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REVIEW

Taxonomy and chemical composition of genus Apium

Taxonomía y composición química del género Apium

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ABSTRACT

Family Apiaceae (Umbelliferae) is a unique family in the flowering plants due to its characteristic inflorescences and fruits besides the distinctive chemistry reflected in odor, flavor and even toxicity of many of its members. Plants of the family Apiaceae are usually used medicinally as a cure for gastrointestinal complaints, cardiovascular ailments, they are also used as antispasmodics, sedatives and a source of resins, gum resins, flavouring agents, flavonoids, coumarins , foods and even poisons. Subfamily Apioideae comprises numerous members reputed for their high content of coumarins, flavonoids and volatile oils. One member belonging to this subfamily were chosen as a subject for the present work, viz. Apium. Taxonomy, phytochemicals and biological activities of genus Apium were listed here.

Keywords: Flavonoids; Coumarins; Apium; Leptophyllum; Gravelones; Antioxidant; Volatile Oils.

RESUMEN

La familia Apiaceae (Umbelliferae) es única entre las plantas con flores debido a sus características inflorescencias y frutos, además de la singular composición química que se refleja en el olor, el sabor e incluso la toxicidad de muchos de sus miembros. Las plantas de la familia Apiaceae se utilizan habitualmente con fines medicinales para tratar afecciones gastrointestinales y cardiovasculares; también se emplean como antiespasmódicos, sedantes y como fuente de resinas, gomas resinosas, aromatizantes, flavonoides, cumarinas, alimentos e incluso venenos. La subfamilia Apioideae comprende numerosos miembros conocidos por su alto contenido en cumarinas, flavonoides y aceites volátiles. En el presente trabajo se seleccionó un miembro de esta subfamilia, el género Apium. Aquí se describen la taxonomía, los fitoquímicos y las actividades biológicas de este género.

Palabras clave: Flavonoides; Cumarinas; Apium; Leptophyllum; Gravelonas; Antioxidantes; Aceites Volátiles.

INTRODUCTION

Taxonomy

The family Apiaceae; synonyms: Umbelliferae, Ammiaceae, Daucaceae, is also known as carrot , coriander, celery, parsnip , parsley Family.[1] It belongs to the order umbellifora[2] or Apiales,[3] subclass; Archichlamydeae; class ; Dicotyledoneae, subdivision; Angiospermae.

The family includes 300-400 genera and 2500-3000 species. Members of the family are commonly found in the northern temperate regions, not in arctic ones and relatively rare in tropical latitudes except in the hilly tracts or cultivated in the winter season.[4]

Most of Apiaceous plants are annuals, biennials or perennials. They are mainly herbaceous. Several of the herbaceous species develop some degree of woodiness. Woody tree-like or shrubby species e.g. Eryngium bupleuroides and E. sarcophyllum also occur. Several species are spiny, such as Eryngium species.[5]

The family is divided into three subfamilies according to the fruit characters.[6]

1. Hydrocotyloideae: The fruits are characterized by the presence of woody endocarps, the absence of secretory canals (or present only in the primary ridges). The carpophore is not free. The leaves are usually stiplulate. e.g Azorella and Centella.
2. Saniculoideae: The fruits are usually scaly, characterized by the presence of soft parenchymatous endocarp and various secretory canals. The base of style is surrounded by a ring-like disk (stylopodium). The leaves are always exstipulate e.g. Eryngium, Astranta and Sanicula.
3. Apioideae: The fruits are not scaly. They possess soft endocarps which are sometimes hardened by woody subepidermal layers. The vittae are usually present in the ripe fruits. The style is surrounded by a ring-like disk (stylopodium). The leaves are always ex-stipulate e.g. Apium, Ferula and Pseudorlaya.

Distribution of the subfamilies

The three subfamilies have characteristic distribution. The Apioidea is bipolar but it is mainly distributed in the Northern Hemisphere in the old world. The Saniculoideae is also bipolar but it is more represented in the Southern Hemisphere than the Apioidea. The Hydrocotyloideae is distributed mainly in the Southern Hemisphere. [5]

Genus Apium (tribe:Apieae)

Members belong to genus Apium are characterized by: glabrous annuals or perennials. The leaves are pinnately or ternately divided. The umbels are terminal or axillary. Bracts and bracteoles are absent or conspicuous. The flowers are mostly bisexual. Calyx is minute and teeth shaped. Petals are white, greenish or reddish in color and mostly entire. Stylopodium is short and conical in shape. Styles are short. The fruit is broadly ovoid to subglobose. The carpophore is undivided or slightly 2-fid. Mericarps are with prominent ribs. oil ducts are 1-3 in each furrow. It is cultivated in temperate and warm regions but especially in south America.[7]

Apium leptophyllum (Pers.) F. Muell.ex Benth

Sison ammi Jacq., Cnidium tenuifolium Moench., Pimpinella leptophylla Pers., Apium ammi Jacq., Apium tenuifolium Moench.

