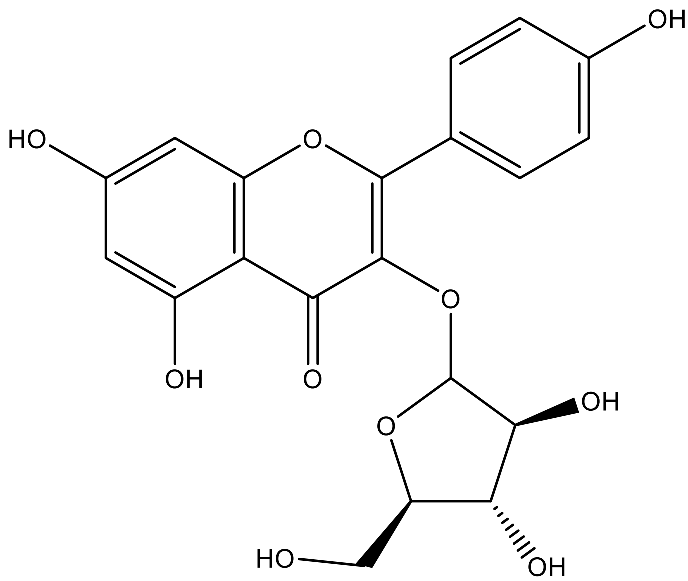


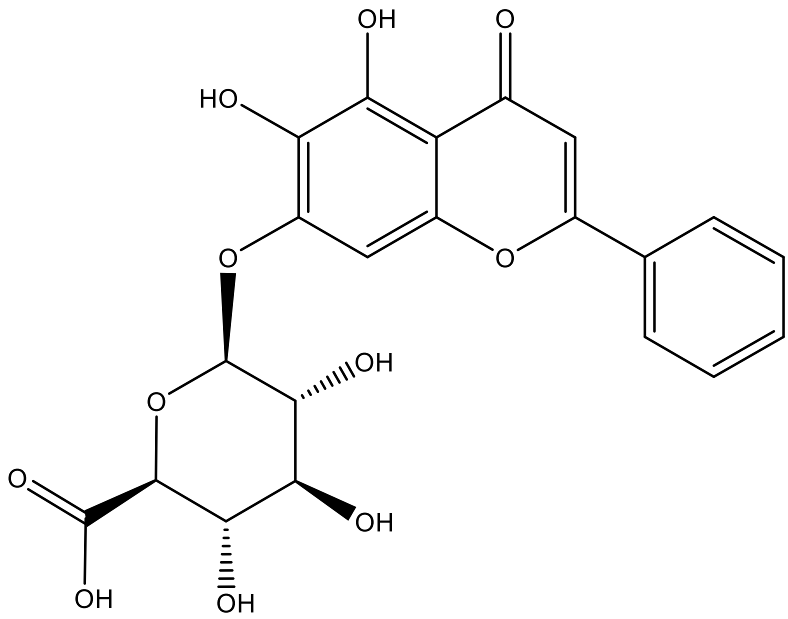
Artemetin



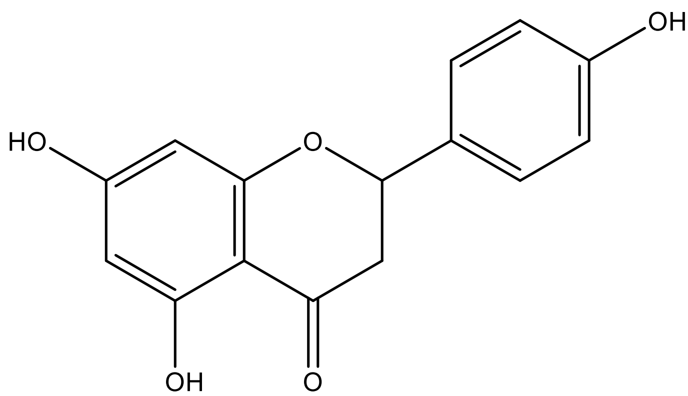
Epigallocatechin



Kaempferol - 3 – arabinoside



Baicalin



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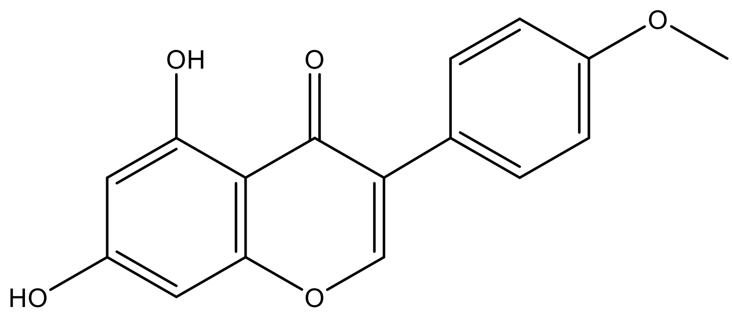
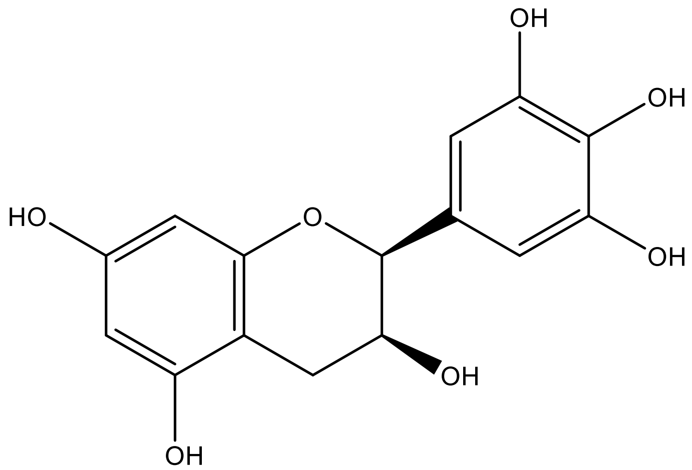
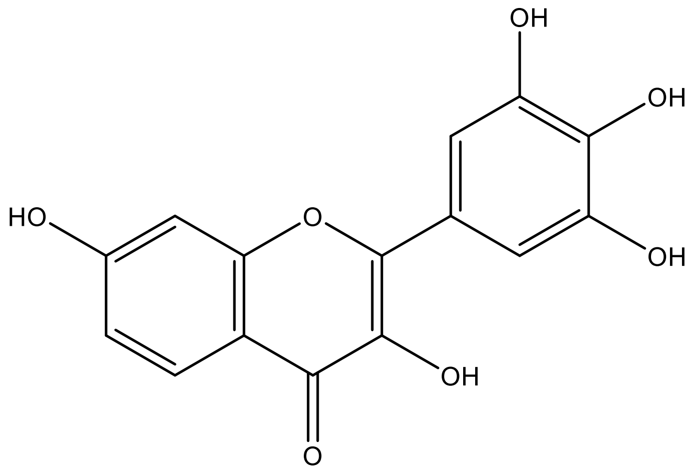


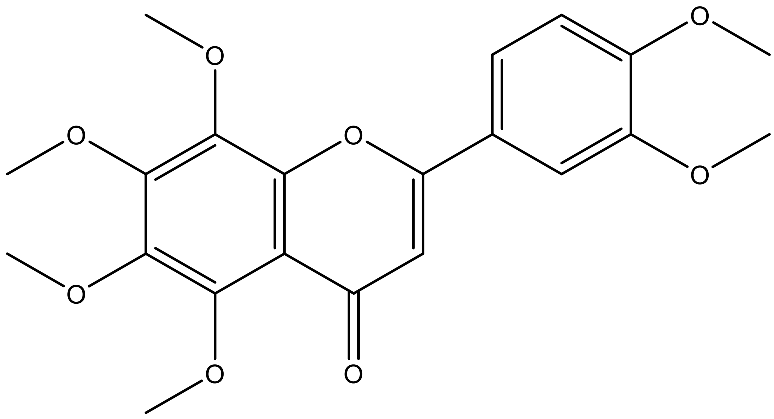
Biochanin



Gallocatachin



Robinetin



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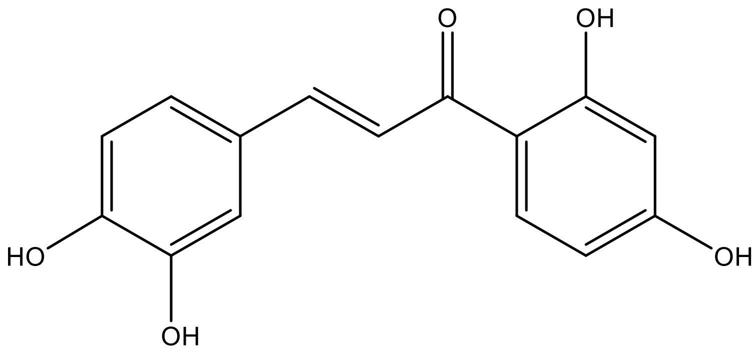
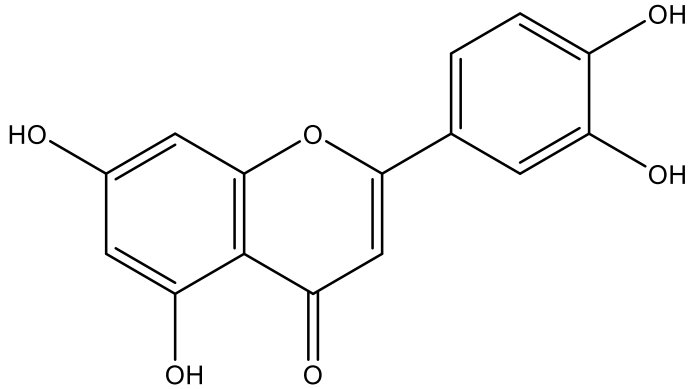
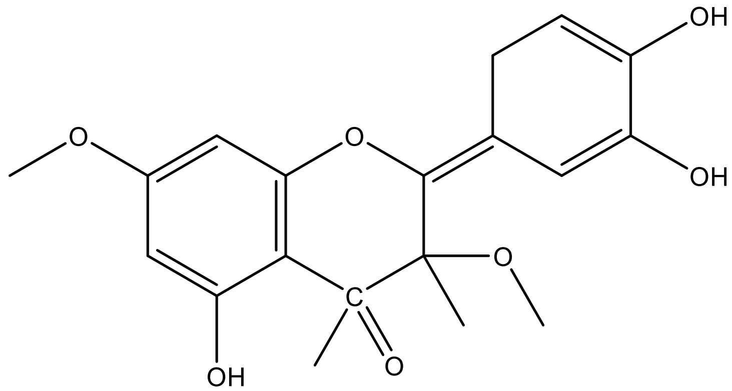


