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Comprehensive Dossier on Ayurvedic Medicinal plant *Acacia catechu* Willd. : A Review

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ABSTRACT

The plant Acacia catechu, commonly known as the cutch tree is a tropically abundant plant which is widely used in Indian subcontinent with some presence in Central Asia and in China. The species has lent its name to important catechins, catechols. The most used part of this plant is stem or heartwood as water extract. Some pharmacological demonstrations have also been done with ethyl acetate extract. Leaves of the plant found some primary applications in biological actions. Presence of several polyphenolic compounds like tannins, flavonoids are responsible for many biological activities. The ethno pharmacological values of the plant make it a potent therapeutic and cosmetic agent. In the present review, comprehensive information on pharmacognostic evaluation, botanical aspects, therapeutic values, modern pharmacological activities and chemical constituents along with their ^{1}H NMR data are provided to explore the potential and to advance research.

Keywords: *Acacia catechu*, Pharmacognosy, Therapeutic activity, Chemical constituents, ^{1}H NMR,

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INTRODUCTION

The genus *Acacia* belongs to the family Mimosaceae. Out of 800 species of this genus, 25 species are of Indian origin, of which *Acacia catechu* Willd is an important medicinal plant in Ayurvrdic literature. *Acacia catechu* is known as khadira in Sanskrit and cutch tree in English. Khadira is well known for its therapeutic uses in dermatological, cardiovascular and respiratory practices. Further it is having an action on lowering pH nature of the skin with its pharmacological and pharmacokinetics action described in Ayurvedic texts [1,2]. It has also used as dyeing agent (Varnya) with profound antimicrobial action.

Most popular use in society apart from its medicinal usage is as 'tambola'. In combination of Nagevalli (*Piper betle* L.) popularly known as paan among India and also in many countries of south Asia. Chewing of paan with khadira and lime is traditional practice since remote past. It also paints lips and mouth due to its reddish brown colour in presence of alkali (lime). Hence in ancient days it was also used for cosmetic look. Khadira is a concentrated boiling water extract of the heartwood of *A. catechu*. The therapeutic actions of this were described in Vedic literature, viz., Rigveda, Atharva Veda. Water extract of heartwood of the tree contains many important chemical

compounds including several antioxidants. It is having carminative, digestive, demulcent, anti flatulent etc. Further it gives good smell and reduces foul smell of mouth (*durgandhanashini*). It improves the repairing mechanism of the skin and restores the pH value. Its specific activities are antibiotic (*krimighna*) and antiviral (*bhutanashini*), the wound healing (*vranaropana*), kapha, vata hara [3,4]. Decoction of the stem bark is used in vaginal wash (*doush*) for cervical erosion, leucorrhoea etc.

MATERIAL AND METHODS

Origin and Distribution:

Origin: *Acacia catechu* Willd. is an angiosperm belongs to the family "*Fabaceae*", sub family "*Mimosoideae*" and order "*Fabales*". It is also known as 'black catechu'. The generic name came from Greek word "Throns" meaning "point or a barb" and the specific name came from word "cutch" which depicts the tanning extract obtained from heartwood of plant [5,6].

Distribution: *Acacia catechu* Willd. (Fam: Mimosaceae) The plant is a moderate sized, deciduous tree up to 3m high and distributed throughout the Central Asia especially Thailand, Pakistan, Bangladesh and in India specially the sub-Himalayan tract of Punjab to Assam ascending to 1200m, Peninsular region, particularly in drier parts i.e. Madhya Pradesh, Maharashtra, Gujarat, Bihar, Rajasthan and Tamil Nadu [7,8,9,10].

Common Names [11,12] **of *Acacia catechu* Willd. in Different (Table. 3) Indic Languages:**

Table. 3

Sl. No.	Language	Name
1.	Assamese	Kharira, Khayar
2.	Bengali	Khera, Khayera
3.	Gujarati	Khair, Kathe, Kher
4.	Hindi	Khair
5.	Kannada	Kachinamara,
6.	Kashmiri	Kath
7.	Malayalam	Karingali
8.	Marathi	Kharira, Khair
9.	Oriya	Khaira
10.	Punjabi	Khair
11.	Sanskrit	Khadira,
12.	Tamil	Karungkali, Karungali
13.	Telugu	Chandra, Kaviri
14.	Urdu	Chanbe, Kaath

Taxonomical, Botanical, Pharmacognostical Descriptions:

Fig.1: Flowering branch of *Acacia catechu*

Fig. 2: Fruiting branch of *Acacia catechu*

Macroscopic Characters of *Acacia catechu* Willd:

Acacia catechu Willd. is a medium sized thorny deciduous tree upto 3- 15 m high [7,8] ; stem straight and grayish brown, bark dark grey to dark grayish brown, exfoliating in narrow strips brown and red in side; The leaves are bipinnately compound, with 9-30 pairs of pinnae and a pubescent glandular rachis; leaflets 16-50 pairs, oblong-linear, 2-6 mm long, glabrous or pubescent with a pair of short, hooked shape, recurved prickles or spines at the base of the rachis; inflorescence cylindrical, axillary pedunculate spike (Fig.1). Flowers are actinomorphic to zygomorphic, 5-10 cm long, sessile, pentamerous, creamy whitish to pale yellow and with a campanulate calyx of 1-1.5 mm length, and a corolla of 2.5-3 mm length. Stamens are numerous and far exerted from the corolla, with white to yellowish white filaments, bisexual and have single superior carpel; pod is one chambered legume, glabrous oblong, 3-10 seeded, straight, flat and brown in colour (Fig.2) with triangular beak at the apex, shiny, narrowed at base [7-13].

A. catechu heartwood is light, red, turning brownish red to nearly black with age and attached with whitish sapwood. The fracture is hard, odour, characteristic and taste is astringent. The gummy extract of the wood is called *katha* or *cutch* which is mostly shining black or brownish mass, hard and brittle, and breaks easily. The fractured surfaces show brownish color but dull gloss and small cavities. It gives dull brown fine odorless powder having strong astringent taste [14,15].

Microscopic study of *Acacia catechu* Willd:

A transverse section through *A. catechu* heartwood (Fig.3) shows the presence of numerous uniseriate and biseriate medullary rays, with xylem vessels occurring single or in small groups of two to four; usually xylem parenchyma is predominantly paratracheal forming a sheath around vessels; xylem fibres with narrow lumen occupy major portion of wood consisting of crystal fibres having prismatic crystals of calcium oxalate. A few tracheids with scalariform thickening are also present [9,13].

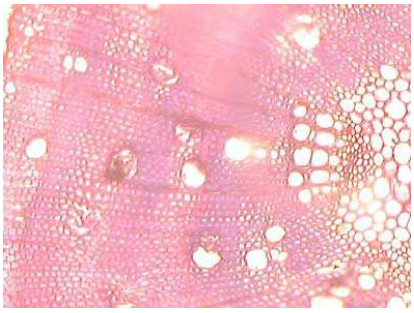


Fig. 3: T.S. through heartwood of *Acacia catechu* Willd

Tannin was histochemically appeared brown and localized in cortex, pericyle, xylem of *A. catechu* stem (Fig.4); protein was appeared blue-greenish and localized in cortex, pericycle and xylem of stem; cellulose was appeared black brownish and localized in epidermis and cortex; starch granules appeared blue to black in colour and localized in cortex and xylem; Lignin appeared dark pink and localized in cortex, pericycle and xylem part of *A. catechu* stem [6,12,13].

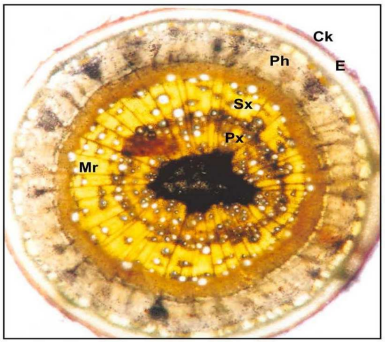


Fig. 4: T.S. of stem of *A. catechu* showing colour pattern of histochemical localization of tannins (yellow-brown)

Histochemical analysis of stem of *Acacia catechu* revealed that the deposition of lipid and lignin was high (Table. 1) in the vascular region compared to the deposition of starch and protein [5,6].

Table.1

S.No.	Compound	Reagents Employed	Tissue localized
1	Cellulose	Iodine-potassium iodide	Epidermis and outer cortex
2	Tannin	Lugol's iodine	Cortex, percicyle and xylem
3	Starch	Iodine-potassium iodide	Cortex and xylem
4	Protein	Amido black	Cortical, pericycle and xylem
5	Lignin	Phloroglucinol	Cortex, pericycle and xylem part

Physicochemical parameters *Acacia catechu*:

The evaluated physico-chemical parameters [5] are mentioned below (Table. 2). The ash obtained from the drug has been found to be positive for inorganic radicals i.e. CO_3^{2-}, PO_4^{3-}, SO_4^{2-}, Al^{3+}, Ca^{2+}, Mg^{2+} and K^+.

Table. 2

Sl.No.	Tests	Results % (range)
1	Loss on drying at 105˚C	9.00-11.00 %
2	Total ash	1.16-2.00 %
3	Acid insoluble ash	0.20-0.4.00 %
4	Water soluble ash	0.09-0.25 %
5	Water soluble extractives	23.00-25.00 %
6	Alcohol soluble extractives	19.00-21.00%
7	pH of water extract	6.02-6.04
8	Volatile oil	Nil
9	Fibre content	49.00-53.00 %
10	Swelling index	4.00-5.00 ml/gm
11	Foaming index	<100
12	Total sugar	1.20-1.90 %
13	Reducing sugar	0.70-1.50 %

Traditional practices and Therapeutic uses of the plant [16-22]:

Uses of Acacia is an ancient practices in mainland of Asia. Its vast uses are mentioned in ancient scriptures. It is tikta rasa, sheeta (sheeta veerya); subdues pitta and kafa; digestive; useful in the treatment of skin disease, cough, dyscrasia, oedema, pruritis and ulcer; bark: astringent; useful in passive diarrhea either alone or in combination with cinnamon or opium; decoction given internally in leprosy; heartwood: the concentrated aqueous extract known as khayer gum or cutch is astringent, cooling and digestive; beneficial in cough and diarrhea; applied externally to ulcers, boils and eruptions of the skin; used extensively in Ayurvedic formulations [16]. *A. catechu* is reported to be a drug for leprosy, various plant parts are used in sreouth [17], pain in chest [18], cancer, colic pain, gravel, dysentery, phthisis, bronchitis, asthma, conjunction and strangulation of intestine [19]. Bark is useful in skin diseases. Extract of bark with asafoetida used in haemoptysis. Medicated mixture of flower tops, cumins etc. given in ganorrhoea [20].

Concentrated decoction of *A. catechu* along with the bark of *Bridelia airy-shawii* homogenized with fruit powder of *Emblica officinalis, Terminalia belerica and Terminalia chebula* on administration cured fistula [21].

Recently, an important medicine named AYUSH KD, for external use has been prepared form Katha of Acacia catechu Willd. for application in vaginal infection to mother after child birth by CCRAS, Govt. of India, under Reproductive Child Health project [22]

Biological activities of Acacia catechu in the light of modern pharmacological investigation [17,18,19,20,23-25]: The large number of active chemical constituents like flavonoids, tannins and many other polyphenols are responsible for its multifaceted pharmacological activities.