It includes delicate glabrous annual herbs of about 15-50 cm in length. The tap root is slender. The stems are erect, ascending or procumbent, branched especially from the base and striate. The lower and central cauline leaves are 5-8 cm in length. They are sheathing 0,3-1,5 cm, with broad scarious margins. The upper leaves are shorter, with a few segments up to 2,5 cm. They are tri-pinnate. The segments are 0,5-2 x 0,1 cm, filiform mucronate. The umbels are 2-4 rayed , sessile. The umbel-rays are 1-3 cm. The flowers are 5-15 in each umbellule. The pedicel is 3-8 mm. The calyx is minute teeth like in shape. The petals are 0,3-0,5 mm, white, glabrous. The fruit is 1-1,5 mm, subglobose. The primary ribs are broad. The styles are very short. It is native to Central America, naturalized in many tropical and subtropical regions.[7]

Apium graveolens L

It includes glabrous aromatic annual herbs. It reaches 20-80 cm in length. The roots are fusiform. The stems are erect or ascending, branched, strongly grooved. The leaves are rather fleshy. The basal leaves are petiolate. They are uni-pinnatisect. The segments are 3-5, 1-3 cm in length, deltoid, incised-dentate. The cauline leaves are short-petiolate or sessile, ternately divided. The umbels are axillary and terminal, short-pedunculate or sessile. The umbel-rays are few to many, subequal. The pedice is 1-2,5 mm. The flowers are 0,5 mm. The petals are greenish –white or white in colour. The styles are longer than the stylopodium. The fruit is 1,5 mm and broadly ovoid. The mericarp is 1 mm, subglobose and with 5 prominent ribs. It is cultivated in temprate and subtropical regions.[7]

Apium nodiflorum (L.)

Sium nodiflorum L., Helosciadium nodiflorum L.

It includes glabrous perennial herbs of about 30-80 cm in length. The roots are fusiform. The stems are ascending to procumbent. They are grooved and hollow. The leaves are petiolate and uni-pinnatisect with 3-6 pairs of segments. The segments are 1,5-3,5x1-1,8 cm and lanceolate to ovate and sessile. The base is oblique. The margin is serrate. The umbels are opposite . The leaves are sessile. The rays are few and unequal. The bracteoles are 4-6 and usually exceeding the short pedicle, with scarious margin and 3-nerved. The flowers are 0,6 - 1 mm. The petals are white in colour. The styles are longer than the stylopodium. The fruit is 1,5 mm, with narrow and prominent ribs. It is cultivated in temprate and warm regions.[7]

Apium crassipes (Koch ex Rchb.)
Helosciadium crassipes Koch ex Rchb.

It includes perennial herbs of about 10-30 cm in length. It is usually partly or entirely submerged. The leaves are 1,5 - 4 cm in length. They are pinnate. The lower leaves are with segments divided into filiform lobes. The upper leaves are with ovate, often 3-lobed segments. The umbel-rays are 3-5. The fruiting pedicel is thickened at the base. The bracteoles are 5-8, herbaceous and without scarious margin. The styles are longer than the stylopodium. It is cultivated in Egypt (Alexandria), Italy, Sardinia, Sicily and Corsica.[7]

Apium repens (Jacq.)

The stem is creeping throughout its length. The rooting is at every node. The leaf-segments are 5-14 mm in length. They are ovate to suborbicular. The peduncle is usually 2-3 times as long as rays. The rays are 3-6. The bracts are 3-7. The fruit is usually 1 mm and wider than long.[6]

Apium inundatum (L.)

