Artemisia annua L. A review of its ethnobotanical history, bioactive compounds beyond Artemisinin, and pharmacological potentials

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Review

Abstract

Background: Plants are known to be reservoir of primary and secondary metabolites. Because secondary metabolites are naturally occurring compounds with the potential to improve human health, they are extremely important. *Artemisia annua* L. is used in traditional medicine to cure a wide range of conditions, such as coughs, diarrhea, malaria, and many more. Crude extracts and pure compounds of *Artemisia annua* L. have been the focus of numerous pharmacological investigations because of its extensive applications in traditional medicine. Existing review focuses on the plant application to treat malaria. Our search for relevant literature has yielded no comprehensive review of evaluations of *A. annua*. The review aimed to compile and evaluate its traditional uses, diverse chemical constituents, and its scientifically proven biological activities of *A. annua.*

Methods: Data on the *A. annua*, characteristic chemical constituents and biological activities were retrieved from internationally recognized scientific databases and reputable journals through online platforms such as Web of Science, PubMed, MDPI, Springer Nature, Wiley Online Library, and Elsevier. The World Flora Online (WFO) database (https://www.worldfloraonline.org) was used to taxonomically identify *A. annua*.

Results: The species traditionally has been used to cure various diseases such as malaria, cough, diarrhea, HIV, cancer, and others. It contains 251 different compounds under the groups of sesquiterpene, monoterpene, phenol, flavonoid and others. Pharmacologically, it has been reported to have some strong antioxidants, antibacterial, antimalarial, antiparasitic, and anticancer properties.

Conclusions: This review highlights dozens of non-artemisinin compounds have been identified; most of the *in vivo* research still uses crude extracts or pure artemisinin. Future work must focus on linking specific compounds, such as the flavonoids artemetin and casticin, to the observed *in vivo* anti-inflammatory, antiparasitic effects, anticancer and other biological activities.

Keywords: Artemisinin, Anticancer, Cytotoxicity, Drug discovery, Phytochemistry

Background

Plant resources have thus always been an important part of humans' history and have mostly been used as medicine and food and are now increasingly being used to treat common ailments (Dogara *et al.* 2025). The examination of medicinal plants uncovers numerous unique chemical compounds that provide advantageous pharmacological and therapeutic benefits. These materials can be utilized directly, or their extracts have served as precursors in the manufacture of medicinal compounds (Dogara *et al.* 2024). Research on medicinal plants has effectively fostered a strong impetus to identify lead compounds that confer advantages to human health.

Artemisia annua: Annual wormwood it has been successfully introduced into culture in many countries and in 2001 was recommended by WHO as the main source of artemisinin, a first-line therapy for malaria control. To date, countries producing artemisinin provide about a quarter of the world's health needs. 137 biologically active compounds, including 40 sesquiterpenes, 10 triterpenes, 7 coumarins, 46 flavonoids which can be the basis for drug synthesis, were sourced from *Artemisia annua* (Aadil *et al.* 2014; Hayat *et al.* 2009; Bussmann *et al.* 2025). It has been used to treat many diseases over the centuries, like malaria, and most well-known fever, inflammations bacterial infections and stomach related issues (Allen *et al.* 1997; Xinyan Han *et al.* 2022). Including artemisinin (Coroian *et al.* 2022), other key phytochemical compounds found in *A. annua* include flavonoids, essential oils, and phenolic acids, and coumarins, which all make a broad pharmacological profile (Abate *et al.* 2021).

Many scientific studies prove that *A. annua* is endowed with biologically active compounds, although, it is found to have anti-malarial effect because of artemisinin and its type (Liu *et al.* 1992). This plant too has shown to have strong anti-cancer activity (Zheng, 1994), its compounds, essential oils and crude extracts have been shown to have anti-bacterial and anti-fungal activities on several bacteria, fungi and protozoa (Donato *et al.* 2015). Recent study on artemisinin and its type have shown that this plant can be used for the treatment of many diseases (Coroian *et al.* 2022). It is therefore needed to create a comprehensive research that summarizes the traditional usage, chemical composition and biological activity. Also, the Importance of the plant in treatment has been realized because it is the only source of artemisinin, a sesquiterpene lactone that forms one of the most important drugs to treat malaria. In recent years, scientists have been giving more focus on the numerous biological actions of this plant. Thus, the extensive study is required to summarize and assess its conventional uses, various chemical components, and it's scientifically dated biological actions, other than artemisinin. The review will served as a means to identify the new medicinal uses of *A. annua* to justify its traditional use for future studies.

Methods

Data on *A. annua* and its unique chemical components and biological effects were found through well-known scientific resources and trusted journals through various online databases such as Web of Science, PubMed, MDPI, Springer Nature, Wiley Online Library and Elsevier. The search strategy incorporated the keyword "*Artemisia annua*, *A. annua, Artemisia, annua*" in combination with the following terms: "phenolic compounds," "flavonoids," "terpenoids," "alkaloids," "antioxidant," "antidiabetic," "antimicrobial," "anticancer," and "anti-hyperlipidemic." Taxonomic validation of *Artemisia annua* was conducted using the World Flora Online (WFO) database (https://www.worldfloraonline.org/). A review of all the relevant literature published until July 2025 was conducted to provide information on the phytochemical profiles and biological activities of *Artemisia annua*. The overall number of references included in this systematic review was 118 and covered 42 years (1984 to 2025) of research interest of this plant. Studies were included based on predefined criteria, and full-text articles were assessed for the presence of the search terms in their titles, abstracts, or main body text.

Synonyms of *A. annua*

Artemisia annua f. *annua*; *Artemisia annua* f. *macrocephala* Pamp.; *Artemisia chamomilla* C.Winkl.; *Artemisia exilis* Fisch. ex DC.; *Artemisia hyrcana* Spreng.; *Artemisia plumosa* Fisch. ex Besser; *Artemisia stewartii* C.B.Clarke; *Artemisia suaveolens* Fisch.; *Artemisia wadei* Edgew (Bussmann *et al.* 2025).

Botany and Ecology of *A. annua*

Annual. Plant aromatic, green, glabrous or with scattered, small, approximate hairs. Stems erect, ribbed, brownish or violet-brown, 30-100 cm high. Leaves alveolate-punctate-glandular; lower leaves petiolate, 3-5 cm long and 2-4; cm wide, ovate, thrice pinnately cut, their lobules oblong-lanceolate, short-acuminate, entire or with 1-2 teeth, 1-2 mm long and 0.5 mm wide; middle and cauline leaves twice pinnately cut; upper leaves sessile smaller and less compound; uppermost leaves bracteal, simple or with fewer lateral lobes. Capitula globose, 2.0-2.5 mm in diameter, numerous, divergent or drooping, on short peduncles, approximate on short branches, usually in long pyramidal paniculate inflorescence. Involucre glabrous. Outer involucral bracts linear-oblong, green; inner oval or almost round, with wide scarious border, lustrous. Receptacle convex, glabrous. Peripheral florets pistillate, 10-20, filiform, punctate-glandular; their stigma lobes narrowly linear, obtuse, exserted from corolla tube; disk florets bisexual, 12-30, their corollas cup-shaped-tubular, glabrous; anthers narrowly linear, apical appendages of anthers long, acute, basal appendages very short, subacute; style shorter than stamens, stigma lobes linear, straight, weakly divergent, apically ciliate. Achenes 0.8-0.6 mm long, oblongovate, flattened, with small round areola at apex, scarcely bordered. Flowering August-September. Ural, Caucasus, Altai, Middle Asia, in meadows, sandy areas, on rocks, solonetzous steppes, floodplain forests, river valleys and on their shores, fields, near settlements, along roads as weed.

On ruderal places, roadsides, in gardens and orchards, near water streams, in lower and middle mountain belts, on the elevation 700-1700 m. Flowers from July to September, fruits from August to October (Bussmann *et al.* 2025).

Ethnobotany of *A. annua*

Artemisia annua leaves are used as anthelmintic, for respiratory infections, fever, dysentery, and externally for rheumatism and scabies. *Artemisia annua* is used as anti-malarial in the Himalayas (Bussmann *et al.* 2025). In medieval Armenian medicine it was recommended to treat fevers, hemorrhoids, diseases of the stomach, liver, spleen, and bladder and kidney stones. A decoction and extract as tea is used to treat colds. Fresh crushed leaves, as well as their decoction and extract are used crushed and as soaking therapy for furuncles and abscess. A decoction and extract is used as tea in dysentery and fever (Bussmann *et al.* 2025). Tea made from leaves of *Artemisia annua* helps to cure wounds, when applied as poultice and serves as insect repellant. The extract and fresh leaves are also applied externally on wounds and burns. In the Altai extracts are used for testicles and uterus cancer. In Azerbaijan an extract is used to treat fractures (Bussmann *et al.* 2025). In the Ural, Northern Caucasus and parts of Middle Asia *Artemisia annua* leaves are used as anthelmintic, for respiratory infections, fever, dysentery, and externally for rheumatism and scabies. In Morocco, a decoction of leaves is used to treat infection problems. Leaves used as herbal tea. In modern traditional medicine of Tajikistan and Uzbekistan juice of fresh leaves of a one-year sage-brush dermal diseases - scabies, pustular diseases, herpes. From dry leaves prepare 10% ointment for treatment of eczema. Scientific research taped antioxidant, anti-inflammatory, analgetic, sedative, antibacterial, antiviral, hypolipidemic, antitumoral properties (Bussmann *et al.* 2025). In many countries the Annual Wormwood is an official antimalarial and anti-leishmaniasis agent. Its immunosuppressive, antirheumatic, contraceptive, anticholinesterase properties are perspective. In Kashmir, Jammu and Ladakh to treat jaundice (Bussmann *et al.* 2025).

In Pakistan, the whole plant and leaves of *A. annua* are used to treat malaria, cough, and common cold. A decoction of the entire plant is prepared for malaria, while leaves are used for fever, cough, and cold symptoms. Powdered leaves are also employed against diarrhea, and the oil is valued in local fragrances due to its pleasant aroma (Aadil *et al.* 2014; Hayat *et al.* 2009). In India, the root is utilized for abdominal pain, with an infusion taken orally (Khoja *et al.* 2022; Mir *et al.* 2021). A recent study showed that some parts of *A. annua* including leaves, whole plant, young shoots, and bark are used to treat prostate problems and malaria in Congo and these are crushed in either decoction, infusion, maceration, or direct use (Muhesi *et al.* , 2023). The use of leaves and whole plant to treat malaria were also reported in Burundi, and it is also processed by way of decoction or infusion and ingested orally (Havyarimana *et al.* 2023). Moreover, it is also reported in Nigeria that, the leaves are decocted to treat hypertension, measles, malaria, and diabetes, and the extract is used to apply directly to treat skin conditions (Abdulrahman *et al.* 2022). Also, leaves and tea are popular for the treatment of malaria, eczema, and scabies in China, and decoctions are reportedly taken orally (Allen *et al.* 1997; Xinyan Han *et al.* 2022). Kenya uses leaves, tea, and the whole plant for replaced with, diarrhea, stomach pain, HIV, and malaria infusion or decoction (Willcox *et al.* 2011). Cameroonians used leaves infused for HIV (Noumi *et al.* 2011). Based on ethnobotanical data obtained, *A. annua* is used more frequently by different cultures to treat many diseases with the most common being malaria. The leaf and the whole aerial part of the plant are the most commonly used organ of the plant and are usually used orally as decoction or infusion. The most used part of the plant is the leaf and entire aerial component which is usually used in oral form as a decoction or infusion. There are regional differences (with reported use of roots in India to treat abdominal pain and leaves in Nigeria to treat diabetes and skin conditions). The similarity of the method of preparation, such as decoctions and infusions, across nations indicates the presence of common knowledge in traditional medicine. This prevalence of use of A. annua in traditional systems of medicine emphasizes the significance of this herb in these systems and justifies the fact that additional scientific evidence is needed to confirm its ethnomedicinal statements.

Local food uses of A. annua

In the Caucasus Flowering shoots of *A. annua* are sometimes used as a seasoning for meat and fish dishes (usually as substitute of *Artemisia dracunculus*). Likewise, *Artemisia annua* is used in food as aromatic and tasty seasoning for different meals. The herb of this variety of wormwood is used as a seasoning for food. The leaves are used as flavoring agent for liquors and as spice for cooking. (Bussmann *et al.* 2025).

Local handicraft and other uses of A. annua

In the Caucasus fodder for livestock, especially sheep, goats and camels. Planted as ornamental. A tincture made from leaves helps to heal wounds of cattle. A dye solution is prepared from leaves to obtain tobacco, green, yellow and olive colors. The solution is used for dyeing wool yarn as well as products made of wool (Bussmann *et al.* 2025).

Chemical composition of *A. annua*

The phytochemistry of *A. annua* is highly diverse with different classes of specialized metabolites (Table 1 and Fig. 1). Phenolic compounds form the largest and most varied group in the *A. annua* metabolome, underlining the strong phenylpropanoid pathway of this plant (Fig. 1). This large family encompasses simple phenols, phenolic acids, and the complex derivatives of these, which are powerful antioxidants and the key components of the plant's chemical defense system (Table 1).This great diversity encompasses widespread flavonoids such as quercetin and kaempferol glycosides along with more specialized methoxylated flavones such as artemetin and casticin. Sesquiterpenes are one of the pillars of this profile, and the most famous member of this family is artemisinin (Brown, 2010; Tu, 2011). After the outbreak of strains of

malaria that are resistant to the use of chloroquine, the Chinese government initiated the Project 523 in 1967 to find new antimalarial drugs using traditional remedies. *Artemisia annua* L. (qinghao) was the target of the research because it is a plant mentioned in ancient medical writings in China as a remedy of fever and chills. This discovery gave birth to the active compound, artemisinin which was later isolated in 1972 (Ma *et al.* 2020)

Having Monoterpenes in small amounts are thought to be the reason for its biological activities. Apart from these main classes, *A. annua* produces some other types of special metabolites such as anthocyanins, lignans, coumarins and a wide range of volatile aromatic compounds. This chemical stockpile mirrors the plant's complex metabolic diplomacy and provides a chemical foundation for its biological activities and likely synergies. Besides the detailed phytochemical analysis of *A. annua* unveils a plant of never seen before molecular intricacy whose drug effects cannot be linked to one substance but instead depend on the group of chemical types of diversity. A diverse range of polyphenols could be a sign of a synergistic relation to the better known sesquiterpene lactones which could increase artemisinin bioavailability and efficacy and decrease parasitic resistance (Elfawal *et al.* 2012; Weathers *et al.* 2014). The complex interplay of the component classes, the potent sesquiterpenes, the supporting and synergistic flavonoids and phenolics, and the required structural terpenoids, creates a strong phytochemical matrix from the species.

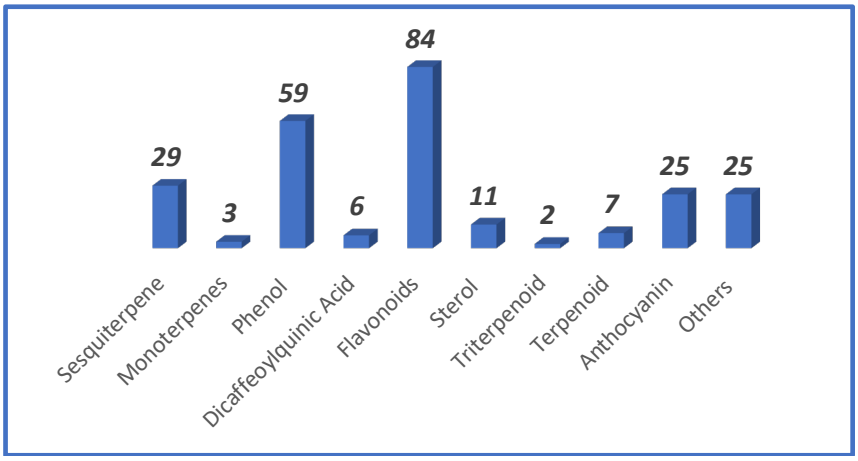

Figure 1. Classes of Compounds of *A. annua* (source author)

Biological activities

***A. annua* Antioxidant activities**

The mechanism of action of *A. annua* involves an antioxidant effect, stopping damage biological systems by oxidative stress, which is a part of the 'stress and immune system' activities of the substance in the living organism. The major mechanism is a powerful, multi-channel antioxidant activity mediated by phenolic compounds and flavonoids as evidenced by the dramatic reduction of activity that occurred after enzyme treatment that empties the compounds (Wan *et al.* 2016). This practice is exhibited by: ABTS, DPPH, nitric oxide (Free radical scavenging) (Ryu *et al.* 2011; Ćavar *et al.* 2012).Power (FRAP assay) reduction (Skowyra *et al.* 2014; Ryu *et al.* 2011). Chelation of metals (Ryu *et al.* 2011; Ćavar *et al.* 2012). Blockage of lipid peroxidation (Iqbal *et al.* 2012; Chukwurah *et al.* 2014).

Administration of *A. annua* mitigates physiological stress by reducing plasmatic glucose and cortisol (Soares *et al.* 2020) and simultaneously promotes immune-protecting functions by increasing leukocyte activity, the presence of lysozyme and antibodies, and the volume of immune organs (Gholamrezaie *et al.* 2013; Soares *et al.* 2020). Similarly, one of the components of this combined effect is the antioxidant effect on the reduction of the level of lipid peroxidation (Soares *et al.* 2020).

Artemisia annua extracts exhibit a significant in vitro antioxidant activity and the strength of extraction depends on plant part, solvent used and assay type (Table 2). The overall antioxidant activity of the methanol leaf extract typically demonstrates the highest values of Trolox Equivalent Antioxidant Capacity (TEAC) and the greatest potency of lipid peroxidation inhibition (Iqbal *et al.* 2012; Skowyra *et al.* 2014). Flower and leaf extracts are always the most active when compared by part of the plant, especially when testing 2,2-diphenyl-1-picrylhydrazyl (DPPH) and 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) radical scavenging assays (Song *et al.* 2016). Moreover, with the use of enzymatic treatment, the phenol and flavonoid content is dramatically decreased, which proves the presence of these compounds as one of the main contributors to the antioxidant activity of the plant (Wan *et al.* 2016). It was shown that *A. annua* administration possesses a potent immunomodulatory effect *in vivo.* Food supplementation promotes cellular and humoral immunity, which is reflected in the increased leukocyte activity, antibody titers, and weights of immune organs such as the thymus (Gholamrezaie *et al.* 2013; Soares *et al.* 2020). Simultaneously, it eliminates physiological stress significantly decreasing the plasma cortisol, glucose, and lipid peroxidation (Soares *et al.* 2020).

Table 1. Chemical Composition of *A. annua*

Plant Part	Compound	Class	Molecular formula	Reference
Seeds	1β-Hydroxy-4(15),5-eudesmadiene	Sesquiterpene	$C_{15}H_{24}O$	(Brown *et al.* 2003)
	1β-Hydroxy-4(15),7-eudesmadiene		$C_{15}H_{24}O$	
	5α-Hydroperoxy-eudesma-4(15),11-diene		$C_{15}H_{24}O_2$	
	4α,5α-Epoxy-6α-hydroxy amorphan-12-oic acid		$C_{15}H_{22}O_4$	
	4α,5α-Epoxy-6α-hydroxy amorphan-12-ol		$C_{15}H_{26}O_3$	
	1-Oxo-2β-[3-butanone]-3α-methyl-6β-[2-propanol formyl ester]-cyclohexane		$C_{15}H_{24}O_5$	
	1-Oxo-2β-[3-butanone]-3α-methyl-6β-[2-propanoic acid]-cyclohexane		$C_{15}H_{22}O_4$	
	1α-Aldehyde-2β-[3-butanone]-3α-methyl-6β-[2-propanoic acid]-cyclohexane		$C_{15}H_{22}O_4$	
	α-Epoxy-dihydroartemisinic acid		$C_{15}H_{22}O_3$	
	Norannuic acid formyl ester		$C_{14}H_{22}O_2$	
	3α-Hydroxy-4α,5α-epoxy-7-oxo-(8(7→6))-abeo-amorphane		$C_{15}H_{22}O_4$	
	15-nor-10-hydroxy-ophopan-4-oic acid		$C_{14}H_{22}O_3$	
	3α,7α-Dihydroxy amorph-4-ene 3-acetate		$C_{17}H_{28}O_4$	
	3α,15-Dihydroxycedrane		$C_{15}H_{26}O_2$	
	Artemisinic acid		$C_{15}H_{22}O_2$	(Brown, 2010; Kohler *et al.* 1997; Zheng, 1994)
	Arteannuin B		$C_{15}H_{22}O_5$	(Abate *et al.* 2021; Lang *et al.* 2019; Sy *et al.* 1998; Zheng, 1994)
	Artemisitene		$C_{15}H_{18}O_4$	(Abate *et al.* 2021; Acton *et al.* 1985)
Aerial part	Artemisinin (Qinghaosu)		$C_{15}H_{22}O_5$	(Abate *et al.* 2021; Acton *et al.* 1985; Carbonara *et al.* 2012; De Jesus-Gonzalez *et al.* 2003; Foglio *et al.* 2002; Hao *et al.* 2002; Klayman *et al.* 1984; Kohler *et al.* 1997; Liu *et al.* 1992; Sy *et al.* 1998; Woerdenbag *et al.* 1993; Zheng, 1994)
	Arteannuic acid		$C_{15}H_{22}O_2$	(Lang *et al.* 2019)
	Qinghaosu I and III		$C_{15}H_{22}O_5$	(TU *et al.* 2015)

	Dihydro-epideoxyarteannuin B		$C_{15}H_{24}O_4$	(Brown, 1992; Foglio *et al.* 2002)
	Deoxyartemisinin		$C_{15}H_{22}O_4$	(Foglio *et al.* 2002; Zheng, 1994)
	Dihydroartemisinin		$C_{15}H_{24}O_5$	(Abate *et al.* 2021; Carbonara *et al.* 2012)
	3α,7-Dihydroxy-cadin-4-ene		$C_{15}H_{26}O_2$	(Sy *et al.* 1998)
	5α-Hydroxy-eudesma-4(15),11-diene		$C_{15}H_{24}O$	
	Artemisinic acid methyl ester		$C_{16}H_{24}O_2$	
	3α-Hydroxy-desoxyartemisinin		$C_{15}H_{24}O_4$	
	Dihydroarteannuin B		$C_{15}H_{24}O_5$	
	Dihydroartemisinic acid		$C_{15}H_{24}O_2$	(Abate *et al.* 2021; Sy *et al.* 1998)
	4-Hydroxy-2-isopropenyl-5-methylene-hexan-1-ol	Monoterpene	$C_{10}H_{16}O_2$	(Juteau *et al.* 2002)
	1,10-Oxy-α-myrcene hydroxide		$C_{10}H_{18}O_2$	
	1,10-Oxy-β-myrcene hydroxide		$C_{10}H_{18}O_2$	
	Chlorogenic Acids	Phenol	$C_{16}H_{18}O_9$	(Carbonara *et al.* 2012)
	Caffeic acid		$C_9H_8O_4$	
	Quinic acid		$C_7H_{12}O_6$	
	5-Nonadecylresorcinol-3-O-methyl ether		$C_{26}H_{46}O_2$	(Brown, 1992)
Aerial parts	1,3-di-O-Caffeoylquinic acid		$C_{25}H_{24}O_{12}$	(Abate *et al.* 2021)
	Acetyl eugenol		$C_{12}H_{14}O_3$	
	4,5-di-O-Caffeoylquinic acid		$C_{25}H_{24}O_{12}$	
	4-Ethylphenol		$C_8H_{10}O$	
	4-Vinylphenol		C_8H_8O	
	5-Nonadecenylresorcinol		$C_{25}H_{42}O_2$	
	5-Pentacosenylresorcinol		$C_{31}H_{54}O_2$	
	5-Pentacosylresorcinol		$C_{31}H_{56}O_2$	
	2,3-Dihydroxy-1-guaiacylpropanone		$C_{10}H_{12}O_5$	
	2-Methoxy-5-prop-1-enylphenol (Eugenol)		$C_{10}H_{12}O_2$	
	3,4-DHPEA-EA (Hydroxytyrosol acetate)		$C_{10}H_{12}O$	
	Ferulaldehyde		$C_{10}H_{10}O_3$	
	Hydroxytyrosol		$C_8H_{10}O_3$	
	Hydroxytyrosol 4-O-glucoside		$C_{14}H_{20}O_8$	
	p-HPEA-EDA (Oleocanthal)		$C_{17}H_{20}O_5$	
	Phenol		C_6H_6O	
	Phlorin (Phloroglucinol glucoside)		$C_{12}H_{16}O_7$	
	Pyrogallol		$C_6H_6O_3$	
	3-Hydroxybenzoic acid		$C_7H_6O_3$	
	Ellagic acid glucoside		$C_{20}H_{16}O_{13}$	
	Gallic acid ethyl ester		$C_9H_{10}O_5$	
	Syringic acid		$C_9H_{10}O_5$	
	Gallic acid		$C_7H_6O_5$	
	5-O-Galloylquinic acid		$C_{14}H_{16}O_{10}$	
	Ellagic acid arabinoside		$C_{19}H_{14}O_{12}$	
	Valoneic acid dilactone		$C_{27}H_{18}O_{17}$	
	2,6-Dihydroxybenzoic acid		$C_7H_6O_4$	
	3,5-Dihydroxybenzoic acid		$C_7H_6O_4$	
	Gentisic acid		$C_7H_6O_4$	
	Protocatechuic acid		$C_7H_6O_4$	
	Avenanthramide 2f		$C_{18}H_{17}NO_5$	
	3,4-Diferuloylquinic acid		$C_{34}H_{32}O_{12}$	

	3,5-Diferuloylquinic acid		$C_{34}H_{32}O_{12}$	
	p-Coumaroyl glucose		$C_{15}H_{18}O_8$	
	2,5-di-S-Glutathionyl caftaric acid		$C_{34}H_{42}N_6O_{19}S_2$	
	Hydroxy caffeic acid		$C_9H_8O_5$	
	Ferulic acid 4-O-glucoside		$C_{16}H_{20}O_9$	
	Feruloyl glucose		$C_{16}H_{20}O_9$	
	3-p-Coumaroylquinic acid		$C_{16}H_{18}O_8$	
	4-p-Coumaroylquinic acid		$C_{16}H_{18}O_8$	
	5-p-Coumaroylquinic acid		$C_{16}H_{18}O_8$	
	p-Coumaroylquinic acid		$C_{16}H_{18}O_8$	
	1,2'-Disinapoyl-2-feruloylgentiobiose		$C_{53}H_{58}O_{27}$	
	Avenanthramide 2c		$C_{17}H_{15}NO_5$	
	Avenanthramide K		$C_{21}H_{21}NO_7$	
	Methyl-3,4-di-O-caffeoylquinic acid		$C_{26}H_{26}O_{12}$	
	Methyl-3,5-di-O-caffeoylquinic acid		$C_{26}H_{26}O_{12}$	
	5-8'-Dehydrodiferulic acid		$C_{20}H_{18}O_6$	
	8-O-4'-Dehydrodiferulic acid		$C_{20}H_{18}O_6$	
	Verbascoside		$C_{29}H_{36}O_{15}$	
	3-Caffeoylquinic acid		$C_{16}H_{18}O_9$	
	4-Caffeoylquinic acid		$C_{16}H_{18}O_9$	
	5-Caffeoylquinic acid		$C_{16}H_{18}O_9$	
	Caffeic acid 4-O-glucoside		$C_{15}H_{18}O_9$	
	Caffeoyl glucose		$C_{15}H_{18}O_9$	
	3,4-Dicaffeoylquinic acid	Dicaffeoylquinic Acid	$C_{25}H_{24}O_{12}$	(Carbonara *et al.* 2012)
	3,5-Dicaffeoylquinic acid		$C_{25}H_{24}O_{12}$	
	4,5-Dicaffeoylquinic acid		$C_{25}H_{24}O_{12}$	
	3,4-Diferuloylquinic acid		$C_{34}H_{32}O_{12}$	
	3,5-Diferuloylquinic acid		$C_{34}H_{32}O_{12}$	
	4,5-Diferuloylquinic acid		$C_{34}H_{32}O_{12}$	
	Vitexin	Flavonoid	$C_{21}H_{20}O_{10}$	(Carbonara *et al.* 2012)
	Isovitexin		$C_{21}H_{20}O_{10}$	
	6-C-arabinosyl-8-C-glucosyl apigenin		$C_{26}H_{28}O_{15}$	
	6-C-glucosyl-8-C-arabinosyl apigenin		$C_{26}H_{28}O_{15}$	
	Luteolin-7-O-glucoside		$C_{21}H_{20}O_{11}$	
	Chrysoeriol rutinoside		$C_{28}H_{32}O_{15}$	
	Patuletin glycoside		$C_{22}H_{22}O_{12}$	
	Jaceidin		$C_{18}H_{16}O_8$	
	Cirsilineol		$C_{18}H_{16}O_7$	(Abate *et al.* 2021; Carbonara *et al.* 2012; Sy *et al.* 1998)
	Eriodictyol		$C_{15}H_{12}O_6$	(Carbonara *et al.* 2012)
	Chrysosplenetin		$C_{19}H_{18}O_8$	(Brown, 1992; Sy *et al.* 1998)
	Coumarin		$C_9H_6O_2$	(Brown, 1992)
	Scopoletin		$C_{10}H_8O_4$	(Abate *et al.* 2021; Carbonara *et al.* 2012)
	Artemetin		$C_{20}H_{20}O_8$	(Abate *et al.* 2021; Brown, 1992; Sy *et al.* 1998; Zheng, 1994)
	5-Hydroxy-3,6,7,4′-methoxyflavone		$C_{18}H_{16}O_7$	(Carbonara *et al.* 2012)