- **Antibacterial Effect [**23,24,25,26,27,28] **:** Ethyl alcohol (50%) extract of stem was found to be a significant antiviral and spasmolytic activity [23]. An *in vitro* study reported to have a broad spectrum antiviral activity. Methanolic extract of *Acacia catechu* Willd has antimicrobial activity [24] against pathogenic as well as nonpathogenic bacteria e.g. *Bacillus subtilis*, *Staphylococcus aureus*, *Salmonella typhi*, *Escherichia coli*, *Pseudomonas aeruginosa* and *Candida albicans*. It is effective against gram positive as well as gram negative bacteria [25]

- **Antifungal Effect** [25,29]**:** Heartwood extract has been found to be antifungal [25,29]. Ethanolic extract of Heartwood of *Acacia catechu* Willd. was tested for antifungal (antimycotic) activity against *Candida albicans, Aspergillus niger, Aspergillus fumigates, Mucor spp.* and *Penicilium marneffei.*

- **Anticancer property** [25,30] **:** Study was conducted to evaluate the cytotoxic effect of aqueous extract of *Acacia catechu* Willd. heartwood in a human epithelial carcinoma cell line (A431) and anti-tumour activity against DMBA/TPA induced squamous cell carcinoma in mice. It was investigated that chemopreventive effect of aqueous extract of *Acacia catechu* Willd. heartwood maybe was due to its polyphenolic compounds that exhibit powerful antioxidant activity.

- **Antidiarrhoeal property** [18,25,31,32,33] **:** Ethyl acetate extract of *Acacia catechu* Willd. was evaluated for antidiarrhoeal property in castor oil induced model of diarrhoea in albino rats. *Acacia catechu* at a doses of 250 mg/kg, p.o., (single doses) has been found to posses highly significant antipyretic activity ($P<0.01$) in respect of latent period of onset of diarrhoea, average number of stool passed and purging index.

- **Antimicrobial effect** [24,25] **:** *In vitro*, *Acacia catechu* Willd is reported to have broad spectrum anti-microbial activity [24,25]. Phytochemical studies of *Acacia catechu* Willd leaves show the presence of alkaloids, carbohydrates, flavones, glycosides, phenolic compounds, saponins, steroids and tannins which may be responsible for its anti-microbial activity.

- **Anti oxidant** [25,34,35,36,37] **:** Total anti oxidant content was determined in terms of tannic acid equivalent and found to be 20.07 ± 0.23 mg TAE/ DW. The total antioxidant activity was estimated by phosphor molybdenum method. Antioxidant principles of *Acacia catechu* Willd were analysed by Dot-blot assay & quantitative analysis by DPPH radical scavenging assay with ascorbic acid as standard.

- **Antipyretic and Antiinflammatory Activity** [18,25,38,39]**:** To prove the effect of *Acacia catechu* Willd in yeast induced pyretic rats Ray et al., conducted a study in Albino rats (150-200 g) after inducing fever by injecting subcutaneously 20% suspension of dried yeast in 2% gum acacia in normal saline at a dose of 20 ml/kg of body weight. The ethyl acetate extract of *Acacia catechu* Willd and aspirin significantly decreased the temperature of pyretic rats at 2nd, 3rd and 4th hour after drug or extract treatment.

- **Anti-secretory and Anti-ulcer Activity** [25,40] **:** Study was conducted on antisecretory and antiulcer activity of *Acacia catechu* Willd against indomethacin plus pyloric ligation induced gastric ulcers in rats. The results of the study suggested that *Acacia catechu* Willd causes an inhibitory effect on release of gastric hydrochloric acids and protects gastric mucosal damage due to presence of flavonoids and tannins in the plant extract.

- **Immunomodulatory Activity [**25,41] **:** Immunomodulatory activity of aqueous extract of *Acacia catechu* after oral administration (5 mg/kg and 50 mg/kg). The effect was studied in neutrophil adhesion test, mice lethality test, carbon clearance assay, cyclophosphamide induced neutropenia, serum immunoglobulin levels and the heamagglutination test. *Acacia catechu* extract showed an increase in the neutrophil adhesion to the nylon fibres, produced a significant increase in the phagocytic index and a significant protection against cyclophosphamide induced neutropenia indicating its effect on cell mediated immunity.
- **Antidiabetic activity [**18,19,25,42,43,44] **:** In an experiment, ethyl acetate extract of *Acacia catechu* Willd at a concentration of 500mg/kg/day used for 7 days, significantly decreases blood glucose level of normal as well as alloxan induced diabetic albino rats but it was not effective as that of standard drug.
- **Wound healing [**25,45,46] **:** In Asia crushed bark of *Acacia catechu* is used on wounds as it is potent wound healing medicinal plant. It has astringent effect and also cause precipitation of skin which makes it very good wound healing plant.
- **Sore throat [**25,47,48]**:** People of different ages use it for healing of sore throat, because of its astringent and soothing effect. Tannins present in *Acacia catechu* Willd are responsible for this property.
- **Hepatoprtective activity [**18,25,49] **:** Hepatoprotective activity of the plant has been found in rats. Flavonoid constituents of the extract of *Acacia catechu* Willd possess antioxidant properties and are found to be useful in the treatment of liver damage. Hepatoprotective action of heartwood powder of *Acacia catechu* Willd was studied in the treatment of liver damage in rats exposed to carbon tetrachloride. Hepatoprotective activity of ethyl acetate extract of *Acacia catechu* Willd was studied in albino rats.
- **Toxicity study** [49] **:** LD_{50} was determined in albino mice in group of 6 each for each dose. The animals were administered intraperitoneally with graded doses of ethyl acetate extract. The LD50 for the ethyl acetate extract of *Acacia* is found to be 2500 mg/kg in albino mice.

Class of compounds (Table. 4) and their corresponding biological activities [18,24,25,50,51,55]

Table. 4

Sl. No.	Biological activities	Class of class of compounds
1	Antibacterial Effect	Taxifolin
2	Antifungal Effect	Flavonoids and Tannins
3	Anticancer property	Polyphenols
4	Antidiarrhoeal property	Flavonoids
5	Antimicrobial effect	Steroids,Tannins,Glycosides
6	Anti oxidant	Tannins, Polyphenols,
7	Antipyretic and Antiinflammatory Activity	Flavonoids
8	Anti-secretory and Anti-ulcer Activity	Flavonoids, Tannins
9	Immunomodulatory Activity	--
10	Antidiabetic activity	Flavonoids
11	Wound healing	Tannins, Flavonoids
12	Sore throat	Tannins

13	Hepatoprotective activity	Flavonoids, Polyphenols
14	Facilitating expectoration in chest infection [55]	Catechuic acid
15	Inhibition in aflatoxin toxicity [79]	Fisetin

Phytochemical screening, Chemical Constituents and their NMR reported from *Acacia catechu*:

Phytochemical presence [18,27,52,53]: *A. catechu* confirmed the presence of various plant metabolites (Table. 5) in plant tissue. *A. catechu* was reported to have maximum studied compounds. The bark and pods of *A. catechu* contained maximum plant metabolite including alkaloids, tannins, saponins, flavonoids, and carbohydrates.

Table. 5

Sl. No.	Class of compounds/compounds	Presence
1.	Tannins	+
2.	Saponins	+
3.	Flavonoids	+
4.	Phlobatannins	+
5.	Terpenoids	-
6.	Cardia glycosides	-
7.	Steroids	-
8.	Catechuic & Catechutannic acid	25-35%
9.	Acacatechin	10-12%
10.	Phlobatannin	25-33%
11.	Catechin	2-12%
12.	Total phenolic content (mg TAE/g DW)	47.32 ± 0.29 mg TAE/g DW

List of Chemical constituents isolated (Table 6) from heartwood and leaves of *Acacia catechu* & their ^{1}H NMR spectra [18,27,52,53-78]:

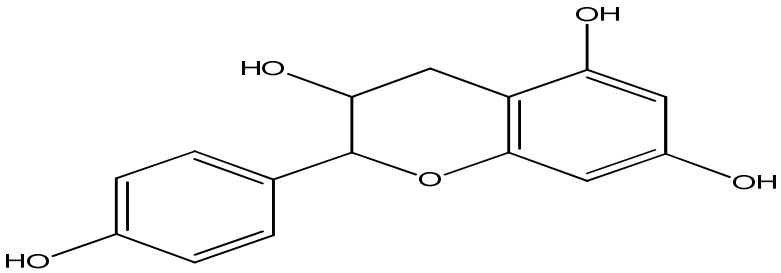
Like its huge pharmacological and therapeutic activities, the species *Acacia catechu* is also a rich source of various chemical entities. The important chemical compounds included proanthocyanidins, flavones, flavanols, flavanols, flavonones, even presence of poriferasterol (a steroid), poriferasterol glucoside are reported. Proanthocyanidins like catechins, epicatechin, afzelechin, procyanidin are having significant presence in the species. Fisetin, isorahmnetin, kaempferol, quercetin, quercetrin, querctagetin are the important flavones obtained in *Acacia catechu*. A few flavonols like aromadendrin, dihydrokaempferol taxifolin are also reported.

Table. 6

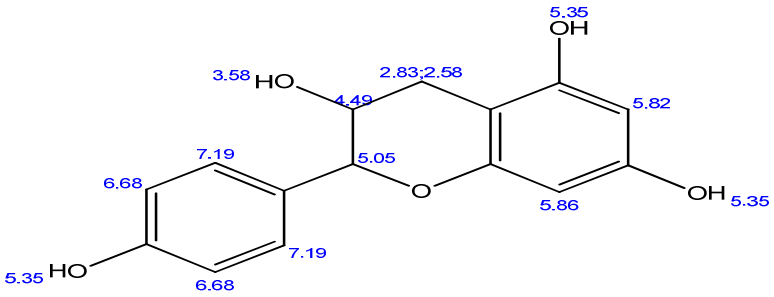
Sl. No.	Name of compounds	Plant parts	Reference No.
1	Afzelechin	Heartwood	67
2	Catechin	Heartwood	68
3	Dihydrokaempferol	Heartwood	69
4	Epicatechin	Bark	70
5	Epicatechin gallate	Heartwood	70
6	Epigallocatechin	Heartwood	70
7	Epigallocatechin gallate	Heartwood	70
8	Fisetin	Heartwood	71
9	Gallic acid	Heartwood	72
10	Isorahmnetin	Heartwood	72
11	Kaempferol	Heartwood	73, 74
12	Phloroglucinol	Heartwood	69
13	Poriferasterol	Leaves	75
14	Procyanidin	Heartwood	67
15	Quercetagetin	Heartwood	76, 77
16	Quercetin	Leaves	78
17	Quercetrin	Heartwood	69, 80
18	Taxifolin	Heartwood	66
19	Procatechuic acid	Heartwood	65
20	Catechinic acid	Heartwood	64
21	Quercetin-3-arabinofuranoside	Leaves	-
22	Quercetin-3-O-galactoside	Leaves	-
23	Poriferasterol-3β-D-glucoside	Leaves	-

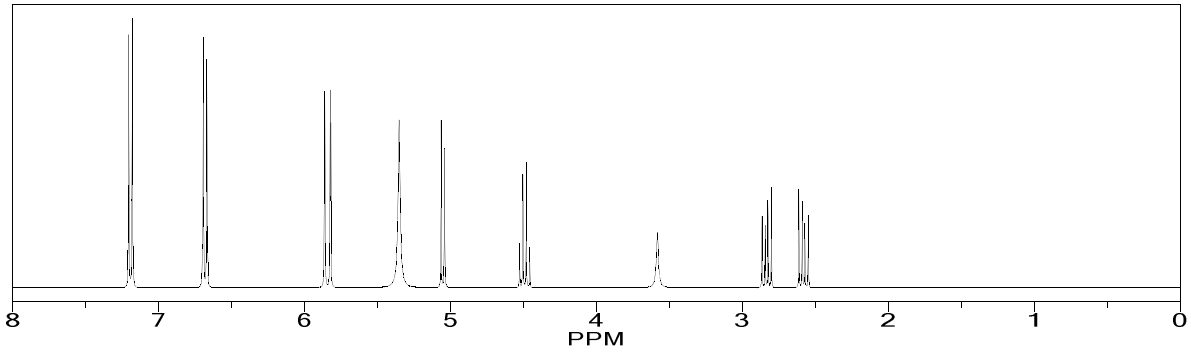
The comprehensive ^{1}H NMR data with corresponding structure