It is a perennial herb attains up to 75 cm in length. The leaves are pinnate. The lower divided into filiform or linear lobes, the upper is with ovate, often 3-lobed segments which is 5 mm in length. The peduncle is about as long as the rays. The umbels are leaf-opposed. The rays are 2-4. The pedicels are not thickened in fruit. The bracts are absent. The bracteols are 3-6, herbaceous and are lanceolate in shape. The styles are much shorter than stylopodium in fruit. The fruit is elliptic to oblong in shape and measures 2-3,5 mm in length.[6]

Π-Chemistry of genus Apium
Volatile oil

Almost all umbelliferous plants are aromatic. They produce essential oils and biogenetically related resins which are excreted in schizogenous canals in roots, stems, leaves, inflorescence and in the vittae of the fruits. Many well known essential oil constituents were isolated for the first time from an umbelliferous plant and were named accordingly after this source.[8]

Apium leptophyllum (Pers.) F. Muell. ex Benth

Steam distillation of fresh plants yielded 0,25 % of essential oil consisting of thymohydroquinone dimethyl ether (29 %), carvacrol methyl ether (9 %), thymol methyl ether (7 %), in addition to 11 monoterpene hydrocarbons (totally 45 %) identified by gas chromatography as γ-terpinene, p-cymene, δ-pinene, α-pinene, myrcene, α-thujene, limonene, sabinene, cis- and trans-ocimene and δ-phellandrene (in order of decreasing relative amount).[9]

Analysis of the essential oil from the aerial parts of Apium leptophyllum (Pers.) F. Muell herb yielded 0,3 % of the oil. The oil was separated into 32 % hydrocarbons and 68 % oxygenated compounds. The principle component of the latter was identified as apiole through tR and IR spectrum as compared with an authentic sample.[10]

The essential oil of the fresh fruiting plant, Apium leptophyllum (Pers.) F. Muell. yield was 0,3 %. The oil is colorless to pale yellow, has specific gravity 0,89-0,91, aromatic characteristic odor and taste. It was found to contain the phenolic ether thymohydroquinone dimethyl ether (31,7 %), thymyl methyl ether (22,7), carvacryl methyl ether (7,4 %), the monoterpene hydrocarbons p-cymene (17,5 %) , δ-phellandrene (10,3 %), δ-pinene (0,59 %), the monoterpene alcohol δ-terpineol (0,33 %) and the sesquiterpene hydrocarbons germacrene C (1,3 %), germacrene D (0,71 %) , bicycogermacrene (0,59 %) and cadinene (0,12 %).[11]

The essential oils of the aerial parts of Apium leptophyllum (Pers.) F. Muell were also investigated. The oil yields obtained were 0,33-0,42 % on fresh herbs. The characteristic components were found to be thymohydroquinone dimethyl ether (46,2-50,7 %), isothymol methyl ether (10,6- 11,5 %), thymol methyl ether (6,46- 7,28 %), carvacrol methyl ether (0,42- 0,54 %), P-cymene (5,79- 10,7 %), γ-tepinene (3,4- 6,2 %), δ-pinene (1,33- 2,33 %), δ-caryophyllene (0,71- 1,02 %), α-humulene 1,86- 2,65 %), germacrene-D (1,04- 2,53 %) and germacrene-B (1,56- 2,14 %).[12] b- Apium graveolens L. The essential oil of celery fruit includes d-limonene, selinene, sesquiterpene alcohols, sedanolide and sedanonic anhydrid.[13]

The volatile aroma of a local variety of celery from Libya was analysed. Three constituents made up 70 % of the total volatiles, apiole (23 %), 3-butyl phthalide (22 %) and 3-butyltetrahydrophthalide or sedanolide (24 %). The latter two compounds are known to possess strong characteristic celery aroma. They isolated several other components p-cymene, limonene, cryptone, p- mentha-1,3,8-triene, p-methylacetophenone, carvone, δ-selinene, valencene, α-selinene, myristicine and sedanenolide.[14]

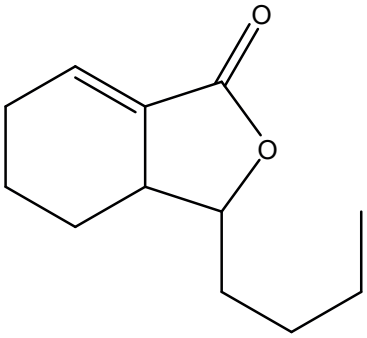
Cultivated celery (Apium graveolens L.var.dulce.) and celeriac (Apium graveolens L. var.rapaceum) are closely related members of the umbelliferae but whereas the leaf stem is the edible part of celery, the part of the celeriac that is eaten is the swollen base of the stem often referred to incorrectly as a root.[15]

The volatile components of celery and celeriac were studied by the same authors. They found some interesting