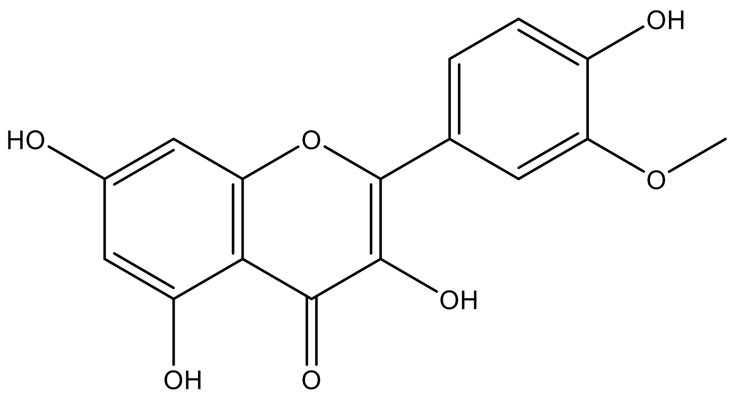
Butein



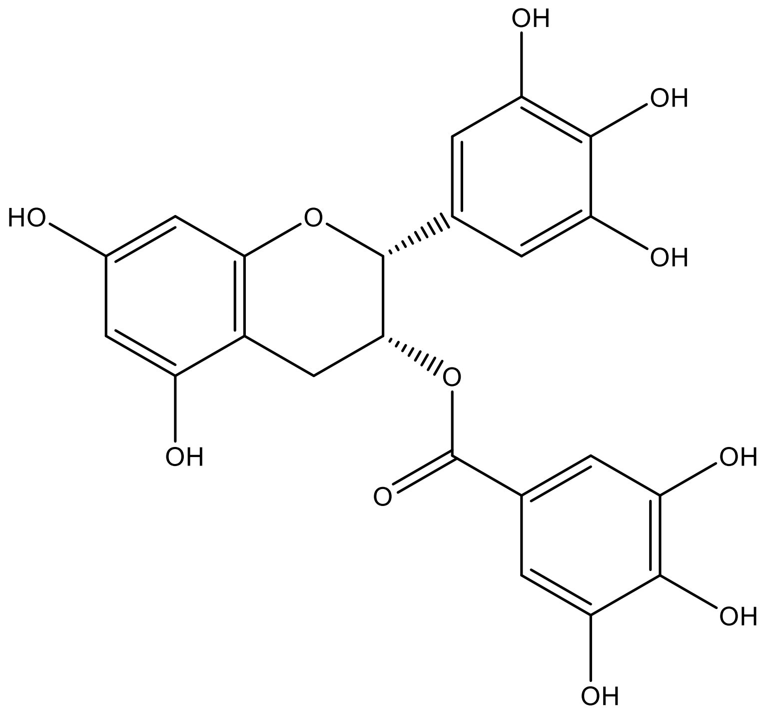
Luteolin



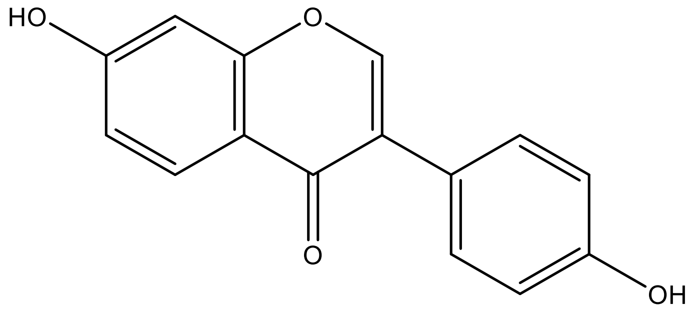
Quercetin3,7,3,4 tetramethylether



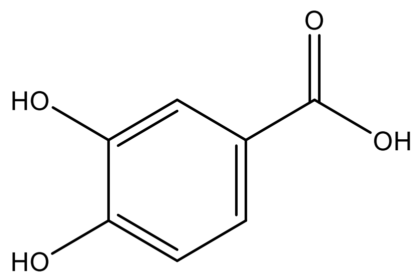
Isorhamnetin



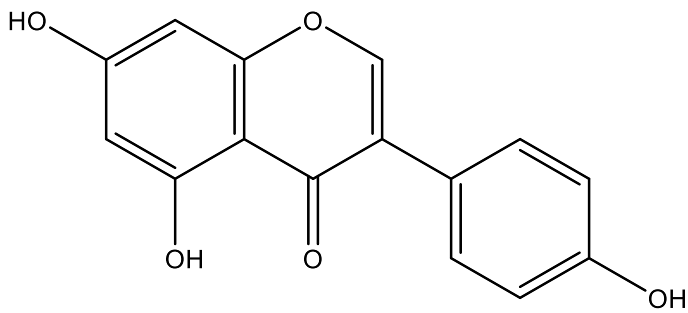
Epigallocatechin - 3 - gallate



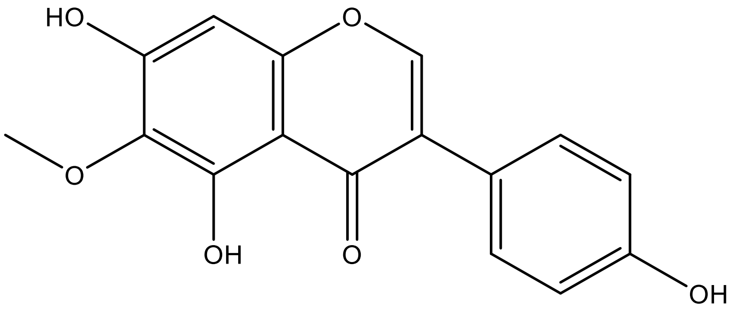
Daidzein



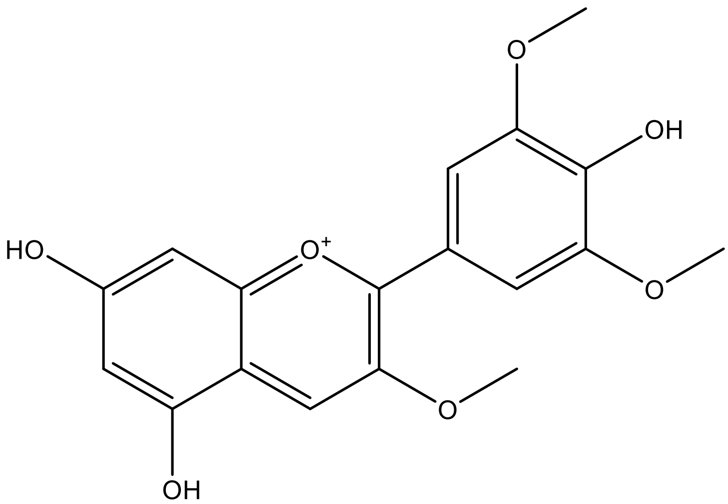
Protocatechuic acid



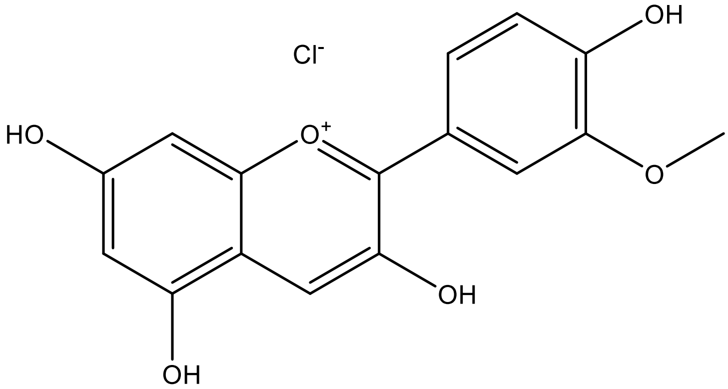
Genistein



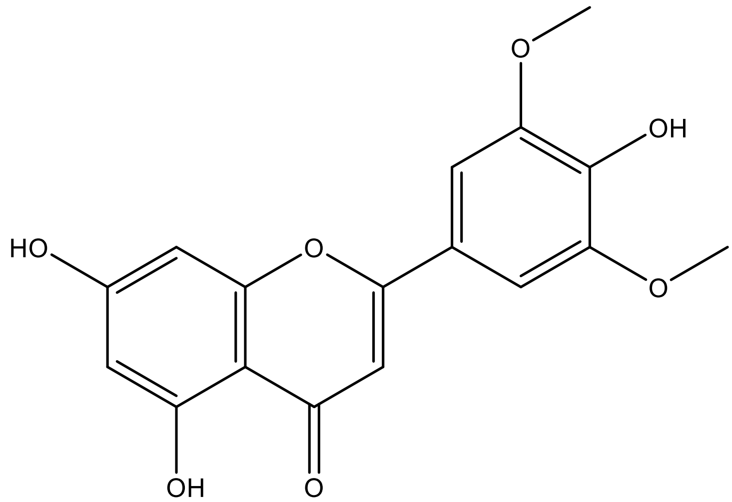
Tectorigenin



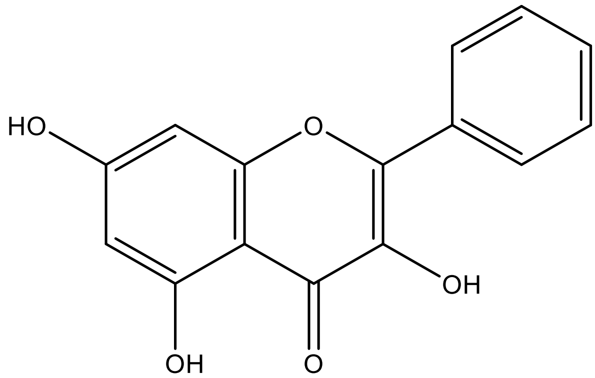
Methylmalvidin



Peonidin

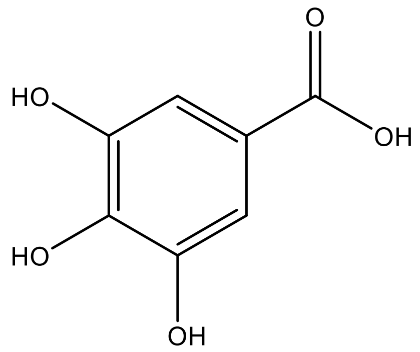


Chrysin

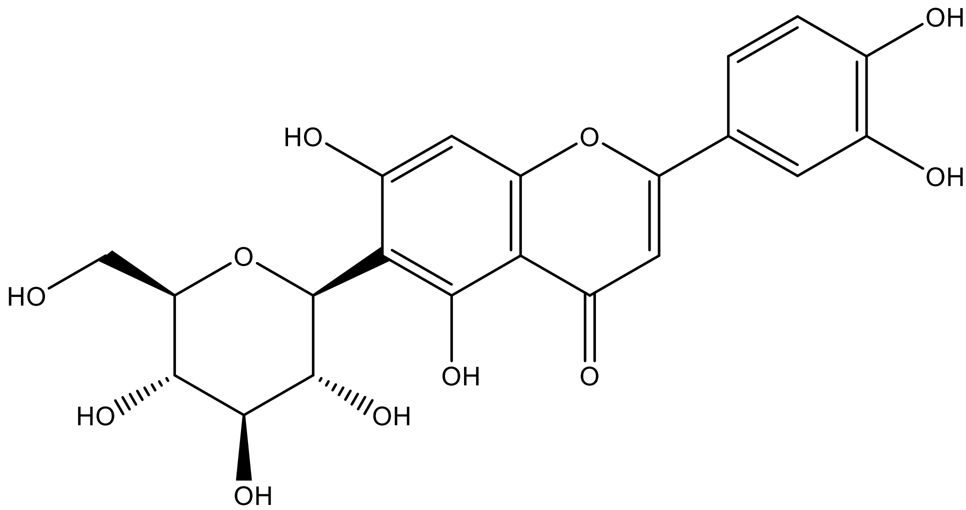


Galangin

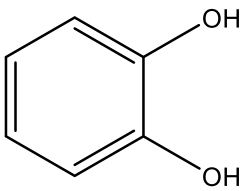
Appendix A4. Flavonoids



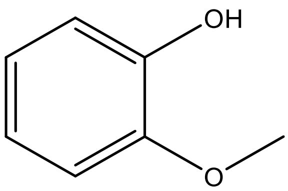
Gallic acid



Homoorientin

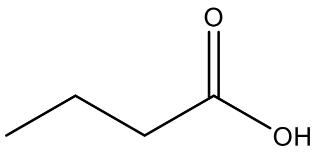


Catechol

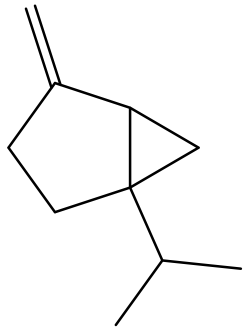


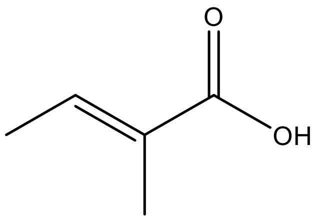
Guaiacol

Appendix A5. Phenolic

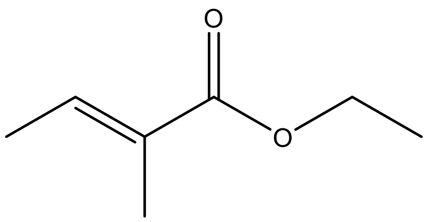


Butanoic acid

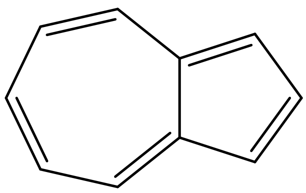

Sabinene

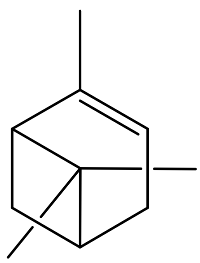


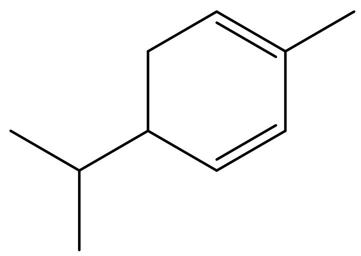
2 -methyl Butenoic acid



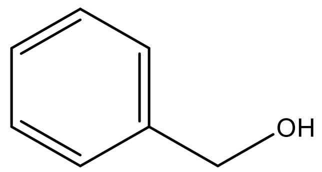
2 -methyl Butenoic acid ethyl ester


Azulene

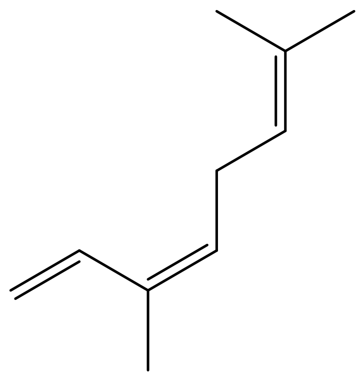