	Quercetagetin 6,7,3',4'-tetramethyl ether		$C_{19}H_{18}O_8$	(Zheng, 1994)
	Chrysosplenol D		$C_{18}H_{16}O_7$	(Abate *et al.* 2021; Lang *et al.* 2019)
	Casticin		$C_{19}H_{18}O_8$	(Lang *et al.* 2019; Liu *et al.* 1992)
	5-Hydroxy-3,4',6,7-tetramethoxyflavone		$C_{19}H_{18}O_8$	(Sy *et al.* 1998)
	Penduletin		$C_{18}H_{16}O_7$	
	Retusin		$C_{20}H_{20}O_7$	
	Pachypodol		$C_{20}H_{20}O_7$	
	Eupatorin		$C_{18}H_{16}O_7$	(Abate *et al.* 2021; Liu *et al.* 1992)
Aerial parts	Dihydroquercetin 3-O-rhamnoside		$C_{21}H_{22}O_{11}$	(Abate *et al.* 2021)
	Eriodictyol 7-O-glucoside		$C_{21}H_{22}O_{11}$	
	Dihydroquercetin		$C_{15}H_{12}O_7$	
	(-)-Epigallocatechin		$C_{15}H_{14}O_7$	
	(+)-Gallocatechin		$C_{15}H_{14}O_7$	
	Theaflavin 3,3'-O-digallate		$C_{43}H_{32}O_{20}$	
	Prodelphinidin dimer B3		$C_{30}H_{26}O_{13}$	
	(-)-Epicatechin 3-O-gallate		$C_{22}H_{18}O_{10}$	
	(+)-Catechin 3-O-gallate		$C_{22}H_{18}O_{10}$	
	Narirutin 4'-O-glucoside		$C_{33}H_{42}O_{19}$	
	Didymin		$C_{28}H_{34}O_{14}$	
	Poncirin		$C_{28}H_{34}O_{14}$	
	6-Geranylnaringenin		$C_{25}H_{28}O_4$	
	Naringin 6'-malonate		$C_{33}H_{40}O_{16}$	
	Apigenin 7-O-diglucuronide		$C_{27}H_{26}O_{17}$	
	Luteolin 6-C-glucoside		$C_{21}H_{20}O_{11}$	
	Luteolin 7-O-glucoside		$C_{21}H_{20}O_{11}$	
	Pebrellin		$C_{22}H_{22}O_{12}$	
	Luteolin 7-O-diglucuronide		$C_{27}H_{26}O_{18}$	
	Apigenin 7-O-(6''-malonyl-apiosyl-glucoside)		$C_{29}H_{30}O_{17}$	
	Arcapillin		$C_{18}H_{16}O_8$	
	Luteolin 7-O-glucuronide		$C_{21}H_{18}O_{12}$	
	Kaempferol 3-O-glucuronide		$C_{21}H_{18}O_{12}$	
	Luteolin 7-O-malonyl-glucoside		$C_{24}H_{22}O_{14}$	
	5,4'-Dihydroxy-3,3'-dimethoxy-6:7-methylenedioxyflavone 4'-O-glucuronide		$C_{25}H_{22}O_{15}$	
	Gardenin B		$C_{19}H_{18}O_8$	
	7,3',4'-Trihydroxyflavone		$C_{15}H_{10}O_5$	
	Baicalein		$C_{15}H_{10}O_5$	
	Hispidulin		$C_{16}H_{12}O_6$	
	Diosmin		$C_{28}H_{32}O_{15}$	
	Neodiosmin		$C_{28}H_{32}O_{15}$	
	Kaempferide		$C_{16}H_{12}O_6$	
	Myricetin 3-O-arabinoside		$C_{20}H_{18}O_{12}$	
	Kaempferol 3-O-(2''-rhamnosyl-6''-acetyl-galactoside) 7-O-rhamnoside		$C_{36}H_{44}O_{20}$	
	Myricetin 3-O-glucoside		$C_{21}H_{20}O_{13}$	
	Quercetin 3-O-rhamnosyl-rhamnosyl-glucoside		$C_{33}H_{40}O_{21}$	
	Kaempferol 3-O-glucosyl-rhamnosyl-glucoside		$C_{33}H_{40}O_{20}$	
	3-Methoxynobiletin		$C_{22}H_{22}O_9$	
	Kaempferol 3-O-(2''-rhamnosyl-galactoside) 7-O-rhamnoside		$C_{33}H_{40}O_{19}$	
	Kaempferol 3-O-xylosyl-rutinoside		$C_{32}H_{38}O_{19}$	

	Kaempferol 3-O-glucosyl-rhamnosyl-galactoside		$C_{33}H_{40}O_{20}$	
	Rhamnetin		$C_{16}H_{12}O_7$	
	Isorhamnetin		$C_{16}H_{12}O_7$	
	Kaempferol 3-O-rhamnosyl-rhamnosyl-glucoside		$C_{33}H_{40}O_{20}$	
	Quercetin 3-O-glucoside		$C_{21}H_{20}O_{12}$	
	5,3',4'-Trihydroxy-3-methoxy-6:7-methylenedioxyflavone 4'-O-glucuronide		$C_{24}H_{20}O_{15}$	
	Isorhamnetin 7-O-rhamnoside		$C_{22}H_{22}O_{11}$	
	Quercetin 3-O-galactoside		$C_{21}H_{20}O_{12}$	
	Patuletin 3-O-(2''-feruloylglucosyl)(1-6)-[apiosyl(1-2)]-glucoside		$C_{43}H_{48}O_{24}$	
	Isorhamnetin 3-O-glucoside		$C_{22}H_{22}O_{12}$	
	Myricetin 3-O-rhamnoside		$C_{21}H_{20}O_{12}$	
	Quercetin 4'-O-glucoside		$C_{21}H_{20}O_{12}$	
	Jaceidin 4'-O-glucuronide		$C_{24}H_{22}O_{15}$	
	Myricetin		$C_{15}H_{10}O_8$	
	Daidzin		$C_{21}H_{20}O_9$	
	Biochanin A		$C_{16}H_{12}O_5$	
	Glycitein		$C_{16}H_{12}O_5$	
	Isorhamnetin 3-O-glucoside 7-O-rhamnoside		$C_{28}H_{32}O_{16}$	
	6,8-Dihydroxykaempferol		$C_{15}H_{10}O_8$	
	Glycitin		$C_{22}H_{22}O_{10}$	
	6''-O-Malonylgenistin		$C_{24}H_{22}O_{12}$	
Leaves	Stigmasterol	Sterol	$C_{29}H_{48}O$	(Zheng, 1994)
	Ergosterol		$C_{28}H_{44}O$	(Lu *et al.* 2000)
	3β,5α,6β-Trihydroxyergosta-7,22-diene		$C_{28}H_{46}O_3$	
	3β-Hydroxy-ergosta-5-ene		$C_{28}H_{48}O$	
	3-Oxo-ergosta-4,6,8(14),22-tetraene		$C_{28}H_{42}O$	
	3β-Hydroxy-5α,8α-epidioxy-ergosta-6,22-diene		$C_{28}H_{46}O_3$	
	3β-Hydroxy-5α,8α-epidioxy-ergosta-6,9(11),22-triene		$C_{28}H_{44}O_3$	
	6-Isoprenylindole-3-carboxylic acid		$C_{14}H_{15}NO_2$	
	3β,5α-Dihydroxy-6β-acetoxy-ergosta-7,22-diene		$C_{30}H_{48}O_4$	
	3-Oxo-ergosta-4-ene		$C_{36}H_{52}O_4$	
	3β,5α-Dihydroxy-6β-phenylacetyloxy-ergosta-7,22-diene		$C_{38}H_{56}O_3$	
Aerial parts	24-Methylcholestanol ferulate		$C_{38}H_{54}O_3$	(Abate *et al.* 2021)
	24-Methylcholesterol ferulate		$C_{38}H_{54}O_3$	
	24-Methylenecholestanol ferulate		$C_{30}H_{50}O$	
Leaves	Friedelin	Triterpenoid	$C_{30}H_{50}O$	(Zheng, 1994)
	Friedelan-3β-ol		3β-ol: $C_{30}H_{52}O$	
Aerial parts	Abscisic acid methyl ester	Terpenoid	$C_{15}H_{20}O_4$	(Abate *et al.* 2021)
	Arteannoide B		$C_{15}H_{22}O_4$	
	Arteannoide M		$C_{15}H_{22}O_4$	
	Arteannoide Q		$C_{15}H_{22}O_5$	
	Arteannoide R		$C_{15}H_{22}O_5$	
	Artemether		$C_{16}H_{26}O_5$	
	Carnosic acid		$C_{20}H_{28}O_4$	
Aerial parts	Peonidin 3-O-rutinoside	Anthocyanin	$C_{28}H_{33}O_{15}^+$	(Abate *et al.* 2021)
	Pelargonidin 3-O-sambubioside		$C_{26}H_{29}O_{14}^+$	
	Cyanidin 3-O-(6''-p-coumaroyl-glucoside)		$C_{30}H_{27}O_{12}^+$	

	Delphinidin 3-O-glucosyl-glucoside		$C_{27}H_{31}O_{17}^+$	
	Delphinidin 3,5-O-diglucoside		$C_{27}H_{31}O_{17}^+$	
	Pelargonidin 3-O-glucosyl-rutinoside		$C_{32}H_{41}O_{19}^+$	
	Delphinidin 3-O-(6''-acetyl-galactoside)		$C_{23}H_{23}O_{13}^+$	
	Delphinidin 3-O-(6''-acetyl-glucoside)		$C_{23}H_{23}O_{13}^+$	
	Malvidin 3-O-(6''-acetyl-galactoside)		$C_{25}H_{27}O_{13}^+$	
	Cyanidin 3-O-(6''-succinyl-glucoside)		$C_{25}H_{25}O_{13}^+$	
	Petunidin 3,5-O-diglucoside		$C_{28}H_{33}O_{17}^+$	
	Cyanidin 3-O-glucosyl-rutinoside		$C_{33}H_{41}O_{20}^+$	
	Pelargonidin 3-O-(6''-succinyl-glucoside)		$C_{25}H_{25}O_{12}^+$	
	Cyanidin 3-O-(6''-malonyl-3''-glucosyl-glucoside)		$C_{33}H_{39}O_{21}^+$	
	Petunidin 3-O-glucoside		$C_{22}H_{23}O_{12}^+$	
	Cyanidin 3-O-(6''-malonyl-glucoside)		$C_{24}H_{23}O_{13}^+$	
	Malvidin 3-O-glucoside		$C_{23}H_{25}O_{12}^+$	
	Malvidin 3-O-galactoside		$C_{23}H_{25}O_{12}^+$	
	Delphinidin 3-O-glucoside		$C_{21}H_{21}O_{12}^+$	
	Petunidin 3-O-galactoside		$C_{22}H_{23}O_{12}^+$	
	Delphinidin 3-O-arabinoside		$C_{20}H_{19}O_{11}^+$	
	Delphinidin 3-O-xyloside		$C_{20}H_{19}O_{11}^+$	
	Peonidin		$C_{16}H_{13}O_6^+$	
	Delphinidin 3-O-feruloyl-glucoside		$C_{31}H_{29}O_{14}^+$	
	Pelargonidin 3,5-O-diglucoside		$C_{27}H_{31}O_{16}^+$	
Aerial parts	Conidendrin	Lignan	$C_{20}H_{20}O_6$	(Abate *et al.* 2021)
	Isolariciresinol		$C_{20}H_{24}O_6$	
	Cyclolariciresinol		$C_{20}H_{24}O_6$	
	Lariciresinol		$C_{20}H_{24}O_6$	
	Medioresinol		$C_{21}H_{24}O_7$	
	Trachelogenin		$C_{21}H_{22}O_7$	
	Matairesinol		$C_{20}H_{22}O_6$	
	Pinoresinol		$C_{20}H_{22}O_6$	
	Secoisolariciresinol		$C_{20}H_{26}O_6$	
	Secoisolariciresinol-sesquilignan		$C_{30}H_{38}O_9$	
Aerial parts	Arteannuoside A-B		$C_{23}H_{28}O_{12}$	(Wu *et al.* 2025)
	Annusesquilignanoside		$C_{36}H_{46}O_{13}$	(Wu *et al.* 2025)
Aerial parts	4-Hydroxycoumarin	Coumarin	$C_9H_6O_3$	(Abate *et al.* 2021)
	Mellein		$C_{10}H_{10}O_3$	
Aerial parts	Curcumin	Curcuminoid	$C_{21}H_{20}O_6$	(Abate *et al.* 2021)
Aerial parts	Juglone	Naphthoquinone	$C_{10}H_6O_3$	(Abate *et al.* 2021)
Aerial parts	Ligstroside	Secoiridoid	$C_{25}H_{32}O_{12}$	(Abate *et al.* 2021)
	Oleoside dimethylester		$C_{18}H_{26}O_{11}$	
	Oleuropein-aglycone		$C_{19}H_{22}O_{10}$	
Aerial parts	Resveratrol 3-O-glucoside	Stilbene	$C_{20}H_{22}O_8$	(Abate *et al.* 2021)
	Resveratrol		$C_{14}H_{12}O_3$	
	Piceatannol 3-O-glucoside		$C_{20}H_{22}O_9$	

Anti-inflammation activities of *A. annua*

The anti-inflammatory and immunomodulatory effects of *A. annua* are mediated through suppression of key signaling pathways (Fig. 2). Compounds inhibit NFκB and MAPK (p38, JNK) activation (Li *et al.* 2015), reducing pro-inflammatory cytokine production (TNF-α, IL-6, IL-1β, MCP-1) (Hunt *et al.* 2015; Li *et al.* 2015; Wu *et al.* 2025). Additionally, they modulate acetylcholinesterase (Acquaviva *et al.* 2023; Chougouo *et al.* 2016), tyrosinase (Acquaviva *et al.* 2023), and amylase activities (Acquaviva *et al.* 2023) and enhance skin barrier function via FLG upregulation and TSLP suppression (Fig. 2). The extract elevated itching thresholds suppressed TSLP expression, and enhanced FLG mRNA levels (Zhao *et al.* 2024). In mice, croton oil-induced ear edema was reduced by casticin (0.5–1.5 μmol/cm²) and chrysosplenol D (1–1.5 μmol/cm²), comparably to indomethacin (55.63–84.58%) (Li *et al.* 2015). Aqueous extract administration decreased mRNA and protein expression of IgE, IL-4, IL-6, IL-13, IL-17, TNF-α, and TSLP in AD mouse models and inhibited p38 MAPK and NFκB phosphorylation in ear tissues (Xinyan Han *et al.* 2022). The multi-target activities highlight its possible use as an inflammatory and immune-related disorder treatment.

Also, these compounds have various enzyme inhibitory properties (Table 2). They are highly acetylcholinesterase inhibitory and artemisinin and chrysosplenetin are the most active, whereas they exhibit diverse activity against butyrylcholinesterase, tyrosinase, and amylase depending on the extraction solvent (Chougouo *et al.* 2016; Acquaviva *et al.* 2023). The therapeutic potential is further indicated by the in vivo evidence of the reduced ear edema in mouse models and the reduction of the signs of atopic dermatitis due to the inhibition of Thymic Stromal Lymphopoietin (TSLP) and various cytokines (Li *et al.* 2015; Zhao *et al.* 2024; Xinyan Han *et al.* 2022).

Antibacterial activities of *A. annua*

The antibacterial mechanism of action of *A. annua* could be attributed to multiple actions or processes, including disruption of the bacterial cell membranes by crude extract, essential oil, pure compound or biofilm formation inhibition or synergistic effect (Fig. 3). Targeting bacterial protein synthesis and oxidative stress pathways. This plant extract shows promising antibacterial action against a broad spectrum of gram-positive and gram-negative bacteria. This activity was ascribed to the presence of secondary metabolites, antioxidant molecules capable of mitigating oxidative damage pathways, which is promising for the advancement of innovative therapeutics.

Essential oil from *A. annua* demonstrated wide-ranging pesticides, especially on Gram-positive bacteria such as *S. aureus* and *B. subtilis* with several studies reported to have shown large inhibition zones (Table 2). Additionally, both pure artemisinin and plant extracts exhibit anti-mycobacterial effects against *M. tuberculosis*, indicating the existence of synergistic active agents that increase it (Martini *et al.* 2020). The performance of antibacterial is strongly dependent on the type of solvent used. Ethanol and methanol extracts have a consistent wide-range of activity against the pathogens such as *E. coli*, *S. aureus*, and *P. aeruginosa* (Massiha *et al.* 2013; Tajehmiri *et al.* 2014). More importantly, aqueous extracts, being less broad spectrum, demonstrate strong, concentration dependent activity, at high concentrations surpassing penicillin with individual strains such as *B. cereus* and *E. faecalis* (Massiha *et al.* 2013). On the contrary, non-polar solvents such as hexane and petroleum ether usually exhibit low to no activity (Gupta *et al.* 2009). *A. annua* can be nano-formulated to promote its efficacy. Silver nanoparticles produced with the use of *A. annua* (*A. annua*/AgNPs) are more active, and the inhibition zone size of these nanoparticles is sometimes larger than that of plant extract (Shaaban *et al.* 2024; Basavegowda *et al.* 2014).

Antifungal activities of *A. annua*

The possible mechanism of action of *A. annua* against fungal strain is ascribed to the disruption of cell membrane, inhibition of spore germination, and oxidative stress induction. The crude extract, pure compound or synergistic both alter the metabolic pathways, protein synthesis reduction and enhancing antioxidant enzyme activity.

Artemisia annua essential oils and extracts show broad antifungal effects (Table 2). Essential oil is remarkably active, exhibiting a high level of effectiveness against yeasts, Candida *albicans*, Saccharomyces *cerevisiae*, more significant than the most common antifungal agent Nystatin (Juteau *et al.* 2002; Verdian *et al.* 2008). The suppression of a broad spectrum of pathogens by endophytic cultures isolated on *A. annua* is concentration-dependent with *Gaemannomyces graminis* and *Rhizoctonia cerealis* being examples (Liu *et al.* 2001). The essential oil possesses fungicidal properties at extremely low doses against such pathogens as *S. sclerotiorum* and *B. cinerea* (Soylu *et al.* 2005). Solvents are also essential, as in the case of extracting leaves with methanol where leaf extracts had extreme inhibitory powers against *F. oxysporum compared* to extracts of roots and stems (Ma *et al.* 2019). Artemisinin is an effective inhibitor of *M. aeruginosa* with the application of physiological stress indicated by the low content of proteins and the change of antioxidant enzymes activities (Ni *et al.* 2012).

Antiparasitic activities of *A. annua*

Artemisia annua exerts its anticoccidial and antiparasitic effects through multiple mechanisms, including direct parasiticidal action (coagulation of parasite cells (Ekanem *et al.* 2010), disruption of trophozoite attachment (Ekanem *et al.* 2010), inhibition of parasite proliferation (Brisibe *et al.* 2008), and reduction of oocyst shedding (Brisibe *et al.* 2008; Coroian *et al.* 2022; Wiedosari *et al.* 2018). It also modulates host responses by improving feed conversion rates (Coroian *et al.* 2022; Drăgan *et al.* 2014), enhancing weight gain (Brisibe *et al.* 2008; Drăgan *et al.* 2014), and reducing intestinal lesions and inflammation (Allen *et al.* 1997; Coroian *et al.* 2022; Wiedosari *et al.* 2018). The alteration of gut microbiota and metabolites

(Liu *et al.* 2025), further contributes to its efficacy, while components like artemisinin and essential oils induce oxidative stress and rapid mortality in parasites (Ekanem *et al.* 2010; Pirali-Kheirabadi *et al.* 2011).

Artemisia annua exhibits a high level of antiparasitic activity especially in the case of *Avian coccidiosis* caused by Eimeria species. In chickens, dietary supplementation with *A. annua* leaves, leaf powder or extracts also consistently lowers the primary disease measures such as the faecal oocyst counts (to a minimum of 95.6% reduction), gut lesion scores (to a maximum of 80% reduction) and the occurrence of bloody diarrhea, and it also positively affects performance parameters such as body weight gain and feed ratio (Allen *et al.* 1997; Drăgan *et al.* 2014; Oh *et al.* 1995). This anticoccidial activity is equivalent to and in some cases better than commercial anticoccidial drugs as indicated by high scores of Anticoccidial Index (ACI) (Oh *et al.* 1995; Goodarzi *et al.* 2004). Artemisinin is an active compound that is very effective. Artemisinin has significant activity than the entire extract of the plant and displays an equivalent performance to healthy birds that are not infected (Goodarzi *et al.* 2004; Ekanem *et al.* 2010). The extract has been demonstrated to possess anticoccidial effects through the regulation of gut microbiota (Liu *et al.* 2025) and other antiparasitic inhibitory effects against *T. gondii* and Giardia (de Oliveira *et al.* 2009; Gholami *et al.* 2014). Moreover, a clinical trial points to the fact that *A. annua* sublingual immunotherapy (SLIT) is better in terms of nasal symptoms and the decrease in medication use in patients, which suggests a larger range of immunomodulatory usage (Yang *et al.* 2022).

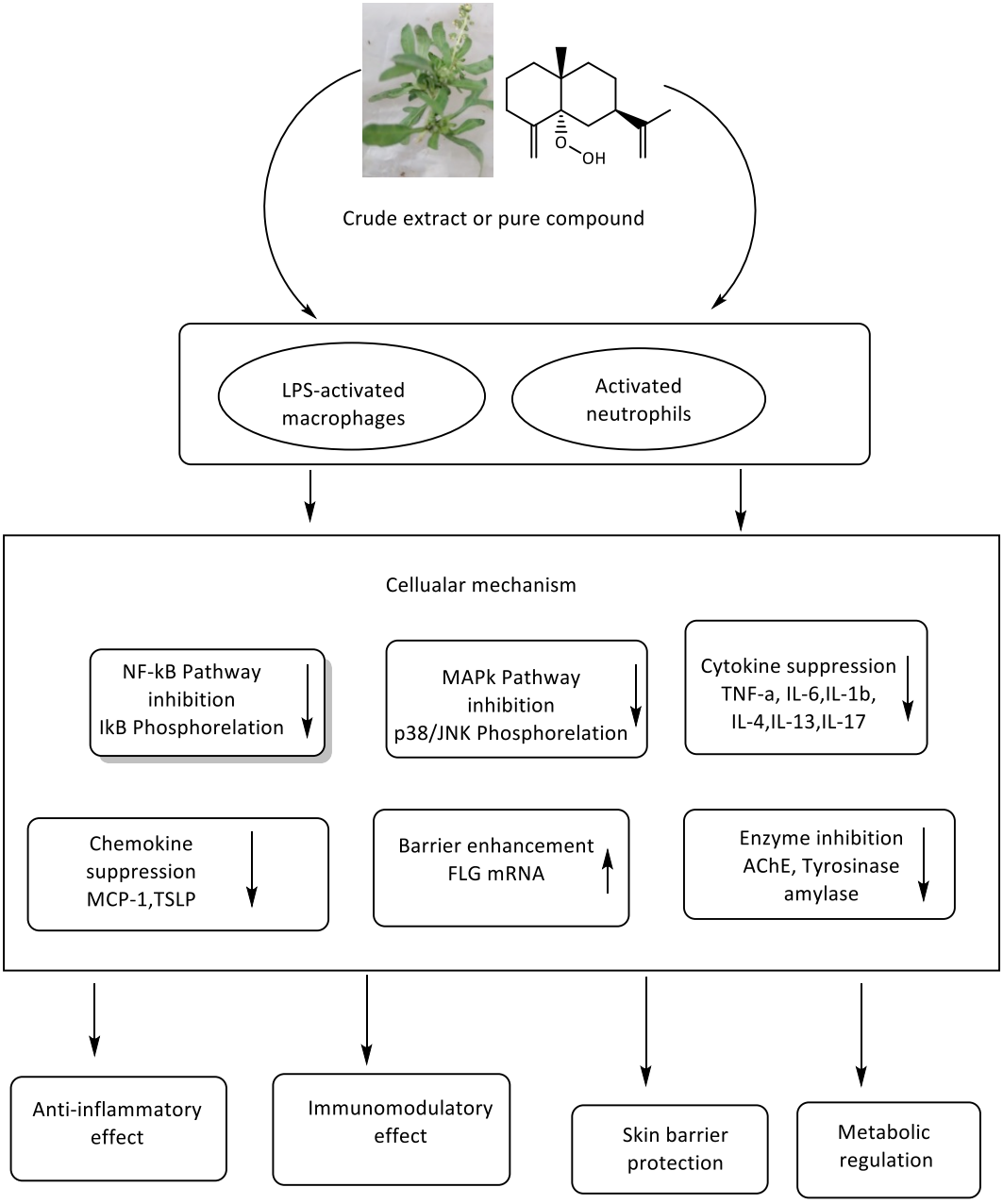

Figure 2. Diagrammatic illustration how *A. annua* crude extract or pure compound target multiple points in the process of inflammation (source author)

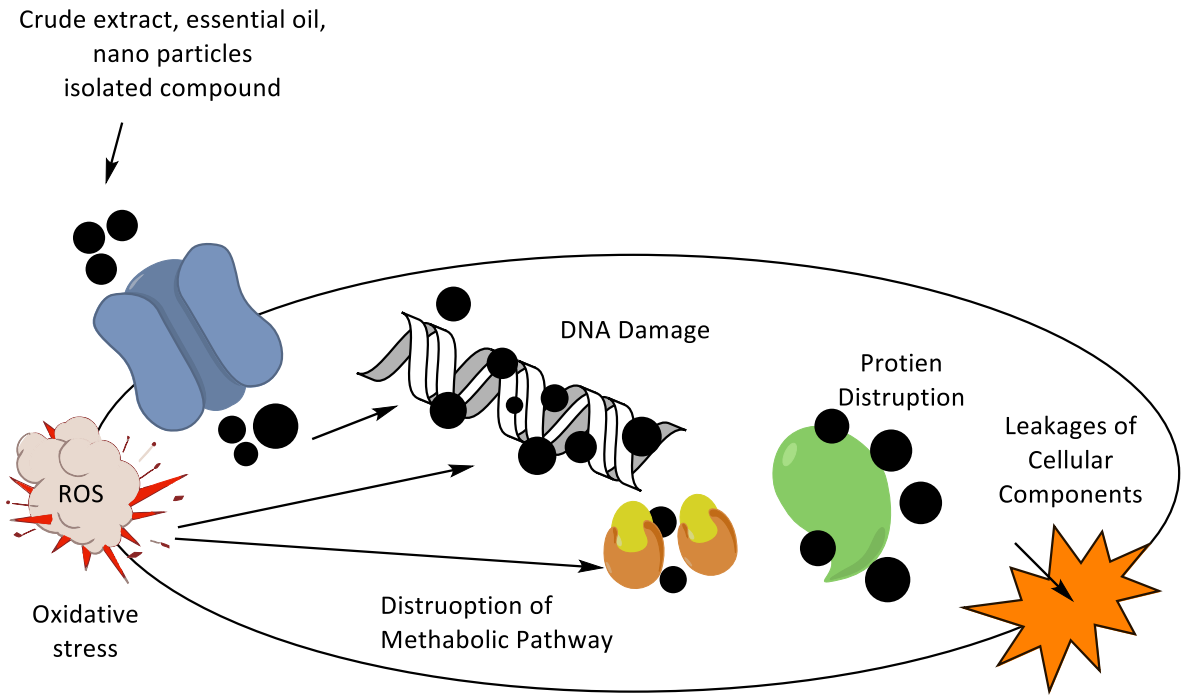

Figure 3. Mechanism of action of *A. annua* against bacterial strain (source author).