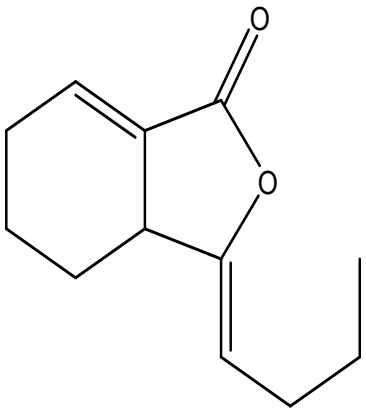
features of the chemical composition of the two isolates being related to their content of terpenoid compounds. As a group, the 18 monoterpene hydrocarbons represented as much as 46 % of the celery isolate, but only 24,8 % of the celeriac sample. Nine of the monoterpene hydrocarbons identified in celery namely camphene, α-thujene, terpinolene, δ-phellandrene, 4-isopropenyl-1-methylbenzene and the p-menthatrienes could not be detected in the celeriac isolate. The major component in both isolates was limonene constituting 35,5 % of the celery volatiles and 14,9 %of the celeriac isolate. Also celery volatiles contained higher concentration of γ-terpinene and α-pinene , the celeriac were characterized by greater quantities of the alternative isomers, α-terpinene and δ-pinene. The absence of δ-selinene in celeriac isolates is another distinguishing feature between them.[15]

On the other hand, α-pinene, δ-pinene , myrcene, p-cymene, Limonene , 3-carene, γ-terpinene, camphor, 4-terpineol, α-terpineol, dihydrocarvone, cis-verbenone, trans-carveol, δ-caryophyllene and α-selinene were identified. They found that as a class, the phthalides represented as high a proportion as 42,3 % of the celery isolate and 37,4 % of the celeriac sample. Two of the celery phthalides, namely (E)-ligustilide and cnidilide, could not be detected in the celeriac volatiles. The major phthalide in both isolates was sedanenolide. The celeriac isolate contained higher concentration of the two isomeric 3-butylhexahydrophthalides, cis-sedanolide, trans-sedanolide, (z)-3-butylidinephthalide and methyl sedanonate.[16]

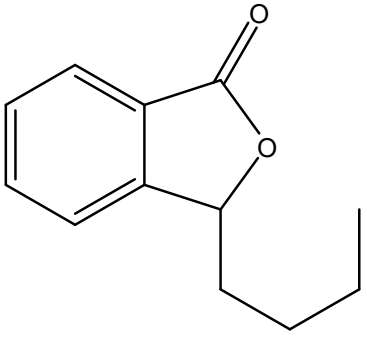
Limonene, sedanolide, δ-selinene, pentyl cyclohexadiene and myrcene constitute more than 90 % of the oil. Unlike several other reported data, n-butyl phthalide was present only in minute amount while, sedanenolide was totally absent.[17] 3-butylphthalide and 3-butylhehxahydrophthalide were isolated from celery and celeriac.[18] δ-selinene and 3n-butyl-4,5-dihydrophthalide were isolated from the hexane extract of Apium graveolens L. fruits.[19] Sedanolide, senkyunolide-N and senkyunolide-J were isolated from celery fruits.[20]
The main constituents in the oil of roots were limonene, carvone and 3n-butyl phthalide. The essential oil of the leaves contained higher amount of limonene comparing to the roots and very small amount of carvone.[21] Phthalides as 3-n- butylphthalide, sedanenolide and sedanolide were reported from celery.[22] Isocnidilide (40,1 %) was identified as the major constituent of A. graveolens oil along with β-Selinene, Senkyunolide A, Phytyl acetate, and 3-Butylphthalide.[23]