α-Pinene



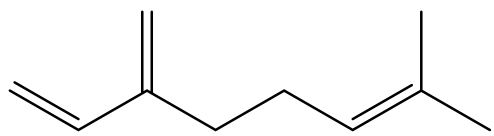
Phellandrene



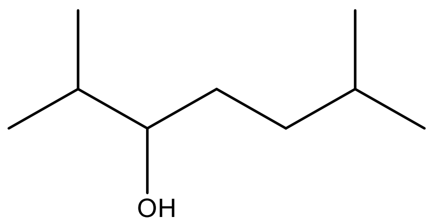
Benzyl alcohol



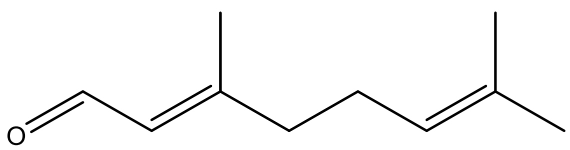
cis –Ocimene



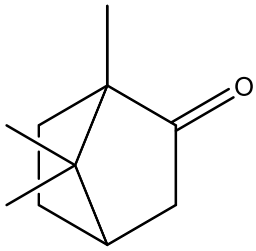
Myrcene



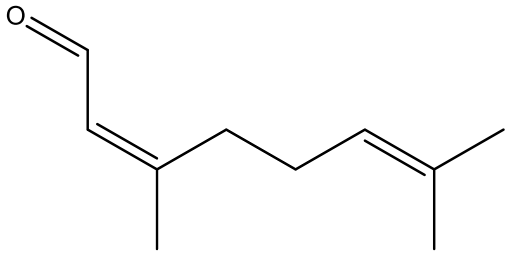
2,6-Dimethyl-5- heptanol



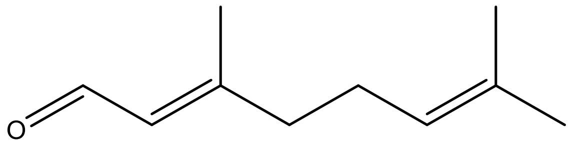
Citral



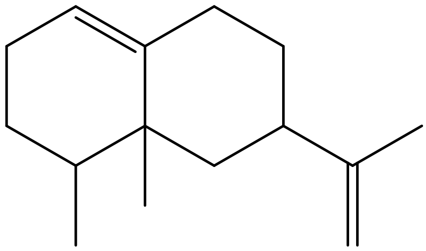
Camphor



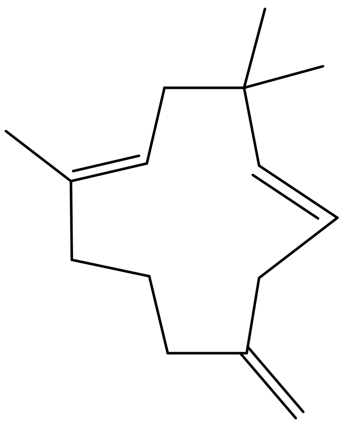
Neral



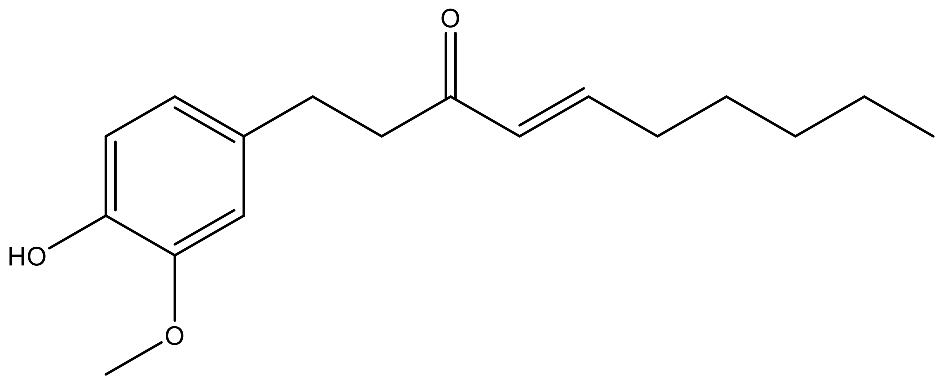
Geranial



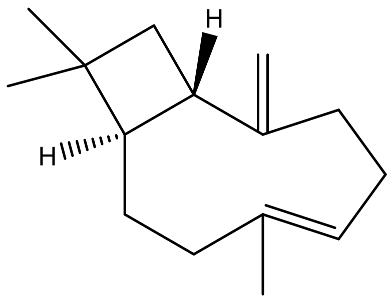
Valencene



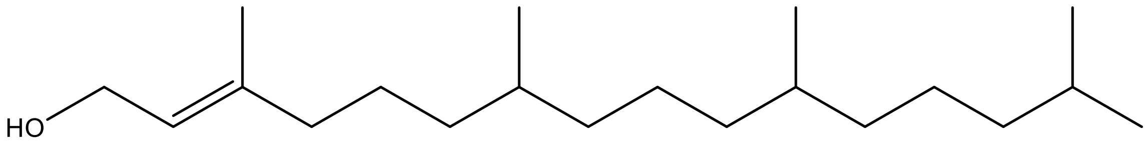
Humulene



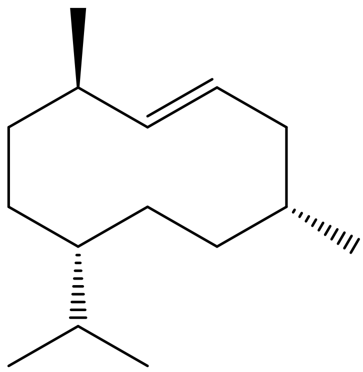
Shogaol



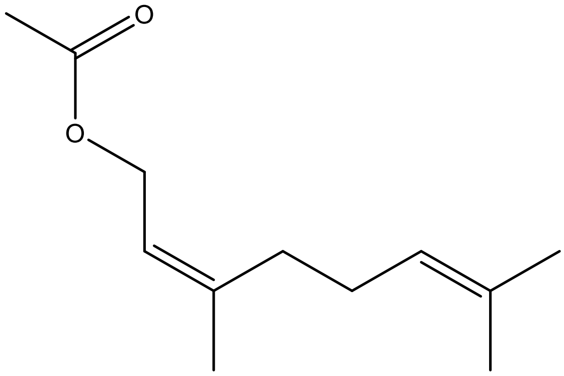
Caryophyllene



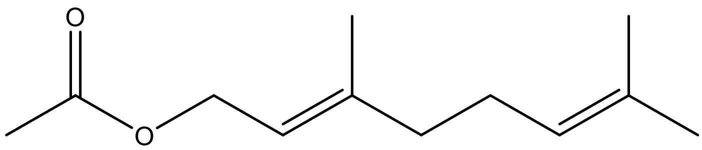
Phytol



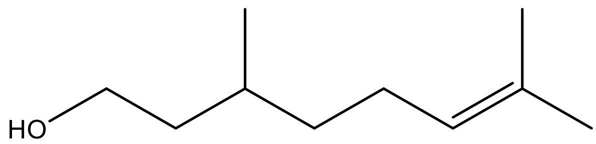
Germacrene D



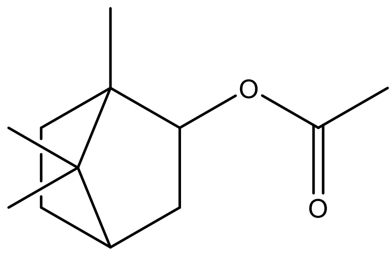
Neryl acetate



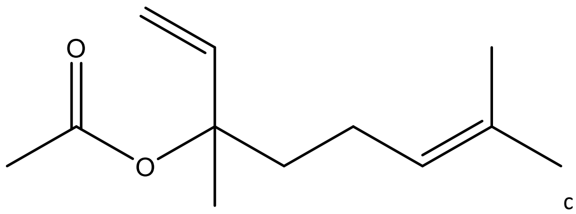
Geraanyl acetate



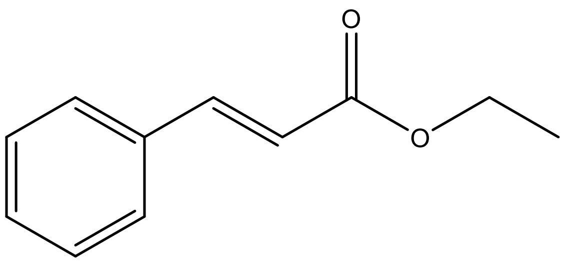
Citronellol



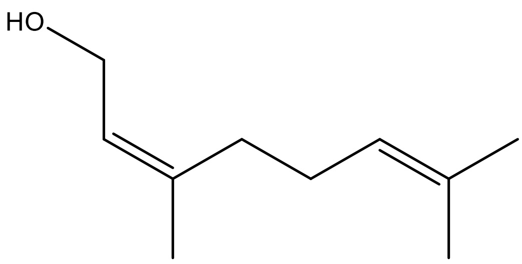
Borneol acetate



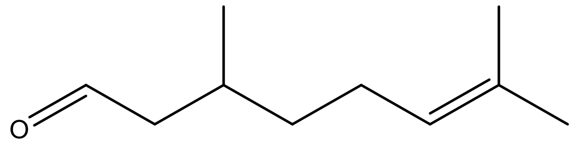
Linalyl Acetate



Ethyl cinnamate



Nerol



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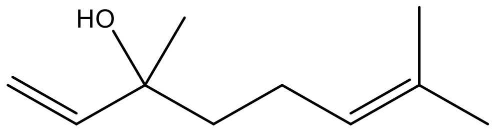
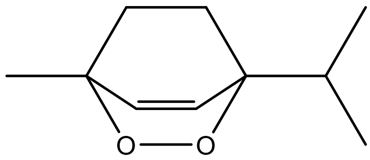
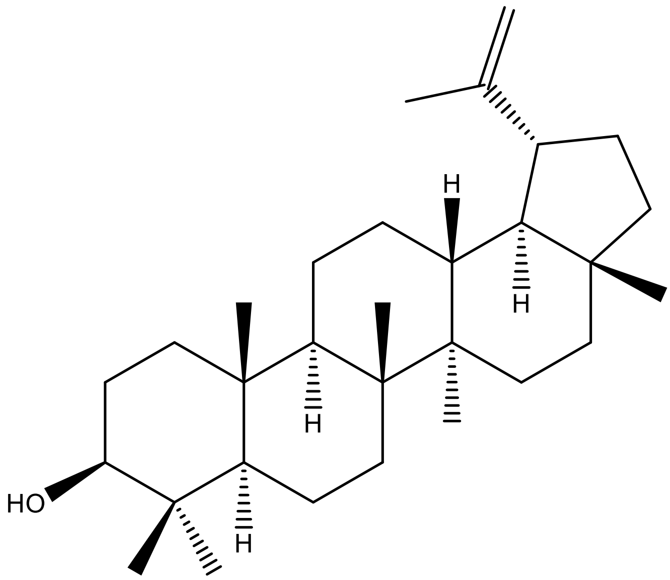