Antiviral activities of *A. annua*

Artemisia annua tea infusion was extremely active, with IC_{50} values as low as 2.0 µg/mL (Lubbe *et al.* 2012). Hot-water leaf extracts containing artemisinin, total flavonoids, or dry leaf mass exhibited antiviral activity with IC_{50} values ranging from 0.1 to 8.7 µM, 0.01 to 0.14 µg, and 23.4 to 57.4 µg, respectively (Nair *et al.* 2021). Hot-water leaf extracts inhibited the newly evolved strains of SARS-CoV-2, with predicted IC_{50} values ranging from 1.1 to 7.9 µM (Nair *et al.* 2022). The results indicated that *A. annua* and the EtOAc fractions F2, F5, and F8 exhibited antiviral effects on infected cells at 24 hours post-infection, with virus titters dropping to 10^2 $TCID_{50}$/mL (EtOAc 50 µg/mL) (Baggieri *et al.* 2023). Mefloquine-artesunate had the most significant antiviral efficacy, with a % inhibition of 72.1% at the anticipated maximum blood concentration (Cmax) (Gendrot *et al.* 2020).

The possible mechanism of action of *A. annua*, could be by disruption of the viral replication and infection. The extracts or pure compounds probably suppress viral protease activity and regulate host cell pathways, decreasing viral titers, and inhibiting the development of infection.

Table 2. *Biological activities of A. annua*

Activity	*Methods*	*PP*	*Infusion*	*Activity*	*Reference*
Antioxidant	*ABTS, DPPH, FRAP, RP*	*Leaves*	*80% aqueous ethanol*	*ABTS, umol TE/g; 108.85, DPPH, % 64.18, DPPH; % 64.18, FRAP, umol FeSO4/g; 205.41, RP; 0.3974,*	*(Wan et al. 2016)*
	DPPH, ABTS, RP, ORAC		*Essential oil*	*DPPH IC_{50} (mg/mL) 27.07 and thymol 4.28, ABTS IC_{50} (mg/mL) 5.97 and thymol 0.0025, RP_{50} (mg/mL) 127.17, ORAC ((mmolTEc/g) 5.09 and thymol 4.48, Metal-chelating ability/HA50 (mg/mL) 20.40 and and thymol 19.04*	*(Ćavar et al. 2012)*
	ABTS, NO, FRAP	*Leaves*	*80% ethanol, aqueous*	*ABTS; leaves aqueous IC_{50} 224.41 µg/mL, leaves ethanol 179.25 µg/mL, stem aqueous 540.61 µg/mL and stem ethanol 974.40 µg/mL,*	*(Ryu et al. 2011)*

				NO; IC_{50} leaves aqueous >2000 µg/mL, leaves ethanol 1937.56 µg/mL, >2000 µg/mL for the stem extract, Fe^{2+} chelating; IC_{50} leaves aqueous 265.98 µg/mL, leaves ethanol 1868.45 µg/mL, stem aqueous 785.60 µg/mL and stem ethanol 1382.45 µg/mL, FRAP; Leaves aqueous 71.73, leaves ethanol 136.96, stem aqueous 143.59 and stem ethanol 124.06 µM $FeSO_4$ eq respectively.	
	Lipid Peroxidation, DPPH, TEAC	*Leaves*	*hexane, chloroform, ethyl acetate, methanol and aqueous*	*Lipid peroxidation; chloroform (24.24%), methanol (10.72%), TEAC (µmol Trolox/g); 17.59, hexane 8.12*	*(Iqbal et al. 2012)*
	ABTS, FRAP, ORAC	*Leaves*	*Ethanol-aqueous*	*ABTS; 314.99 µM (TE)/g DW, ORAC; 736.26 µM TE/g DW, FRAP; 212.18 µM TE/g DW.*	*(Skowyra et al. 2014)*
	Lipid peroxidation, erythrocyte hemolysis,hydroxyl radical scavenging, nitric oxide radical scavenging,hydrogen peroxide radical scavenging	*Leaves*	*ethanol, absolute methanol, 70% ethanol and 70% methanol)*	*Lipid peroxidation (79.81%-86.70%), erythrocyte hemolysis (40.02%-49.91%), IC_{50} values for hydroxyl radical scavenging at 2.39–3.81 mg/mL, nitric oxide radical scavenging at 107.24–144.49 µg/mL, and hydrogen peroxide radical scavenging at 28.53–53.20 µg/mL.*	*(Chukwurah et al. 2014)*
Antibacterial	*Diffusion method*	*Aerial parts*	*Essential oil*	*S. aureus (GIC_{50}: $3x10^{-4}$ mg/mL; CI: $5x10^{-4}$ mg/mL) and E. hirae (GIC_{50}: 0.05 mg/mL; CI: 0.1 mg/mL), Penicilline G GIC_{50}: $3x10^{-4}$ mg/mL; CI: $8x10^{-4}$ mg/mL*	*(Juteau et al. 2002)*
	Disc diffusion	*Leaves*	*Chloroform, methanol, ethanol*	*Chloroform S. aureus (7 mm), E. coli (10 mm), S. aureus (12 mm), B. cereus (10 mm), Bacillus sp. (10 mm), E. faecalis (7 mm), UPEC (12 mm), and P. aeruginosa (10 mm), ethanol S. aureus (8 mm), E. coli (16 mm), S. aureus (11 mm), B. cereus (8*	*(Massiha et al. 2013)*

				mm), Bacillus sp. (12 mm), E. faecalis (10 mm), UPEC (11 mm), and P. aeruginosa (10 mm), methanol S. aureus (10 mm), E. coli (14 mm), S. aureus (10 mm), B. cereus (8 mm), Bacillus sp. (10 mm), E. faecalis (8 mm), UPEC (12 mm), and P. aeruginosa (12 mm) and positive control (P-S-C) of S. aureus (12 mm), E. coli (13 mm), S. aureus (14 mm), B. cereus (13 mm), Bacillus sp. (15 mm), E. faecalis (14 mm), UPEC (16 mm), and P. aeruginosa (13 mm).	
	Agar diffusion		*Essential oil*	*S. aureus ATCC 6538 (20 mm), S. aureus ATCC 25923 (28 mm), B. subtilis (20mm), E. faecalis (27 mm), S. pneumoniae (50mm), E. coli (20mm), P. aeruginosa (15 mm), and H. influenzae (60 mm)*	*(Ćavar et al. 2012)*
	MIC	*Leaves*	*Dichloromethane*	*M. tuberculosis (4.81 mg/mL)*	*(Martini et al. 2020)*
	Disk Diffusion, MIC			*B. subtilis (1 mm), S. aureus (2-3 mm), B. thuringiensis (1 mm), and Salmonella sp. (1-2 mm).*	*(Appalasamy et al. 2014)*
	Disk Diffusion, MIC	*Flower*	*Essential oil*	*Essential oil; S. aureus (MIC 32 mg/mL) and E. coli (MIC 64 mg/mL)*	*(VERDIAN et al. 2008)*
	Agar well diffusion	*Leaves*	*Methanol, ethanol*	*Ethanol; S. aureus (15 mm), E. coli (12 mm), K. pneumoniae (13 mm), S. enterica (13.5 mm), and Sh. dysenteriae (13 mm); methanol; S. aureus (16.5 mm), E. coli (11.5 mm), K. pneumoniae (13 mm), S. enterica (15.5 mm), and Sh. dysenteriae (12.5 mm); and the ciprofloxacin; S. aureus (25 mm), E. coli (17 mm), K. pneumoniae (20 mm), S. enterica (22*	*(Tajehmiri et al. 2014)*

				mm), and Sh. dysenteriae (19 mm).	
	Disc diffusion	*Ag nanoparticles, leaves*		*Ag nanoparticles E. aerogenes (22), E. aerogenes (23), leaves E. aerogenes (20), E. aerogenes (23).*	*(Basavegowda et al. 2014)*
	Disc diffusion	*Flower*	*Essential oil*	*E. coli (1.27 mm), S. Enteritidis (2.33 mm), S. Typhi (1.27 mm), S. Typhi (1.25 mm), Y. enterocolitica (1.50 mm), Yersinia enterocolitica (1.50 mm), L. monocytogenes (1.60 mm)*	*(Donato et al. 2015)*
Antifungal	*Diffusion method*	*Aerial parts*	*Essential oil*	*C. albicans and S. cerevisiae, with identical efficacy (GIC_{50}: 0.1 mg/mL; CI: 0.2 mg/mL), Nystatine (GIC_{50}: $3x10^{-3}$ mg/mL; CI: $6x10^{-3}$ mg/mL).*	*(Juteau et al. 2002)*
	Diffusion method	*Stem*	*Endophyte cultures*	*Endophyte cultures inhibited the growth of all the tested pathogens*	*(Liu et al. 2001)*
	Agar diffusion		*Essential oil*	*Candida krusei (30 mm)*	*(Ćavar et al. 2012)*
	Disk Diffusion, MIC	*Flower*	*Essential oil*	*Essential oil; MIC 2 mg/mL (S. cerevisiae and C. albicans0*	*(VERDIAN et al. 2008)*
	Agar diffusion	*Leaves, root, stem*	*Methanol*	*Leaves inhibit F. oxysporum (36.94%)*	*(Ma et al. 2019)*
Inflammation		*Aerial parts*		*At 100 Mm: Arteannuoside (A) 68 %, arteannuoside (B) 71 % and annusesquilignanoside 61 %. At 50 µM: 33 %, 39 %, and 45 % inhibition respectively.*	*(Wu et al. 2025)*
	In vivo(rat)			*Extract markedly suppressed TNF-α production by activated neutrophils in a dose-dependent manner.*	*(Hunt et al. 2015)*
			Aqueous	*Itching threshold elevation, TSLP suppression, FLG mRNA enhancement.*	*(Zhao et al. 2024)*
Antiparasites	*In vivo (chicken)*	*Leaves*	*Chickens fed*	*Chickens fed a 5% A. annua diet lower lesion score (1.50), un supplemented control group (2.70).*	*(Allen et al. 1997)*
	In vivo (fish)		*Ethanol*	*Extract clear the body of the fish similar to the control.*	*(Ekanem et al. 2010)*

	In vivo (Hu sheep)		*Distilled water and 70% ethanol*	*Alistipes showed a positive connection with OPG (P>0.05) and a substantial negative correlation with ADG (P<0.05).*	*(Liu et al. 2025)*
	In vivo (chicken)	*Leaves*	*Chickens fed*	*Intestinal C. perfringens numbers and lesion severity were reduced by the n-hexane extract at 250 mg/kg*	*(Engberg et al. 2012)*
Antivirus	*HIV bioassay*	*Leaves*	*Tea infusion*	*HIV virus IC_{50} 2.0 µg/mL*	*(Lubbe et al. 2012)*
	SARS-CoV-2	*Leaves*	*Dichloromethane*	*Extracts against SARS-CoV-2 IC_{50} <12 µM*	*(Nair et al. 2021)*
	Vero E6 cells	*Leaves*	*Aqueous*	*SARS-CoV-2; IC_{50} 1.1 to 7.9 µM.*	*(Nair et al. 2022)*
Antimalaria	*Cell suspension*	*Whole plant*	*Flavonoids*	*Artemisinin (IC_{50} of 3.3 x 10^{-8} M), while the flavonoids artemetin, casticin, chrysoplenetin, chrysosplenol-D, cirsilineol, and eupatorin had IC_{50} values of 1.0 x 10^{-5} M, 2.0 x 10^{-5} M, 2.3 x 10^{-5} M, 3.2 x 10^{-5} M, 3.6 x 10^{-5} M, and 6.5 x 10^{-5} M, respectively. When combined with 5 µM flavonoid, the IC_{50} of artemisinin was 2.6 x 10^{-8} M with artemetin, 2.6 x 10^{-8} M with casticin, 2.25 x 10^{-8} M with chrysoplenetin, 1.5 x 10^{-8} M with chrysosplenol-D, 1.6 x 10^{-8} M with cirsilineol, and 3.0 x 10^{-8} M with eupatorin.*	*(Liu et al. 1992)*
				387.625, 226.350, and 12.099 against WT, C580Y, and R539T parasites, respectively)	(Roesch *et al.* 2025).
	In vivo	*Whole plant*		Diminish the parasite	Elfawal *et al.* 2012
Anti-amoebic activity	*In vivo (mice)*	*Aerial parts*	*Ethanol, chloroform*	*Pure artemisinin IC_{50} of 0.09 mg/mL at 24 hours and 0.12 mg/mL at 48 hours, methanol IC_{50} 15.0 mg/mL at 24 hours, 12.5 mg/mL at 48 hours, and 8.1 mg/mL at 72 hours, chloroform extract IC_{50} 17.4 mg/mL at 24 hours, 14.1 mg/mL at 48 hours, and 9.2 mg/mL at 72 hours.*	*(Derda et al. 2016)*

Anticancer	*Cytotoxicity*	*Above ground portion*	*Isolated compounds*	*Artemisinin (1) P-388 murine lymphocytic leukemia cells (ED_{50} = 9.62 x 10^{-2} µg/mL) and HT-29 human colon adenocarcinoma cells (ED_{50} = 4.41 µg/mL, Quercetagetin 6,7,3',4'-tetramethyl ether (9) A-549 human lung carcinoma (ED_{50} = 4.81 x 10^{-1} µg/mL) and HT-29 human colon adenocarcinoma (ED_{50} = 1.25 µg/mL)*	*(Zheng, 1994)*
	In vivo (pet)	*Herba Artemisiae annuae*	*Aqueous*	*One cat and one dog with fibrosarcoma survived 40 and 37 months, respectively, without tumour recurrence.*	*(Breuer et al. 2014)*
	In vivo (Dogs, cats)	*A. annua preparation (Luparte)*		*Survival rate increases >18 months*	*(Saeed et al. 2019)*
		Leaves	*Hot Aqueous*	*Arteannuin Q; IC_{50} 20.0 µM, artemisinic acid, 16.7 µM, and annulide and 21.5 µM, against the HCT116 cell line respectively.*	*(Xiao Han et al. 2022)*
Toxicity	*In vivo (rat)*	*Leaves, stems*	*Ethanol*	*Leaves and stem 5000mg/kg not toxic*	*(Nkuitchou-Chougouo et al. 2022)*
	In vivo (rat)	*Leaves*	*Hexane*	*Leaves lethal dose (LD_{50}) 2750 mg/kg*	*(Ogbole et al. 2014)*

Note: PP; Plant Parts

Antimalarial activities of *A. annua*

The antiplasmodial action of *Artemisia annua* is primarily driven by artemisinin, which induces oxidative stress in parasites through endoperoxide-mediated radical formation (Czechowski *et al.* 2019). Flavonoids like chrysosplenol-D and cirsilineol enhance artemisinin bioavailability and potency synergistically (Liu *et al.* 1992). Whole-plant extracts improve artemisinin absorption and efficacy *in vivo* compared to isolated compounds, likely due to matrix effects that increase bioavailability (Elfawal *et al.* 2012). Resistance mechanisms decrease extract activity, but high selectivity indices against resistant strains imply that they still target weak points of parasites (Roesch *et al.* 2025). When combined with some plant molecules, they show opposition to each other, which shows how complicated the combined effects of natural extracts can be (Suberu *et al.* 2013).

Artemisinin alone exhibited a high strength when tested, with IC50 values low as 3.3 X 10^{-8} M (Liu *et al.* 1992). Other plants can change how well artemisinin works. Most flavonoids do not have much of an effect, but compounds such as chrysosplenol-D can greatly enhance it (Liu *et al.* 1992). Importantly, the entire plant extract often shows improved effects in vivo in comparison to pure artemisinin, a phenomenon known as a full plant matrix, which enhances the drug's bioavailability (Elfawal *et al.* 2012). An aqueous extract with 20 mg/kg artemisinin worked just as well in mice as a dose of the pure drug with 140 mg/kg (Zime-Diawara *et al.* 2015). However, the presence of other compounds in the extract may cause antagonistic interactions, and extracts exhibit much less activity against artemisinin-resistant parasite strains (Suberu *et al.* 2013; Roesch *et al.* 2025).

Anticancer activities of *A. annua*

The plant mechanism of action acts is initiated through various ways. Artemisinin and its types make cells die and stop their growth in the S and G2/M phases (Efferth *et al.* 2003; Isani *et al.* 2019), this is cause by rising the iron inside cells to cause stress (Salaroli *et al.* 2022). Flavonoids like casticin and chrysosplenol D make pro-death signals stronger (Fu *et al.* 2022). Parts of the extract change some main proteins (like ERK, Akt, GSK-3β, β-catenin) and cut some other cells (like VCAM-1) so the cancer can't spread (Ko *et al.* 2016; Son *et al.* 2023). Resistance to the tumour may come from overexpression of MYC,

TFR, and VEGFC (Michaelsen *et al.* 2015). Also, tissue-specificity of the toxic effects (e.g. damage to ovary) shows that there is a real need to develop new drugs that will be more specific (Ajah *et al.* 2010). Induction of apoptosis, cell cycle arrest, and the modulation of intracellular iron and reactive oxygen species (Fu *et al.* 2022; Isani *et al.* 2019; Allemailem, 2022).

Artemisia annua extracts and their derivatives, such as artemisinin and flavonoids, exhibit substantial and broad-spectrum anticancer efficacy in vitro. Artemisinin exhibits considerable efficacy against human colon adenocarcinoma (HT-29) and murine lymphocytic leukemia (P-388) cells (Zheng, 1994). On the other hand, flavonoids like quercetagetin 6,7,3',4'-tetramethyl ether are effective against a wide range of lung and colon cancer cell lines (Zheng, 1994). Case reports, including one that indicated *A. annua* capsules resulted in a transient tumor remission in a patient with advanced prostate cancer (Michaelsen *et al.* 2015), alongside research demonstrating enhanced survival rates in dogs and cats with sarcomas (Breuer *et al.* 2014; Saeed *et al.* 2019), substantiate in vivo efficacy.

Other activities of *A. annua*

As a contraceptive the plants exhibit significant efficacy (Abolaji *et al.* 2014). It also has anti-amoebic properties, with pure artemisinin being the most effective compound. However, the effectiveness of plant extracts depended a lot on the solvent used for extraction and how long they were exposed to it. Methanol and chloroform extracts were the most effective, while hot water infusions were the least effective (Derda *et al.* 2016). Also, *A. annua* extracts have the potential to lower blood sugar levels by blocking alpha-glucosidase, with ethanol-aqueous extracts being the most effective (Acquaviva *et al.* 2023).

Toxicity of *A. annua*

The high dose of stem and leaf extract (5000 mg/kg) did not cause any toxicity in rats in terms of liver, kidney, lung, and heart functions (Nkuitchou-Chougouo *et al.* 2022). Also the same study found that curiosity and motor activity was significantly stimulated by the extract. In fact, one other research underlined that the median deadly dose ($LD5_0$) was 2750 mg/kg body weight containing natural chemicals such as sugars, cardiac glycosides, flavonoids, and terpenes (Ogbole *et al.* 2014). The findings show that A. annua is normally well tolerated at certain doses and can work as a stimulant but its safety depends on the dose.

Hepatic toxicity of *A. annua*

The ethanol extract of leaves has a protective value against gentamycin damage of the liver. The histological analysis proved that pre-treatment with the extract lowered the steatosis of hepatocytes and portal vein congestion and lowered the immunoreactivity of pro-inflammatory COX-2 gene (Althobaiti *et al.* 2024). At the same time, the extract has an effect on the important metabolic parameters. Administration of the ethanol leaf extract significantly decreased blood glucose levels. However, it also induced a mixed lipid profile, characterized by a decrease in high-density lipoprotein (HDL) cholesterol and an increase in low-density lipoprotein (LDL) cholesterol and the atherogenic index. Notably, the extract did not negatively impact liver function, hematological indices, or testosterone levels (Eteng *et al.* 2013).

Conclusion and future research

This comprehensive review notes the enormous healing value of *A. annua* as reported from various traditional uses of different cultures, chemical components of the plant, and its healing properties. Conditions such as malaria and fever through diabetes, skin disorders and respiratory illnesses are treated through traditional preparations, mainly decoctions, infusions and oils with regional variations relating to local knowledge and practices. The wide phytochemical profile of *A. annua* gives it an impressive versatile set of notable biological functions. Although the plant is best known by its most famous compound, artemisinin, a combination of different bioactive molecules, including flavonoids (e.g., casticin, chrysosplenol D), other sesquiterpenes (e.g., artemisinic acid, arteannuin B); and various polyphenols is largely responsible due to its efficacy. *A. annua* has a broad-spectrum activity. Casticin and chrysosplenol D flavonoids play a significant role in inhibiting pro-inflammatory cytokines IL-6, TNF- 2), as well as, inhibiting important signaling pathways NF-2. Quercetagetin 6,7,3',4'-tetramethyl ether and other terpenes including arteannuin Q are dose-dependently cytotoxic to the various cancer cell lines by inducing apoptosis and cell cycle arrest. The toxicological research suggests that the extracts have a high safety margin, and the extracts were not toxic to major organs at a certain dosage. This review highlights a major gap in the literature: while dozens of non-artemisinin compounds have been identified, the vast majority of *in vivo* research still uses crude extracts or pure artemisinin. Future work must focus on linking specific compounds, such as the flavonoids artemetin and casticin, to the observed *in vivo* anti-inflammatory, anti-microbial and antiparasitic effects. Furthermore, little research has been done on the precise biochemical pathways through which phytochemicals work. It is necessary to investigate the extract's mode of action. To conduct in silico analysis of each identified compound to FastTrack the in vitro investigation of each compound. Numerous details on protein expression, functionality, interaction, network structure, and biosynthesis pathways will be revealed by proteomic studies of *A. annua*. These data can be extremely helpful for developing novel drugs and for gaining a thorough understanding of disease preventive processes.

Declarations

List of abbreviations: ChE: Acetylcholinesterase, BChE: Butyrylcholinesterase, DPPH: 2,2-diphenyl-1-picrylhydrazyl , FRAP: Ferric Reducing Antioxidant Power, ORAC: Oxygen Radical Absorbance Capacity , ABTS: 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid), IC_{50}: Half-maximal inhibitory concentration, MIC: Minimum inhibitory concentration,

MBC: Minimum bactericidal concentration, GIC_{50}: Growth inhibitory concentration (50%), EC_{50}: Half-maximal effective concentration, ED_{50}: Effective dose (50%), ROS: Reactive oxygen species, TLR: Toll-like receptor, LPS: Lipopolysaccharide, NF-κB: Nuclear factor kappa B, MAPK: Mitogen-activated protein kinase, TNF-α: Tumor necrosis factor alpha, IL-6: Interleukin 6, IL-1β: Interleukin 1 beta, MCP-1: Monocyte chemoattractant protein-1, TSLP: Thymic stromal lymphopoietin, VCAM-1: Vascular cell adhesion molecule 1, NSCLC: Non-small cell lung cancer

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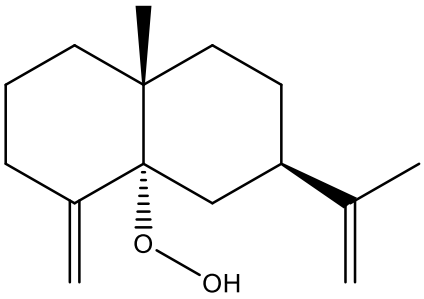
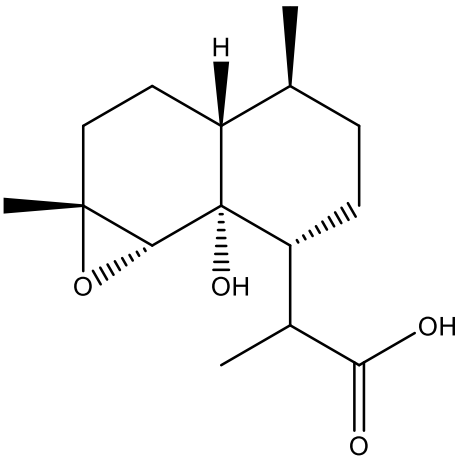
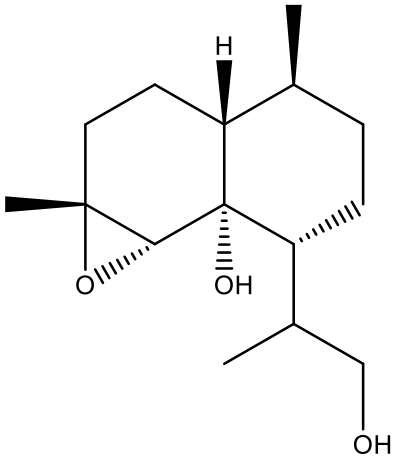
Supplementary Figure 1 - Compunds identifies from *Artemisia annua*



5α-Hydroperoxy-eudesma-4(15),11-diene



4α,5α-Epoxy-6α-hydroxy amorphan-12-oic acid



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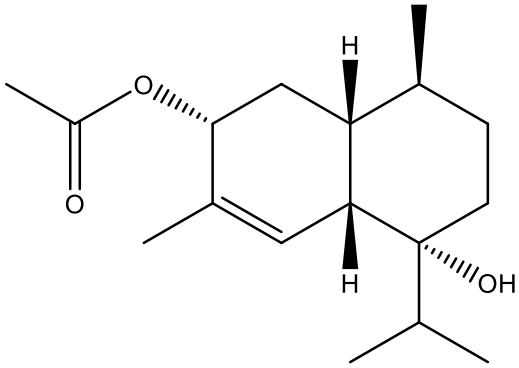
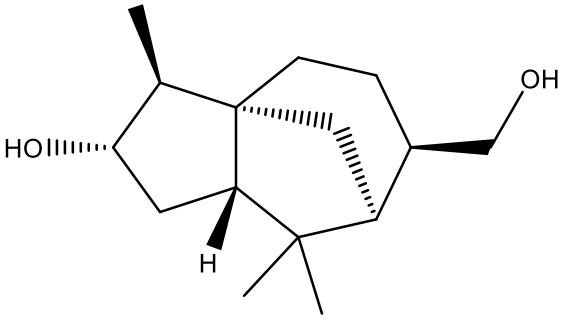
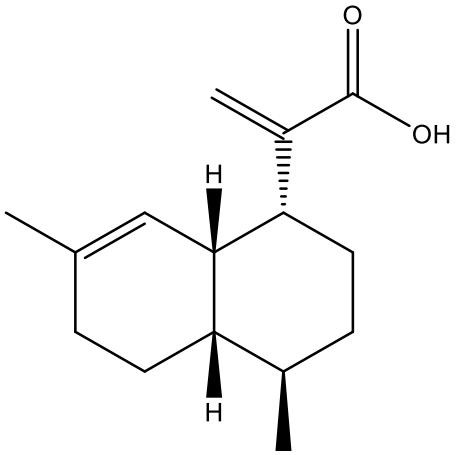