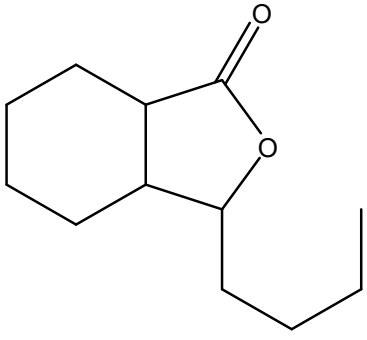
Sedanolide



Sedanonic anhydride



3-Butyl phthalide



Sedanenolide

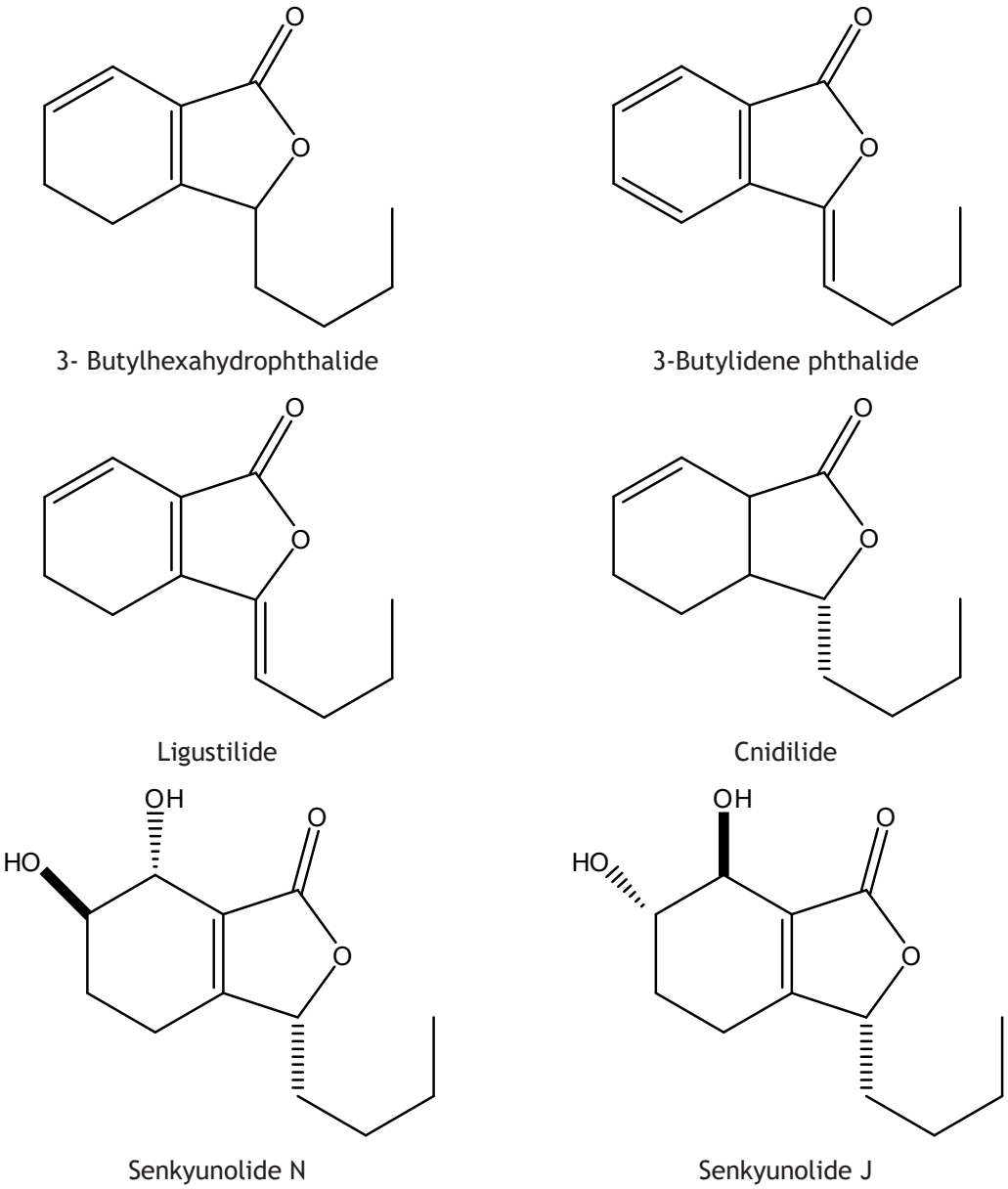


Figure 1. Some volatile oil constituents from Apium

Phenyl propanoids

The family Umbelliferae is rich in phenyl propanoids that were often isolated in the essential oil fraction of fruits and roots.

The hydroxy cinnamic acid pattern was found to be typical to the family especially in the leaves of Caucalideae. Caffeic acid was universal, while ferulic, sinapic and p-coumaric acids were regularly present. Caffeic and chlorogenic acid esters were found to be the major cinnamic esters universal in the leaves.[8]

Synergic acid, p-coumaric acid, o-coumaric acid and ferulic acid were isolated from fruits of Apium leptophyllum (Pers.) F. Muell.[24]

Flavonoids

Flavonoids are universally distributed in family Apiaceae.[25] It is interesting to note that one of the first flavone glycosides to be characterized chemically was the unusual apiosylglucoside of apigenin, apiin, which was isolated from celery fruit as long ago as 1843.