1. Afzelechin

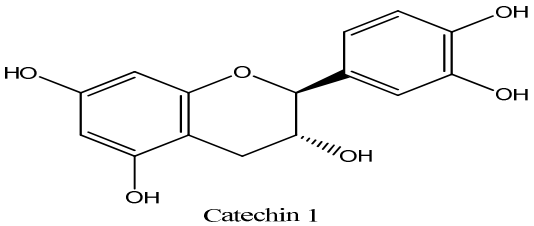


2-(4-hydroxyphenyl)chroman-3,5,7-triol
Chemical Formula: $C_{15}H_{14}O_5$
Exact Mass: 274.08
Molecular Weight: 274.27
m/z: 274.08 (100.0%), 275.09 (16.6%), 276.09 (2.3%)
Elemental Analysis: C, 65.69; H, 5.15; O, 29.17

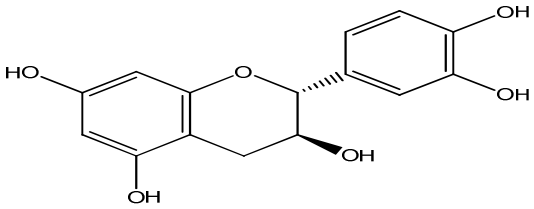




2. Catechin

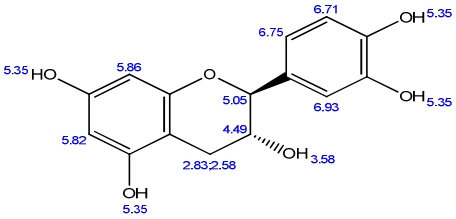


Catechin 1

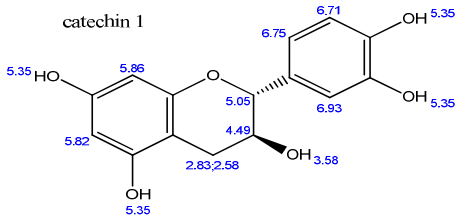


Catechin 2

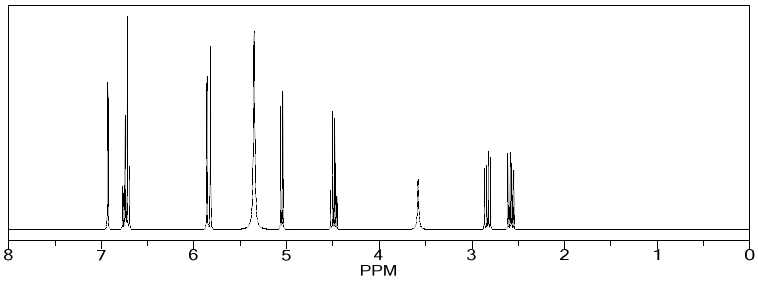
(2*R*,3*S*)-2-(3,4-dihydroxyphenyl)chroman-3,5,7-triol compound with (2*S*,3*R*)-2-(3,4-dihydroxyphenyl)chroman-3,5,7-triol (1:1)
Chemical Formula: $C_{30}H_{28}O_{12}$
Exact Mass: 580.16
Molecular Weight: 580.54
m/z: 580.16 (100.0%), 581.16 (33.2%), 582.16 (7.6%), 583.17 (1.4%)
Elemental Analysis: C, 62.07; H, 4.86; O, 33.07



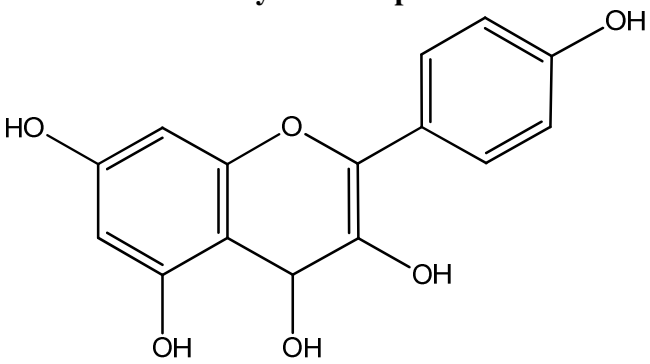
catechin 1



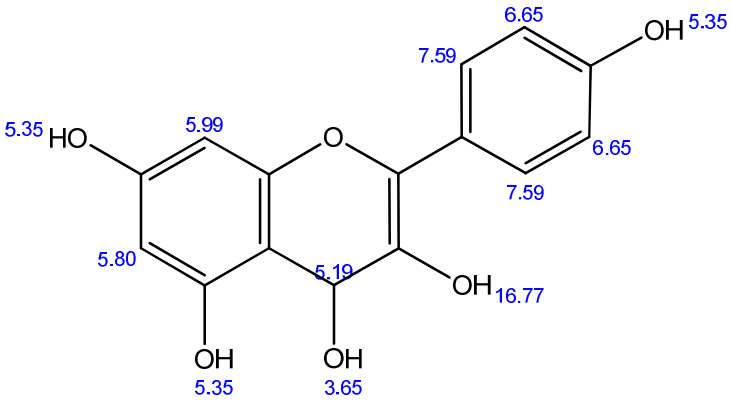
catechin 2

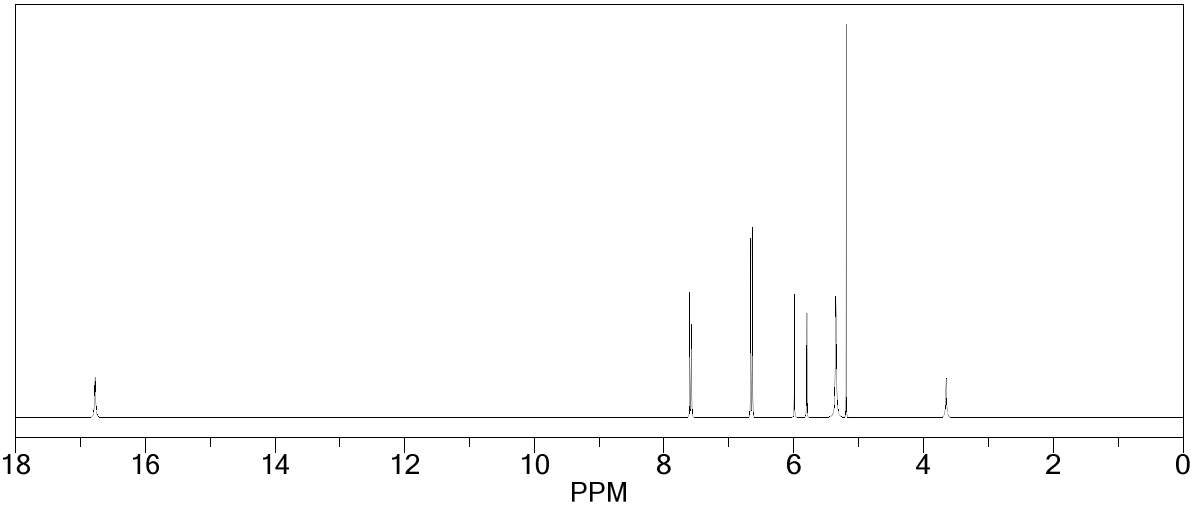


3. Dihydrokaempferol

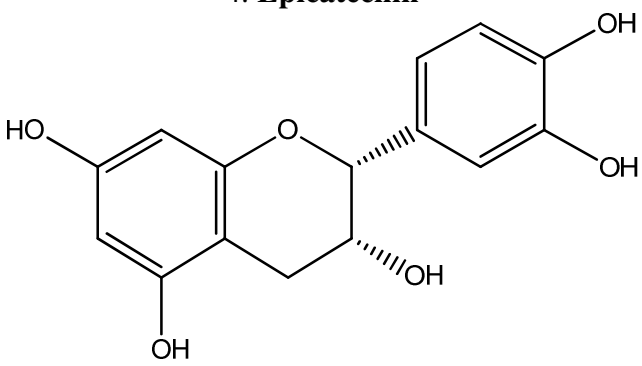


2-(4-hydroxyphenyl)-4*H*-chromene-3,4,5,7-tetraol
Chemical Formula: $C_{15}H_{12}O_6$
Exact Mass: 288.06
Molecular Weight: 288.25
m/z: 288.06 (100.0%), 289.07 (16.6%), 290.07 (2.5%)
Elemental Analysis: C, 62.50; H, 4.20; O, 33.30

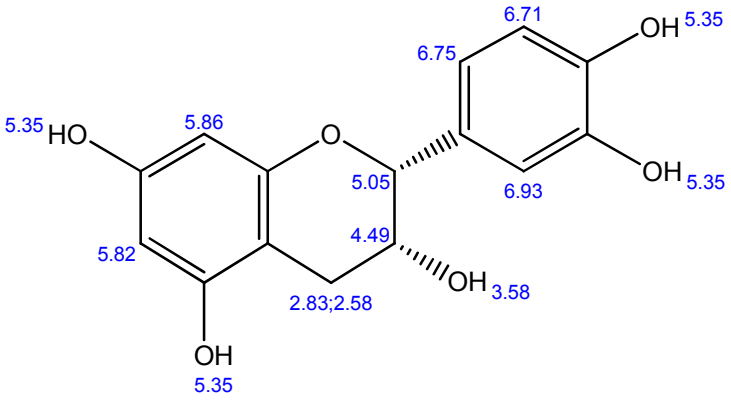


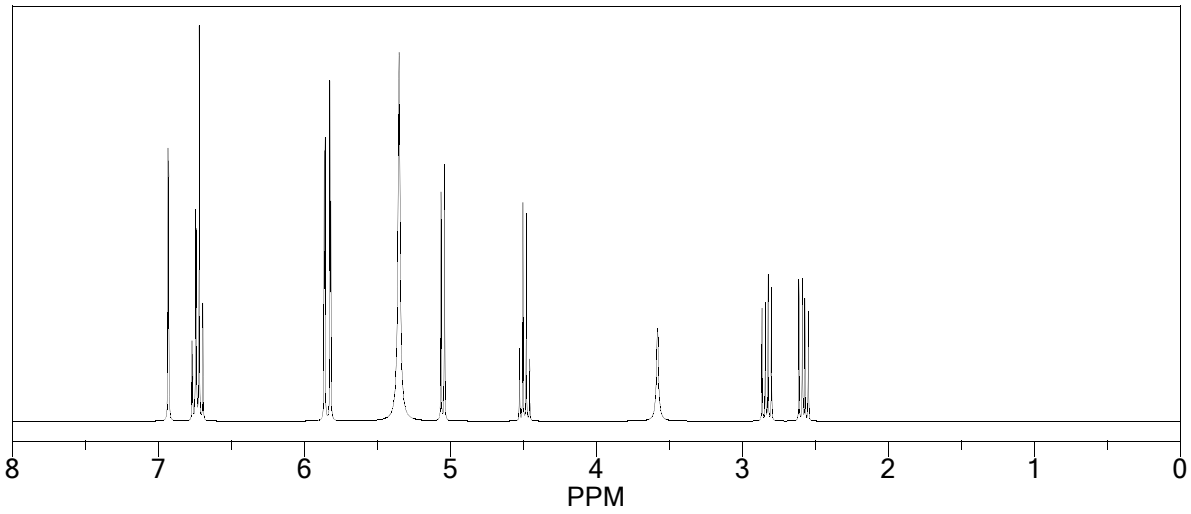


4. **Epicatechin**

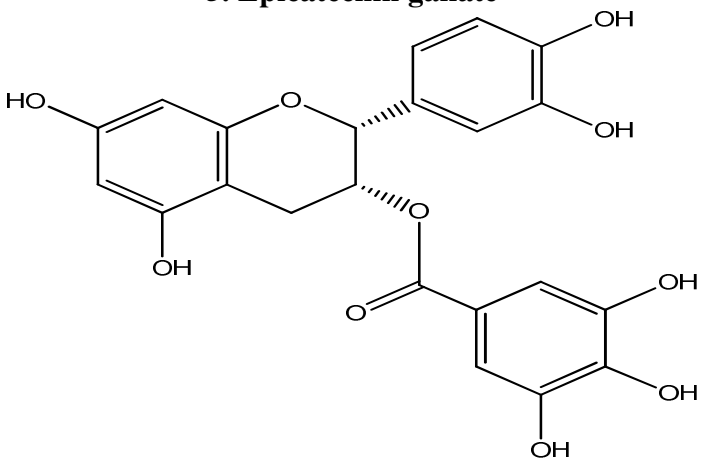


(2*R*,3*R*)-2-(3,4-dihydroxyphenyl)chroman-3,5,7-triol
Chemical Formula: $C_{15}H_{14}O_6$
Exact Mass: 290.08
Molecular Weight: 290.27
m/z: 290.08 (100.0%), 291.08 (16.5%), 292.09 (1.3%), 292.08 (1.2%)
Elemental Analysis: C, 62.07; H, 4.86; O, 33.07