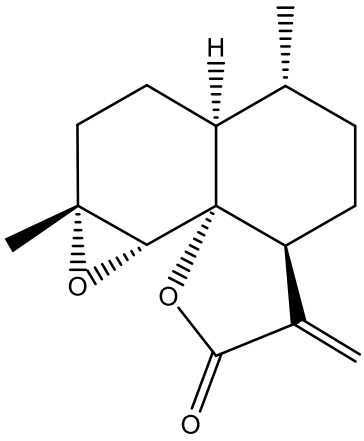
3α,7α-Dihydroxy amorph-4-ene 3-acetate



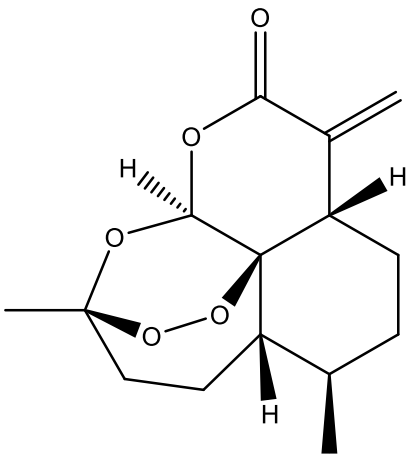
3α,15-Dihydroxycedrane



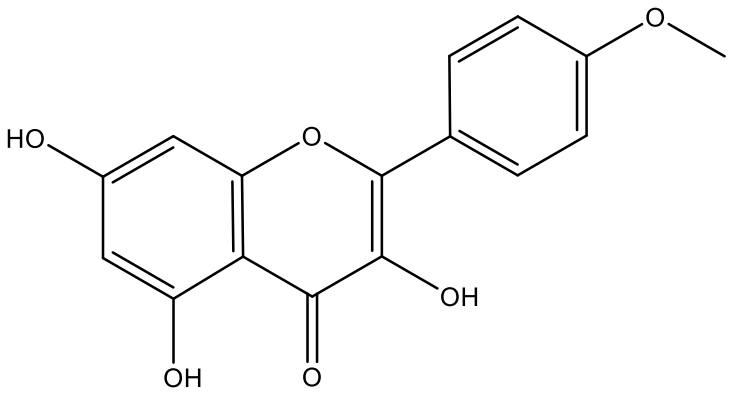
Artemisinic acid



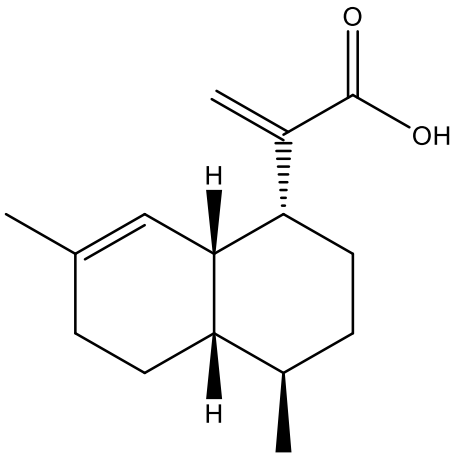
Arteannuin B



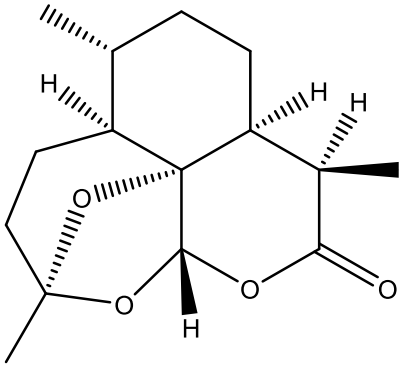
Artemisitene



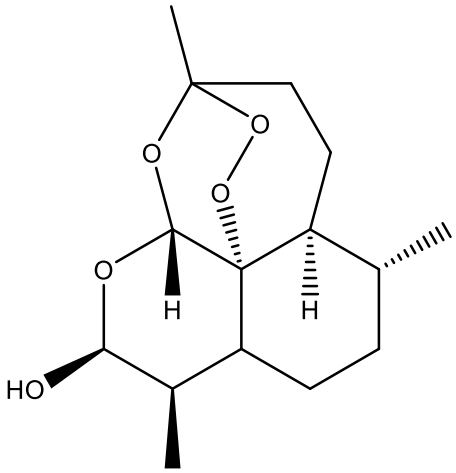
Artemisinin



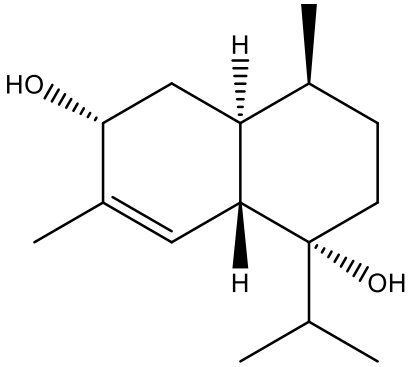
Arteannuicacid



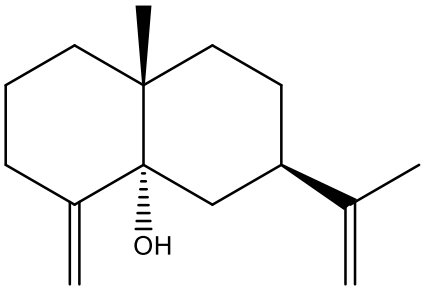
Deoxyartemisinin



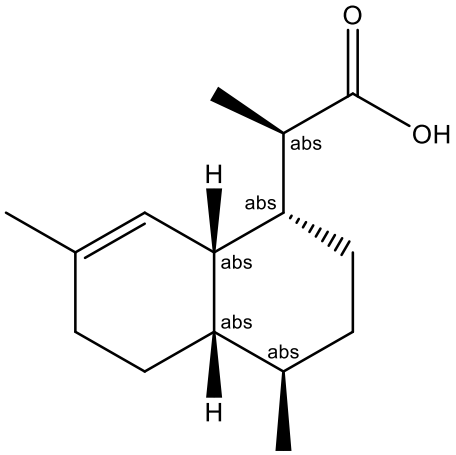
Dihydroartemisinin



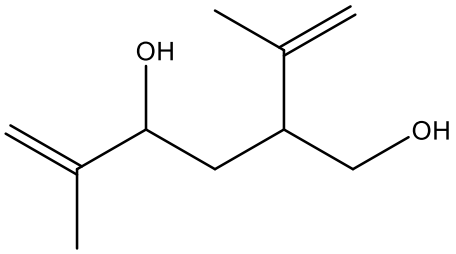
3α,7-Dihydroxy-cadin-4-ene



5α-Hydroxy-eudesma-4(15),11-diene

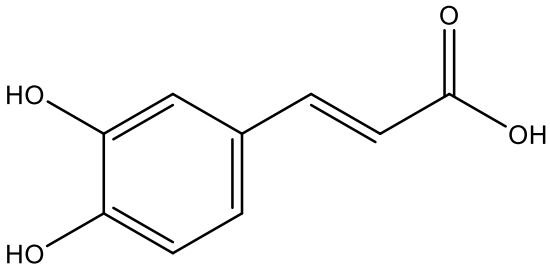


Dihydroartemisinic acid

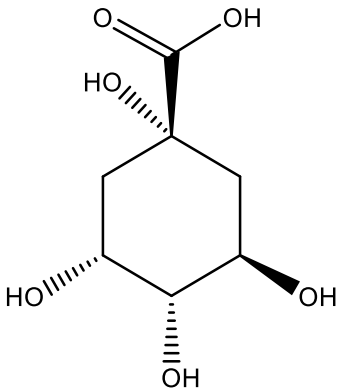


4-Hydroxy-2-isopropenyl-5-methylene-hexan-1-ol

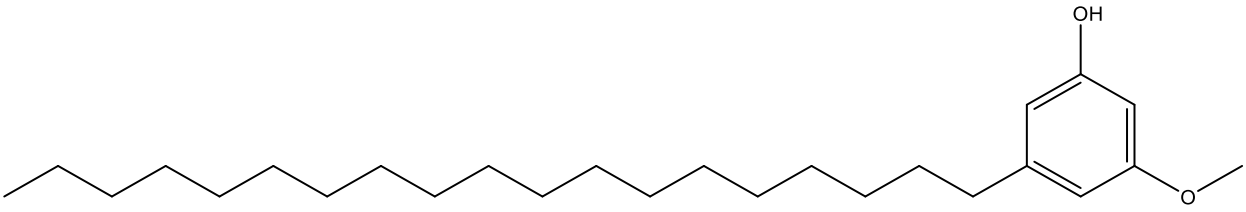
Sesquiterpenes



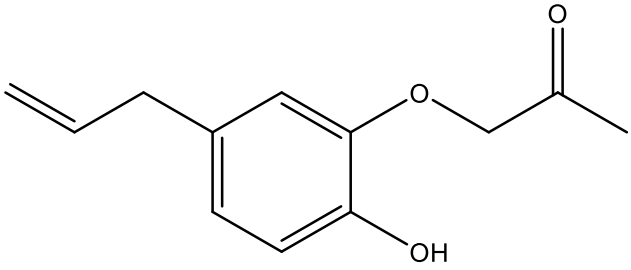
Caffeic acid



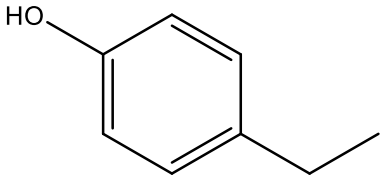
Quinic acid



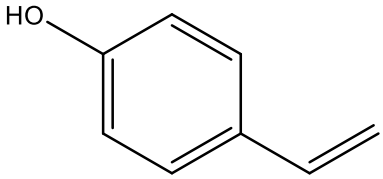
5-Nonadecylresorcinol-3-O-methyl ether



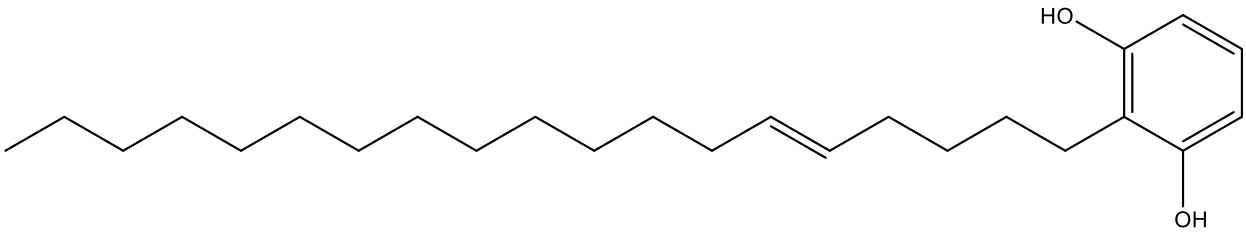
Acetyl eugenol



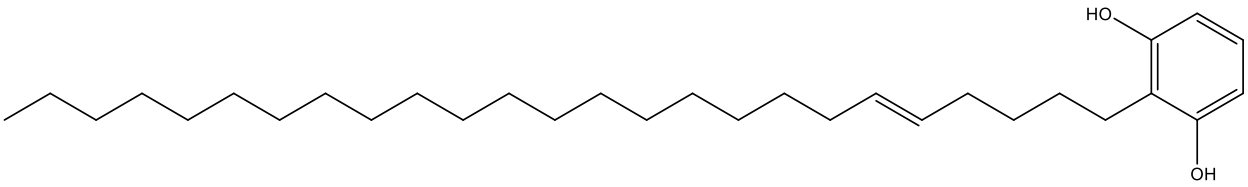
4-Ethylphenol



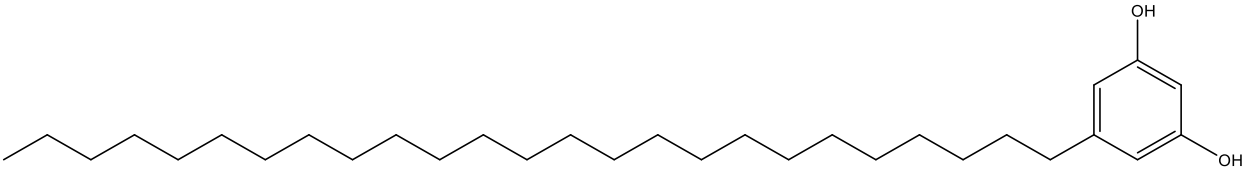
4-Vinylphenol



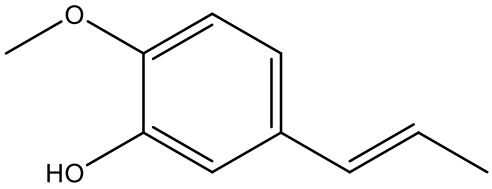
5-Nonadecenylresorcinol



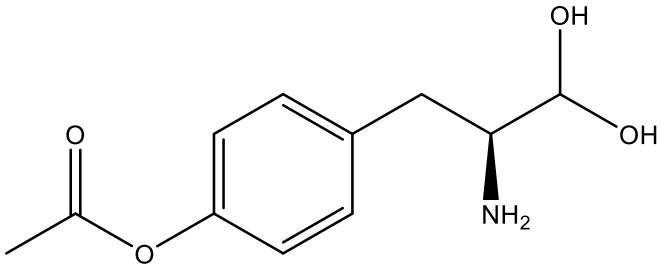
5-Pentacosenylresorcinol



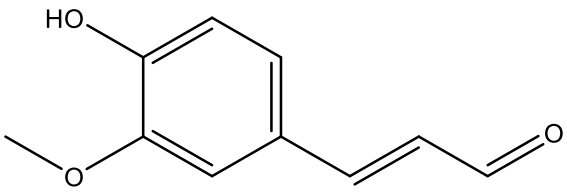
5-Pentacosylresorcinol



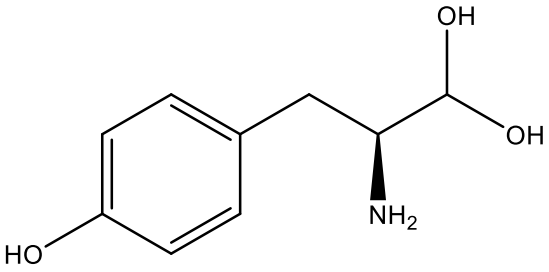
2-Methoxy-5-prop-1-enylphenol



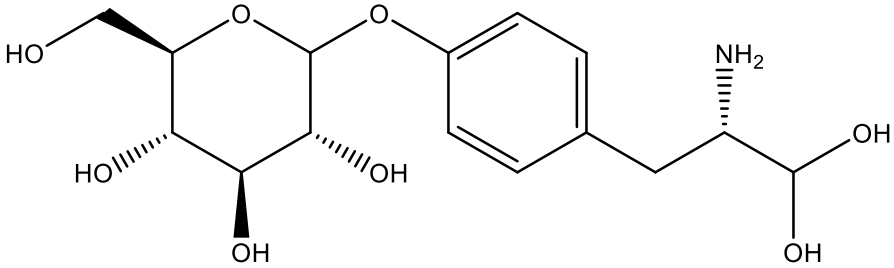
Hydroxytyrosol acetate



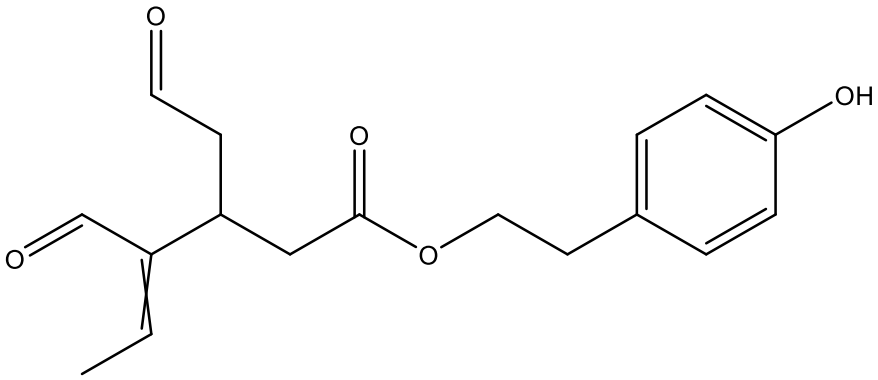
Ferulaldehyde



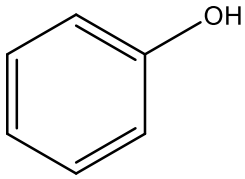
Hydroxytyrosol



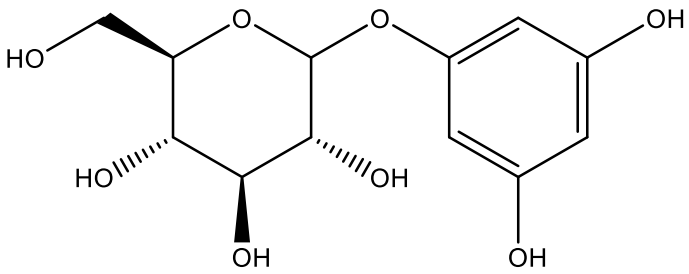
Hydroxytyrosol 4-O-glucoside



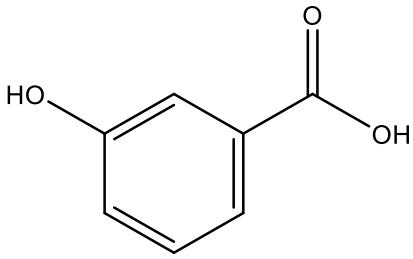
Oleocanthal



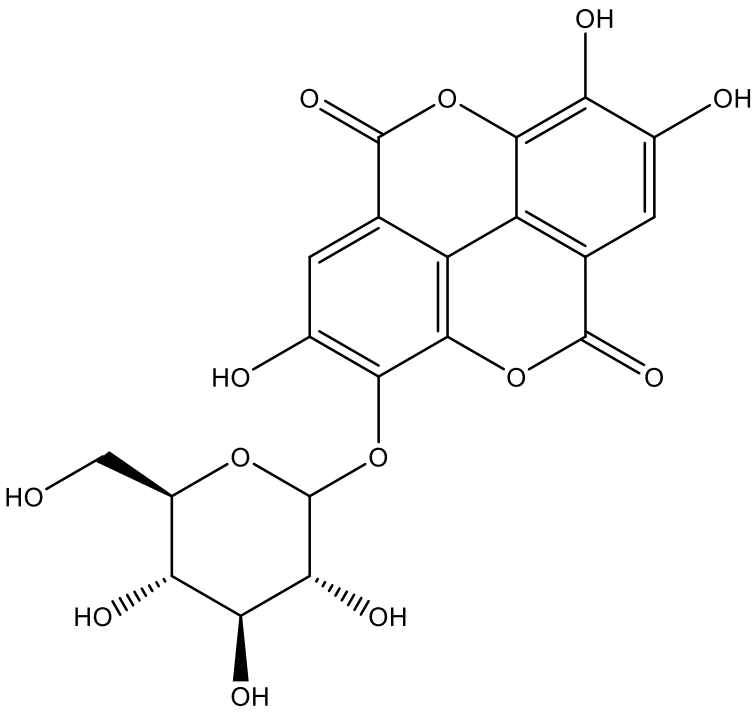
Phenol



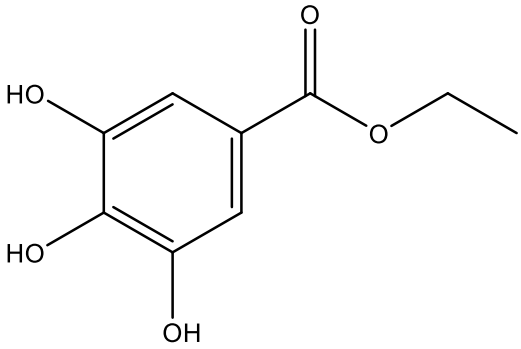
Phloroglucinol glucoside



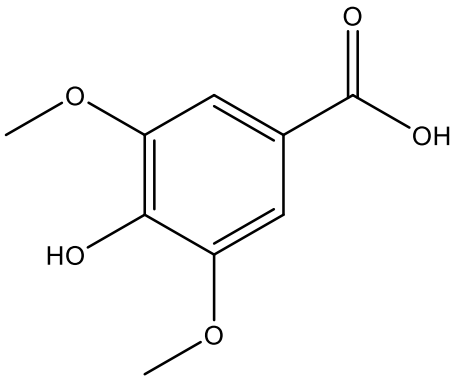
3-Hydroxybenzoic acid



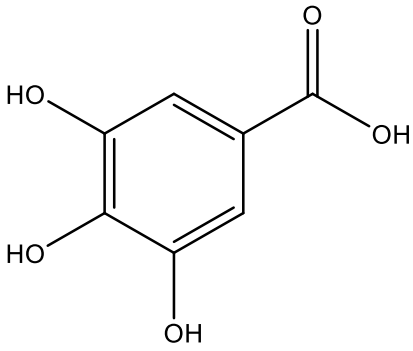
Ellagic acid glucoside



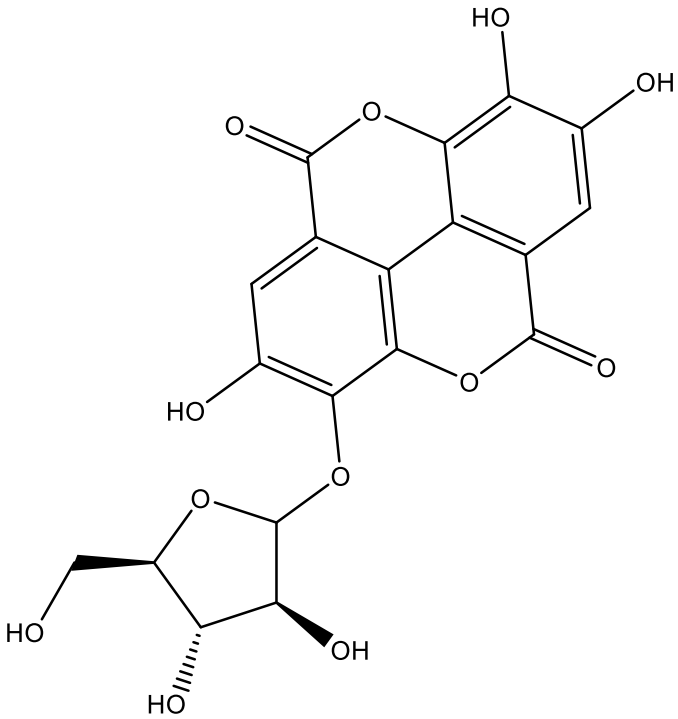
Gallic acid ethyl ester



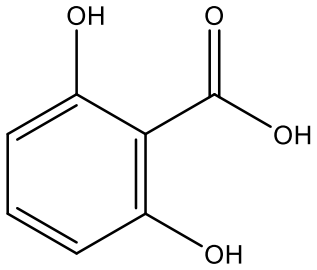
Syringic acid



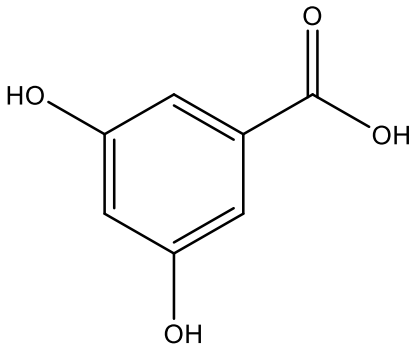
Gallic acid



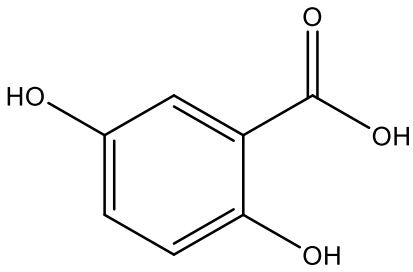
Ellagic acid arabinoside



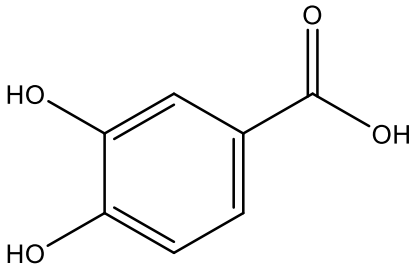
2,6-Dihydroxybenzoic acid



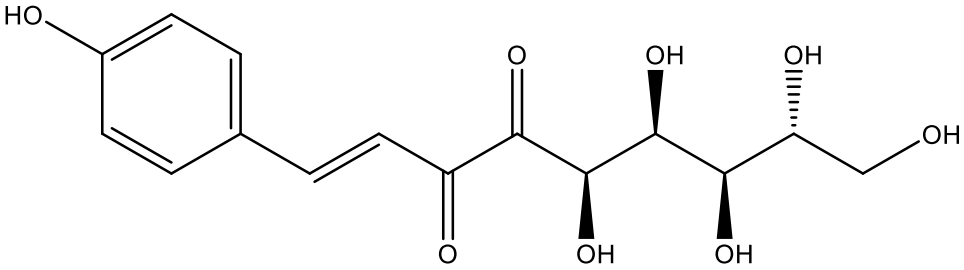
3,5-Dihydroxybenzoic acid



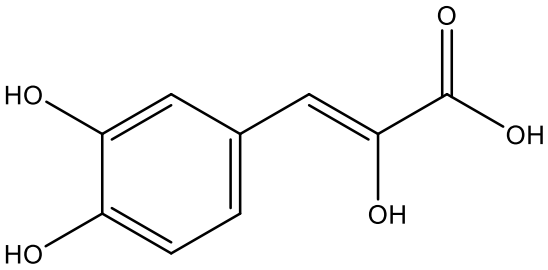
Gentisic acid



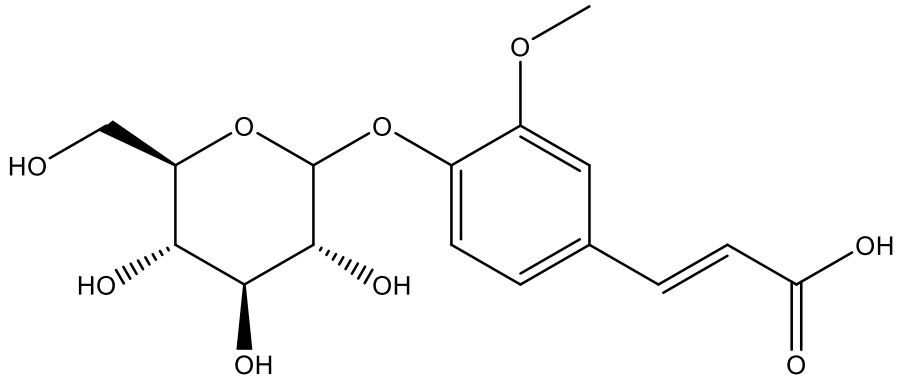
Protocatechuic acid:



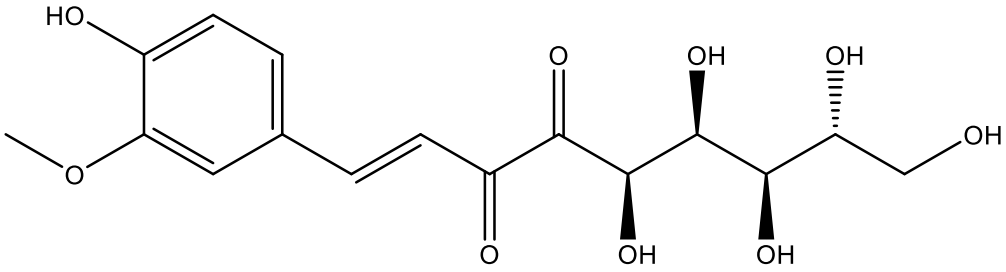
p-Coumaroyl glucose



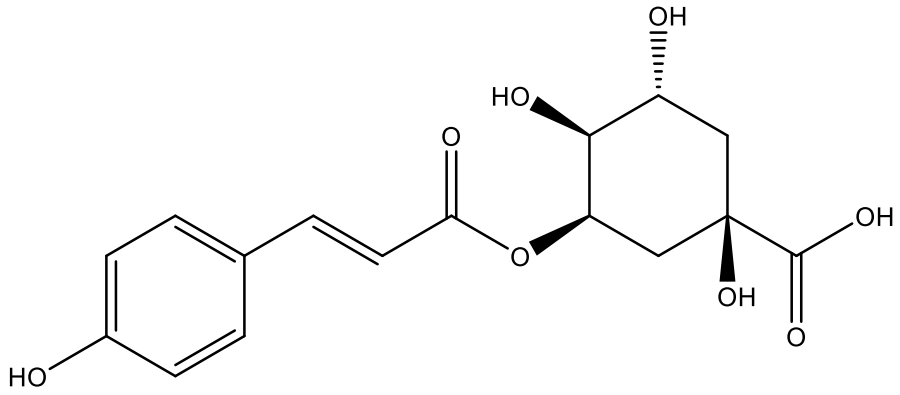
Hydroxycaffeic acid



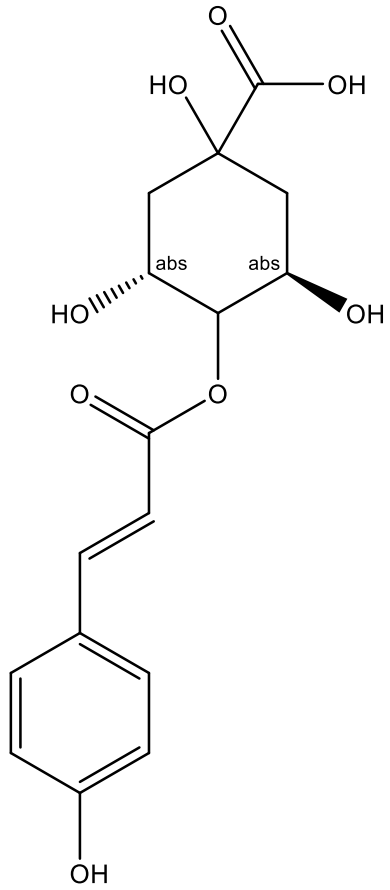
Ferulic acid 4-O-glucoside



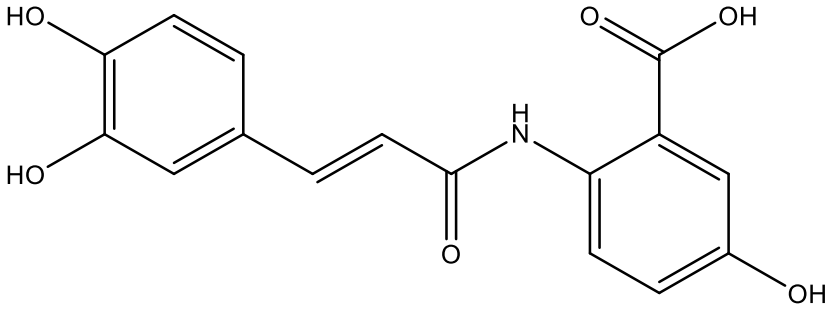
Feruloyl glucose



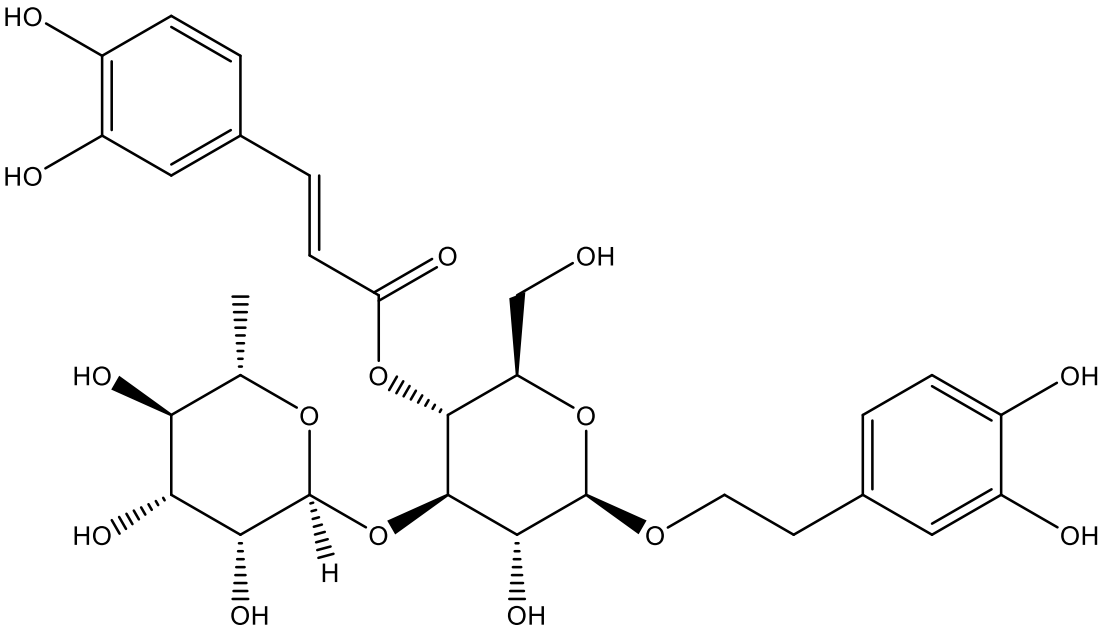
3-p-Coumaroylquinic acid



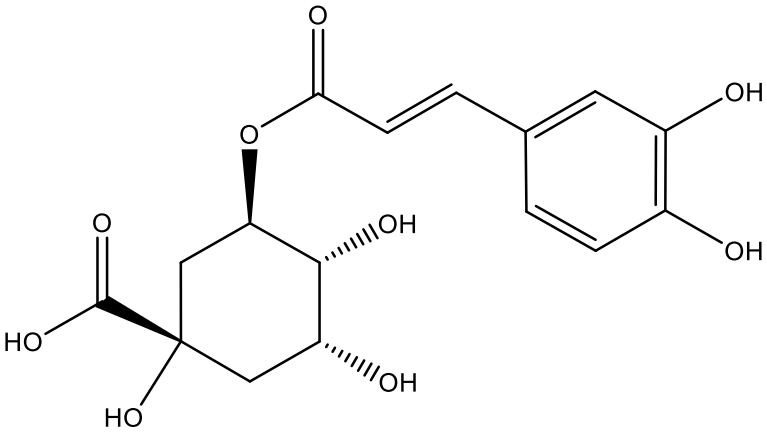
4-p-Coumaroylquinic acid



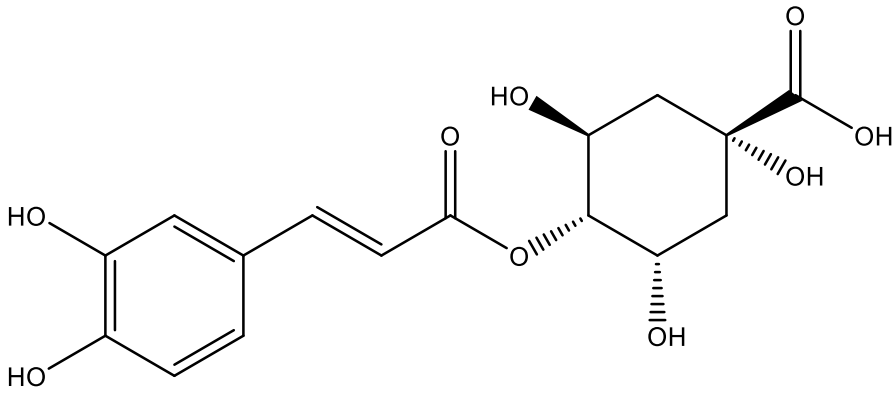
Avenanthramide 2c



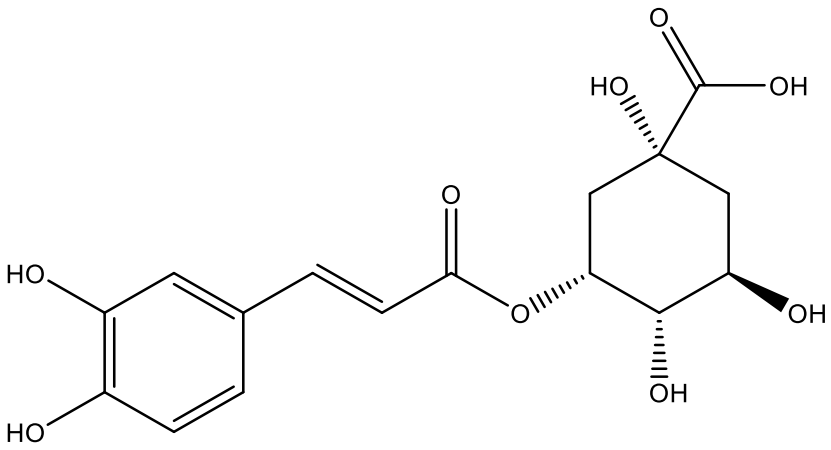
Verbascoside



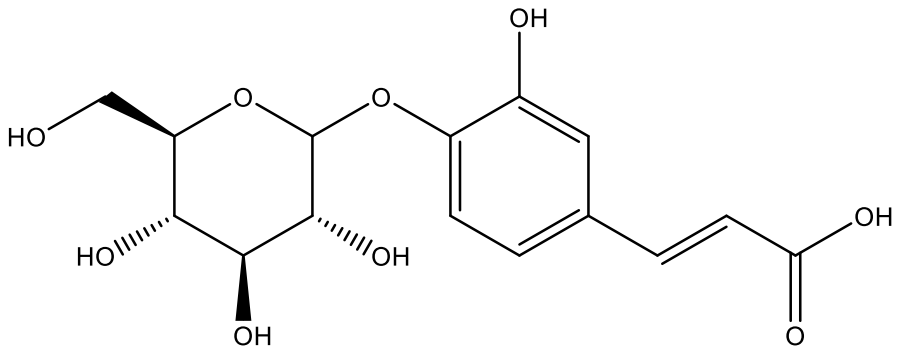
3-Caffeoylquinic acid



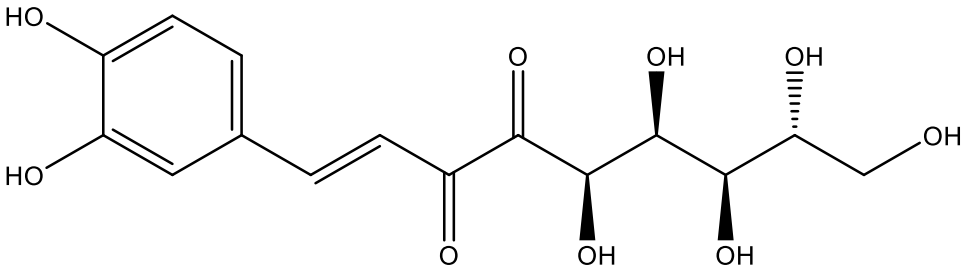
4-Caffeoylquinic acid



5-Caffeoylquinic acid

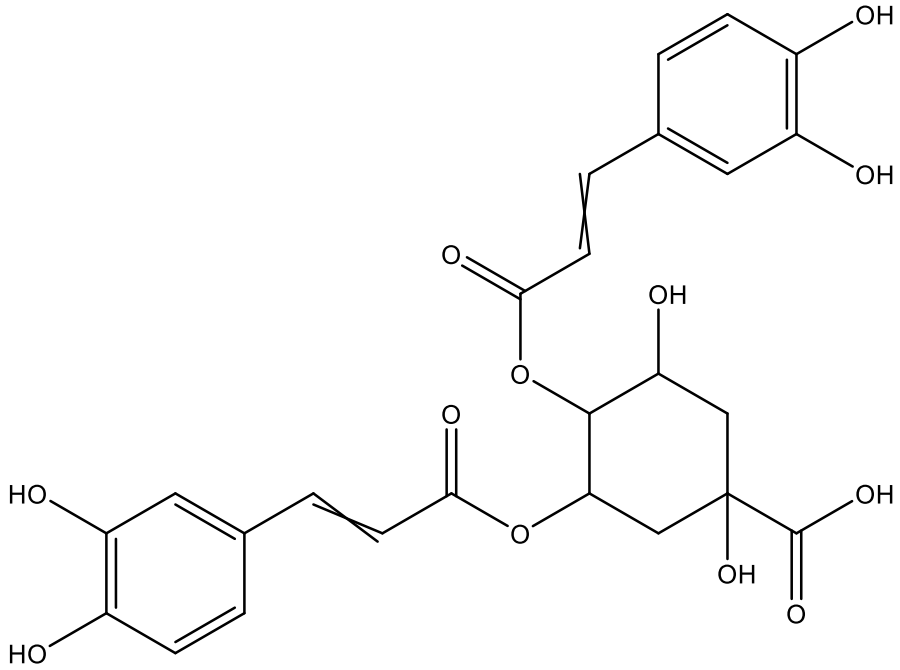


Caffeic acid 4-O-glucoside

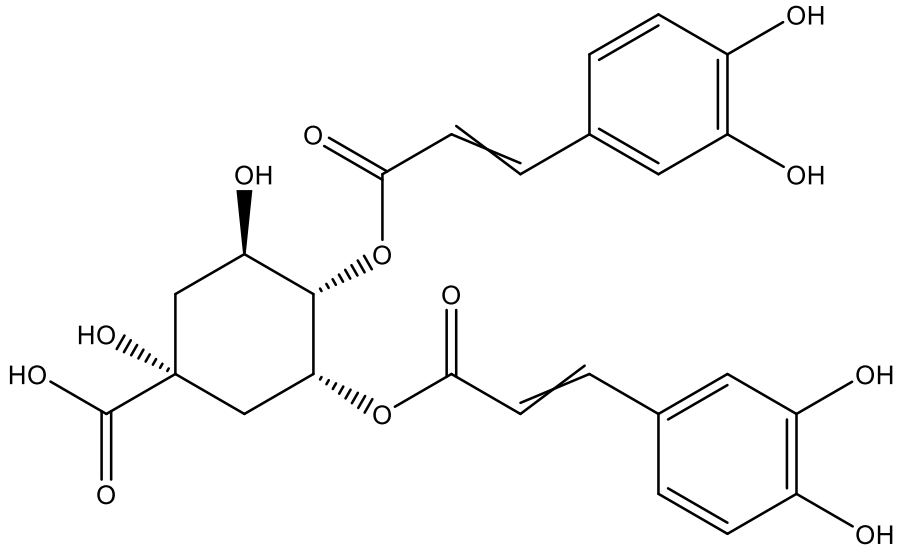


Caffeoyl glucose

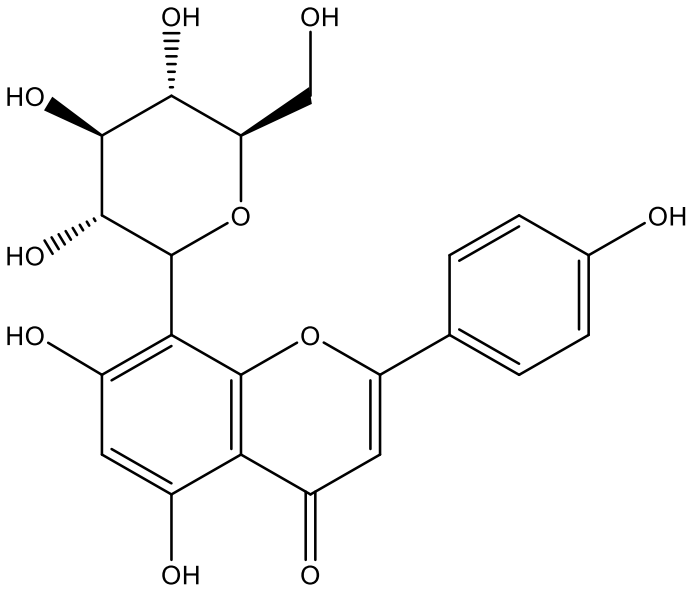
Phenolsic compounds



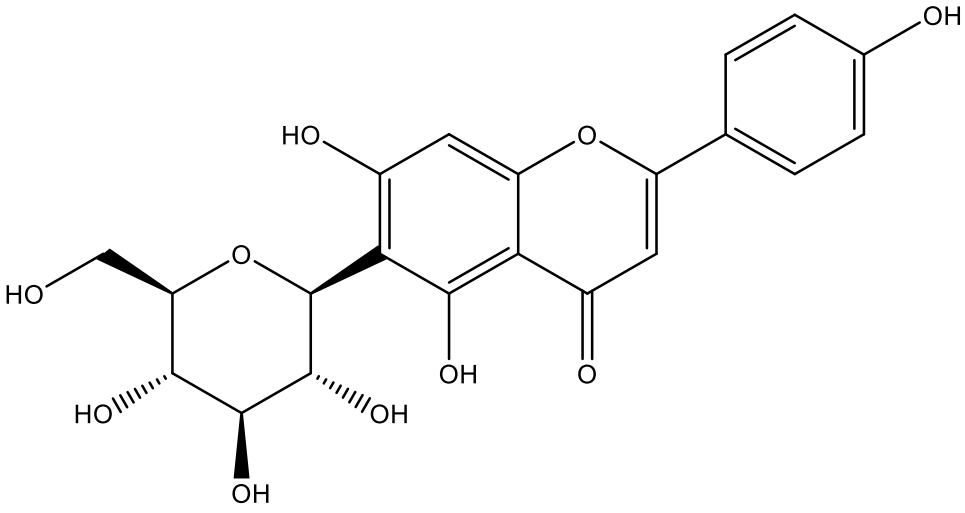
3,4-Dicaffeoylquinic acid



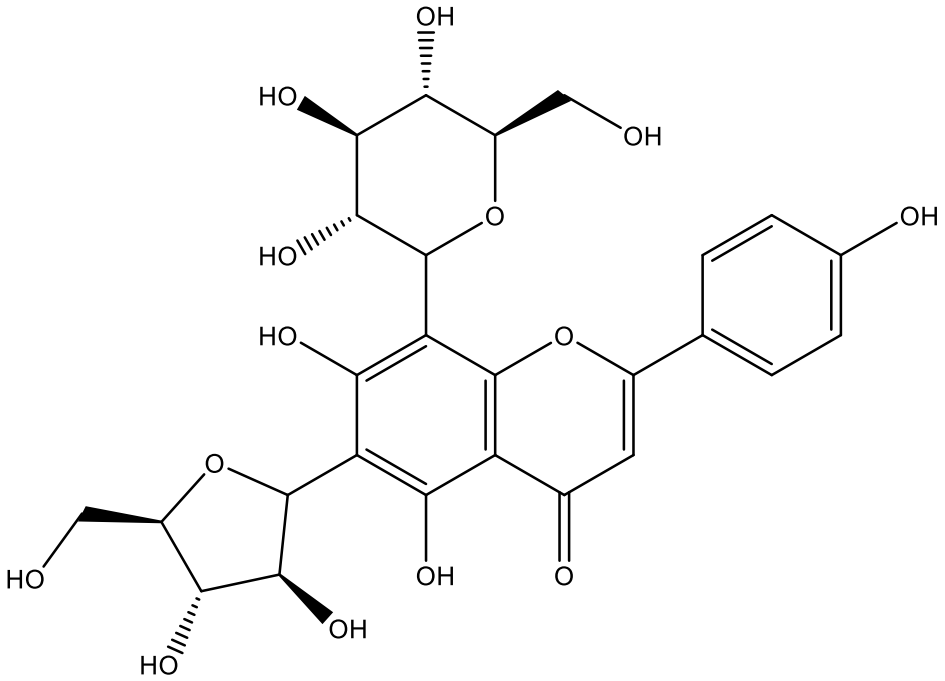
4,5-Dicaffeoylquinic acid



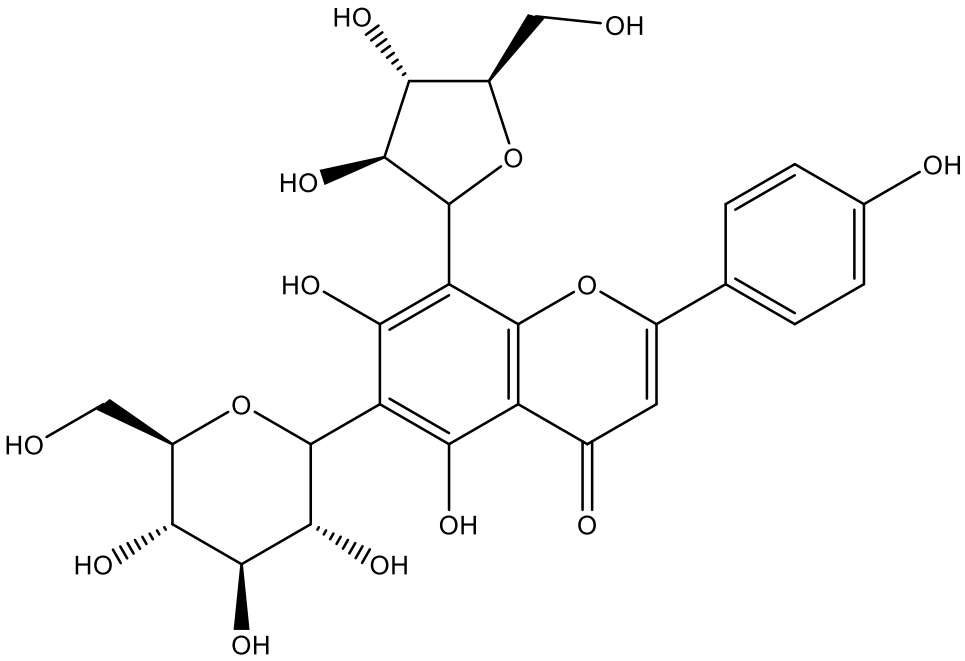
Vitexin



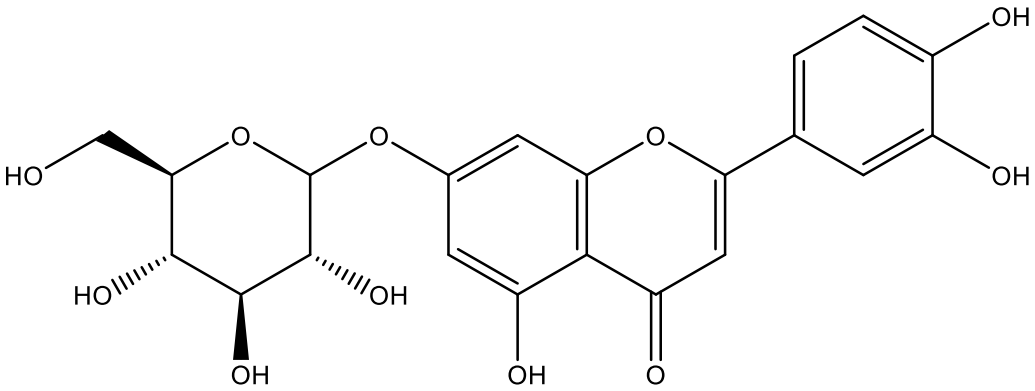
Isovitexin



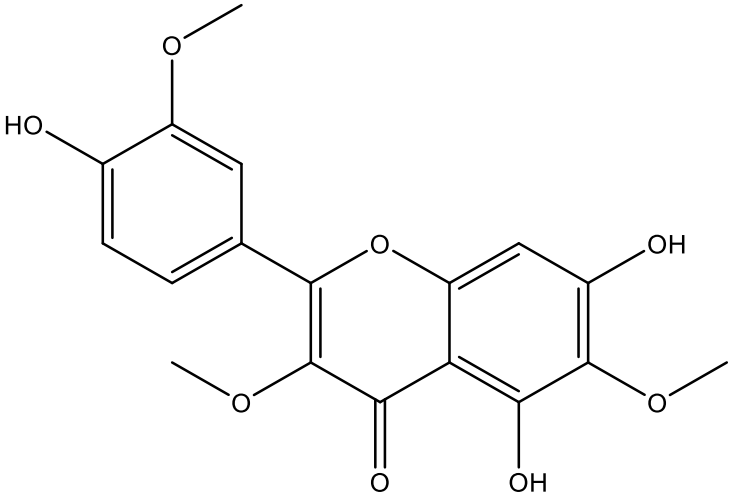
6-C-arabinosyl-8-C-glucosyl apigenin



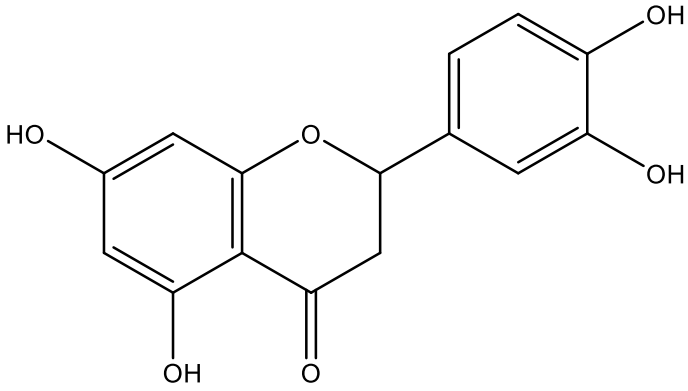
6-C-glucosyl-8-C-arabinosyl apigenin



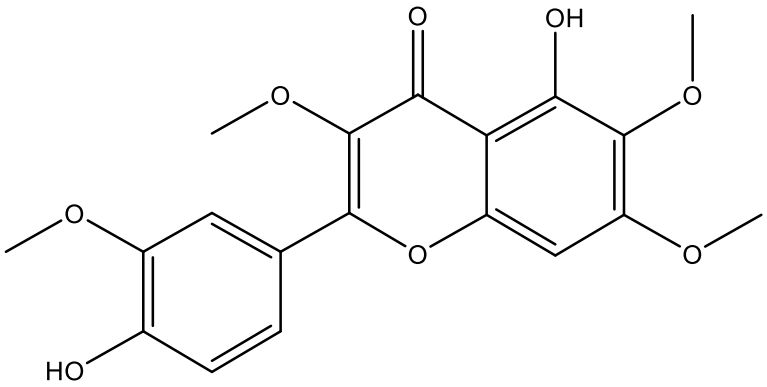
Luteolin-7-O-glucoside