Flavonoids isolated from Apium leptophyllum (Pers.) F. Muell and A. graveolens (L.) are listed in tables 1 and 2 respectively.

Table 1. Flavonoids reported in Apium leptophyllum (Pers.) F. Muell

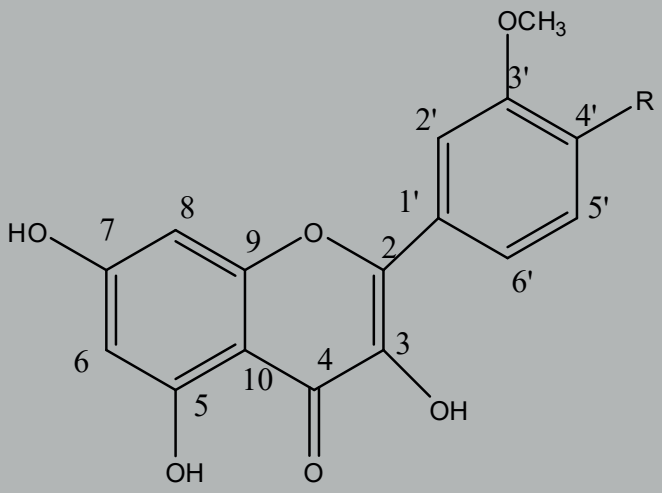
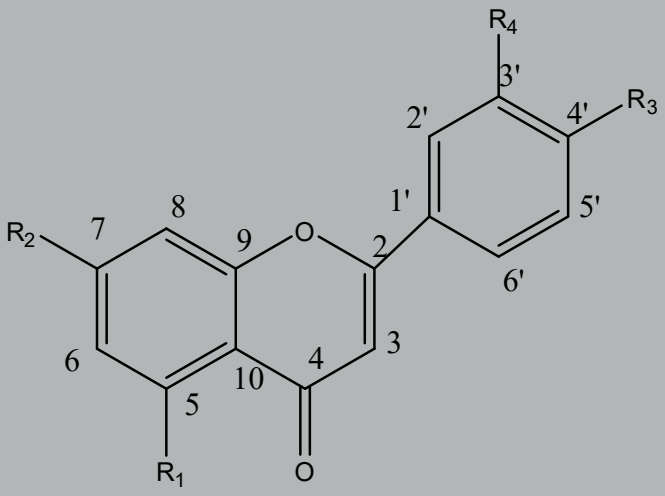
Chemical structure	Name	Source	Reference
			
R=OH	3`- O-methyl quercetin	A.leptophyllum (Pers.) F.Muell. fruits	(24)
R=OCH3	3`,4`-di-O-methyl quercetin	A.leptophyllum (Pers.) F. Muell. fruits	(24)

Table 2. Flavonoids reported in Apium graveolens L

Chemical structure	Name	Source	Reference
			
R1=R2=R3=OH, R4=H	Apigenin	A.graveolens (L.) A.graveolens (L.) (celery) fruits A.graveolens (L.)(local celery)	(26) (27) (28)
R1=R3=OH,R4=H, R2=O-ß-D-apiose(1-2) ß-D-glucose.	Apiin (apigenin-7-O-ß-D-apiosylglucoside)	A.graveolens L. A.graveolens L.var.dul leaves	(8) (29)
R1=R3=OH,R4=H, R2=O-ß-D-apiose(1-2)ß-D-glucose malonate	Apigenin 7-O-ß-D-apiosylglucoside malonate	*A.graveolens L.var.dulce* leaves	(30)

R1=R3=OH,R4=OCH3 R2=O-ß-D-apiose(1-2)ß-D-glucose	3`-methoxy apiin	A.graveolens Linn. fruits	(31)
R1=R2=R3=R4=OH	Luteolin	A.graveolens (L.) (celery) A.graveolens (L.)(local celery	(27) (28)
R1=R3=R4=OH, R2=-O-ß-D-glucose	Luteolin -7-O-ß-D-glucoside	A.graveolens (L.) (celery-chinese fruit)	(30)
R1=R3=R4=OH, R2=O-ß-D-apiose(1-2) ß-D-glucose.	luteolin-7-O-ß-D-apiosylglucoside	A.graveolens L. A.graveolens (L.) (celery-chinese fruit)	(8) (30)
R1=R3=R4=OH, R2=O-ß-D-apiose(1-2)ß-D-glucose malonate	Luteolin 7-O-ß-D-apiosylglucoside malonate	A.graveolens L.var.dulce leaves	(30)
R1=R3=OH,R4=OCH3 R2=O-ß-D-glucose	Chrysoeriol-7-O-ß-D-glucoside	A.graveolens (L.) (celery-chinese fruit)	(30)
R1=R3=OH,R4=OCH3 R2=O-ß-D-apiose (1-2) ß-D-glucose	Chrysoeriol-7-O-ß-D-apiosylglucoside	A.graveolens (L.) (celery-chinese fruit)	(30)
R1=R3=OH,R4=OCH3 R2=O-ß-D-apiose (1-2) ß-D-glucose malonate	Chrysoeriol-7-O-ß-D-apiosylglucoside malonate	A.graveolens (L.) (celery-chinese fruit)	(30)