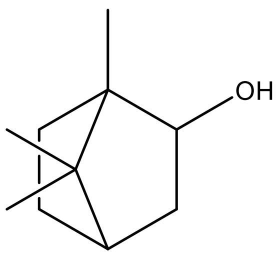
Linalool



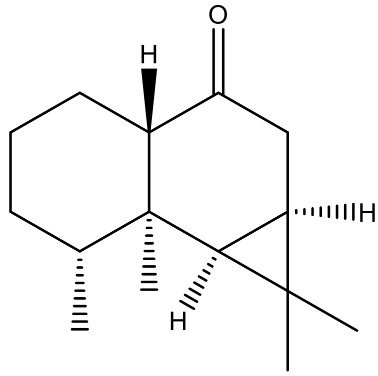
Ascaridole



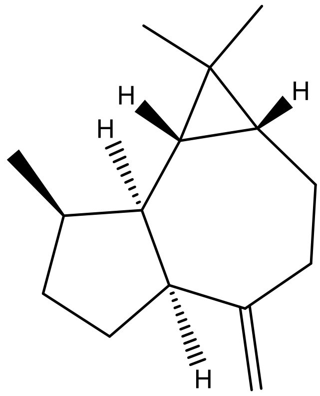
Lupeol



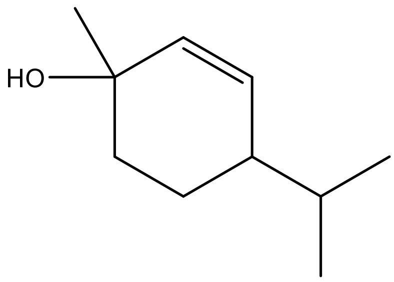
Borneol



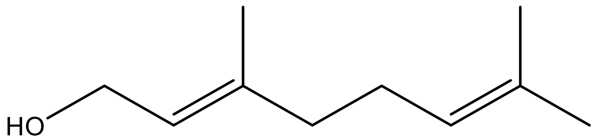
Aristolone



Aromadendrene

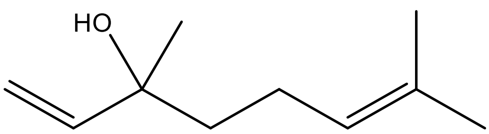


Menth - 2-en- 1-ol

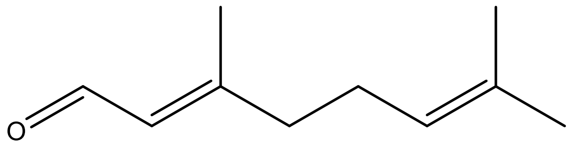


Geraniol

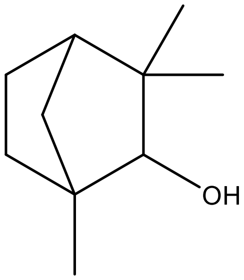
Appendix A6. Terpenoid



Linalool

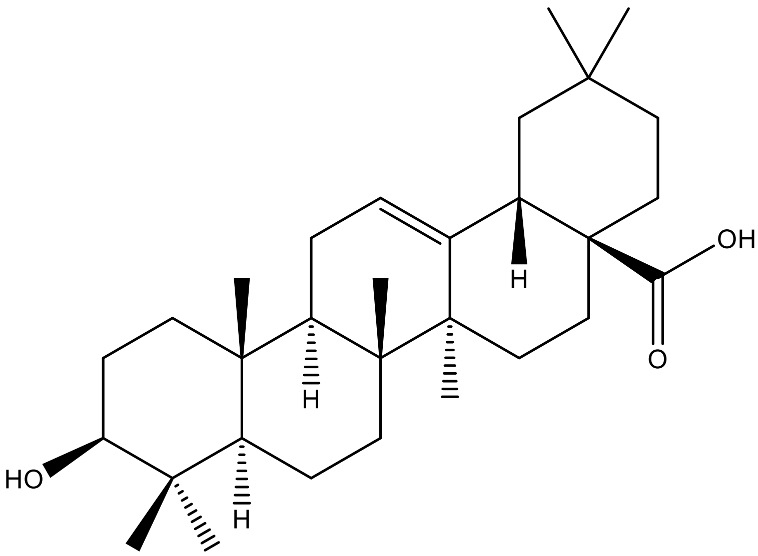


Citral

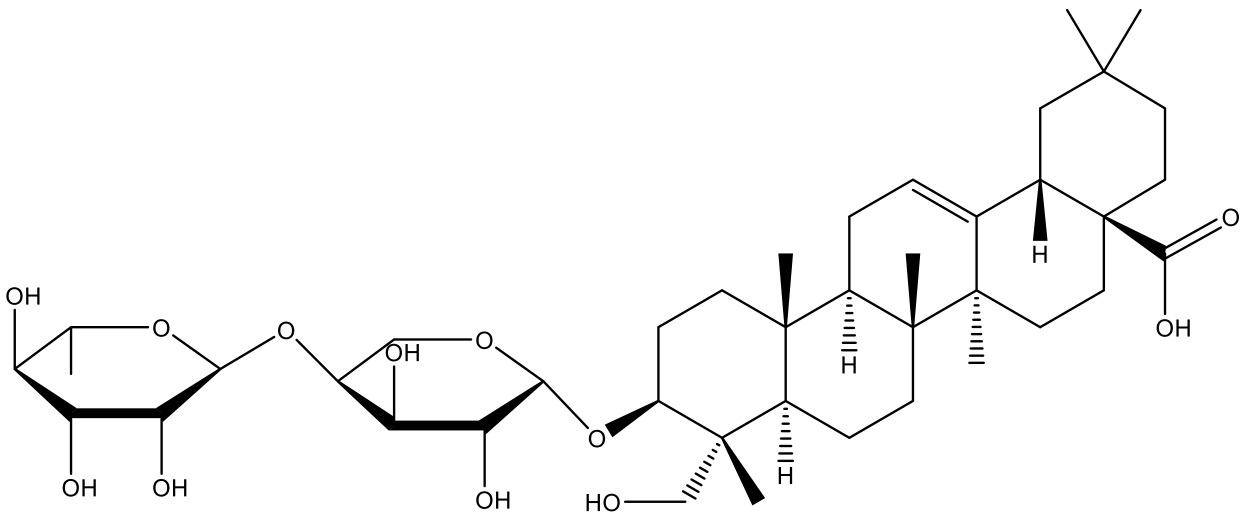


Fenchol, exo-

Appendix A7. Monoterpenoids

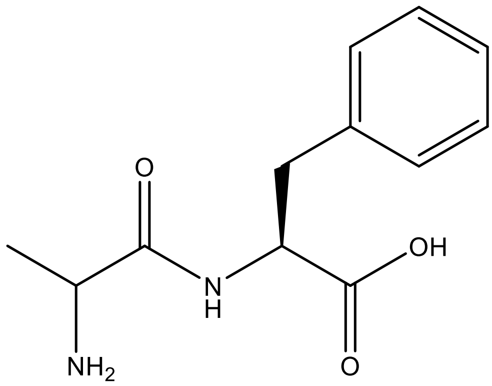


Oleanolic acid



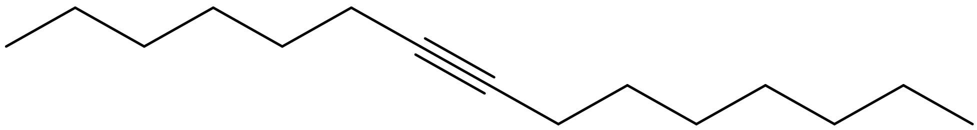
Kalopanaxsaponin A

Appendix A8. Triterpenoid

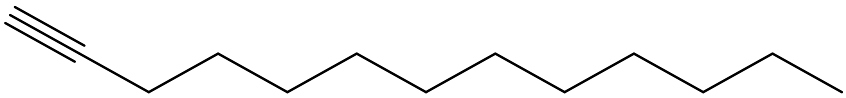


dl — Alanyl-l-phenylalanine

Appendix A9. Amino acid

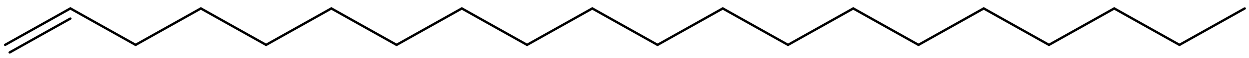


7-Pentadecyne



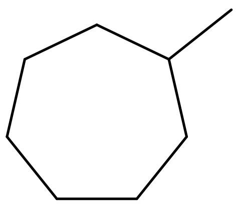
1-Tridecyne

Appendix A10. Alkynes



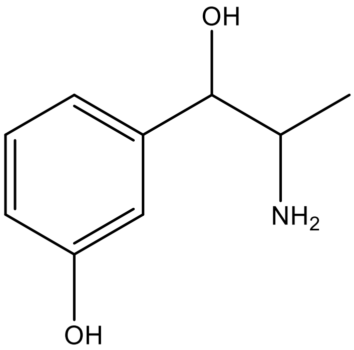
Eicosene

Appendix A11. Alkenes



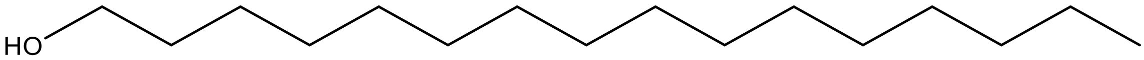
Cycloheptane, methyl-

Appendix A12. Hydrocarbon



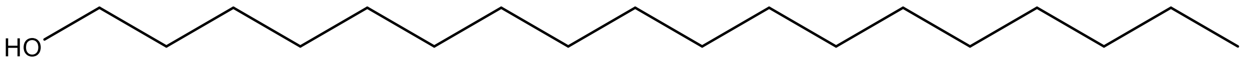
Metaraminol

Appendix A13. Phenethylamines



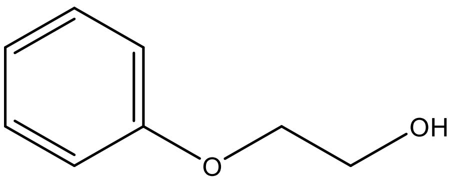
Hexadecanol

Appendix A14. Fatty alcohol

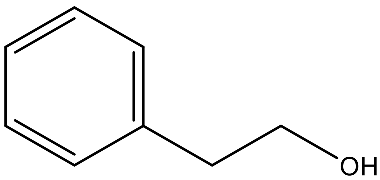


1-Octadecanol

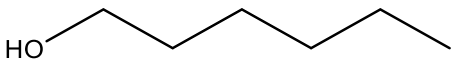
Appendix A15. Fatty alcohol



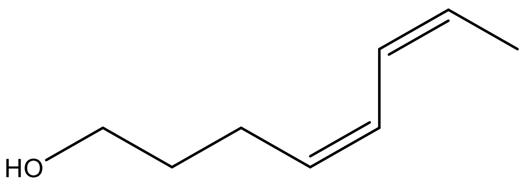
Ethanol, 2-phenoxy-



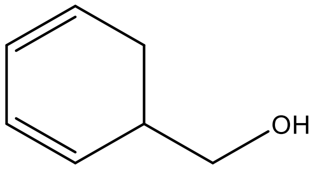
Phenylethyl alcohol



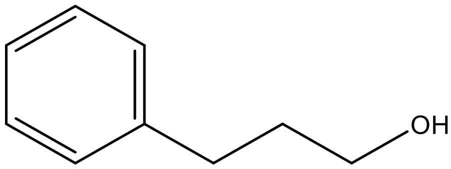
1-Hexanol



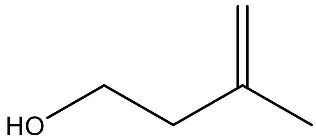
Cis, cis-4,6-octadienol



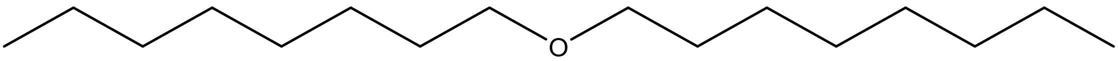
Cyclohexa-2,4-dienylmethanol



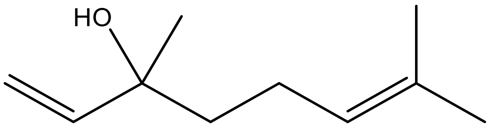
3-Phenylpropanol



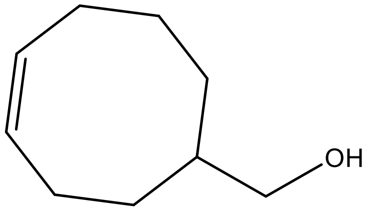
3-Methyl-but-3-en-1-ol



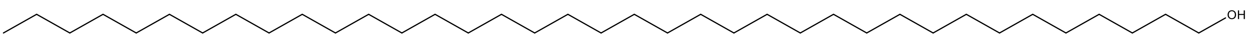
Octylether



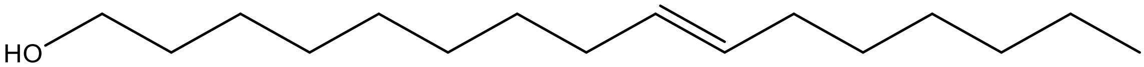
Linalool



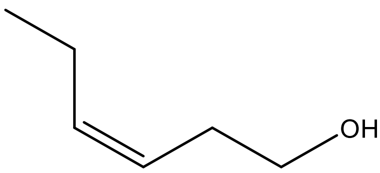
4-Cyclooctene-1-methanol



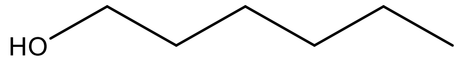
1-Heptatriacotanol



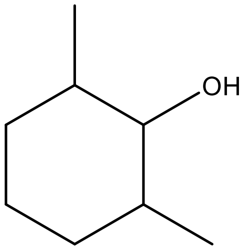
Hexadecen-1-ol, trans-9-



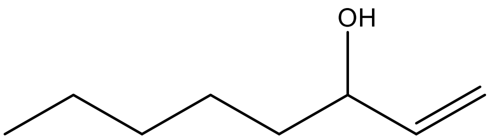
(Z)-3-Hexen-1-ol



Hexan-1-ol

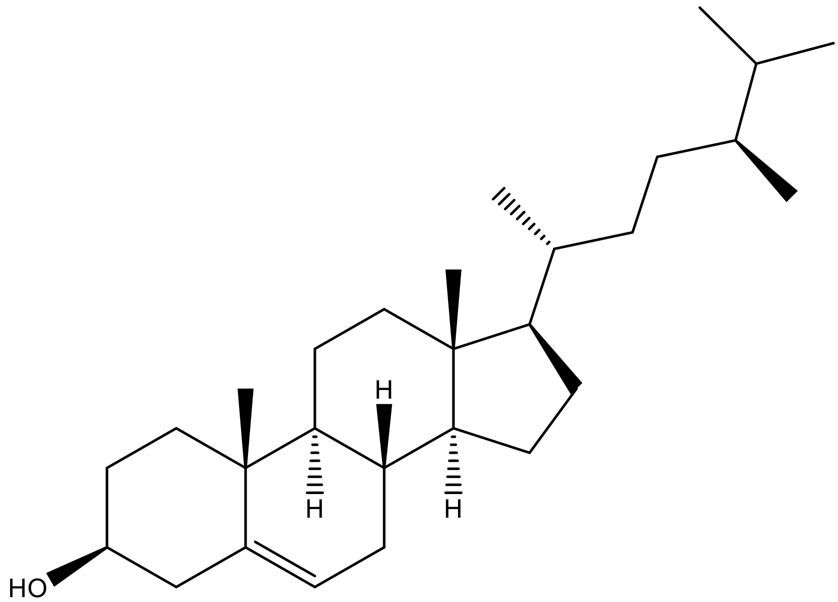


2,6-Dimethylcyclohexanol



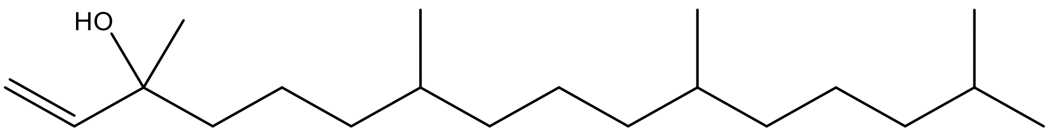
1-Octen-3-ol

Appendix A16. Alcohol

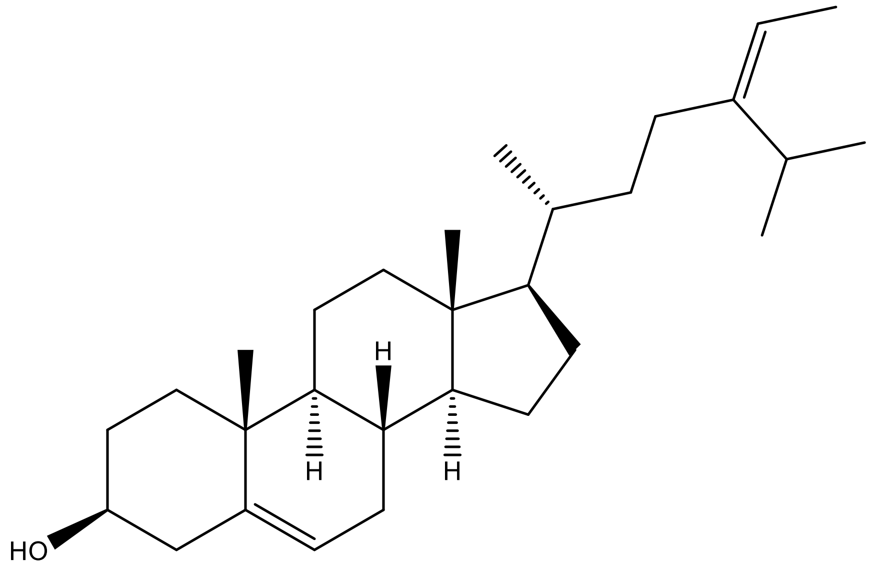


Campesterol

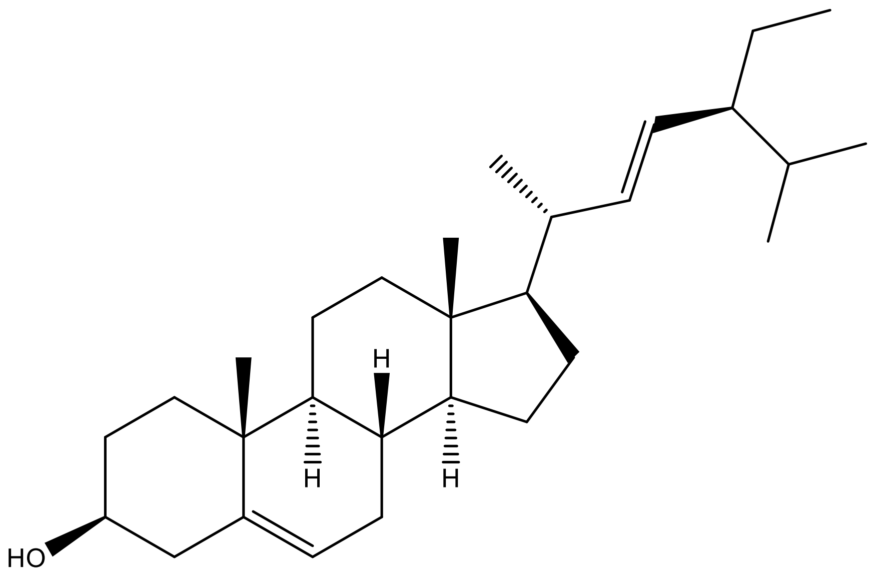
Appendix A17. Phytosterol



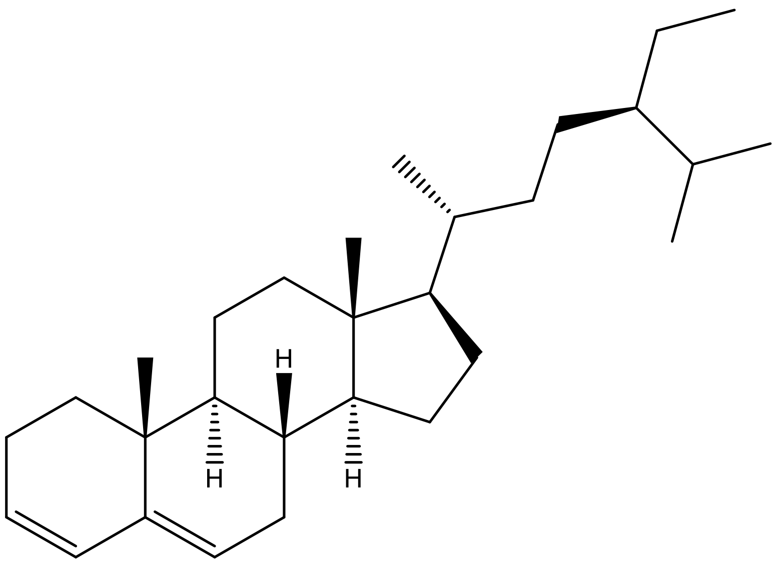
Appendix A18. Isophytol



Stigmasta-5,24(28)-dien-3-ol, (3.beta.,24Z)