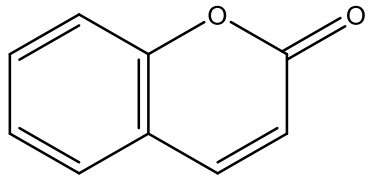
Jaceidin



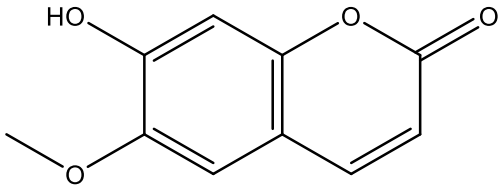
Eriodictyol



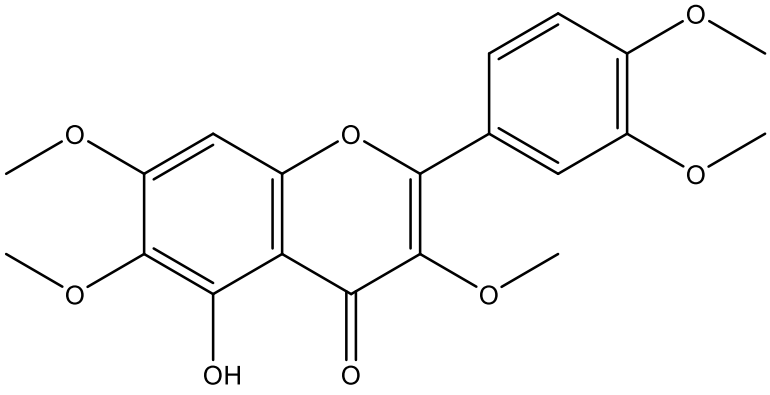
Chrysosplenetin



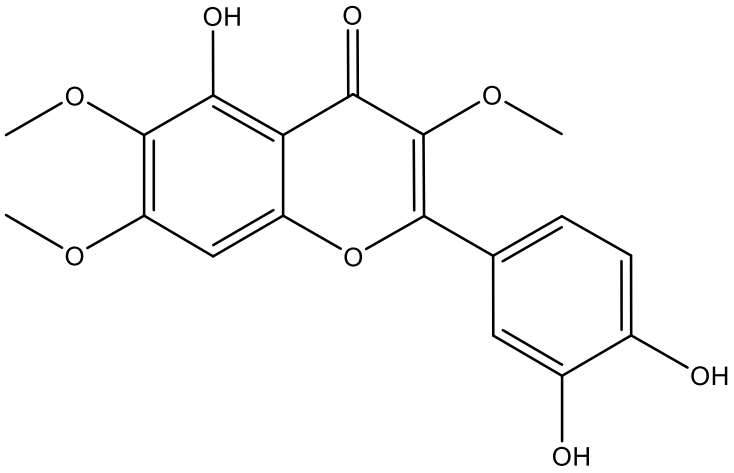
Coumarin



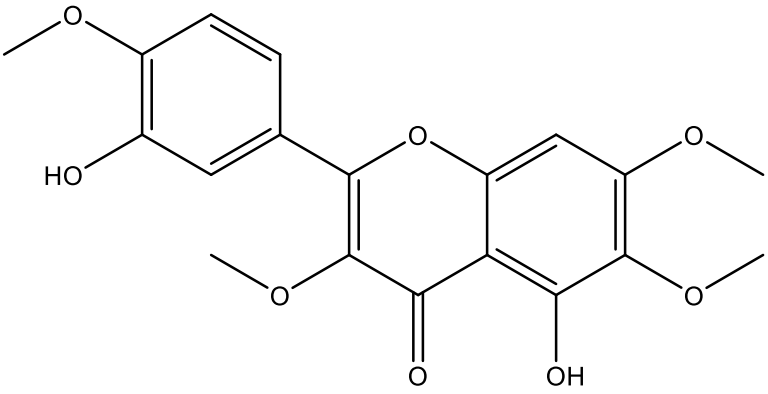
Scopoletin



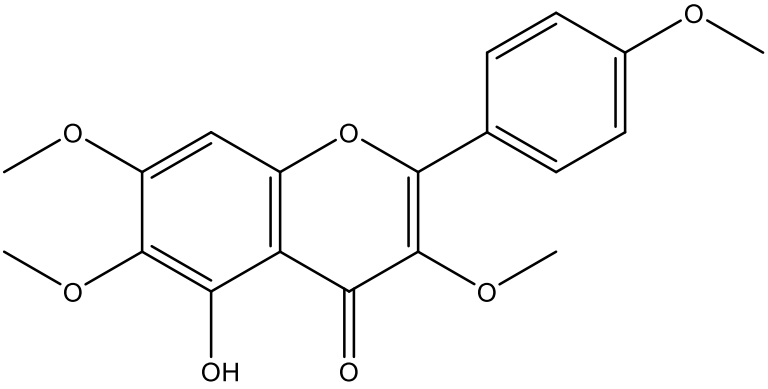
Artemetin



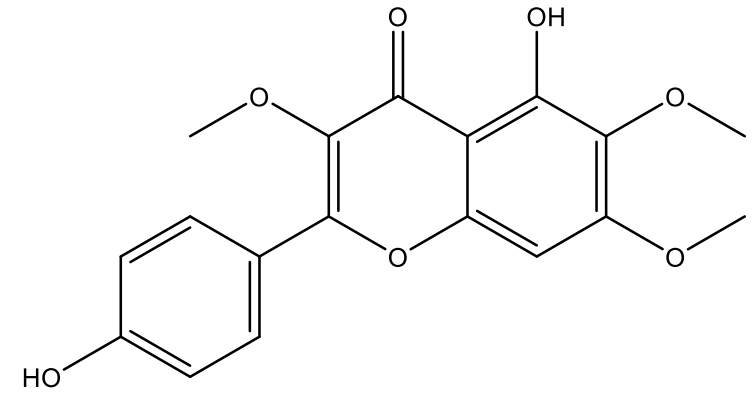
Chrysosplenol D



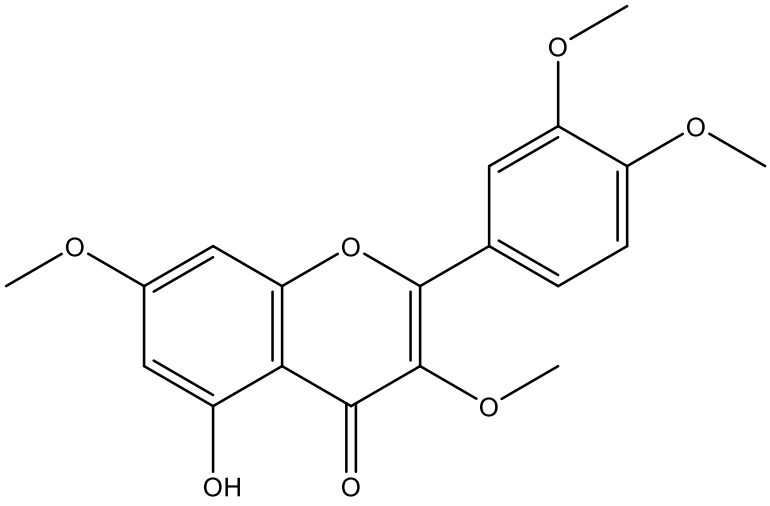
Casticin



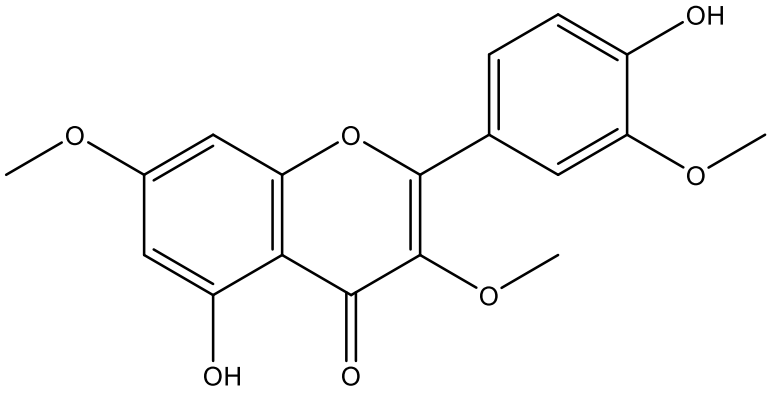
5-Hydroxy-3,4',6,7-tetramethoxyflavone



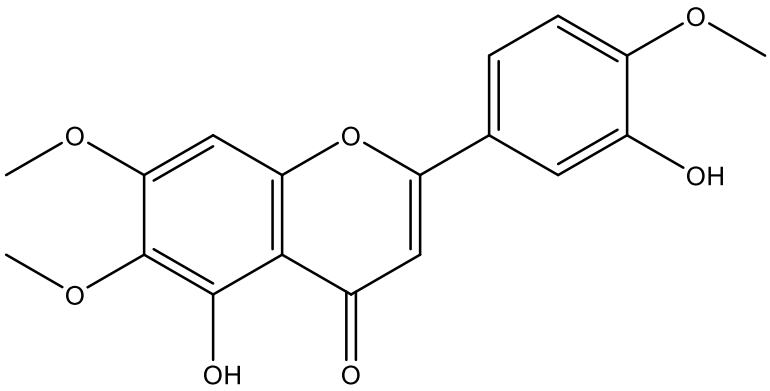
Penduletin



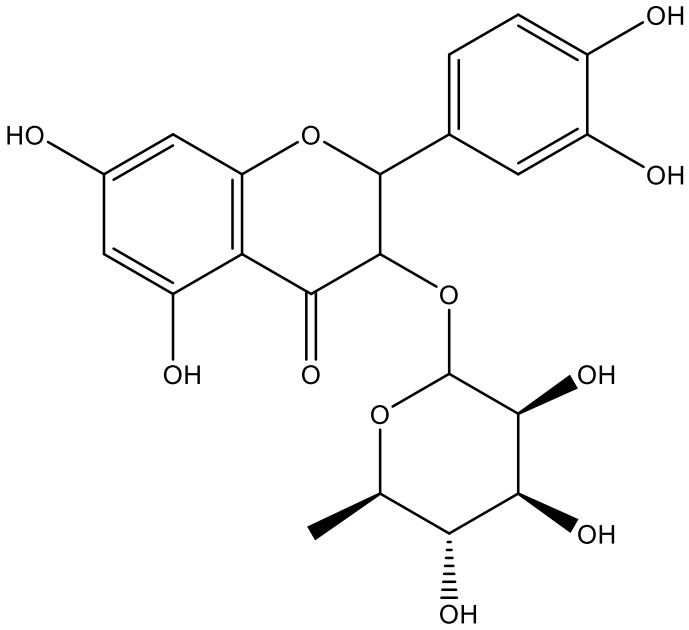
Retusin



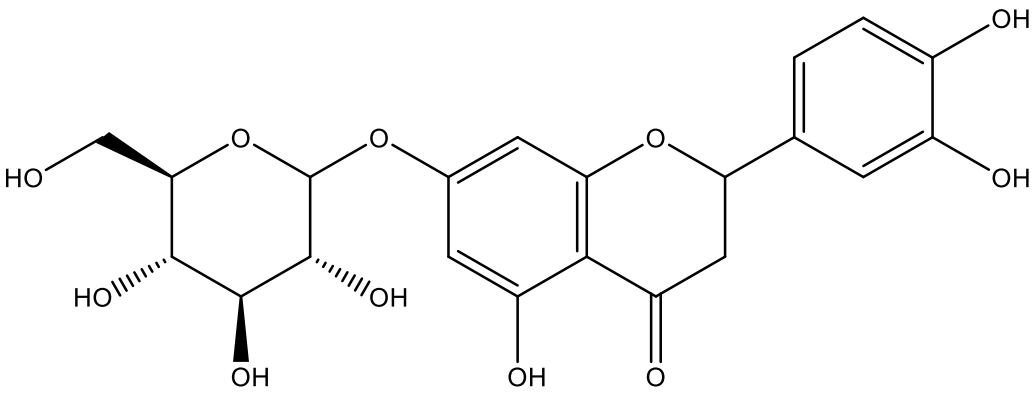
Pachypodol



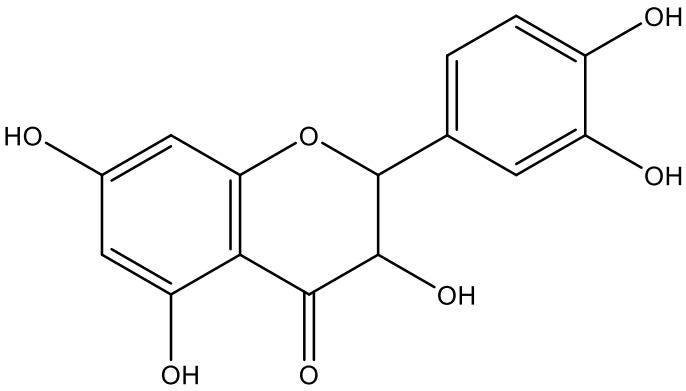
Eupatorin



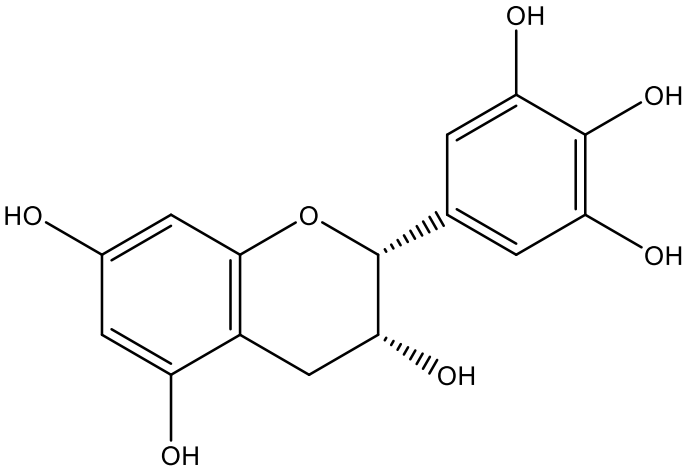
Dihydroquercetin 3-O-rhamnosid



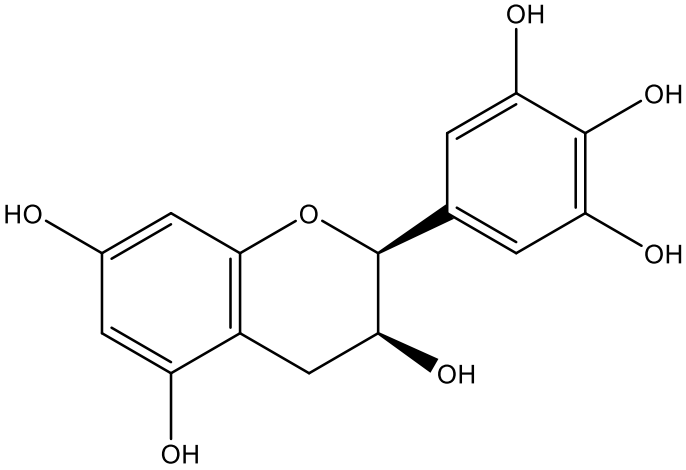
Eriodictyol 7-O-glucoside



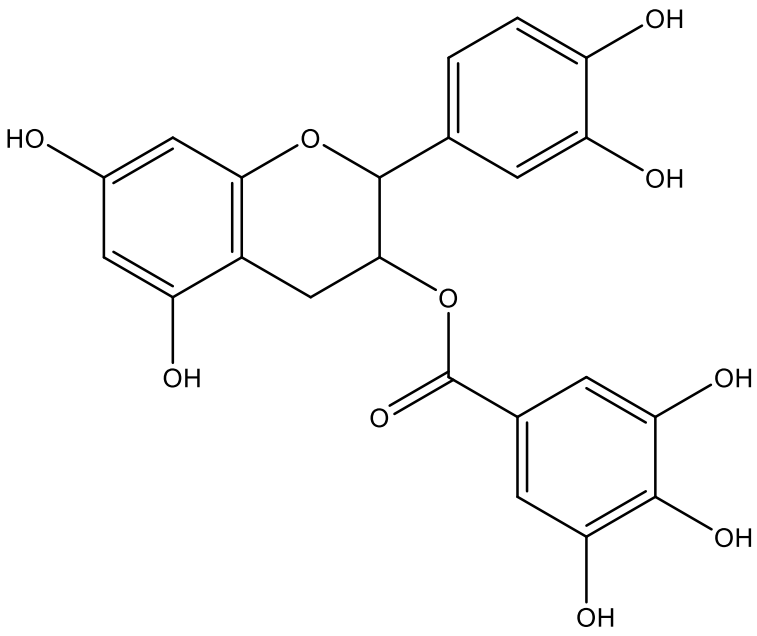
Dihydroquercetin



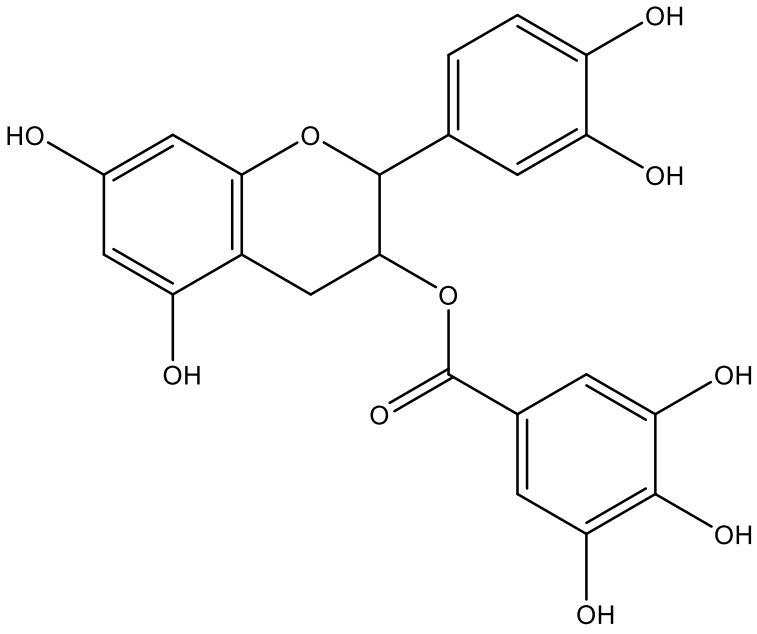
(-)-Epigallocatechin



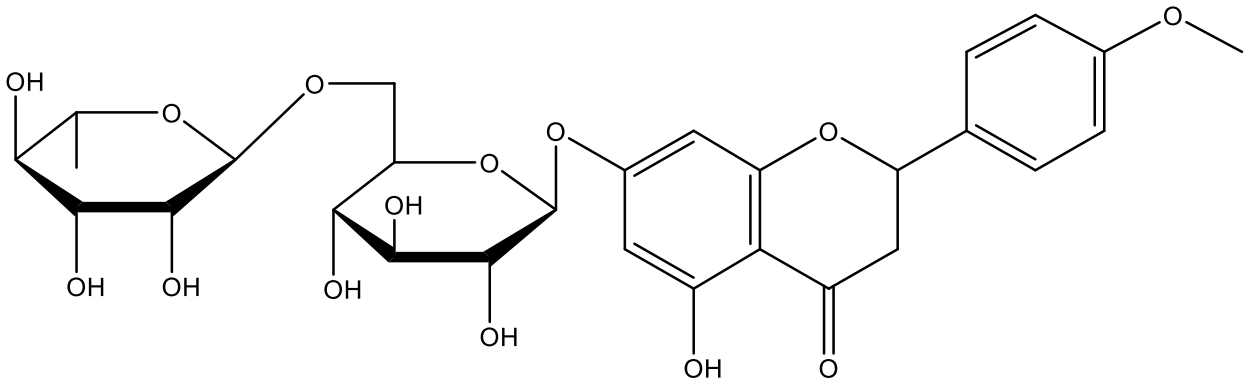
(+)-Gallocatechin



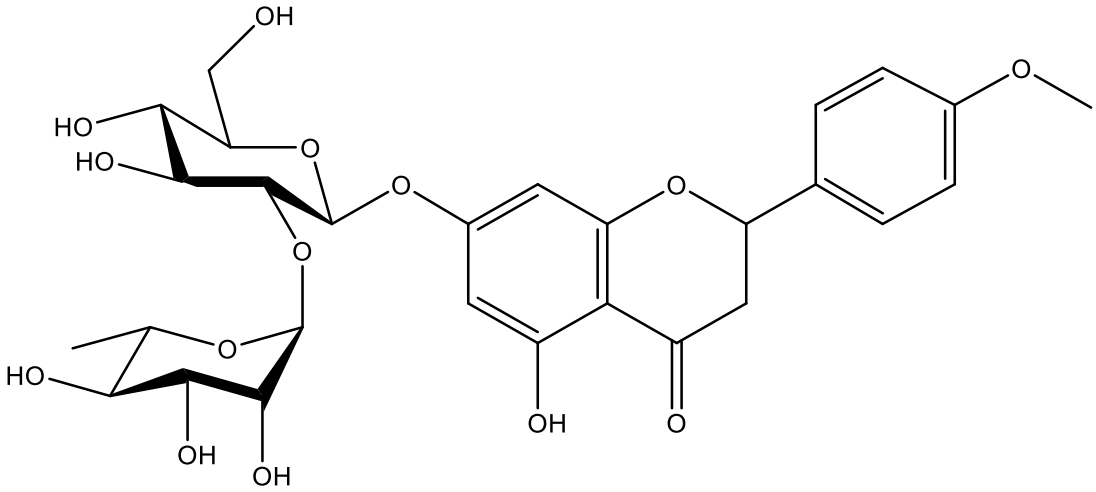
(-)-Epicatechin -O-gallate



(+)-Catechin 3-O-gallate



Didymin



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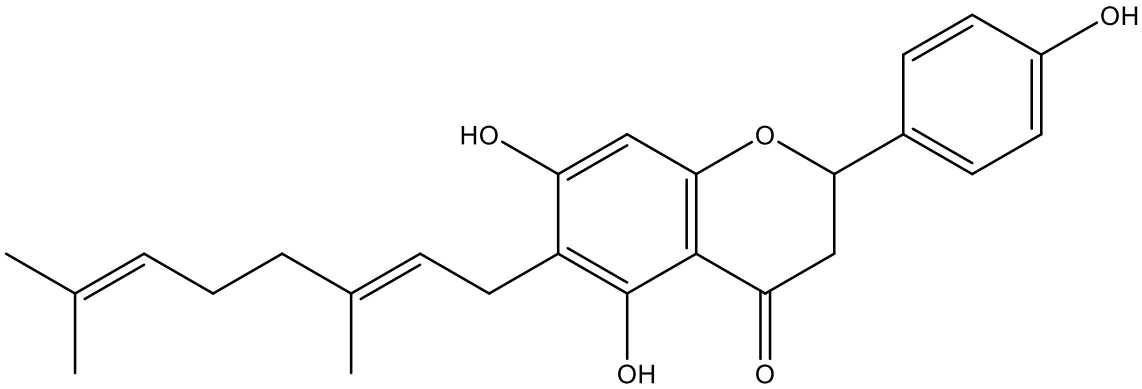
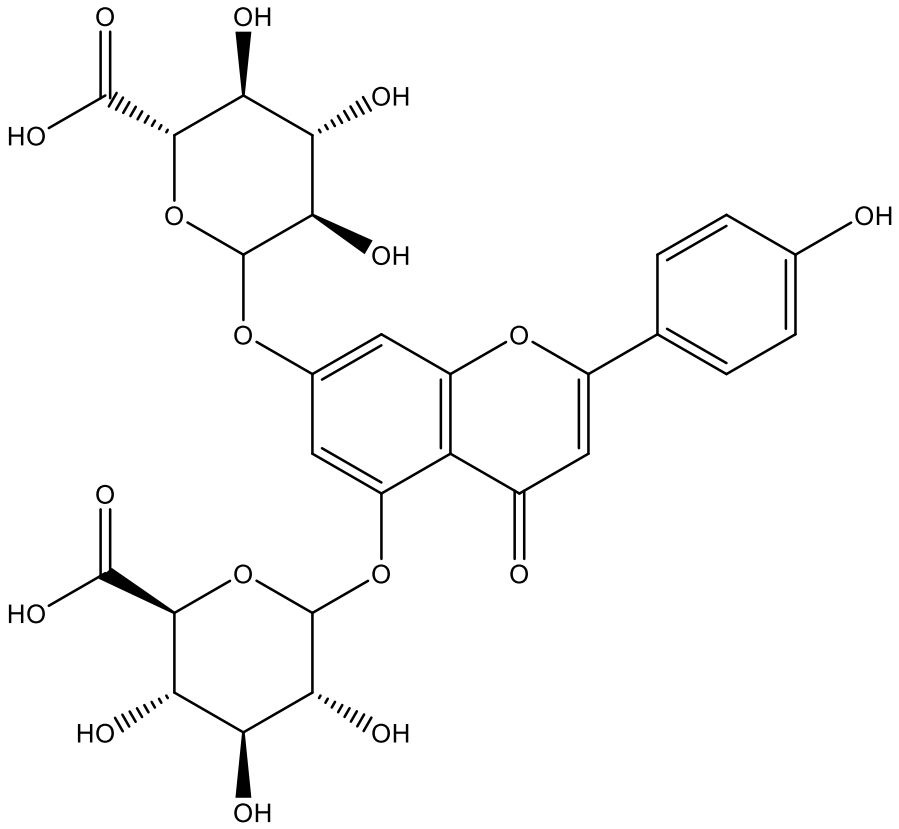
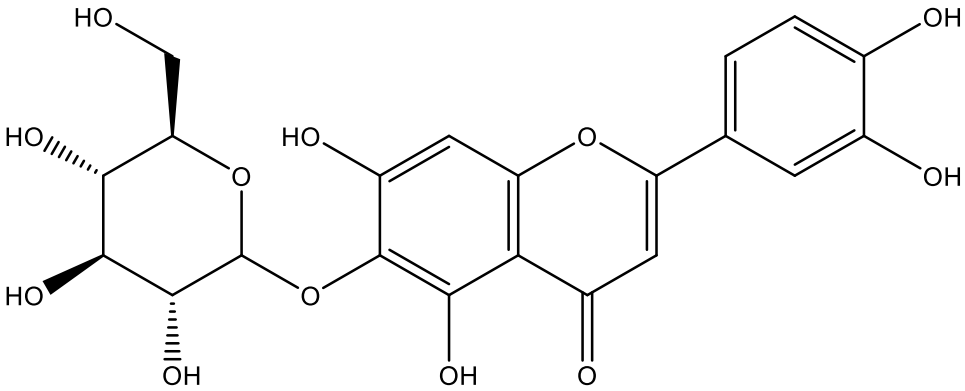