Polyacetylenic compounds

Acetylenic compounds form an outstanding feature of the Umbelliferae.

A chain length of C-17 e.g. falcarinone and falcarinol (panaxynol or carotatoxin) is common in the family. However, C-13 and C-15 compounds co-occur or replace the C-17 compounds in some species. Some of the umbelliferous polyacetylenic metabolites are very toxic.[32] Falcarinol, falcarindiol, 8-O-methylfalcarindiol, and panaxydiol were isolated from the extract of lyophilized and ground subaerial parts of *Apium graveolens* (L.) var. rapaceum.[33]

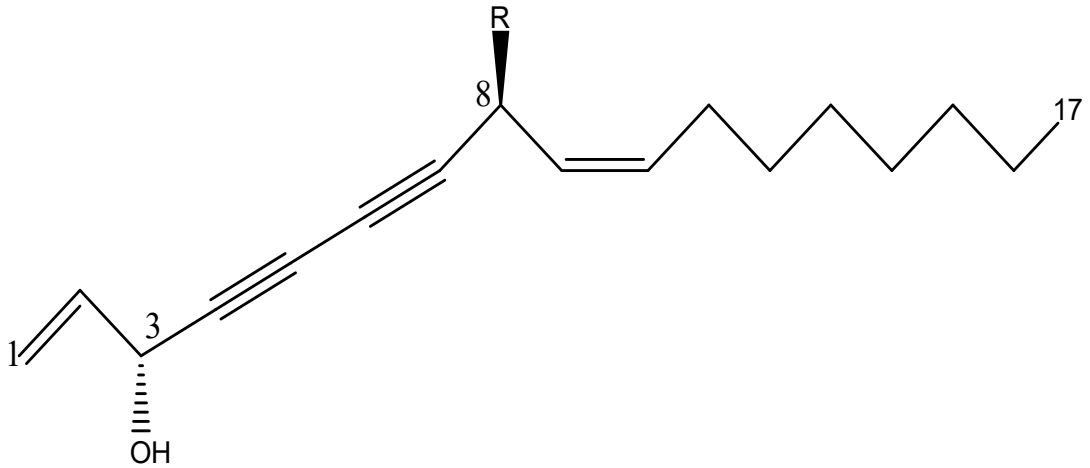


Figure 2. Falcarinol and its derivatives

R=H Falcarinol
R=OH Falcarindiol
R=OCH3 8-O-methylfalcarindiol

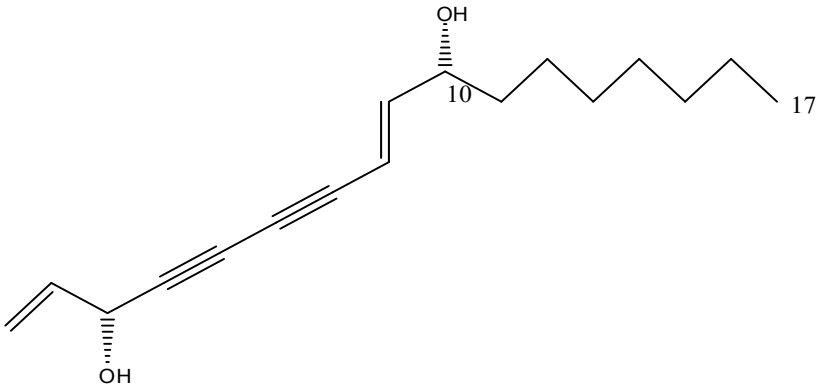


Figure 3. Panaxydiol

Coumarins

Coumarins form another outstanding feature of the Umbelliferae.[8] Coumarins isolated from *Apium leptophyllum* (Pers.) F. Muell and *A. graveolens L.* are listed in tables 3 and 4 respectively.