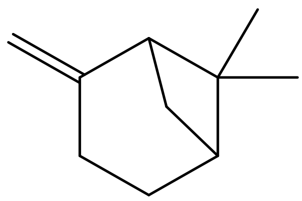


Stigmasterol

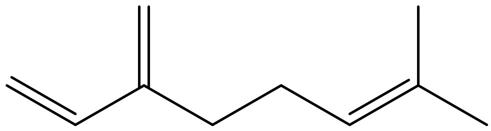


Stigmastan-3,5-diene

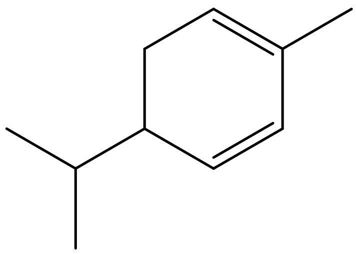
Appendix A19. Sterols



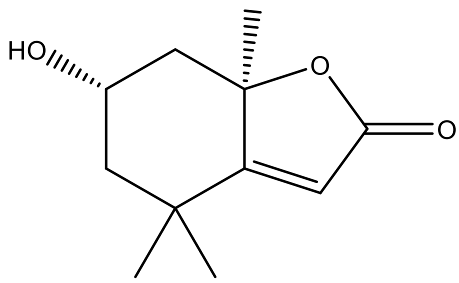
Pinene



Myrcene

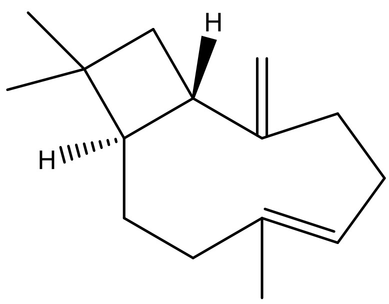


Phellandrene

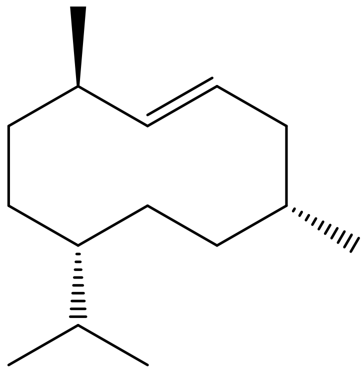


Loliolide

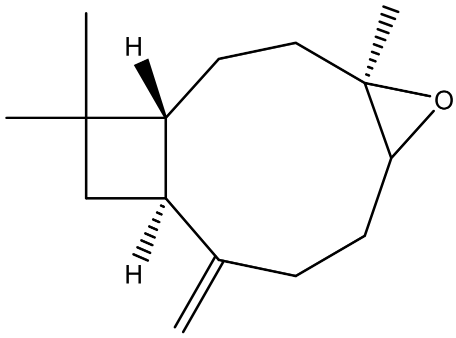
Appendix 20. Monoterpene



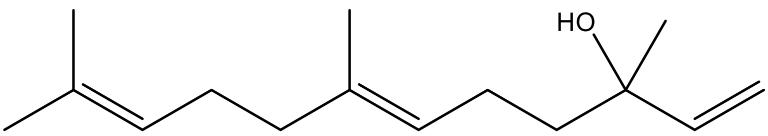
Caryophyllene



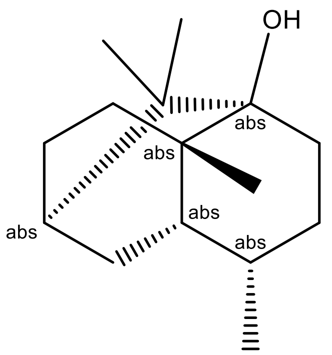
D-Germacrene



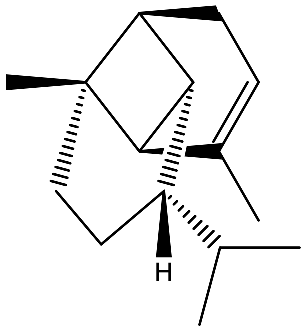
Caryophyllene oxide



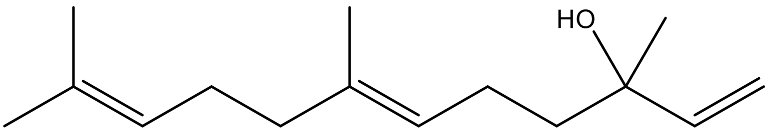
Nerolidol



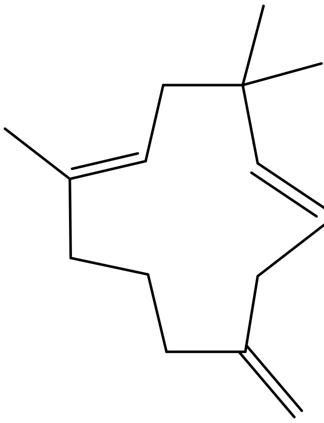
Patchouli alcohol



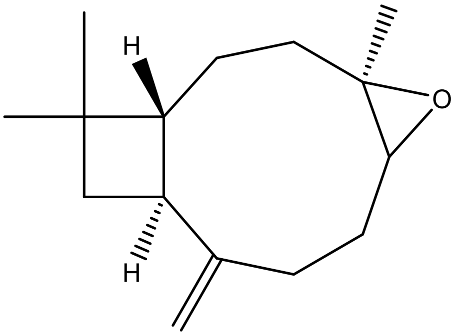
Copaene



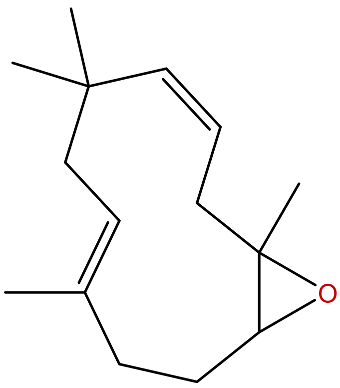
(*E*)-Nerolidol



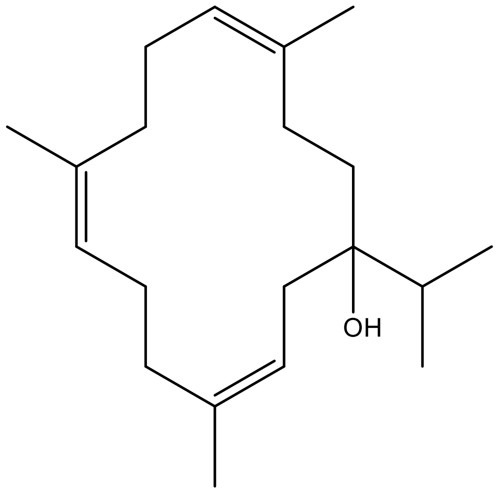
Humulene



Caryophyllene oxide

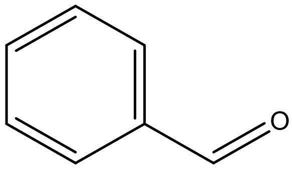


Humulene epoxide II

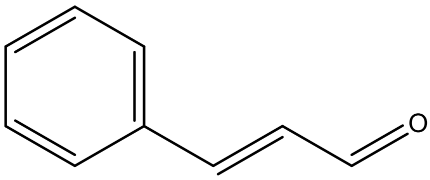


Serratol

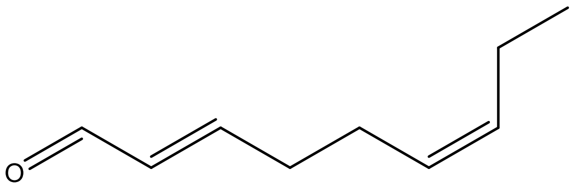
Appendix A21. Sesquiterpene



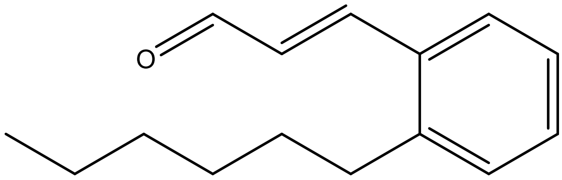
Benzaldehyde



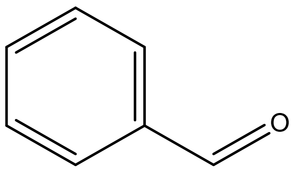
2-Propenal, 3-phenyl-



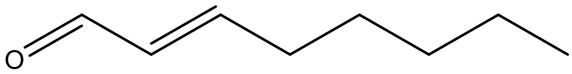
2,6-Nonadienal, (E,Z)-



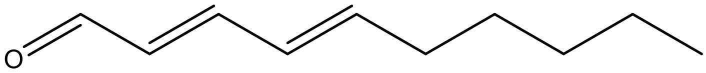
2-Hexyl-(*E*)-cinnamaldehyde



Benzaldehyde

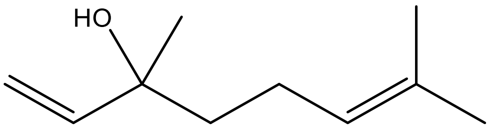


2- Octenal (E)-



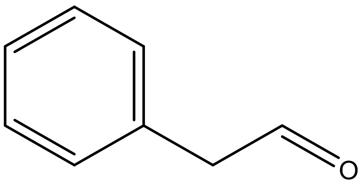
2.4-Decadienal (E, E)

Appendix A22. Aldehyde

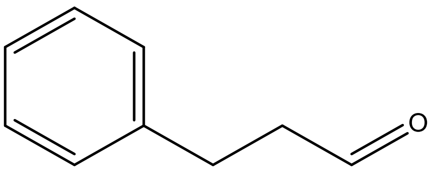


Linalool

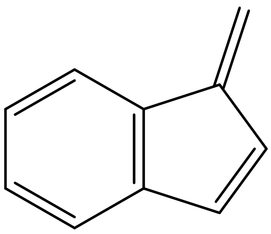
Appendix A23. Terpene alcohol



Benzeneacetaldehyde

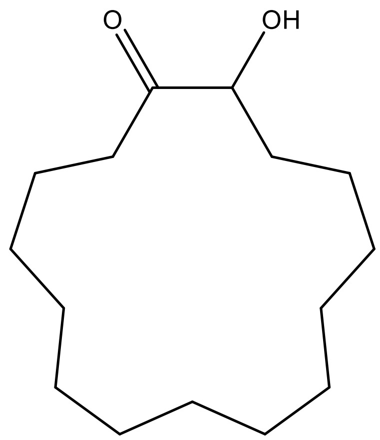


Benzenepropanal

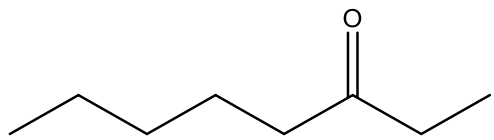


1-Methylene indene

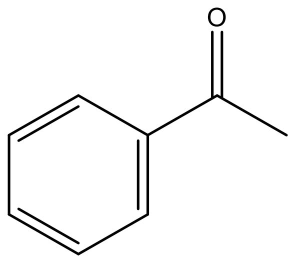
Appendix A24. Benzene



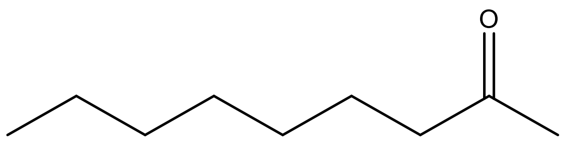
Cyclopentadecanone, 2-hydroxy-



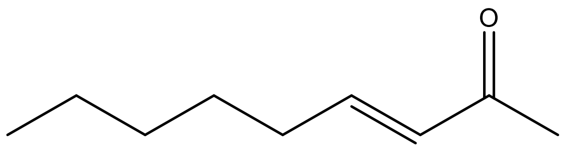
3-Octanone



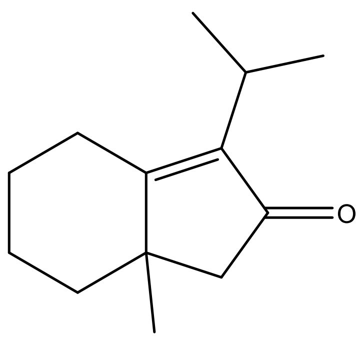
Acetophenone



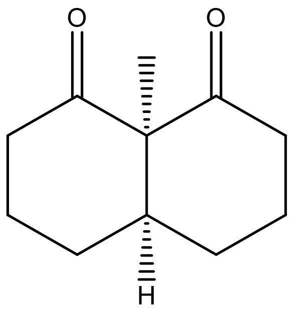
2-Nonanone

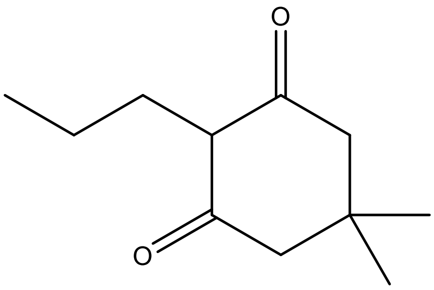


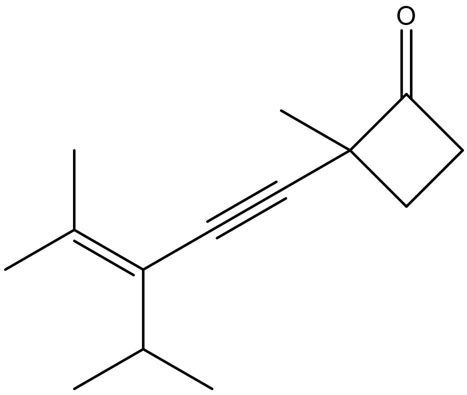
3-Nonen-2-one

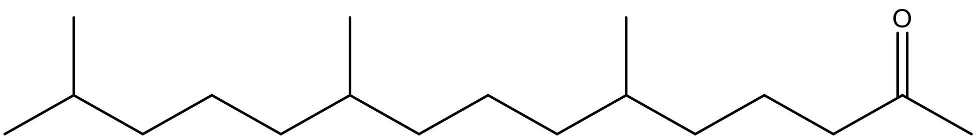


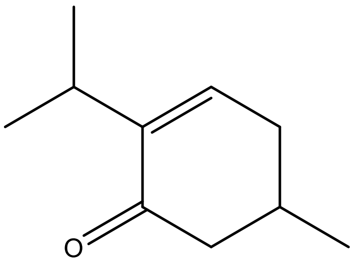
1H-2-Indenone,2,4,5,6,7,7a-hexahydro-3-(1-methylethyl)-7a-methyl

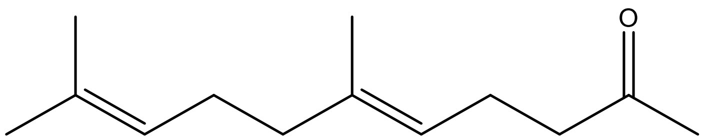

1,8(2H,5H)-Naphthalenedione, hexahydro-8a-methyl-, cis-


1,3-Cyclohexanedione, 5,5-dimethyl-2-propyl-

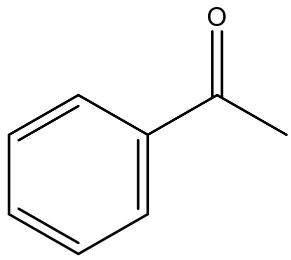

2-(3-Isopropyl-4-methyl-pent-3-en-1-ynyl)-2-methyl-cyclobutanone


2-Pentadecanone, 6,10,14-trimethyl-

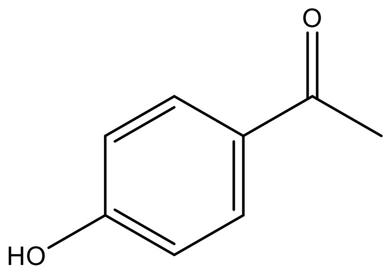

p-Menth-4-en-3-one



Geranyl acetone

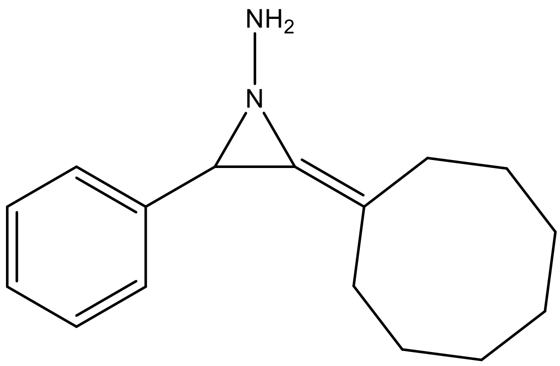


Acetophenone



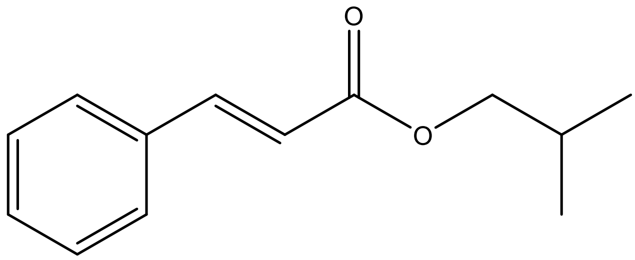
p-Hydroxyacetophenone

Appendix A25. Ketones



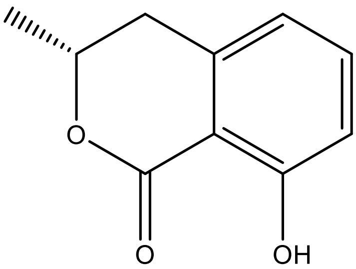
Cyclooctylidene-(2-phenylaziridin-1-yl) amine