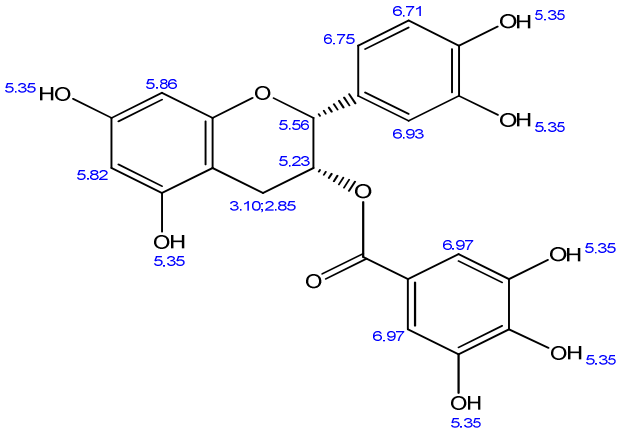


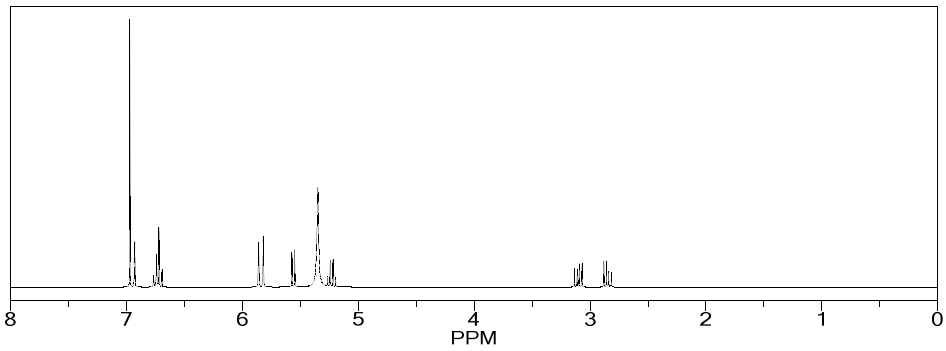


5. Epicatechin gallate

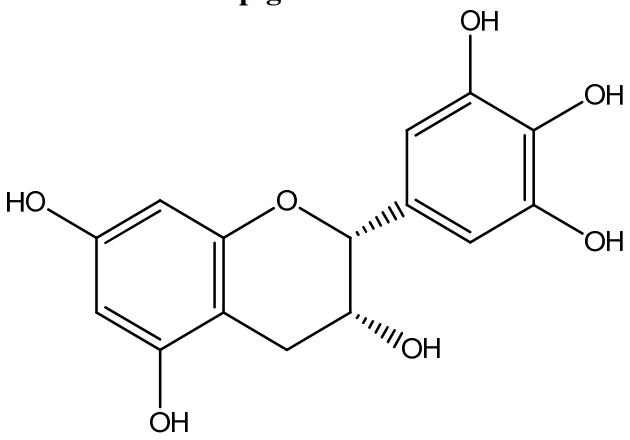


(2*R*,3*R*)-2-(3,4-dihydroxyphenyl)-5,7-dihydroxychroman-3-yl 3,4,5-trihydroxybenzoate
Chemical Formula: $C_{22}H_{18}O_{10}$
Exact Mass: 442.09
Molecular Weight: 442.37
m/z: 442.09 (100.0%), 443.09 (24.2%), 444.10 (2.8%), 444.09 (2.1%)
Elemental Analysis: C, 59.73; H, 4.10; O, 36.17

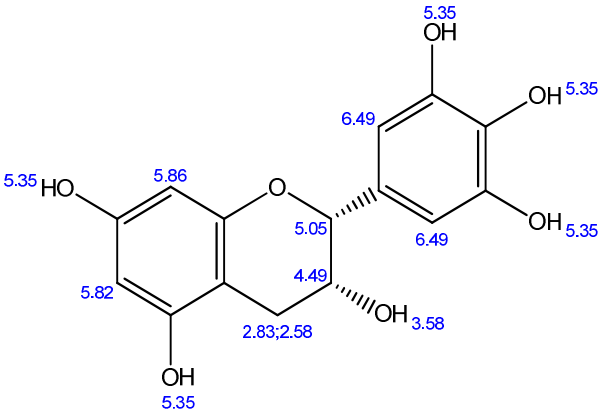


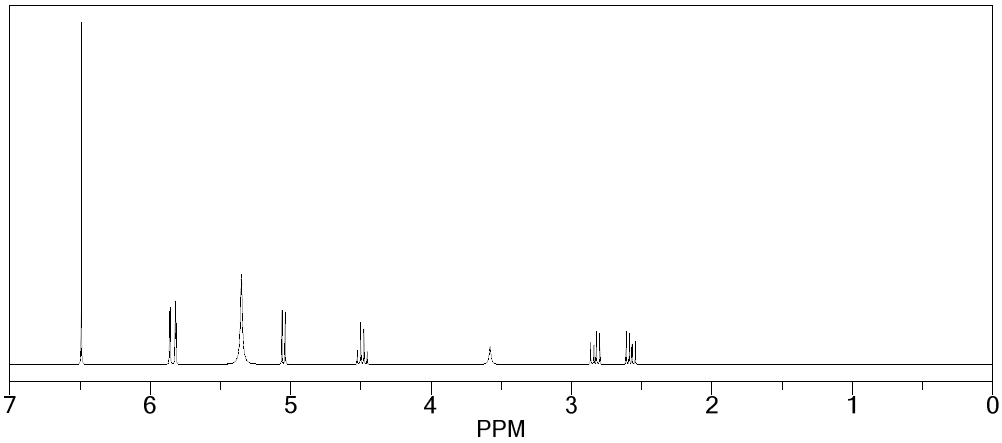


6. Epigallocatechin

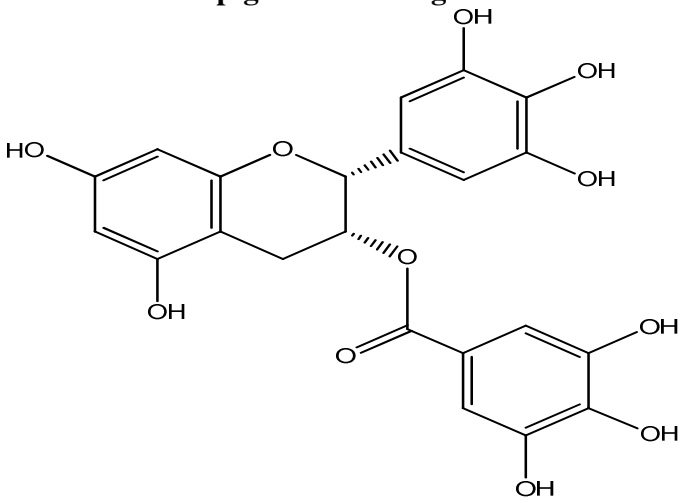


(2*R*,3*R*)-2-(3,4,5-trihydroxyphenyl)chroman-3,5,7-triol
Chemical Formula: $C_{15}H_{14}O_7$
Exact Mass: 306.07
Molecular Weight: 306.27
m/z: 306.07 (100.0%), 307.08 (16.7%), 308.08 (2.7%)
Elemental Analysis: C, 58.82; H, 4.61; O, 36.57

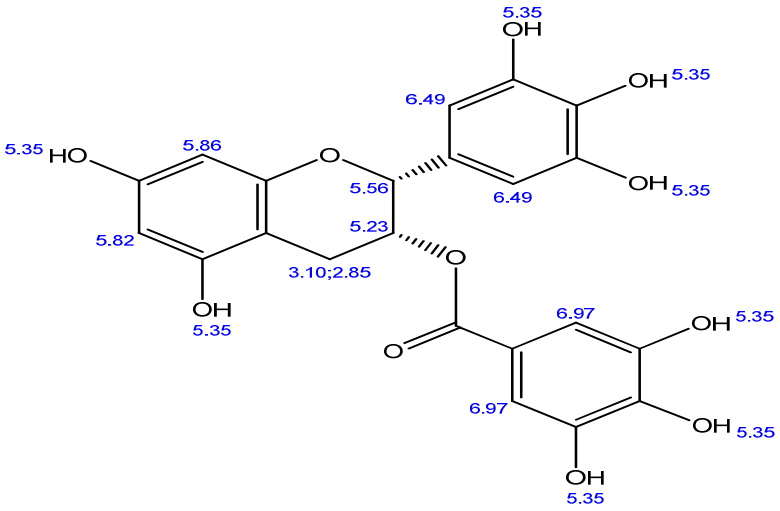


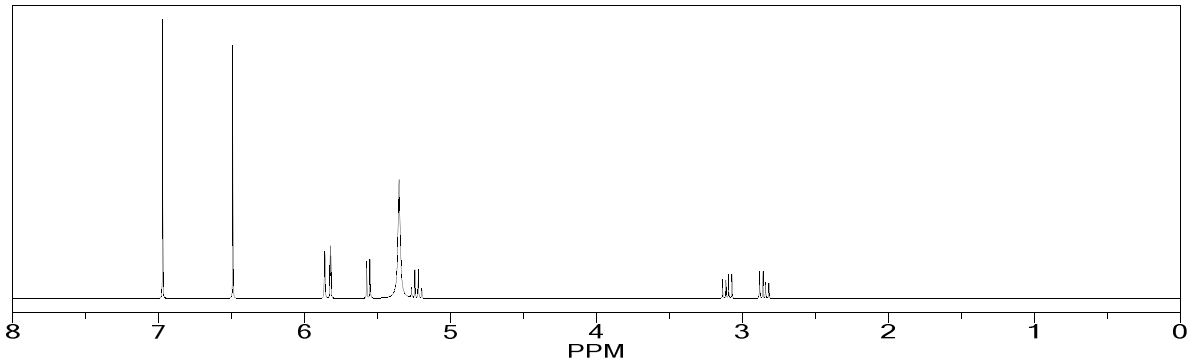


7. Epigallocatechin gallate

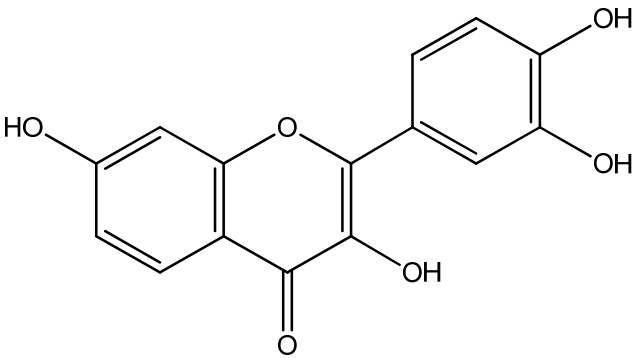


(2*R*,3*R*)-5,7-dihydroxy-2-(3,4,5-trihydroxyphenyl)chroman-3-yl 3,4,5-trihydroxybenzoate
Chemical Formula: $C_{22}H_{18}O_{11}$
Exact Mass: 458.08
Molecular Weight: 458.37
m/z: 458.08 (100.0%), 459.09 (24.4%), 460.09 (5.1%)
Elemental Analysis: C, 57.65; H, 3.96; O, 38.40