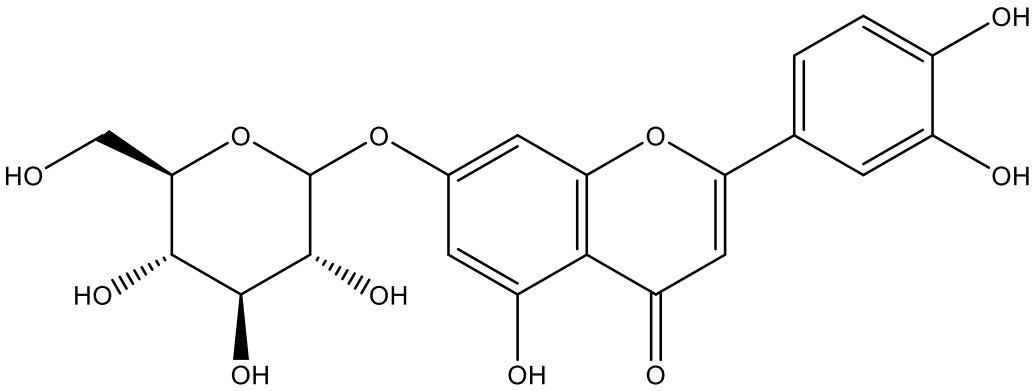
6-Geranylnaringenin



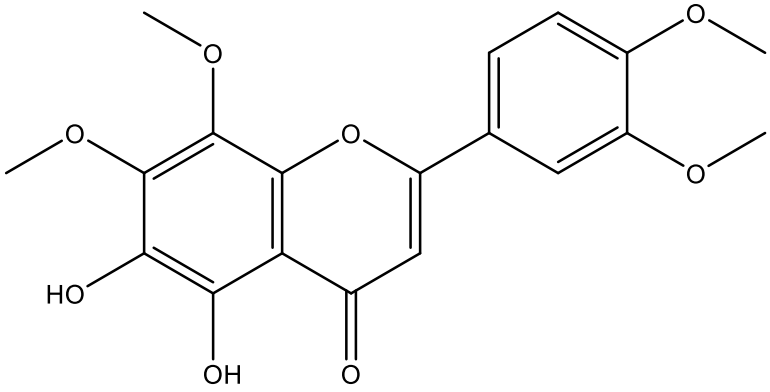
Apigenin 7-O-diglucuronide



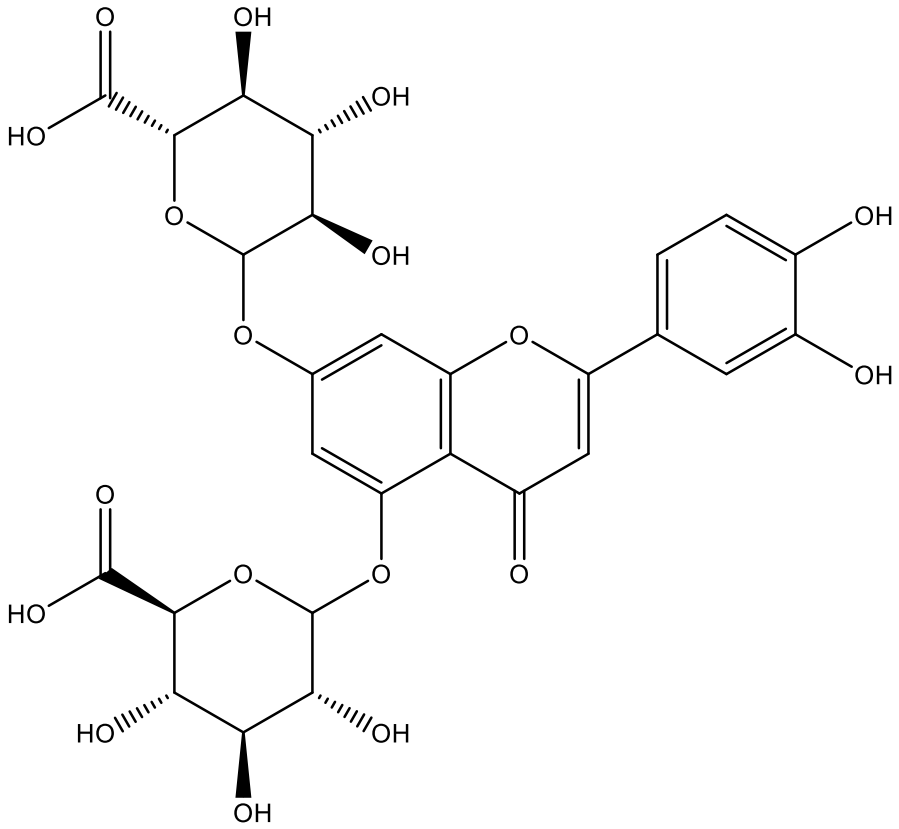
Luteolin 6-C-glucoside



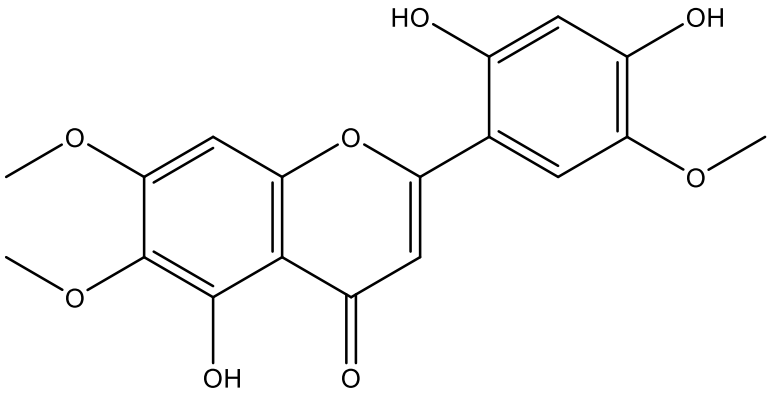
Luteolin 7-O-glucoside



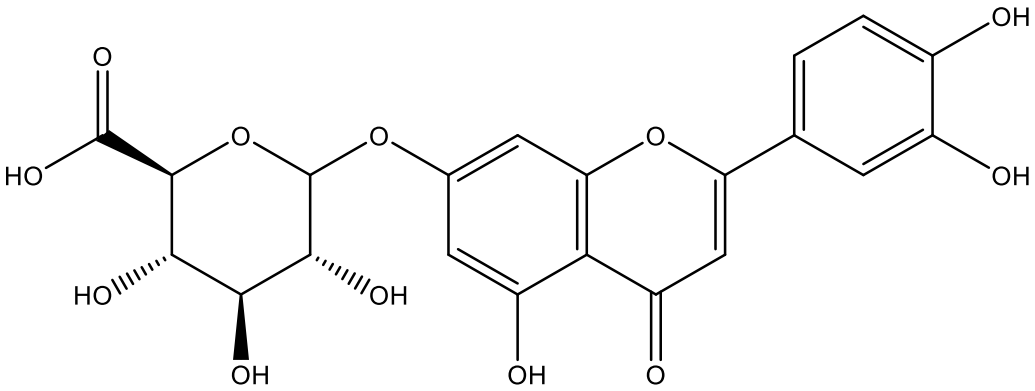
Pebrellin



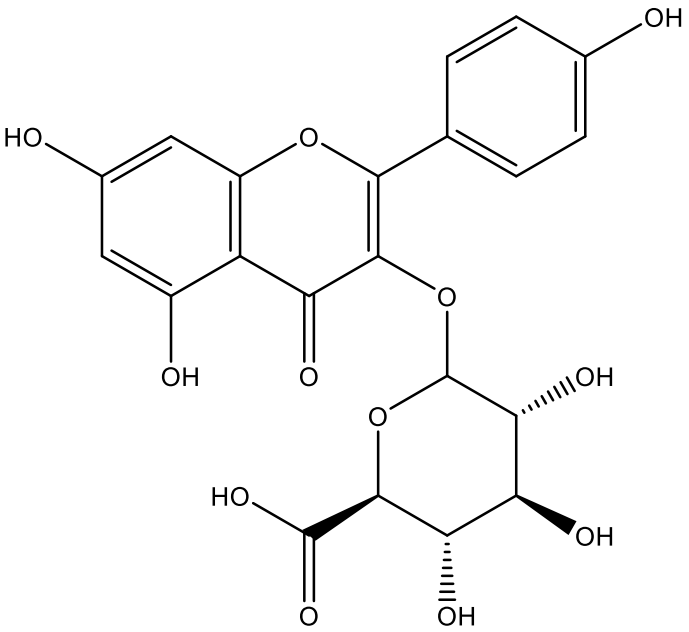
Luteolin 7-O-diglucuronide



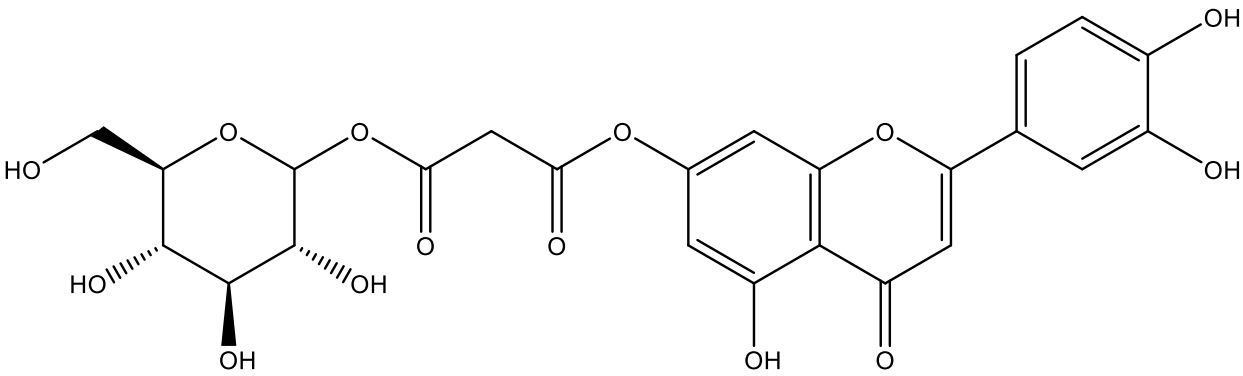
Arcapillin



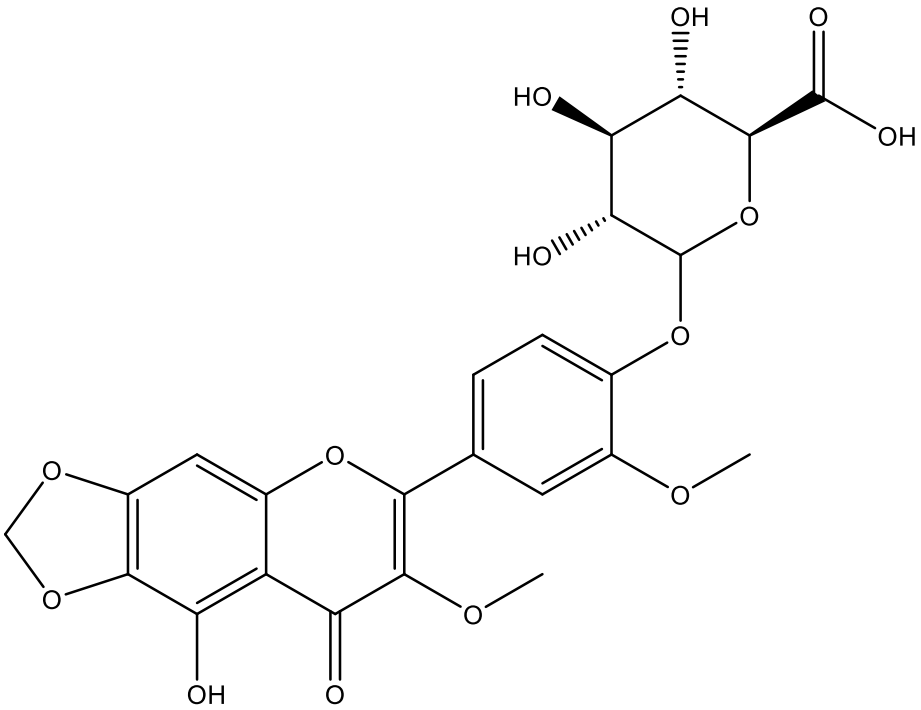
Luteolin 7-O-glucuronide



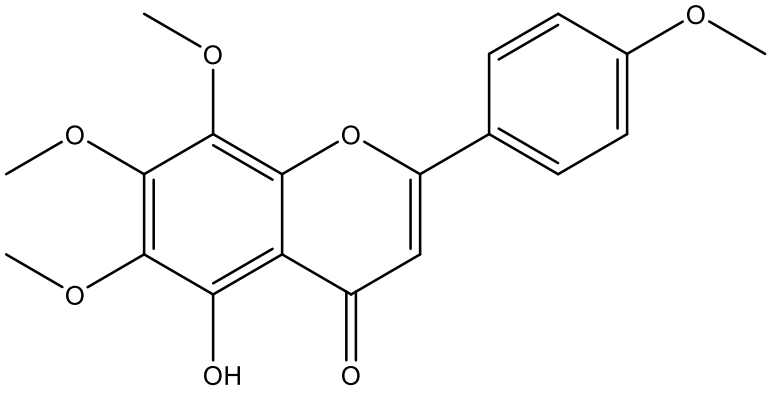
Kaempferol 3-O-glucuronide



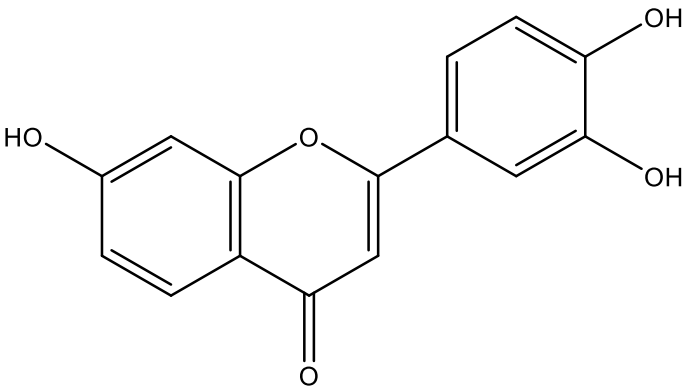
Luteolin 7-O-malonyl-glucoside



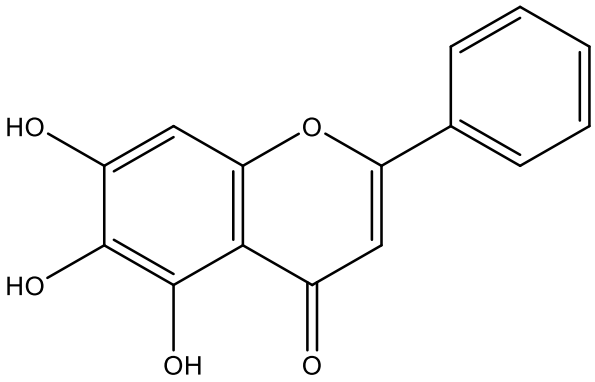
5,4'-Dihydroxy-3,3'-dimethoxy-6:7-methylenedioxyflavone 4'-O-glucuronid



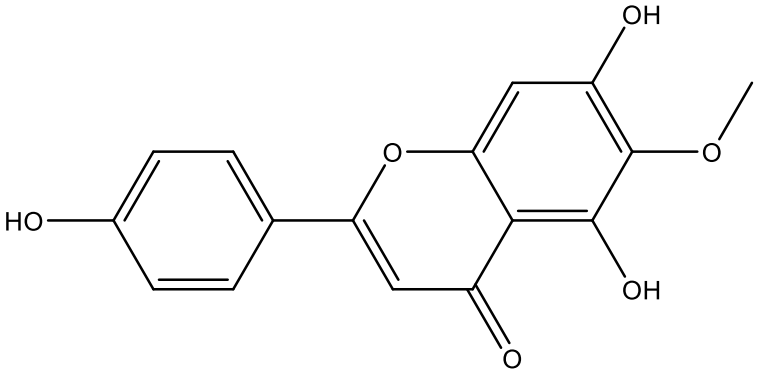
Gardenin B



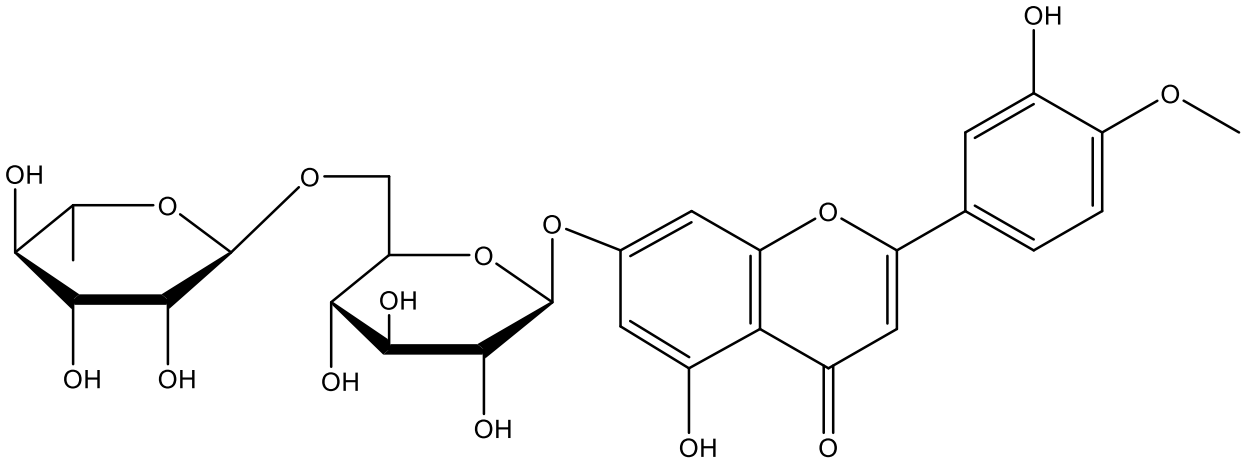
7,3',4'-Trihydroxyflavone



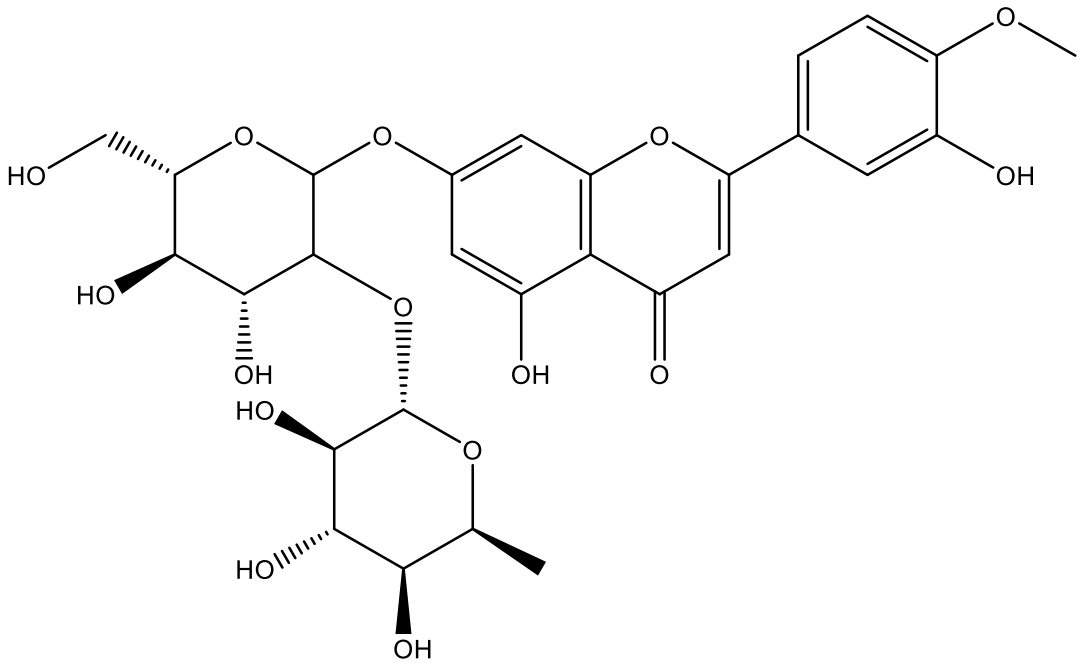
Baicalein



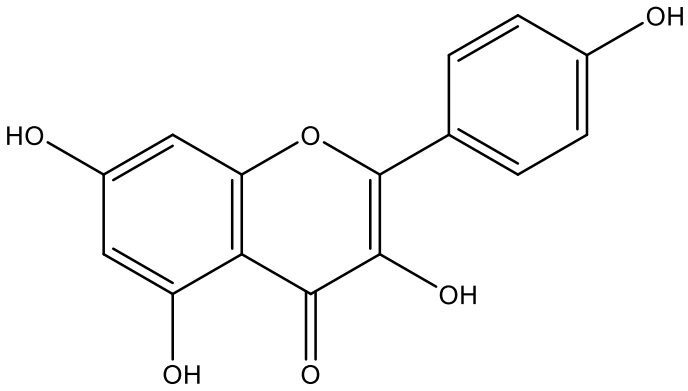
Hispidulin



Diosmin

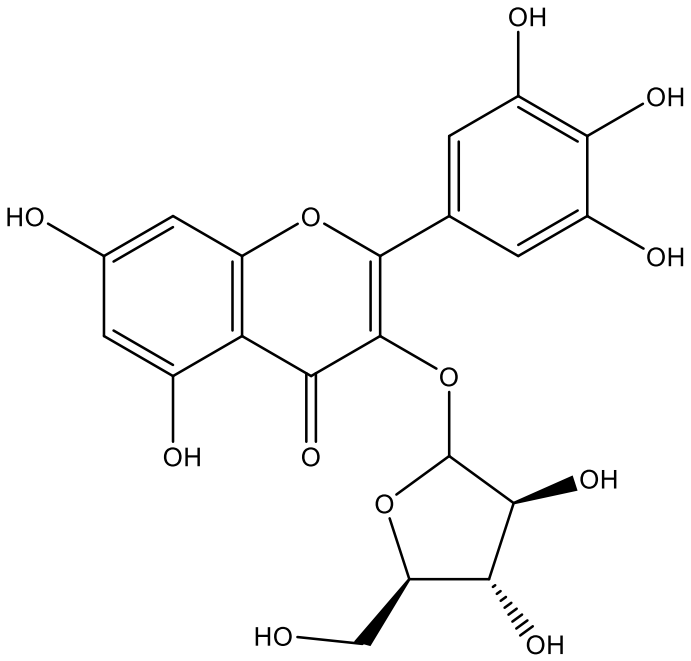


Neodiosmin

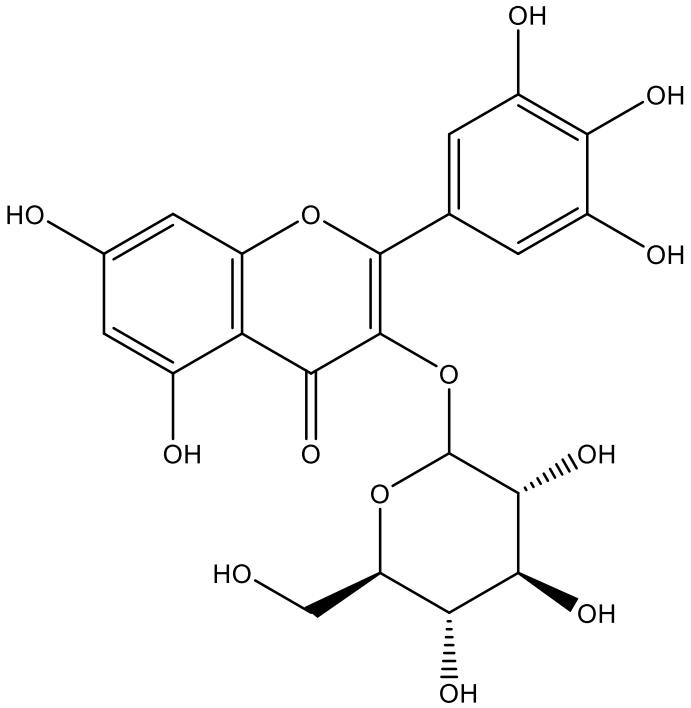


b

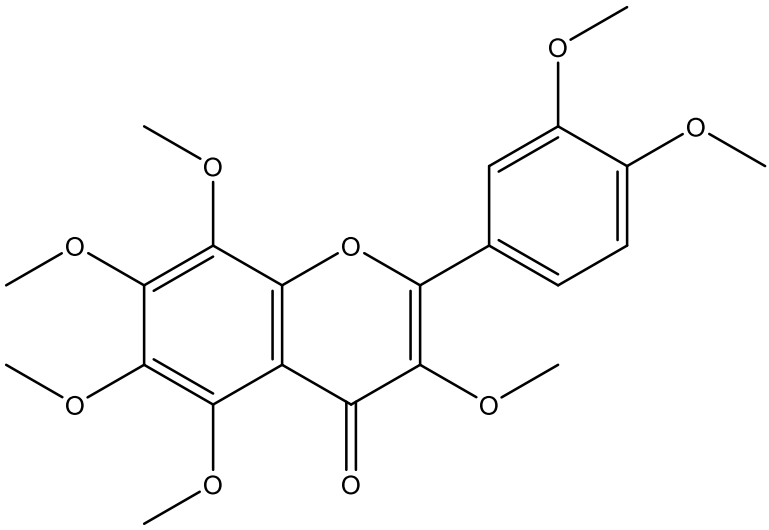
Kaempferide



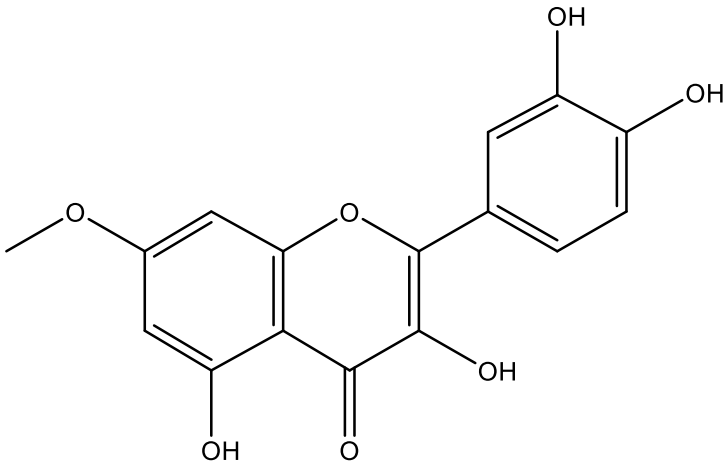
Myricetin 3-O-arabinoside



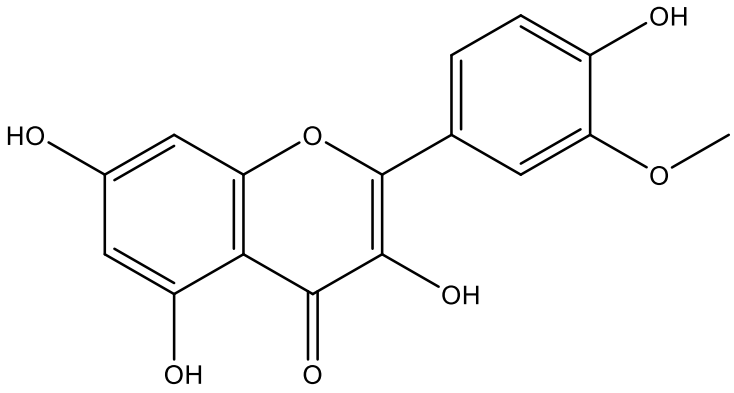
Myricetin 3-O-glucoside



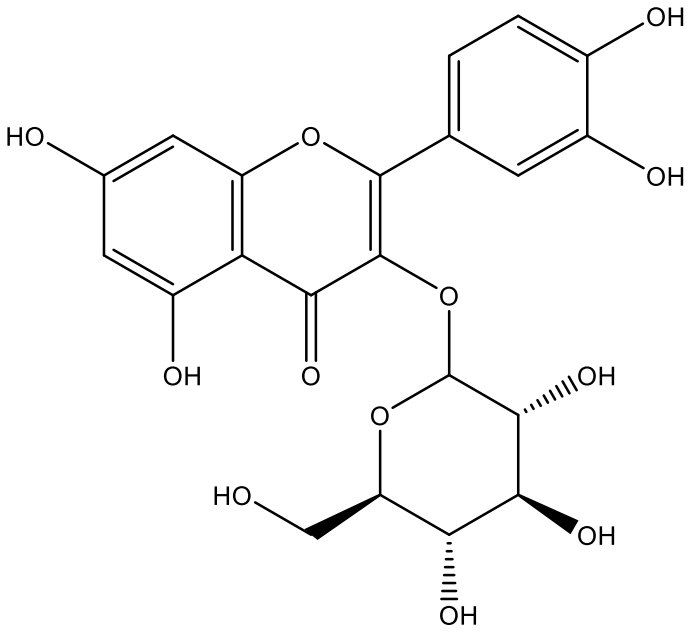
3-Methoxynobiletin



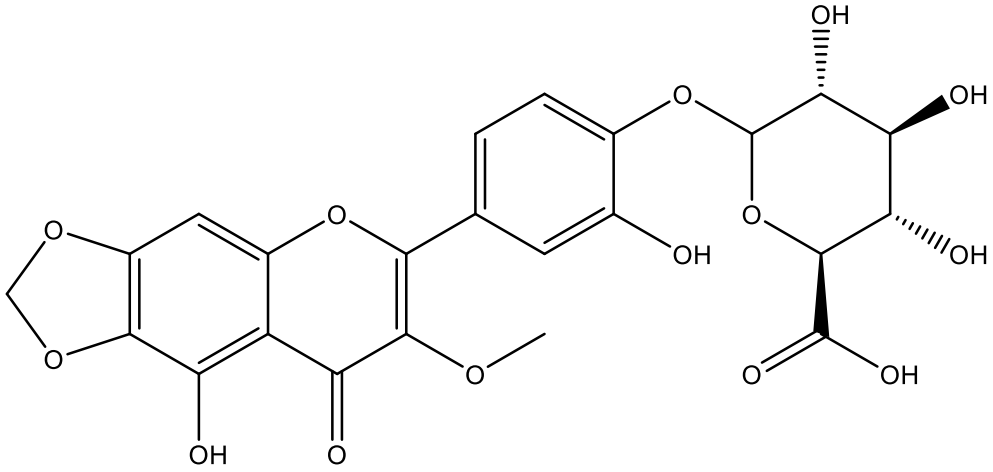
Rhamnetin



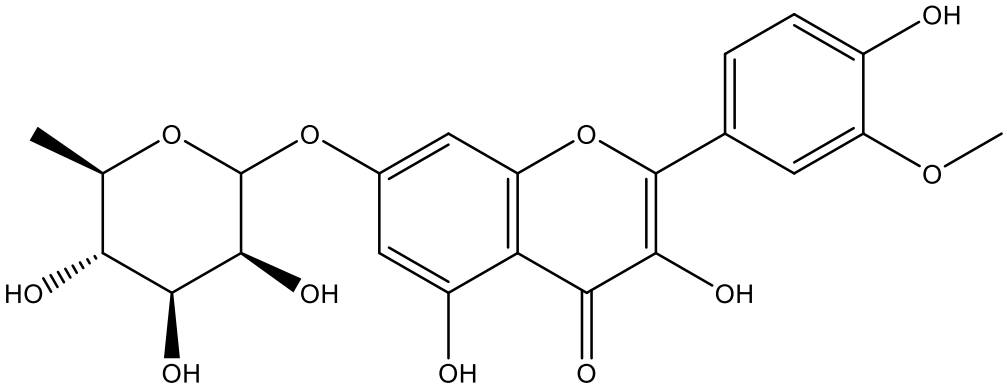
Isorhamnetin



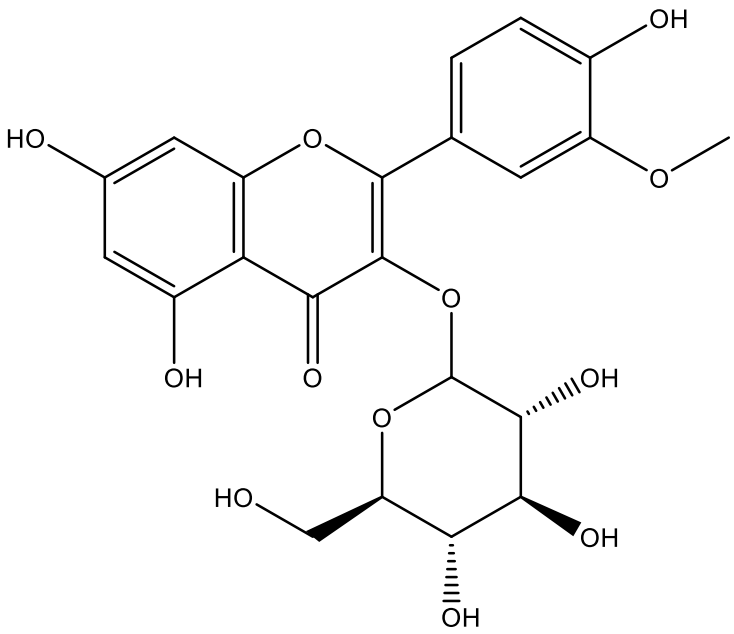
Quercetin 3-O-glucoside



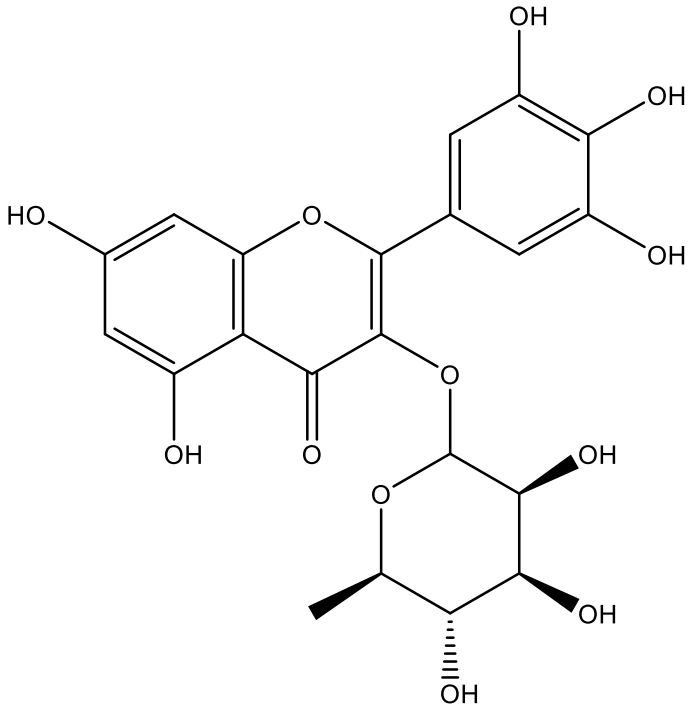
5,3',4'-Trihydroxy-3-methoxy-6:7-methylenedioxyflavone 4'-O-glucuronide