Appendix A26. Aziridine



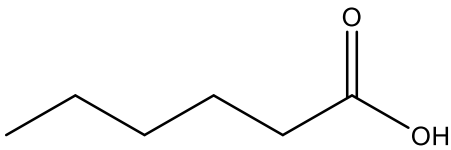
Isobutyl cinnamate

Appendix A27. Cinnamates

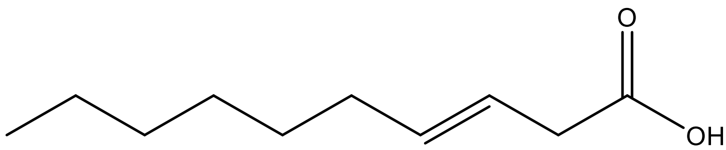


Mullein

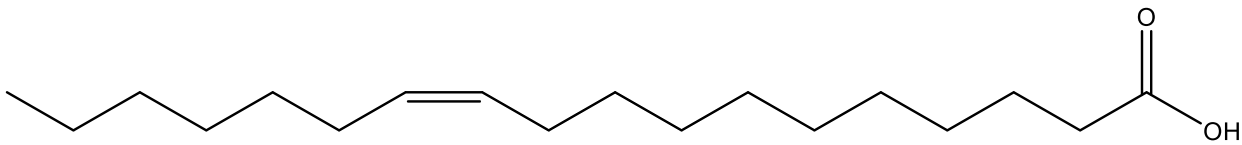
Appendix A28. Dihydroisocoumarins



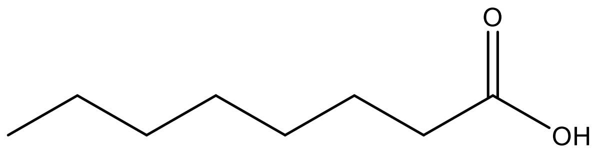
Hexanoic acid



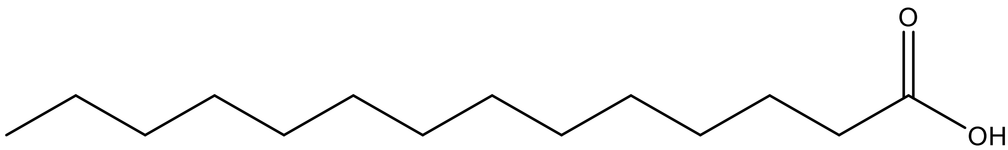
3-Decenoic acid, (E)



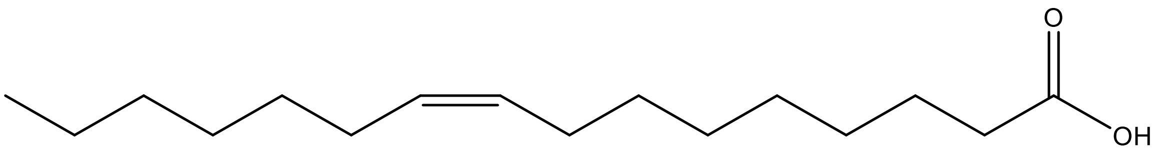
cis-vaccenic acid



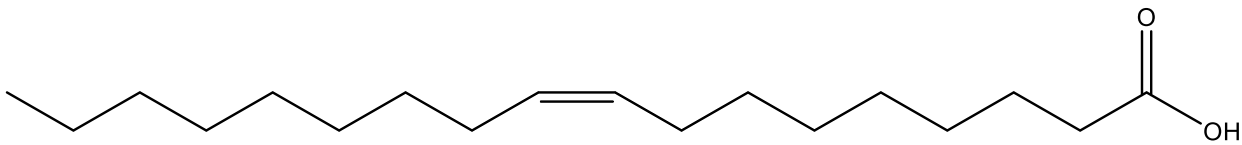
Octanoic acid



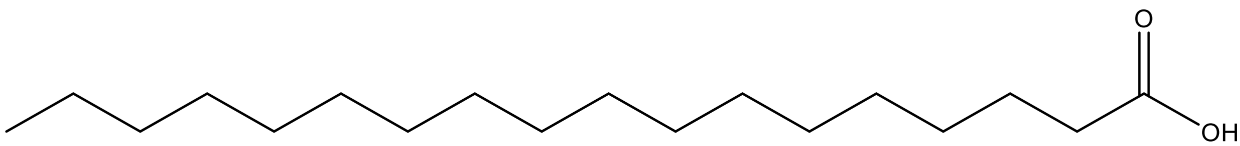
Tetradecanoic acid



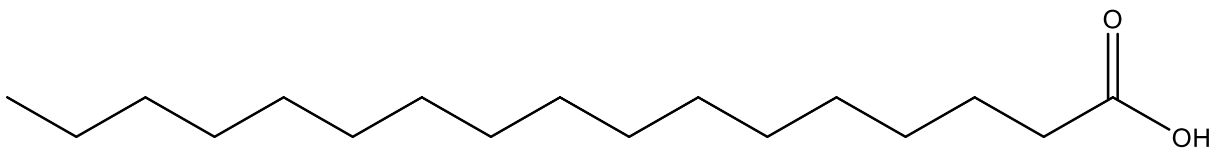
Palmitoleic acid



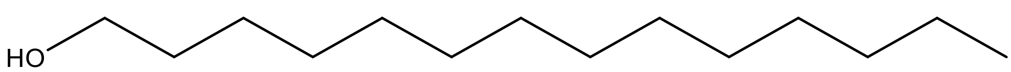
Oleic acid



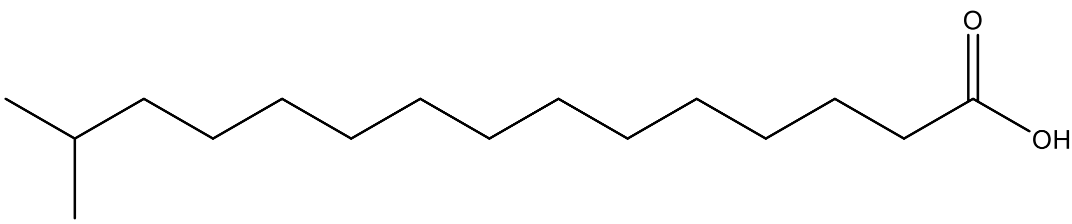
Octadecanoic acid



Margaric acid

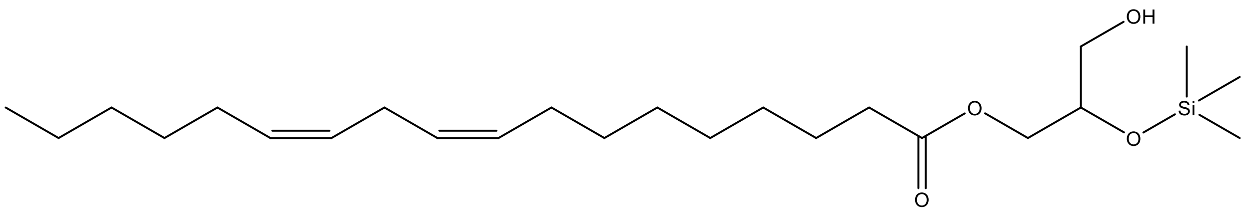


Myristic alcohol



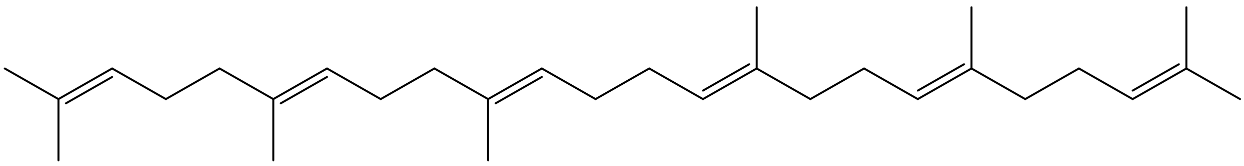
14 methylpentadecanoic acid

Appendix A29. Fatty acid



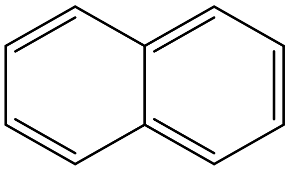
1-Monolinoleoylglycerol trimethylsilyl ether

Appendix A30. Lipid



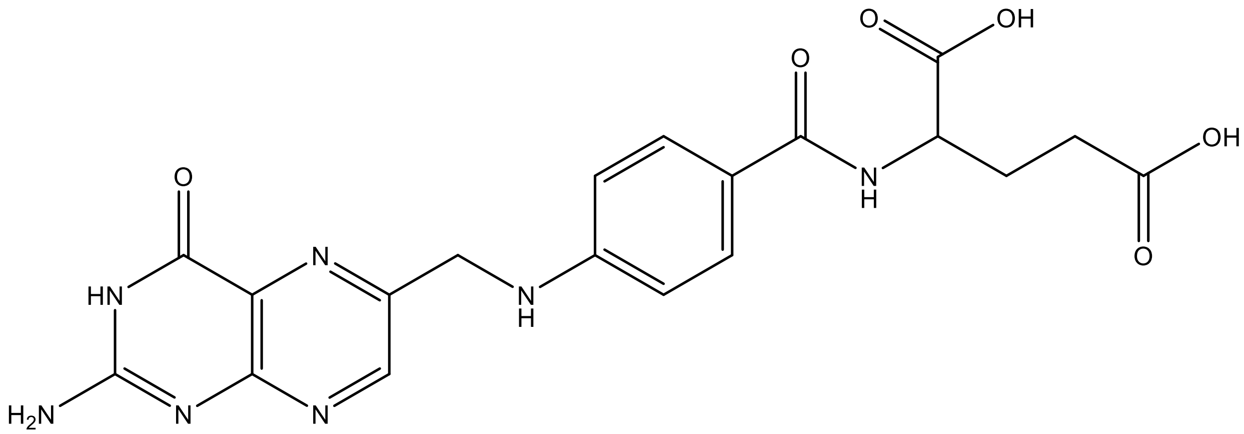
Squalene

Appendix A31. Triterpene



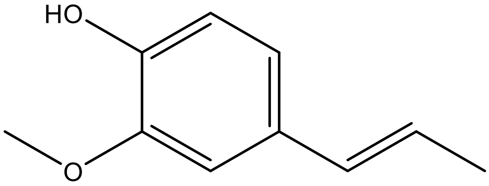
Naphthalene

Appendix A32. Polycyclic aromatic



Folic acid

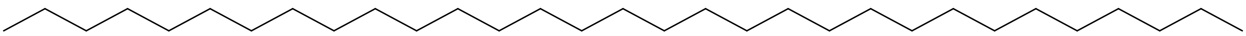
Appendix A33. Vitamin B



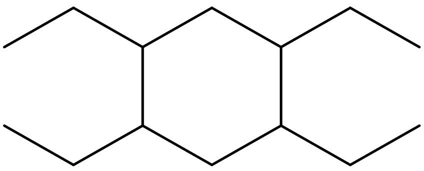
Trans-isoeugenol

Appendix A34. Phenylpropanoids

n-Decane

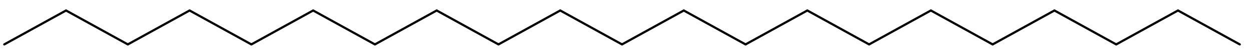


Hentriacontane

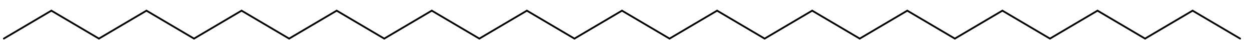


Cyclohexane, 1,2,4,5-tetraethyl-

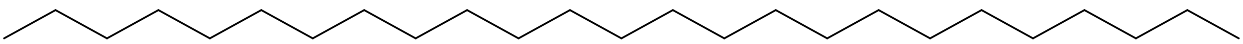
Tetradecane



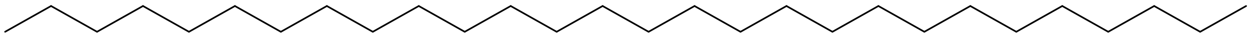
Heneicosane



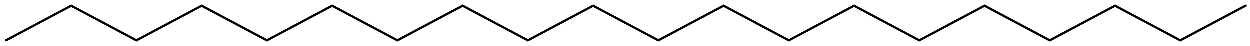
Heptacosane



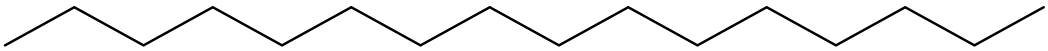
Pentacosane



Octacosane



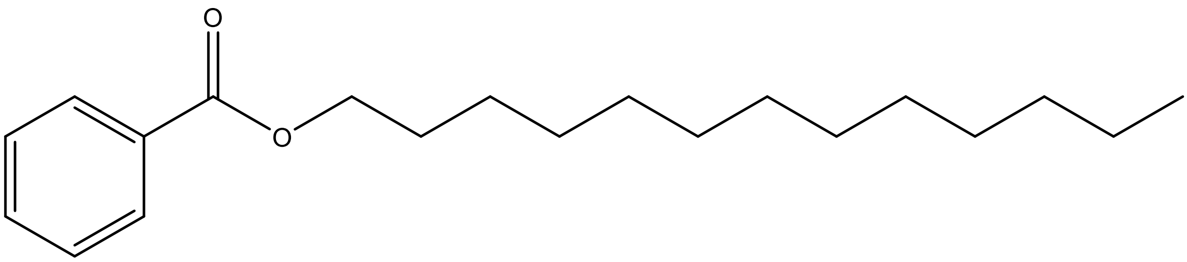
Eicosane



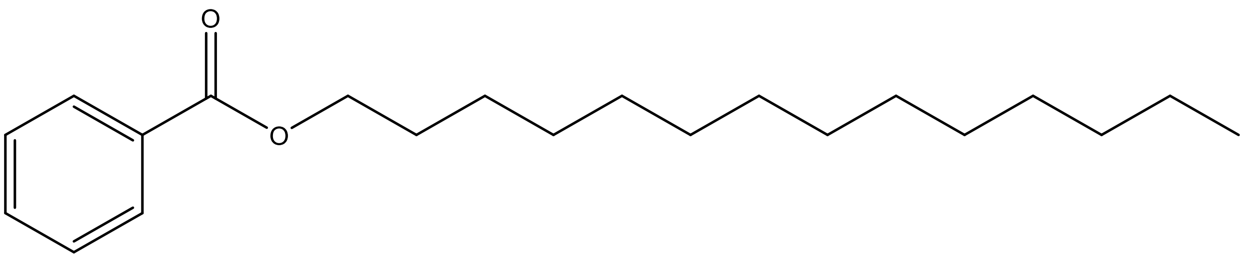
Hexadecane

Octadecane

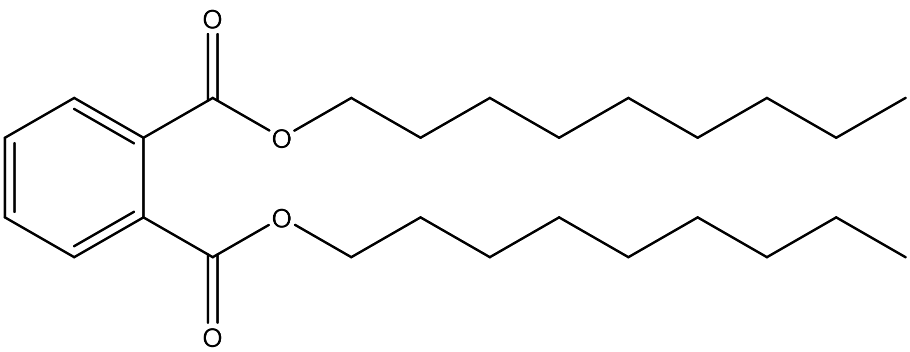
Appendix A35. Alkane



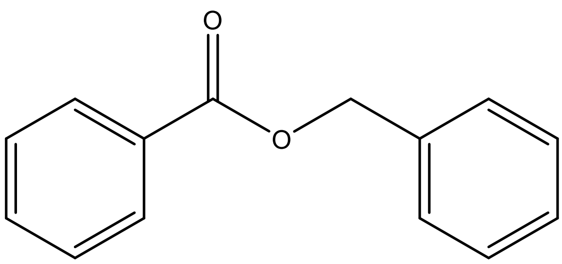
Benzoic acid, tridecyl ester



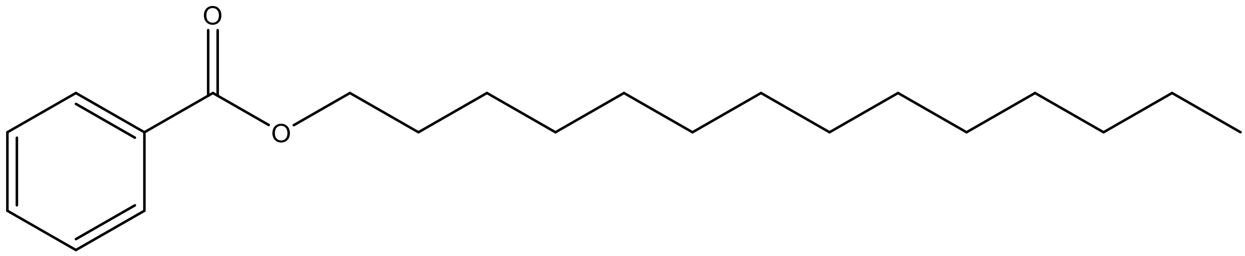
Benzoic acid, tetradecyl ester



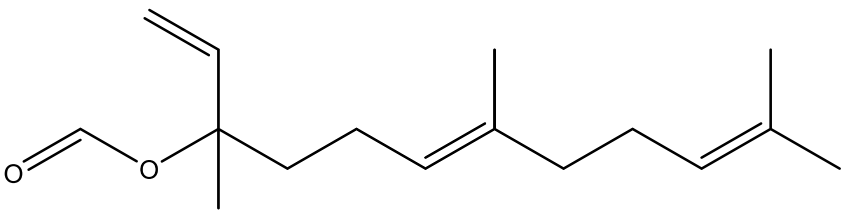
1,2-Benzenedicarboxylic acid, dinonyl ester