8. Fisetin



2-(3,4-dihydroxyphenyl)-3,7-dihydroxy-4*H*-chromen-4-one

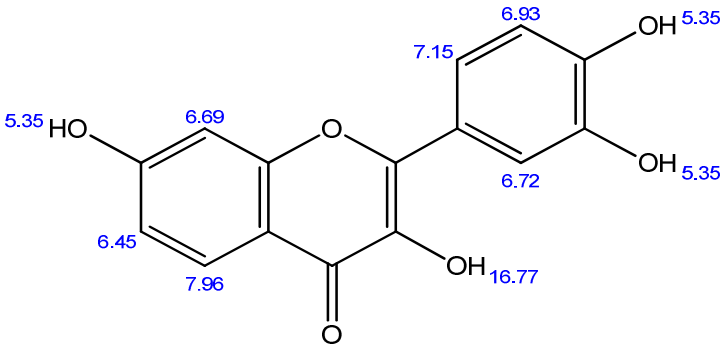
Chemical Formula: $C_{15}H_{10}O_6$

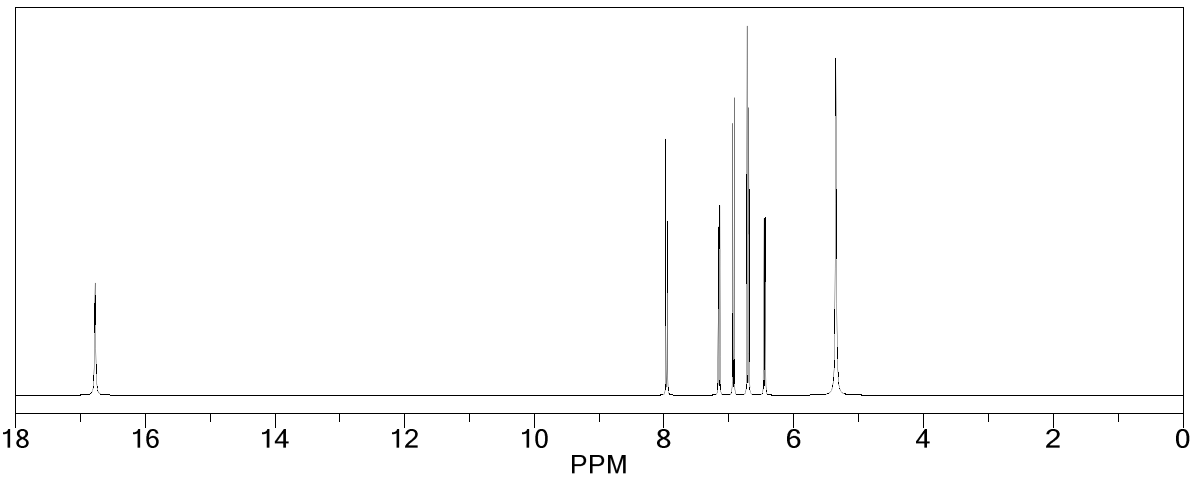
Exact Mass: 286.05

Molecular Weight: 286.24

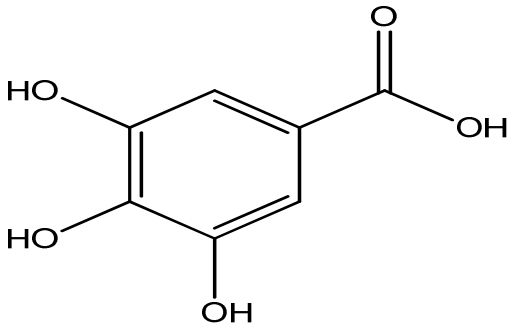
m/z: 286.05 (100.0%), 287.05 (16.6%), 288.05 (2.5%)

Elemental Analysis: C, 62.94; H, 3.52; O, 33.54

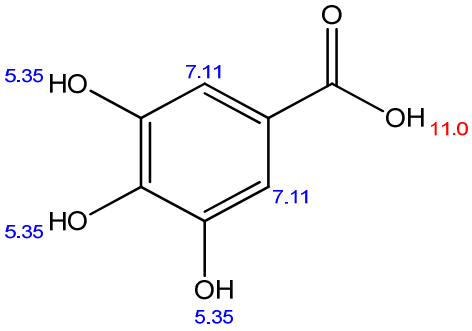


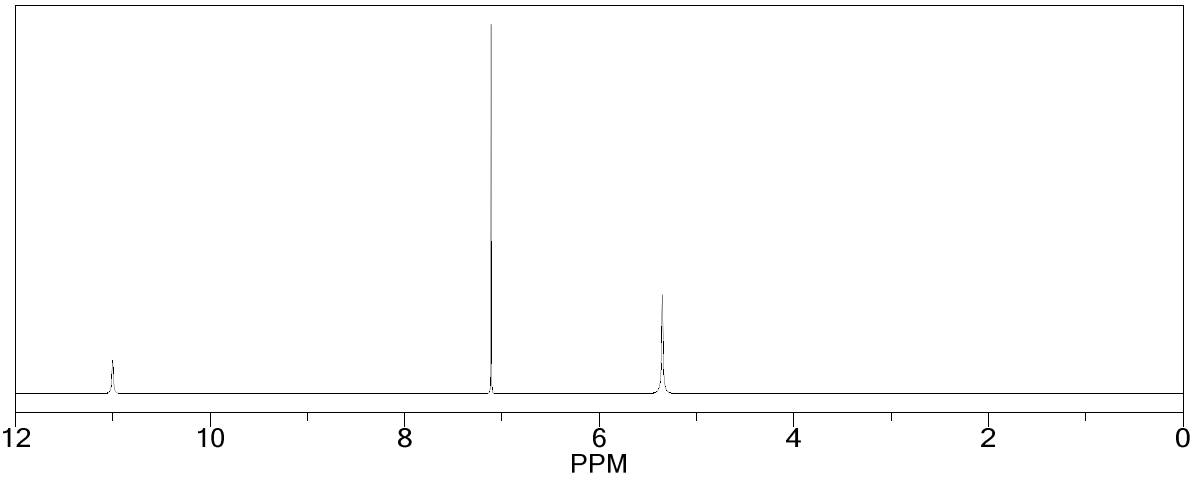


9. Gallic acid

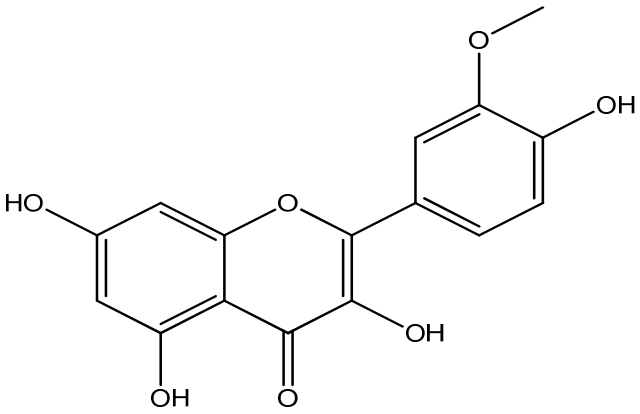


3,4,5-trihydroxybenzoic acid
Chemical Formula: $C_7H_6O_5$
Exact Mass: 170.02
Molecular Weight: 170.12
m/z: 170.02 (100.0%), 171.02 (7.6%), 172.03 (1.3%)
Elemental Analysis: C, 49.42; H, 3.55; O, 47.02





10. Isorhamnetin



3,5,7-trihydroxy-2-(4-hydroxy-3-methoxyphenyl)-4*H*-chromen-4-one

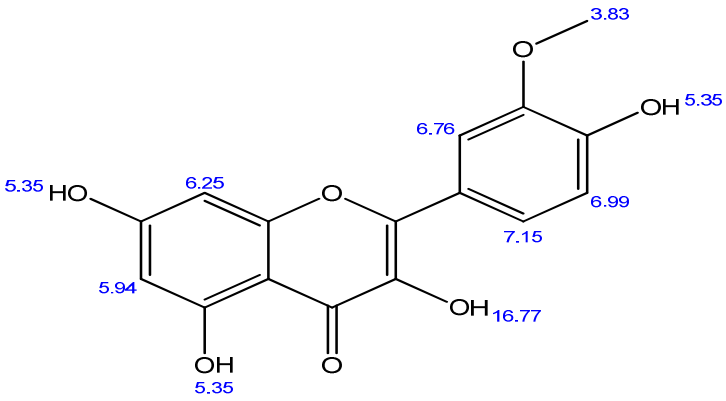
Chemical Formula: $C_{16}H_{12}O_7$

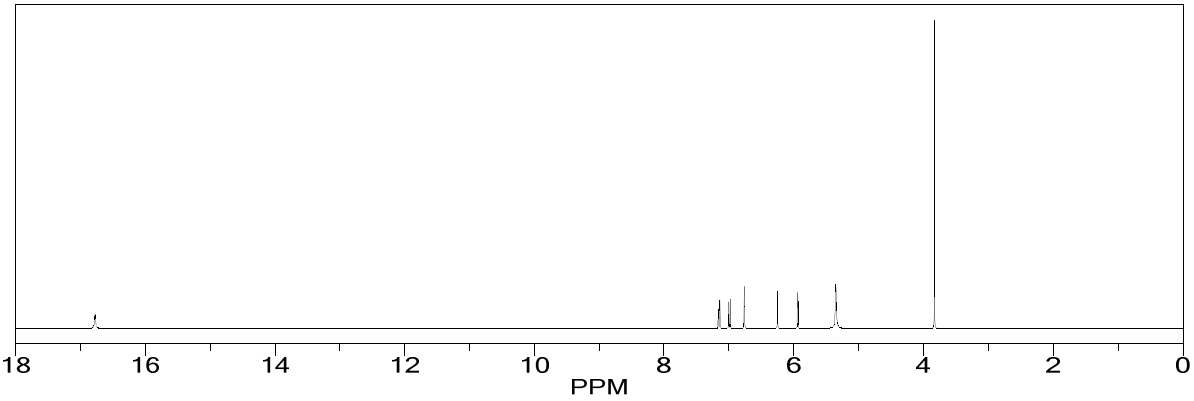
Exact Mass: 316.06

Molecular Weight: 316.26

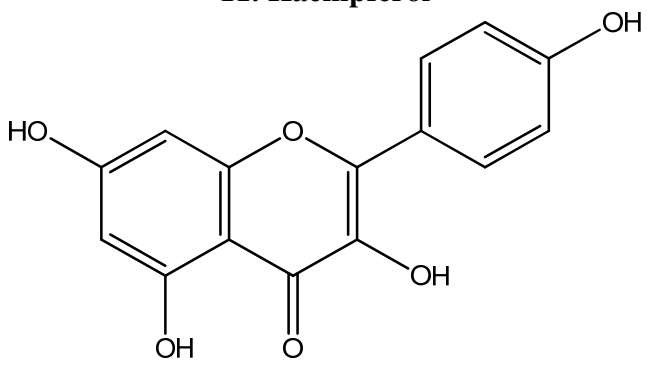
m/z: 316.06 (100.0%), 317.06 (17.7%), 318.07 (1.5%), 318.06 (1.4%)