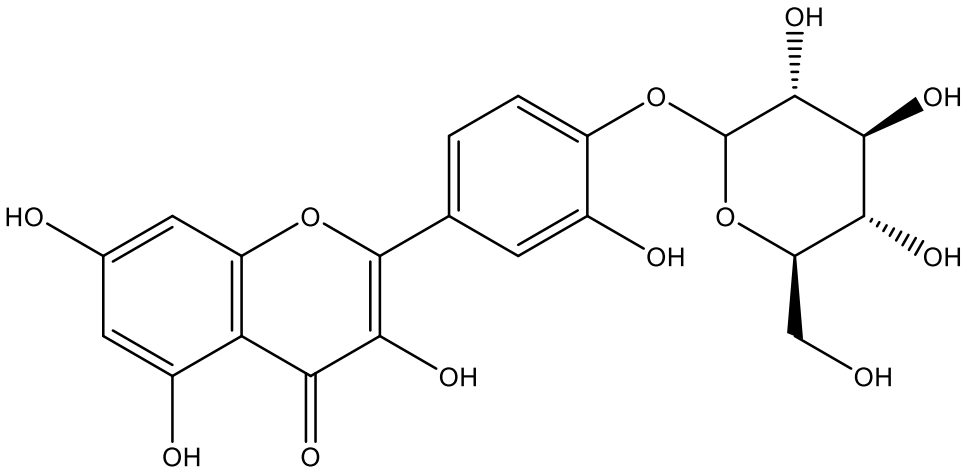
Isorhamnetin 7-O-rhamnoside



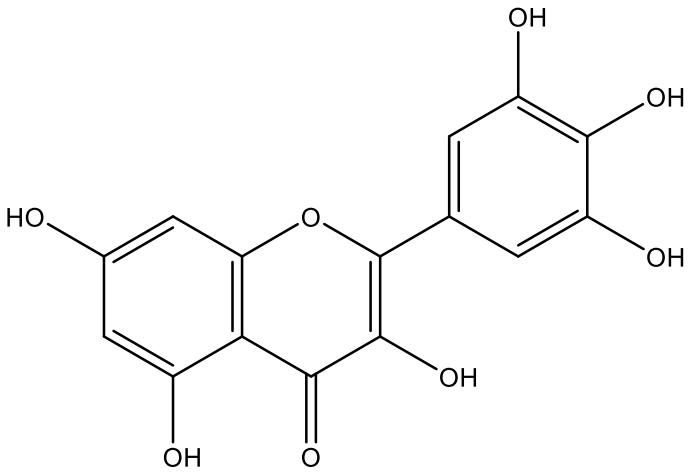
Isorhamnetin 3-O-glucoside



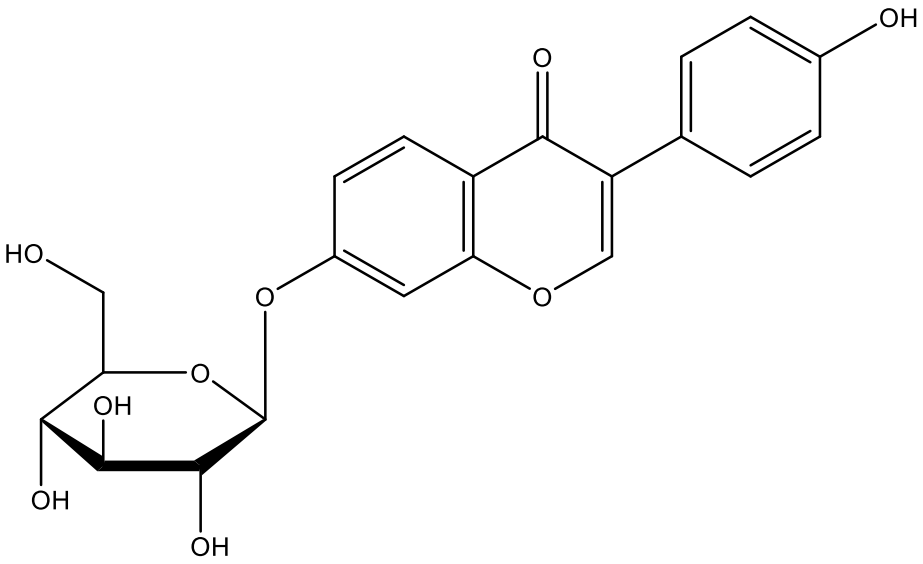
Myricetin 3-O-rhamnoside



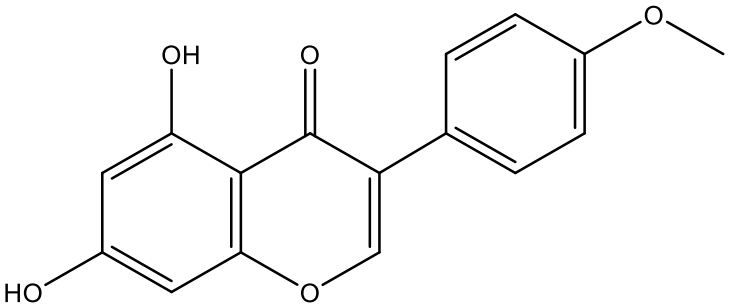
Quercetin 4'-O-glucoside (Spiraeoside)



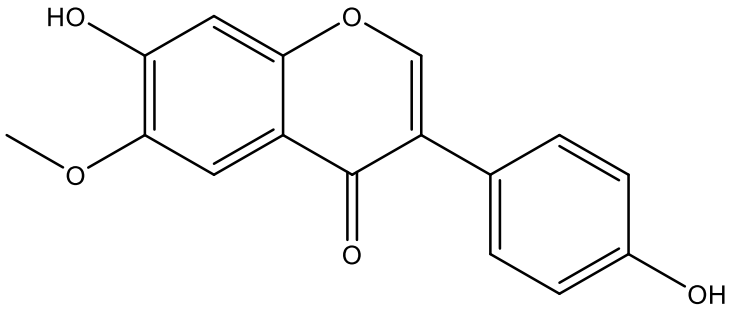
Myricetin



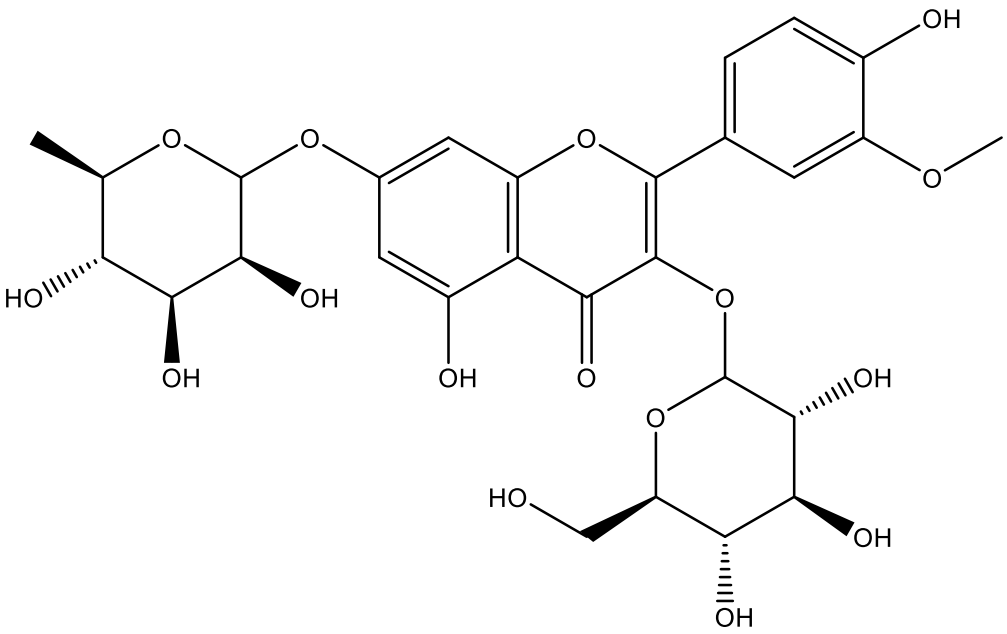
Daidzin



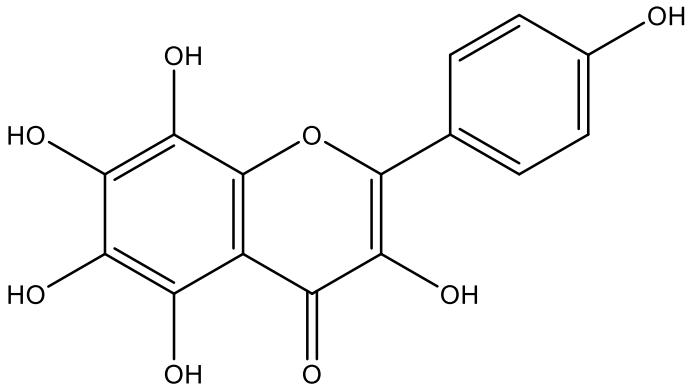
Biochanin A



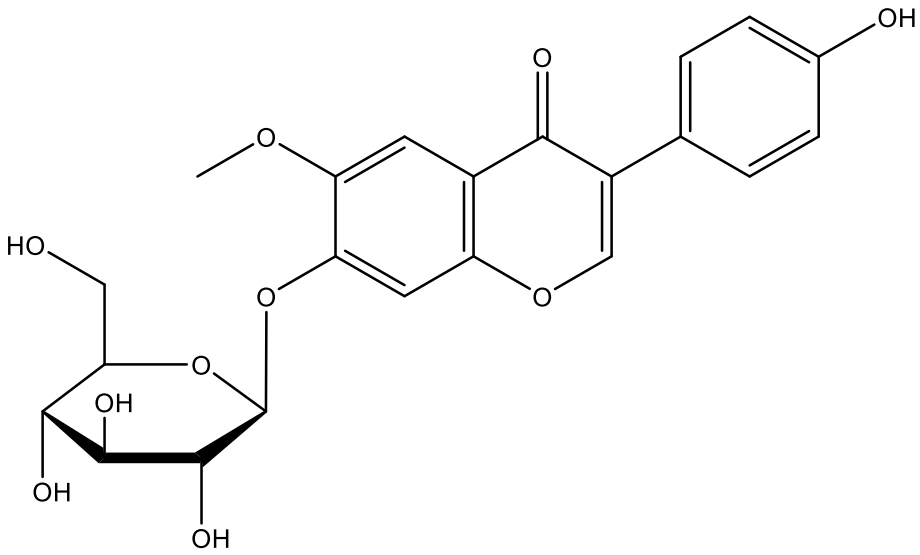
Glycitein



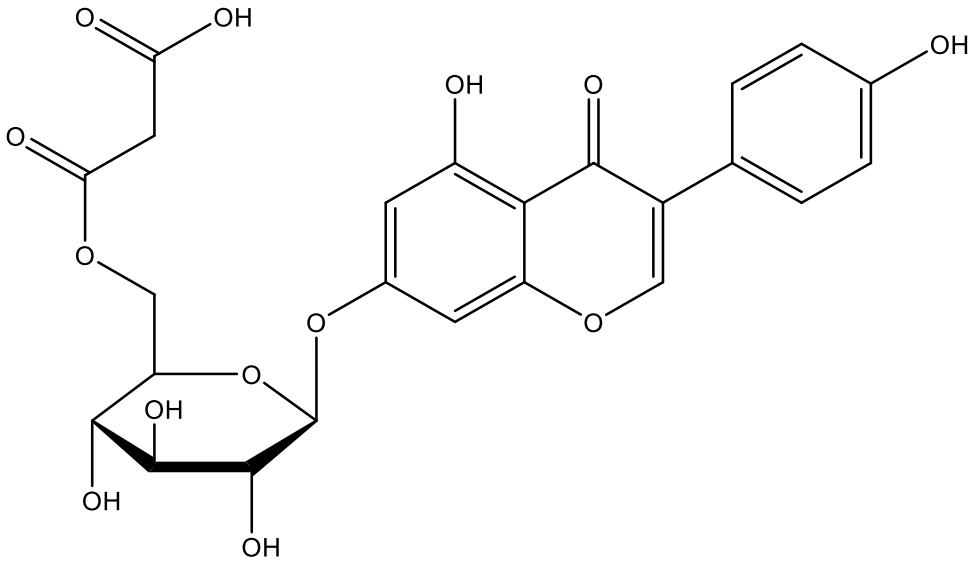
Isorhamnetin 3-O-glucoside 7-O-rhamnoside



6,8-Dihydroxykaempferol

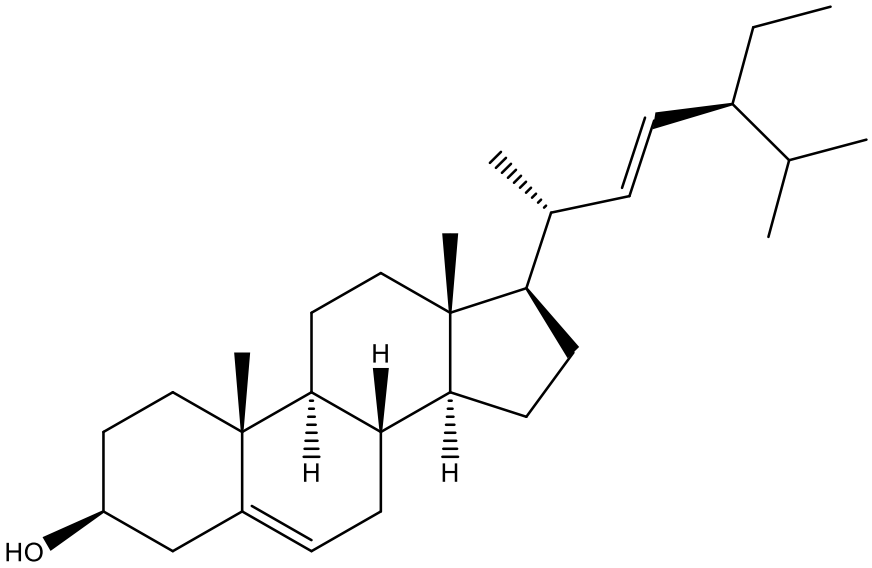


Glycitin

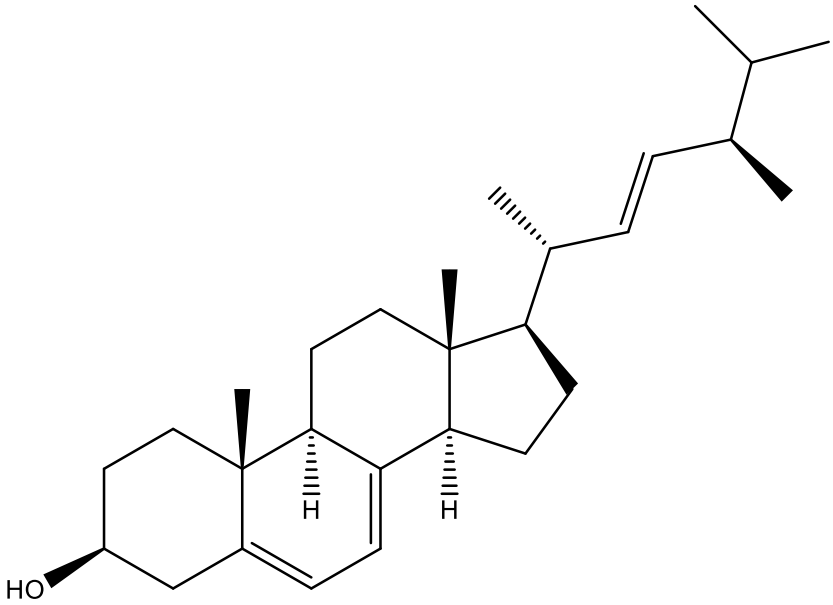


6''-O-Malonylgenistin

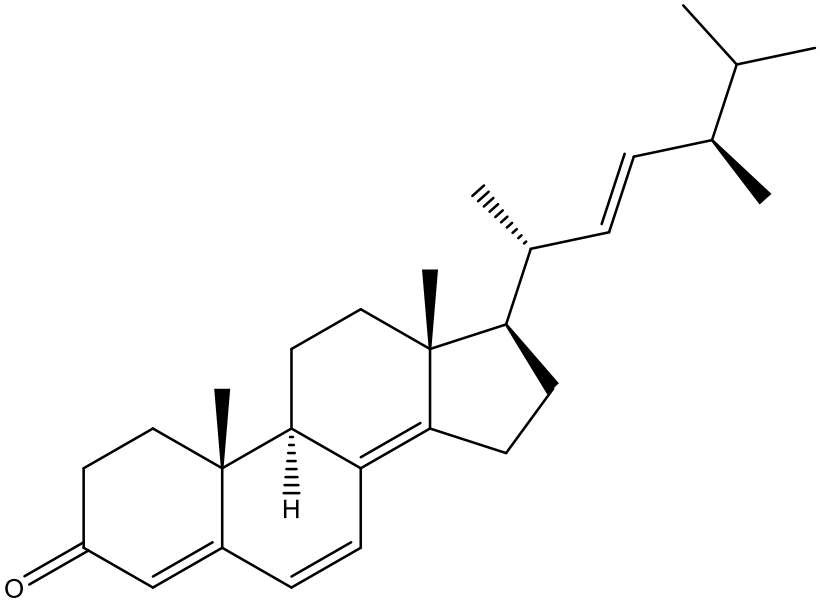
Flavonoids



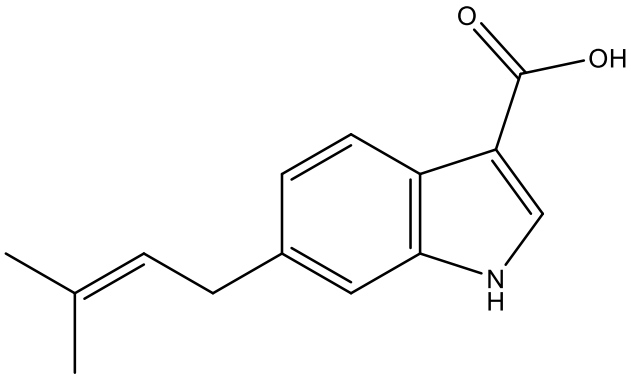
Stigmasterol



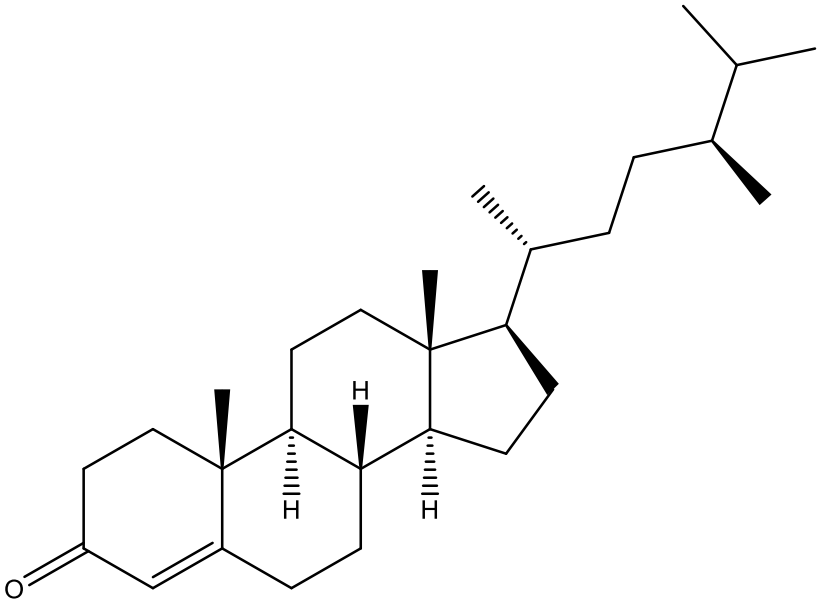
Ergosterol



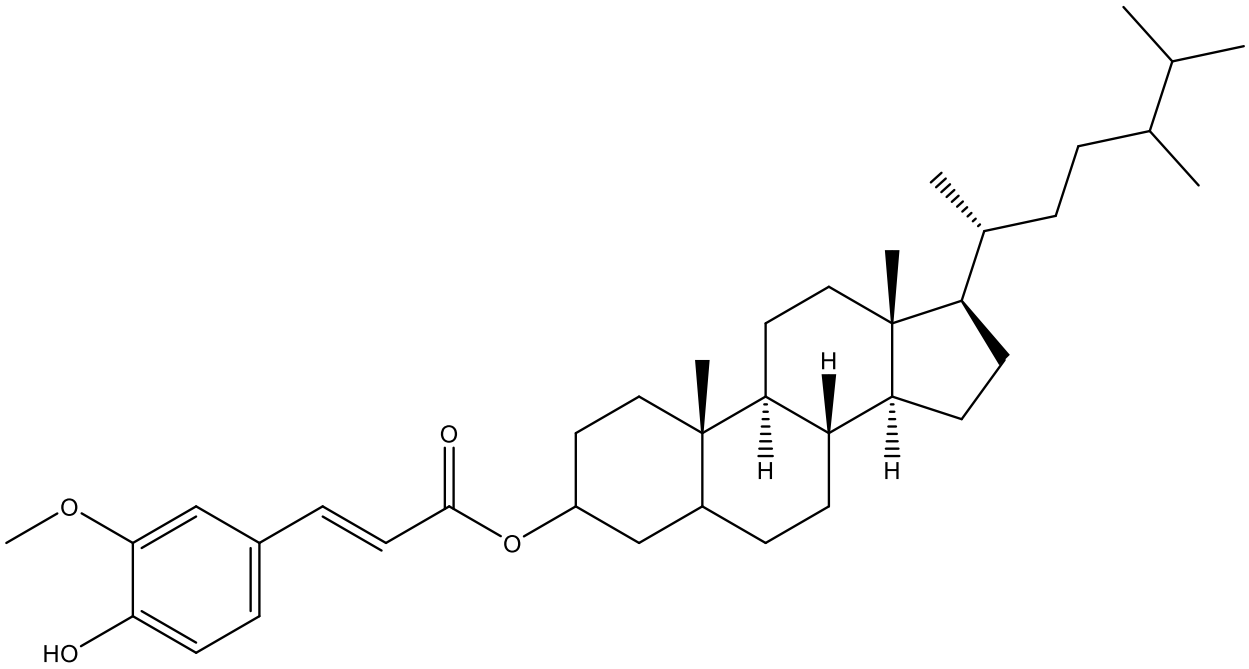
3-Oxo-ergosta-4,6,8(14),22-tetraene



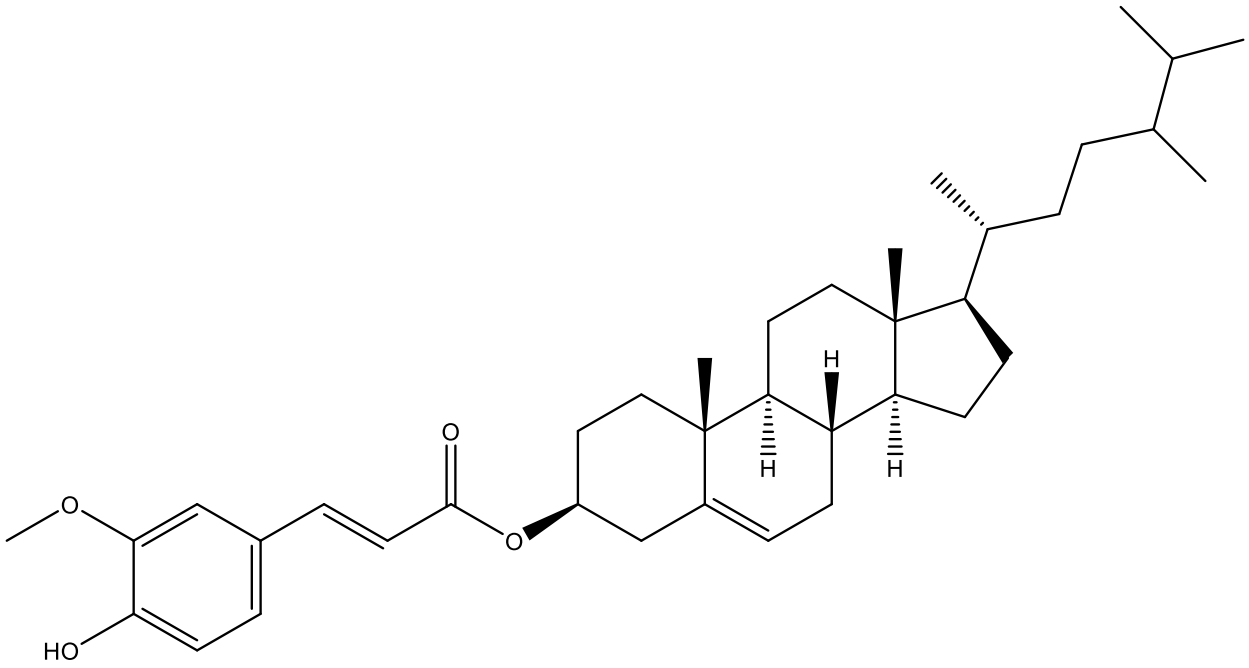
6-Isoprenylindole-3-carboxylic acid



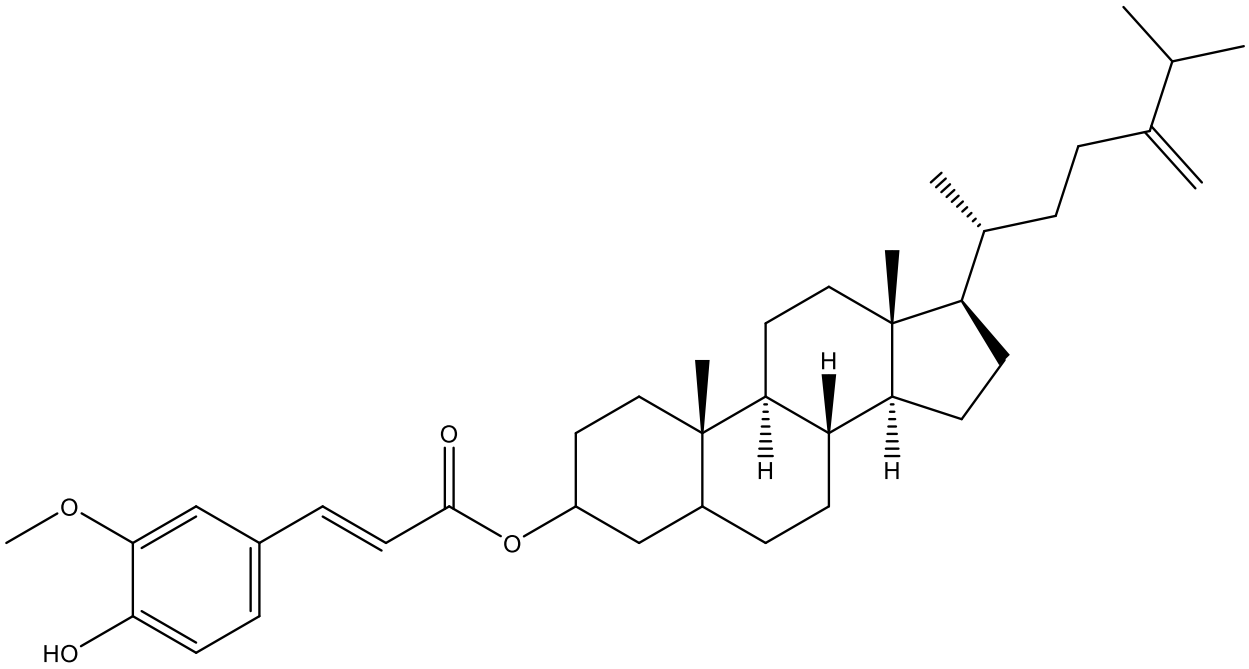
3-Oxo-ergosta-4-ene



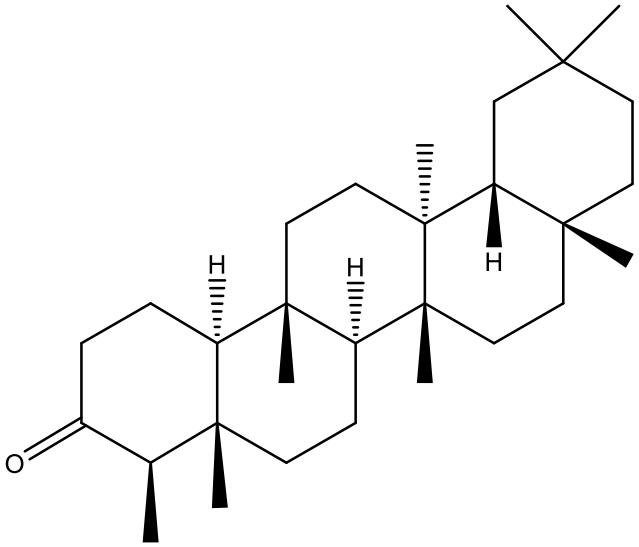
24-Methylcholestanol ferulate



24-Methylcholesterol ferulate

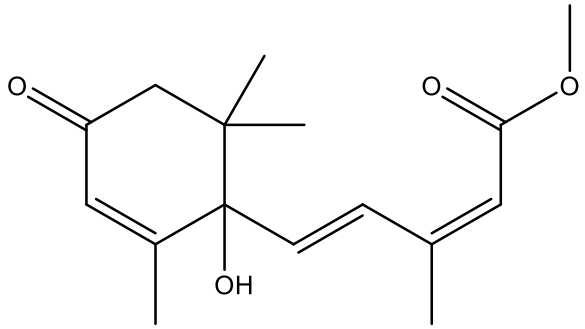


24-Methylenecholestanol ferulate

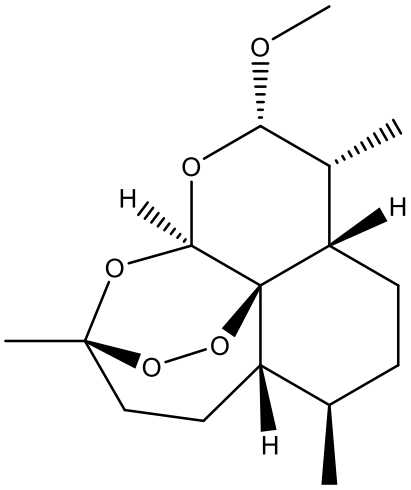


Friedeli

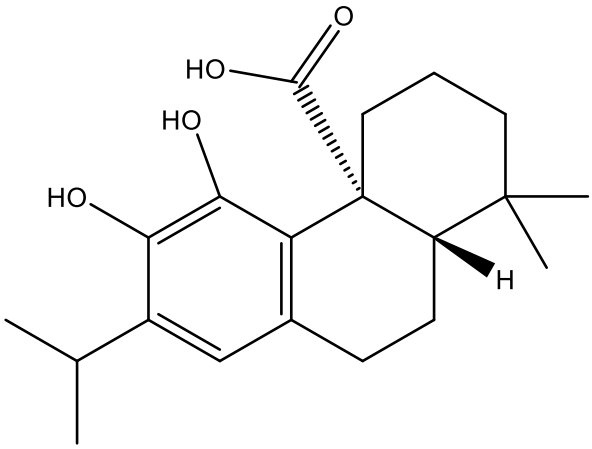
Sterols and Triterpenes



Abscisic acid methyl ester



Artemether



Carnosic acid