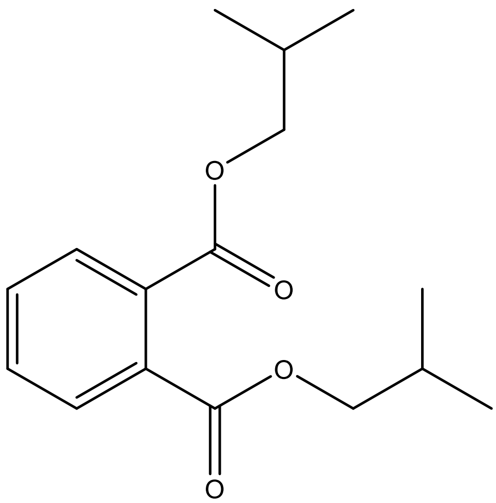
Benzyl benzoate



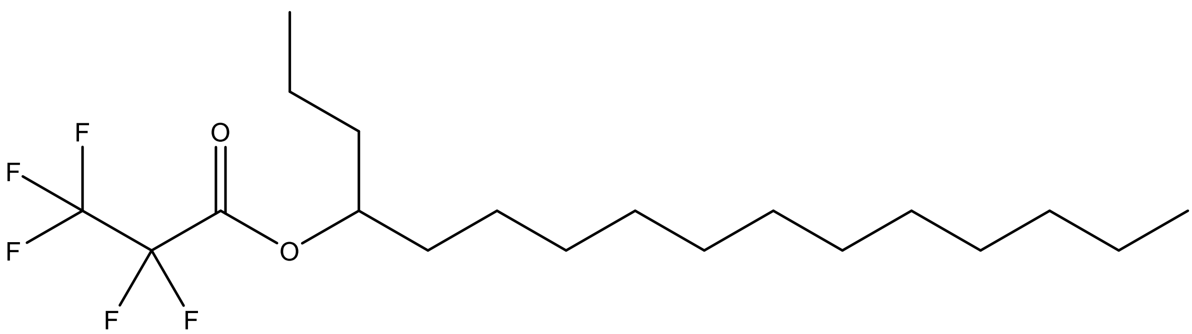
Benzoic acid, tetradecyl ester



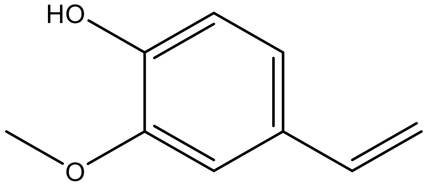
Formic acid, 3,7,11-trimethyl-1,6,10-dodecatrien-3-yl ester



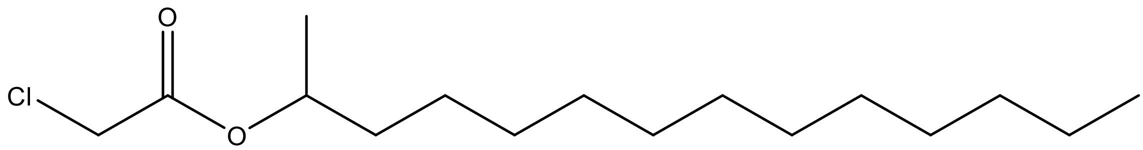
1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester



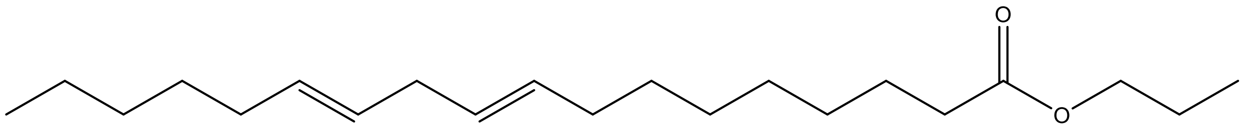
Pentafluoropropionic acid, 4-hexadecyl ester



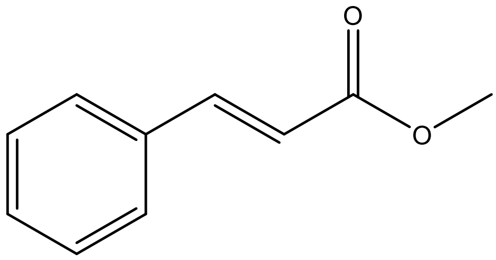
2-Methoxy-4-vinylphenol



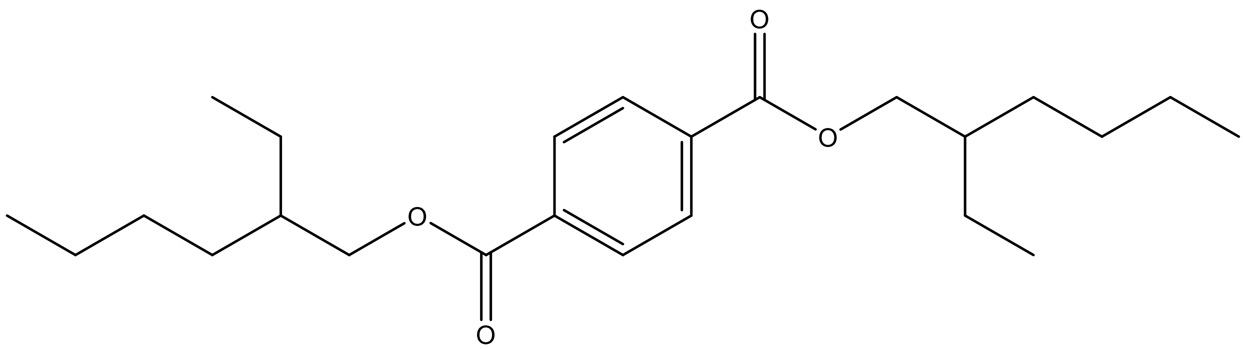
Chloroacetic acid, 2-tetradecyl ester



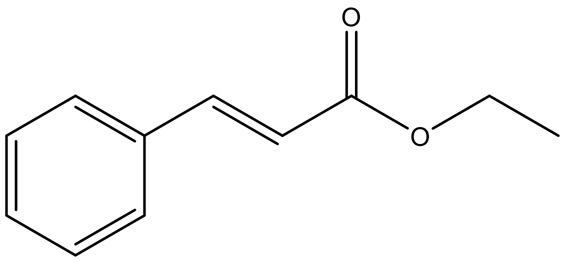
n-Propyl 9,12-octadecadienoate



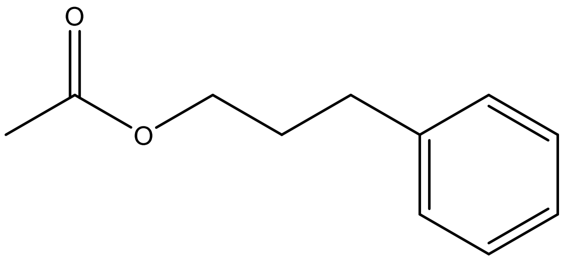
Methyl cinnamate



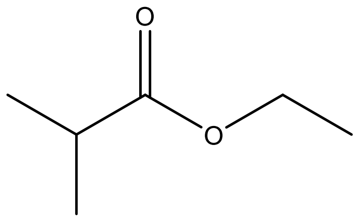
1,4-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester



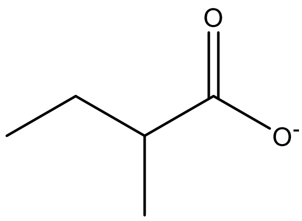
Ethyl cinnamate



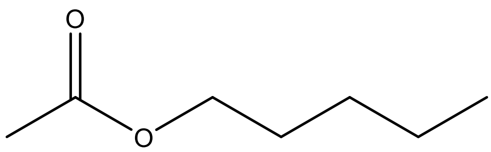
3-Phenyl-1-propanol acetate



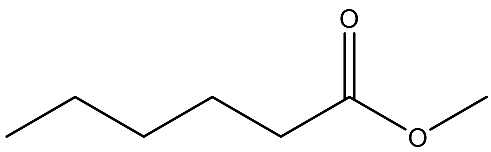
Ethyl-2-methylpropionate



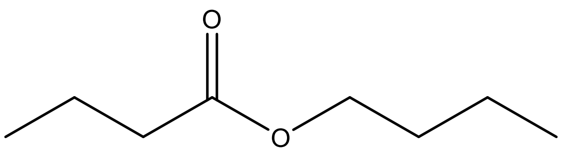
Methylbutanoate



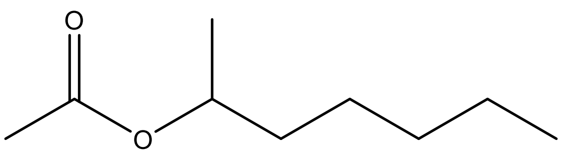
1-Pentyl acetate



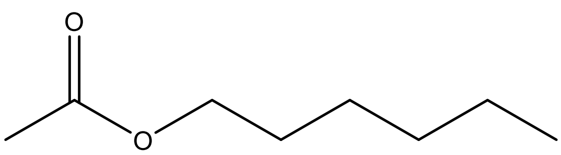
Methyl hexanoate



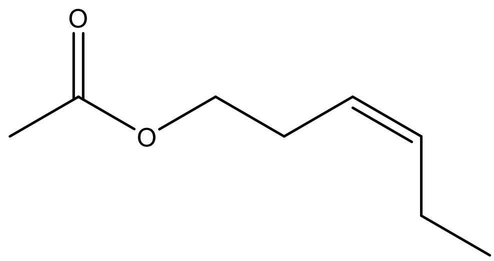
Butyl butanoate



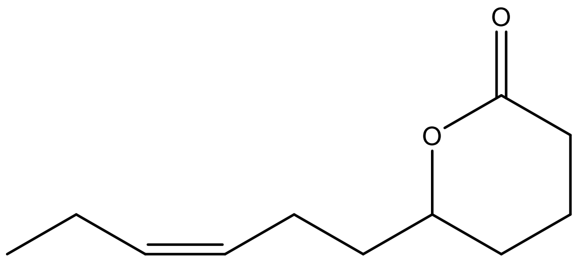
2-Heptyl acetate



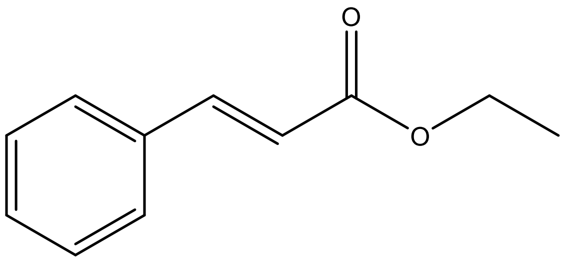
Hexyl acetate



(Z)-3-Hexenyl acetate

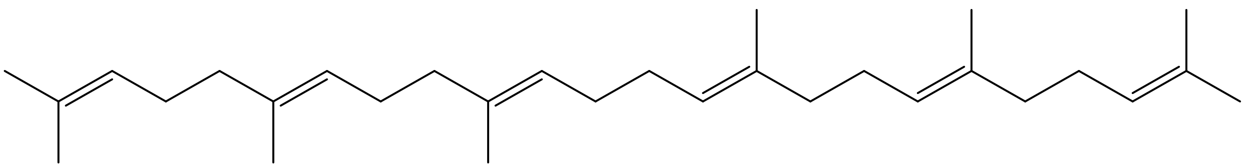


Ɣ-Jasmolactone

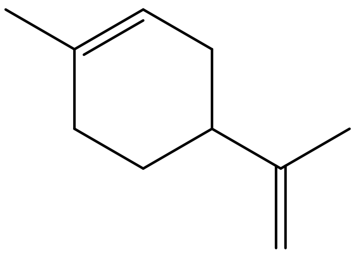


Ethyl cinnamate

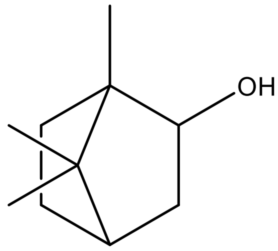
Appendix A36. Esters



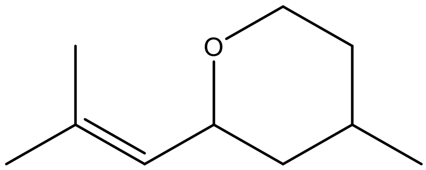
Squalene



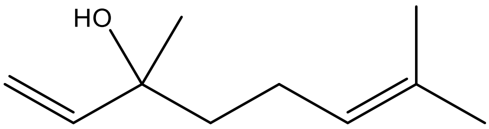
Limonene



Borneol

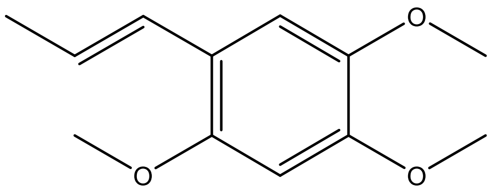


(Z)-Rose oxide



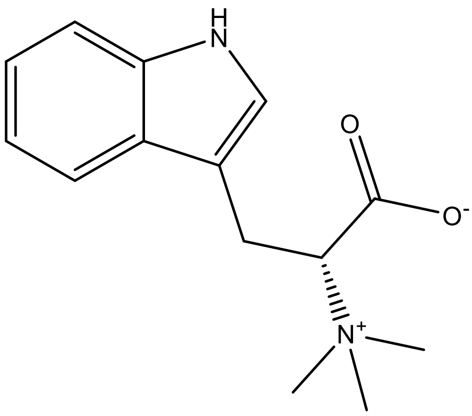
Linalool

Appendix A36. Terpenes



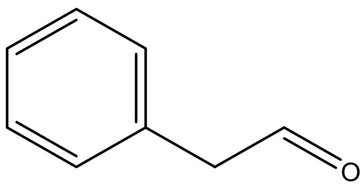
Asarone

Appendix A37. Phenylpropenes

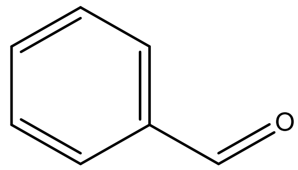


Hyperforin

Appendix A38. Phloroglucinols

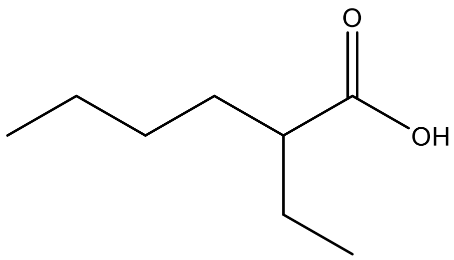


2-Phenylethanal

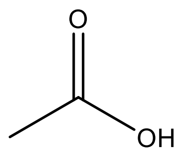


Benzaldehyde

Appendix A39. Aromatic

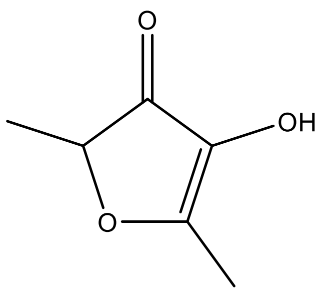


2-Ethyl hexanoic acid



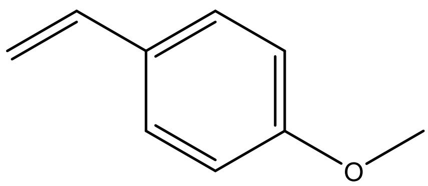
Acetic acid

Appendix A40. Carboxylic Acid



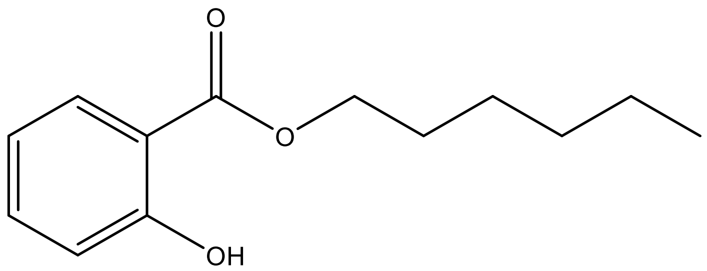
4-Hydroxy-2,5-dimethyl-3(2H)-furanone

Appendix A41. Furanone

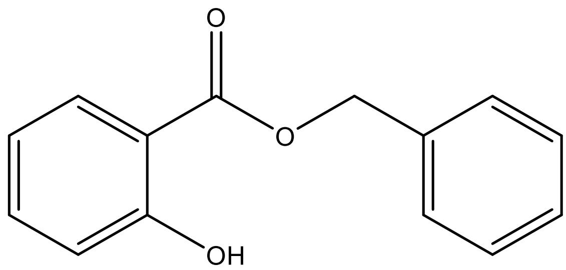


p-Vinylanisole

Appendix A42.Vinyl ethers

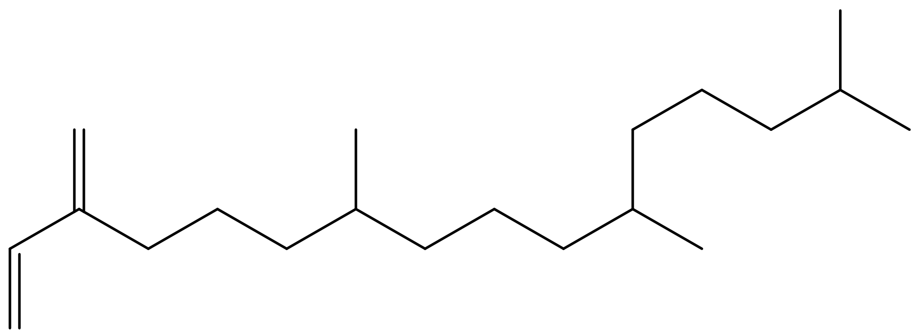


Hexyl salicylate



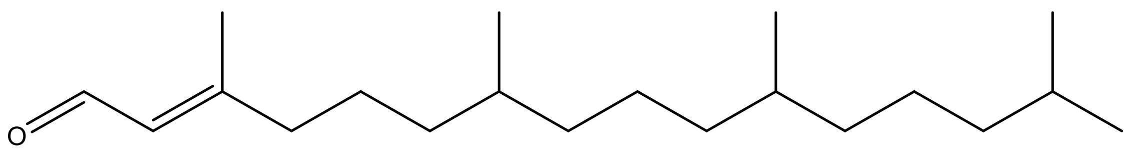
Benzyl salicylate

Appendix A43.Salicylic acid esters



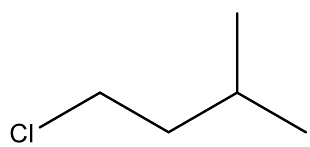
Neophytadiene

Appendix A44.Acyclic diterpene



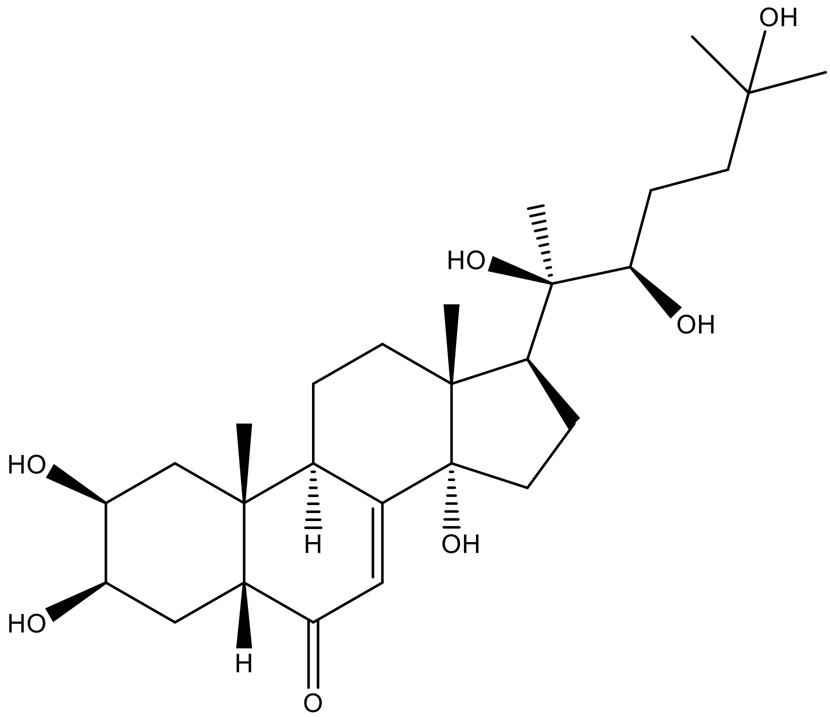
Phytone

Appendix A45.Lipids

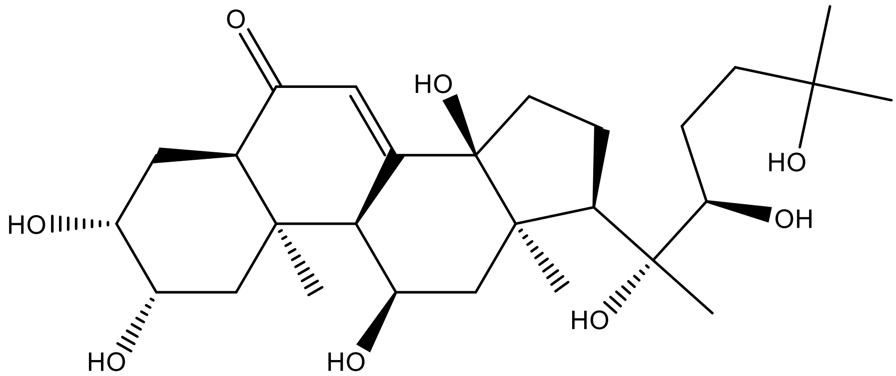


1-chloro-3-methyl-butane

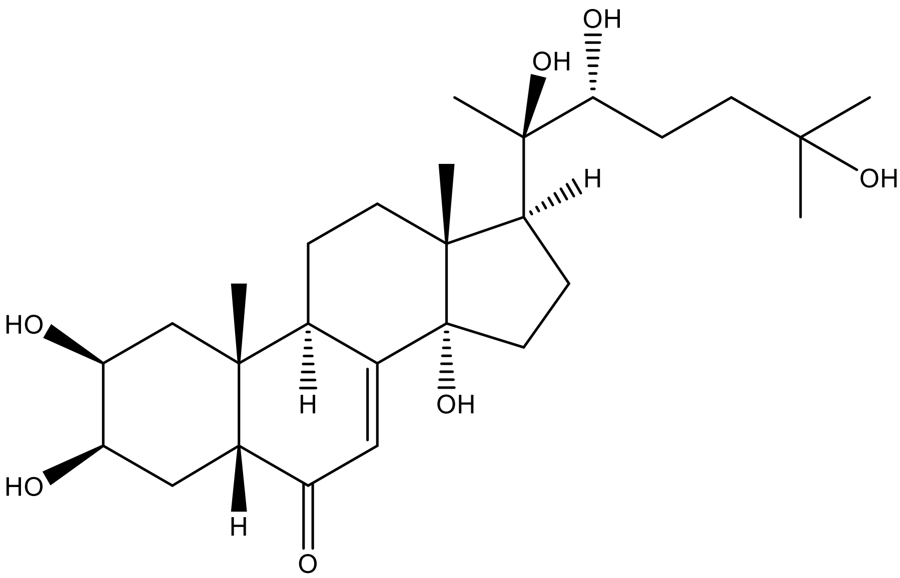
Appendix A46. Alkyl chlorides



20-hydroxyecdysone

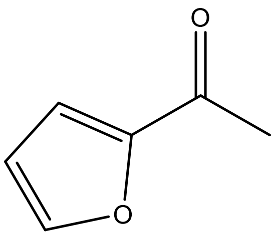


Turkesterone

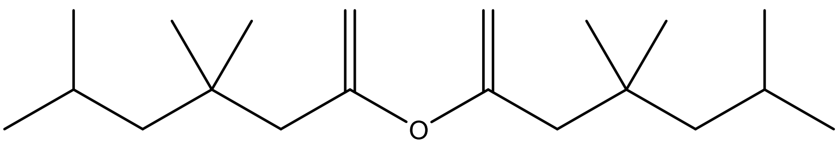


Ecdysterone

Appendix A47. Ecdysteroids

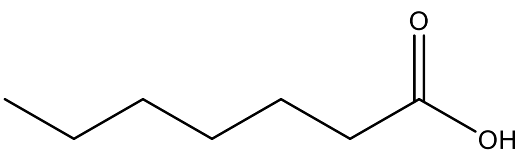


Acetylfuran



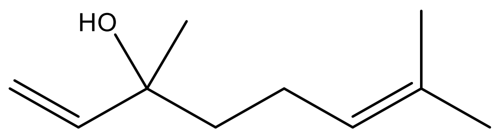
2,2,4-Trimethylpentylvinyl ether

Appendix A48. Ether

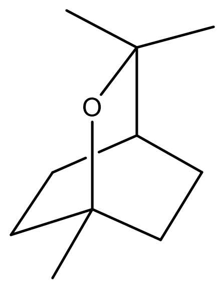


Heptanoic acid

Appendix A49. Carboxylic Acid

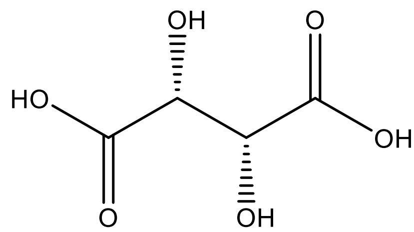


Linalool



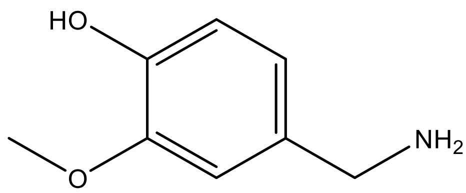
Eucalyptol

Appendix A50. Terpene



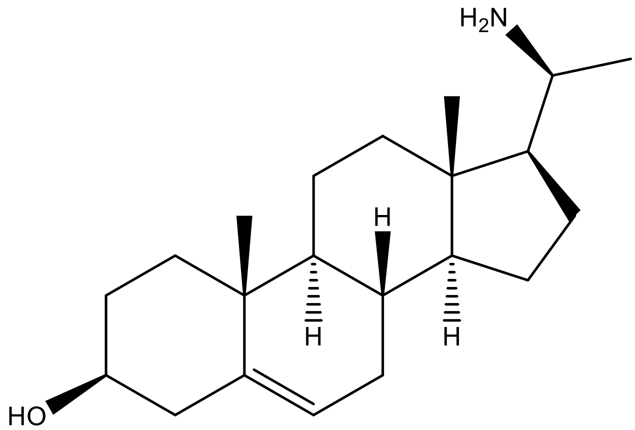
L-Tartaric acid

Appendix A51. Organic Acid



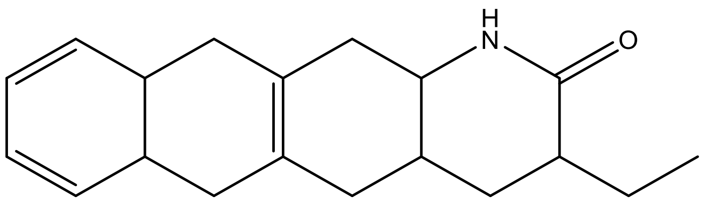
Vanillylamine

Appendix A52. Aromatic Amine



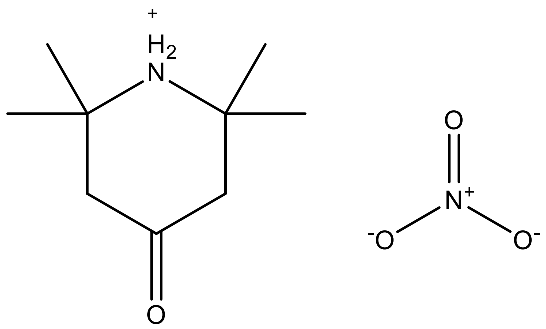
Pregn-5-en-3-ol, 20-amino-, (3.beta.,20S)-

Appendix A53. Steroids



3-ethyl-3,4,4a,5,6,6a,10a,11,12,12a-decahydro-1H-naphtho[2,3,-g]quinolin-2-one

Appendix A54. Naphthoquinolinone derivative



2,2,6,6-tetramethyl-4-oxo-piperidinium nitrate