Elemental Analysis: C, 60.76; H, 3.82; O, 35.41





11. Kaempferol



3,5,7-trihydroxy-2-(4-hydroxyphenyl)-4*H*-chromen-4-one

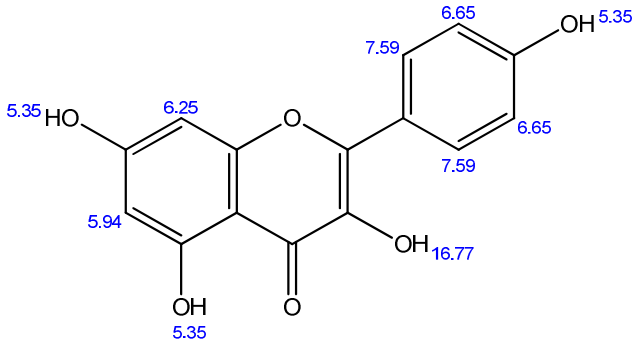
Chemical Formula: $C_{15}H_{10}O_6$

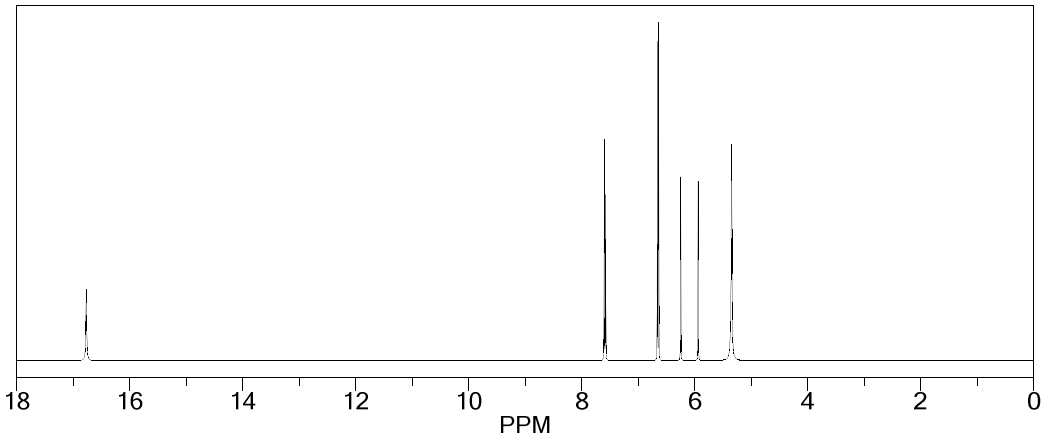
Exact Mass: 286.05

Molecular Weight: 286.24

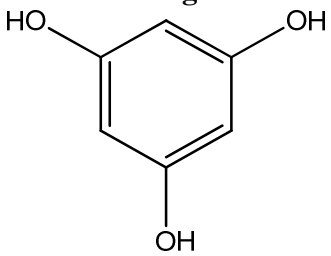
m/z: 286.05 (100.0%), 287.05 (16.6%), 288.05 (2.5%)

Elemental Analysis: C, 62.94; H, 3.52; O, 33.54

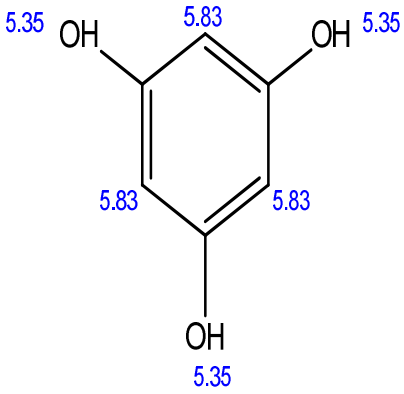


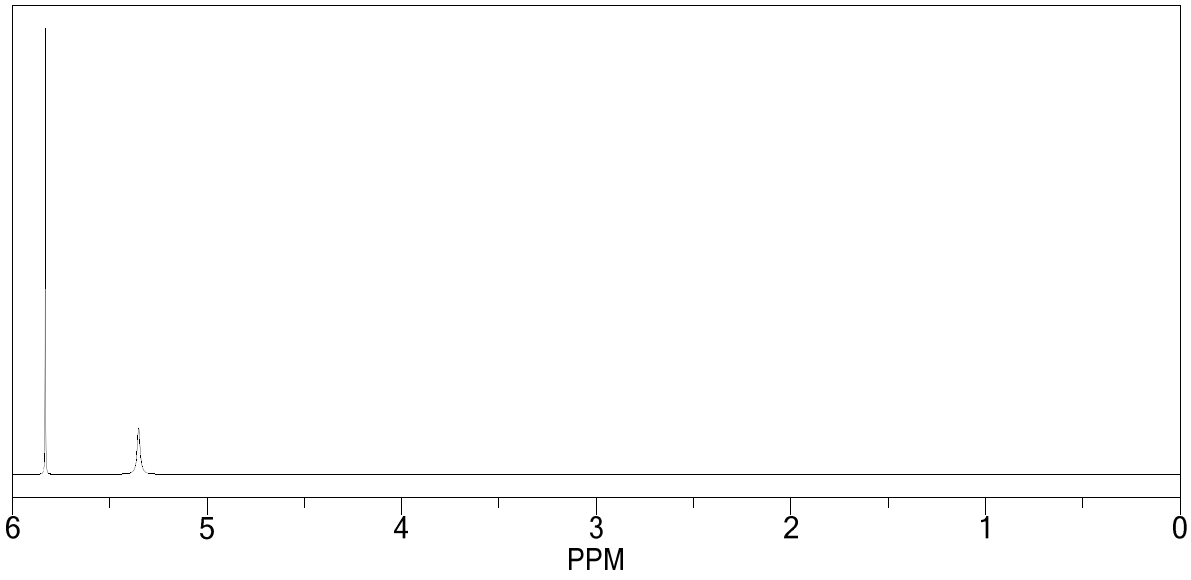


12. Phloroglucinol

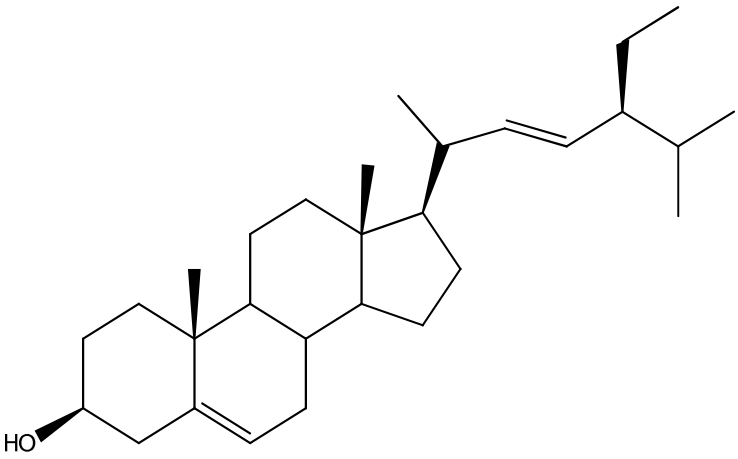


benzene-1,3,5-triol
Chemical Formula: $C_6H_6O_3$
Exact Mass: 126.03
Molecular Weight: 126.11
m/z: 126.03 (100.0%), 127.04 (6.7%)
Elemental Analysis: C, 57.14; H, 4.80; O, 38.06





13. Porifersterol



(3*S*,10*R*,13*R*,17*R*)-17-((2*R*,5*S*,*E*)-5-ethyl-6-methylhept-3-en-2-yl)-10,13-dimethyl-2,3,4,7,8,9,10,11,12,13,14,15,16,17-tetradecahydro-1*H*-cyclopenta[*a*]phenanthren-3-ol

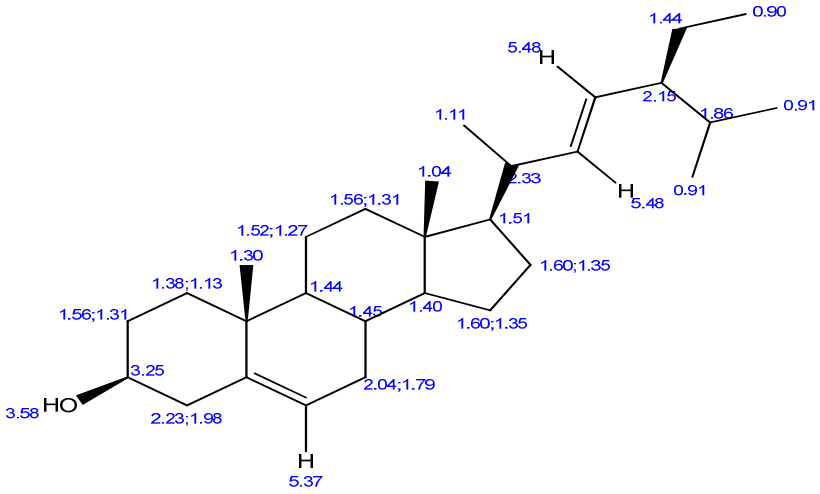
Chemical Formula: $C_{29}H_{48}O$

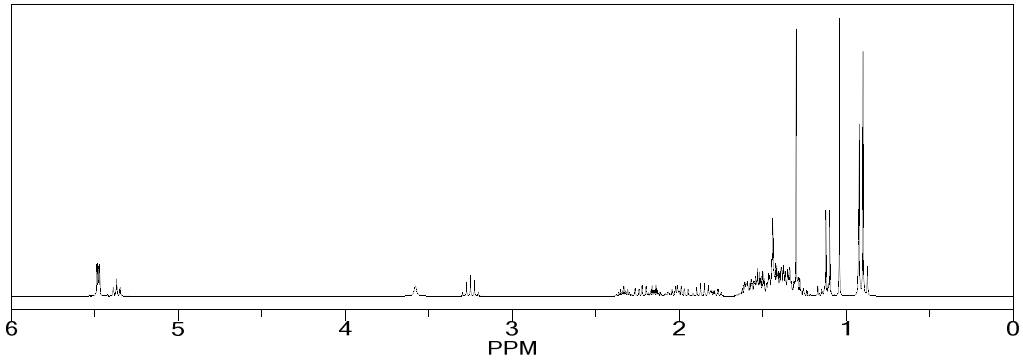
Exact Mass: 412.37

Molecular Weight: 412.69

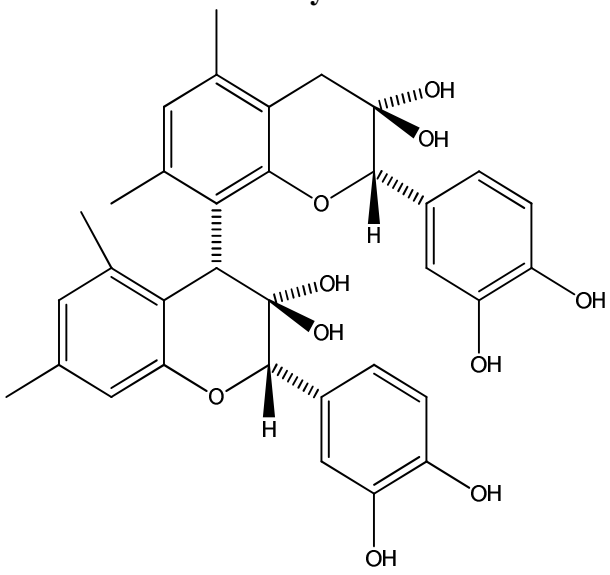
m/z: 412.37 (100.0%), 413.37 (31.4%), 414.38 (4.9%)

Elemental Analysis: C, 84.40; H, 11.72; O, 3.88





14. Procyanidin



(2*S*,2'*S*,4*R*)-2,2'-bis(3,4-dihydroxyphenyl)-5,5',7,7'-tetramethyl-[4,8'-bichroman]-3,3,3',3'-tetraol

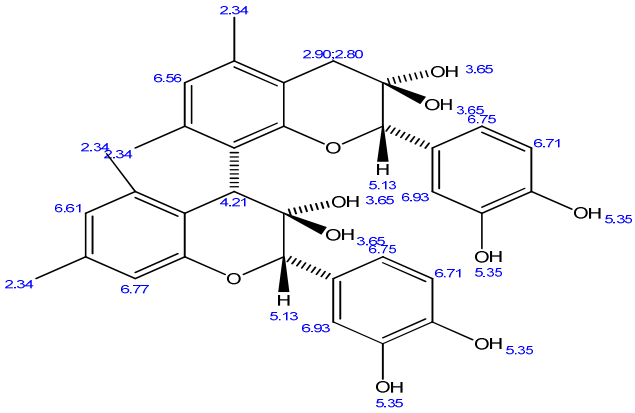
Chemical Formula: $C_{34}H_{34}O_{10}$

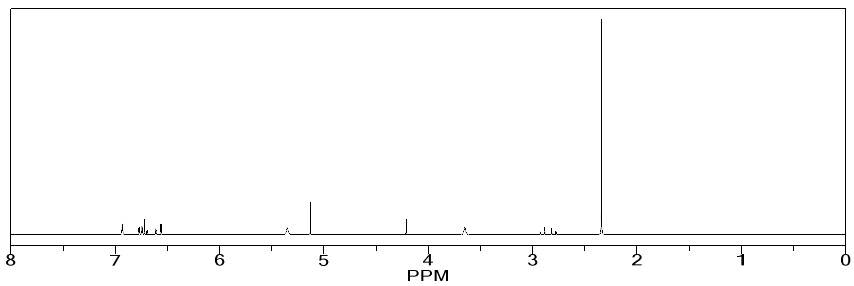
Exact Mass: 602.22

Molecular Weight: 602.63

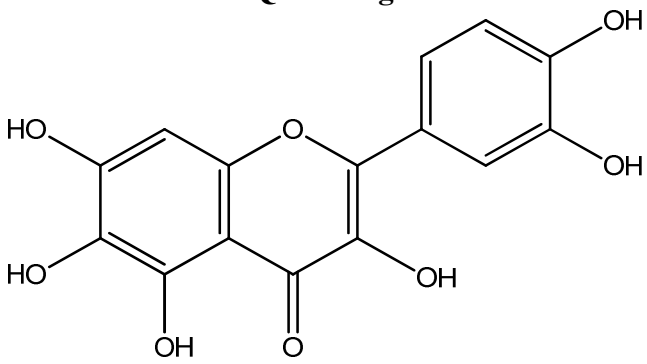
m/z: 602.22 (100.0%), 603.22 (37.5%), 604.22 (8.9%)

Elemental Analysis: C, 67.76; H, 5.69; O, 26.55





15. Quercetagetin



2-(3,4-dihydroxyphenyl)-3,5,6,7-tetrahydroxy-4*H*-chromen-4-one

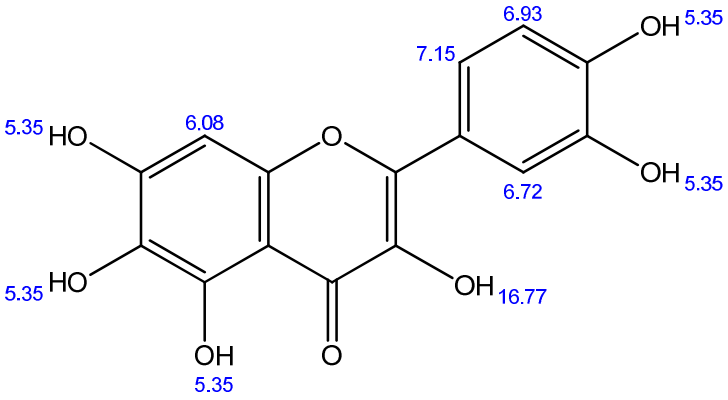
Chemical Formula: $C_{15}H_{10}O_8$

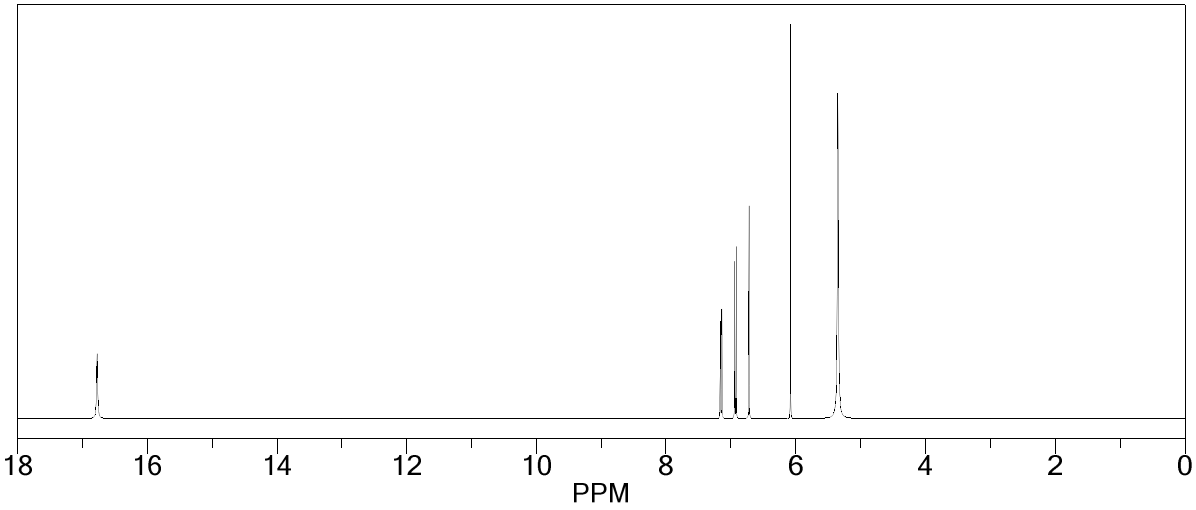
Exact Mass: 318.04

Molecular Weight: 318.24

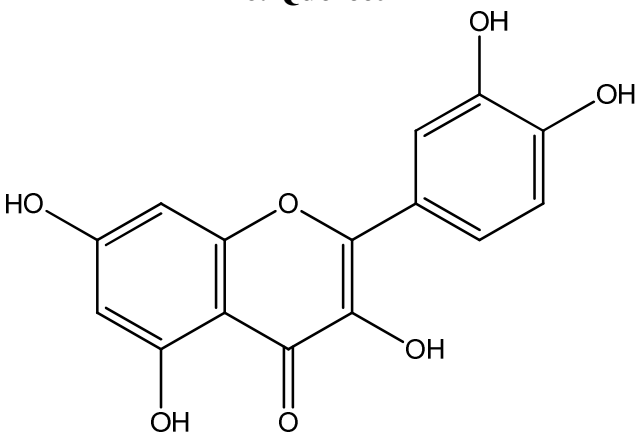
m/z: 318.04 (100.0%), 319.04 (16.6%), 320.04 (2.9%)

Elemental Analysis: C, 56.61; H, 3.17; O, 40.22


6.93
OH 5.35
7.15
5.35 HO
6.08
O
OH 5.35
6.72
5.35 HO
OH 16.77
OH
5.35
O


18
16
14
12
10
8
6
4
2
0
PPM

16. Quercetin



2-(3,4-dihydroxyphenyl)-3,5,7-trihydroxy-4*H*-chromen-4-one

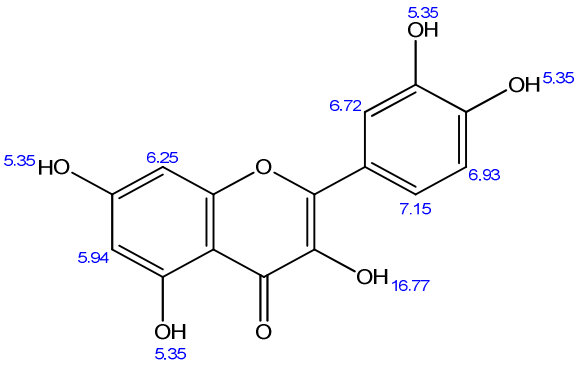
Chemical Formula: $C_{15}H_{10}O_7$

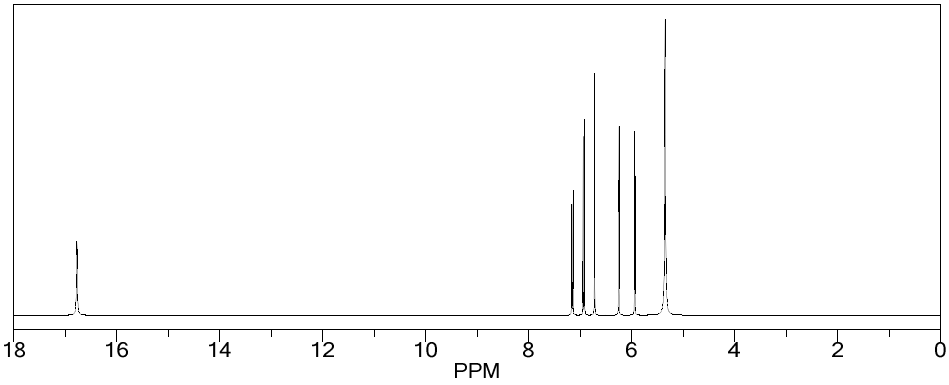
Exact Mass: 302.04

Molecular Weight: 302.24

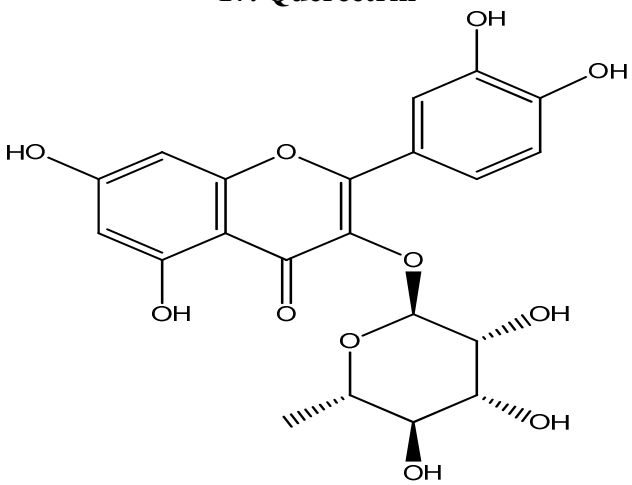
m/z: 302.04 (100.0%), 303.05 (16.6%), 304.05 (2.7%)

Elemental Analysis: C, 59.61; H, 3.33; O, 37.06





17. Quercetrin



2-(3,4-dihydroxyphenyl)-5,7-dihydroxy-3-(((2*S*,3*R*,4*R*,5*R*,6*S*)-3,4,5-trihydroxy-6-methyltetrahydro-2*H*-pyran-2-yl)oxy)-4*H*-chromen-4-one

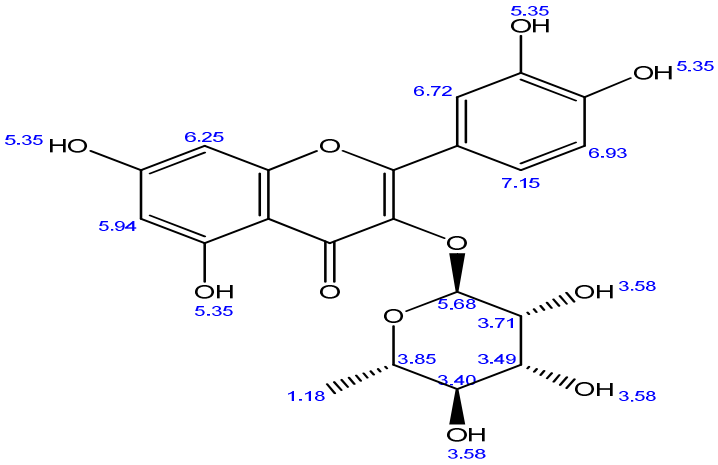
Chemical Formula: $C_{21}H_{20}O_{11}$

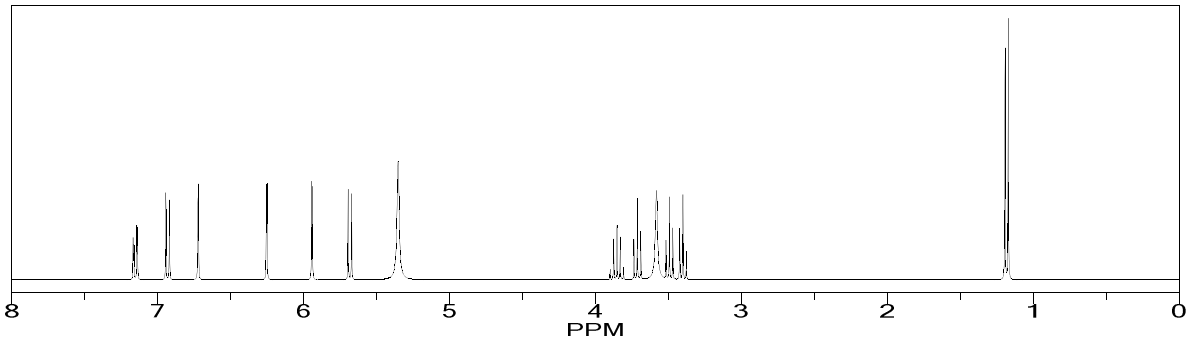
Exact Mass: 448.10

Molecular Weight: 448.38

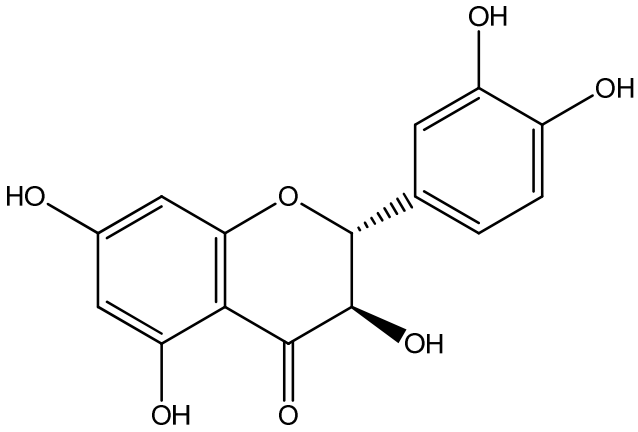
m/z: 448.10 (100.0%), 449.10 (23.1%), 450.11 (2.6%), 450.10 (2.3%)

Elemental Analysis: C, 56.25; H, 4.50; O, 39.25





18. Taxifolin



(2*R*,3*R*)-2-(3,4-dihydroxyphenyl)-3,5,7-trihydroxychroman-4-one

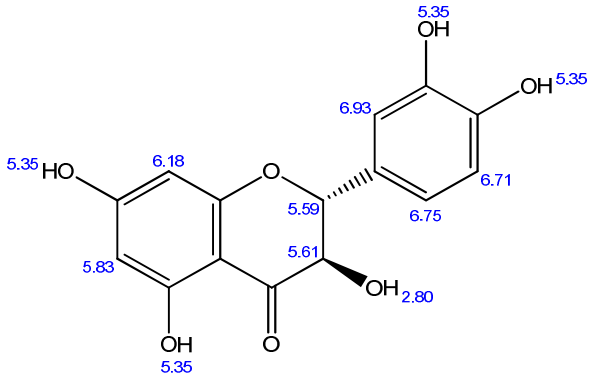
Chemical Formula: $C_{15}H_{12}O_7$

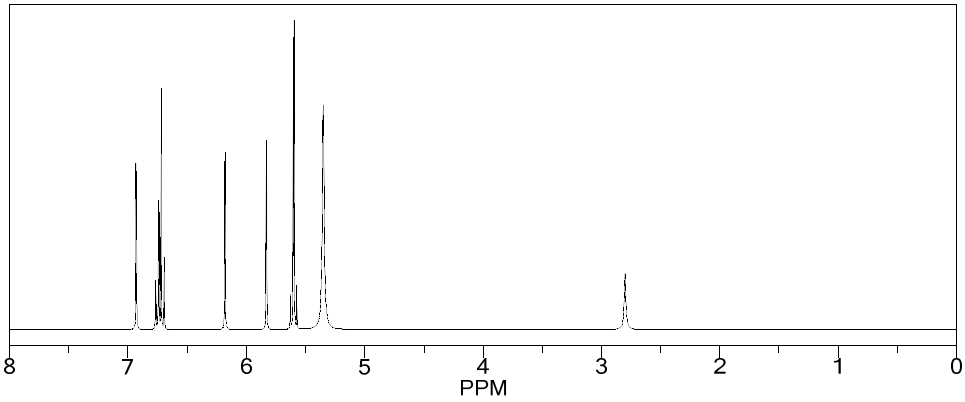
Exact Mass: 304.06

Molecular Weight: 304.25

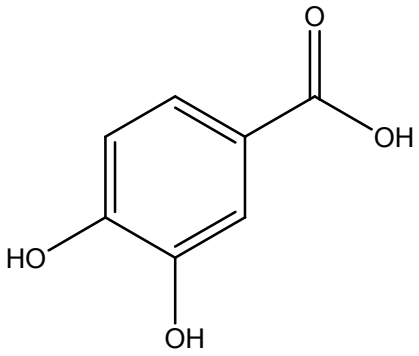
m/z: 304.06 (100.0%), 305.06 (16.6%), 306.06 (1.4%), 306.07 (1.3%)

Elemental Analysis: C, 59.21; H, 3.98; O, 36.81

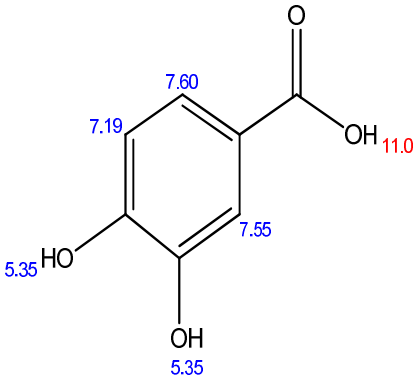


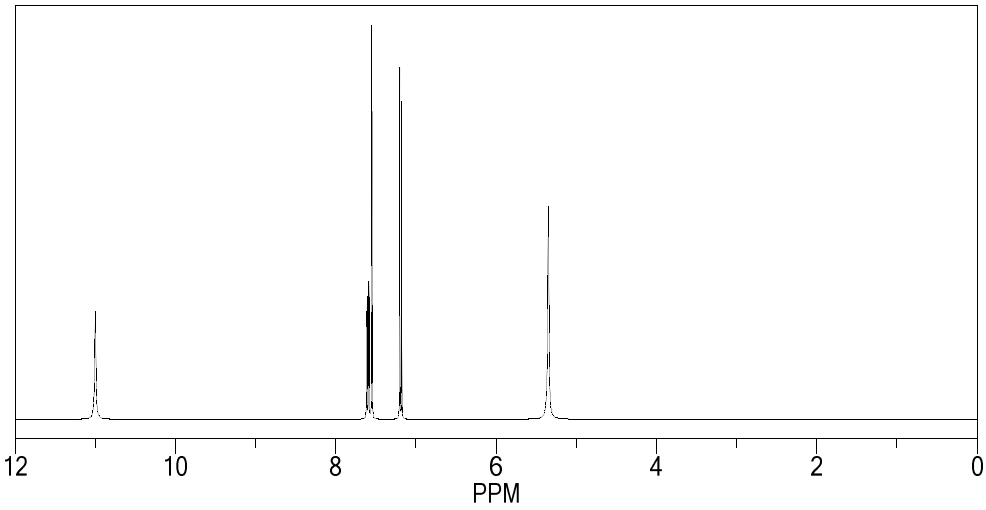


19. Procatechuic acid

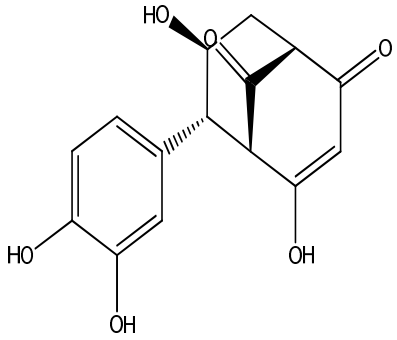


3,4-dihydroxybenzoic acid
Chemical Formula: $C_7H_6O_4$
Exact Mass: 154.03
Molecular Weight: 154.12
m/z: 154.03 (100.0%), 155.03 (7.8%), 156.03 (1.1%)
Elemental Analysis: C, 54.55; H, 3.92; O, 41.52





20. Catechinic acid



(1*R*,5*S*,6*R*,7*S*)-6-(3,4-dihydroxyphenyl)-4,7-dihydroxybicyclo[3.3.1]non-3-ene-2,9-dione

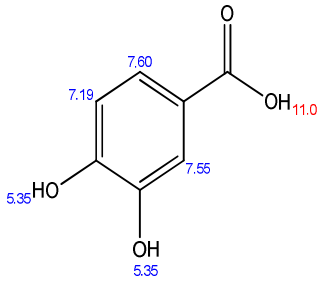
Chemical Formula: $C_{15}H_{14}O_6$

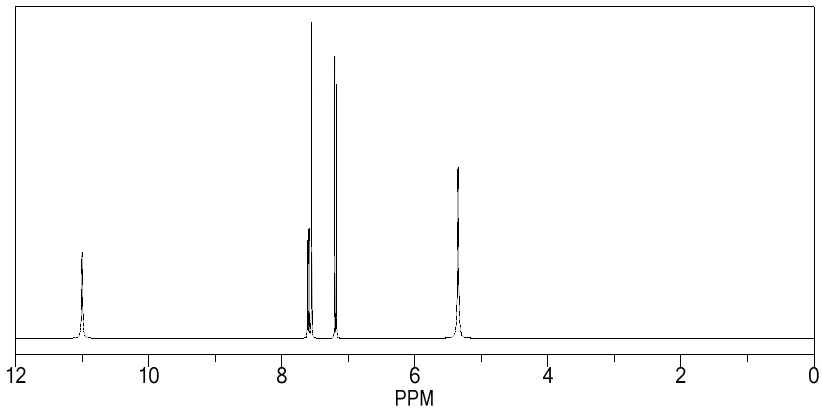
Exact Mass: 290.08

Molecular Weight: 290.27

m/z: 290.08 (100.0%), 291.08 (16.5%), 292.09 (1.3%), 292.08 (1.2%)

Elemental Analysis: C, 62.07; H, 4.86; O, 33.07





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