Table 3. Coumarins reported in Apium leptophyllum (Pers.) F. Muell

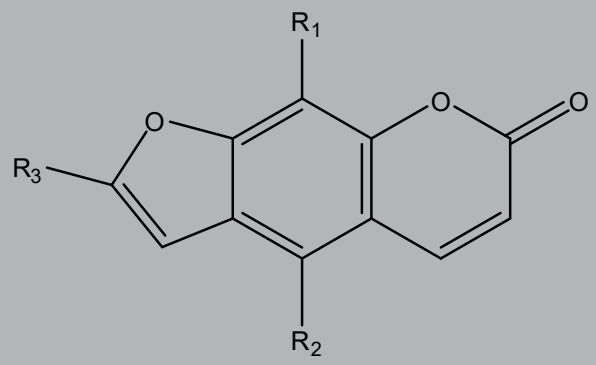
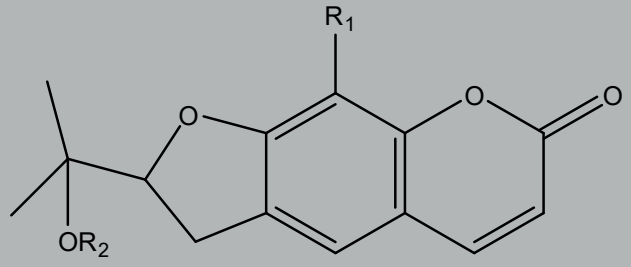
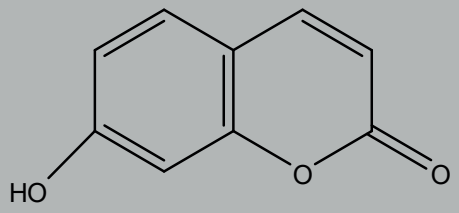
Chemical structure	Name	Source	Reference
			
R1=R3=H, R2=OCH3,	Bergapten	Apium leptophyllum (Pers.) F. Muell fruits Apium leptophyllum (Pers.) F. Muell fruits	(34) (35)
R1=R2= OCH3, R3=H	Isopimpinellin	Apium leptophyllum (Pers.) F. Muell fruits	(35)
R1=OH ,R2=OCH3,R3=H	8-hydroxy-5-methoxy psoralen	Apium leptophyllum (Pers.) F. Muell fruits	(36)
R1=OH,R2=H, R3= isopropyl	Anhydrorutaretin	Apium leptophyllum (Pers.) F. Muell fruits	(35) (36) (37)

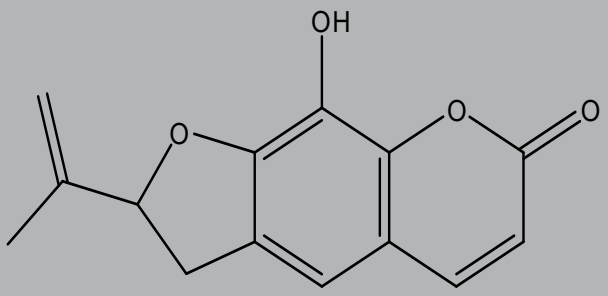
Table 4. Chemical Structure and Data of Marmesin and Derivatives (Coumarins)"

Chemical structure	Name	Source	Reference
			
R1=R2=H	Marmesin	A.leptophyllum (Pers.) F. Muell fruits	(36)

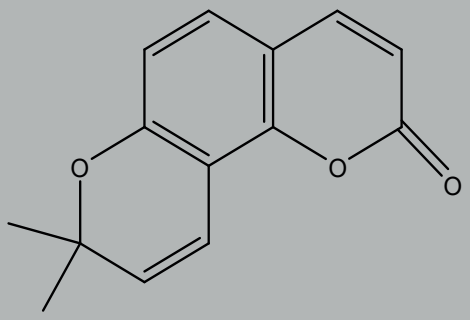
R1=OH, R2=H	Rutaretin (Leptophyllin)	A.leptophyllum Muell fruits	(Pers.)	F.	(35) (36)
		A.leptophyllum Muell fruits	(Pers.)	F.	(37)
		A.leptophyllum Muell fruits	(Pers.)	F.	
R1=OH, R2=glucose	Leptophylloside	A.leptophyllum Muell fruits	(Pers.)	F.	(35) (36)



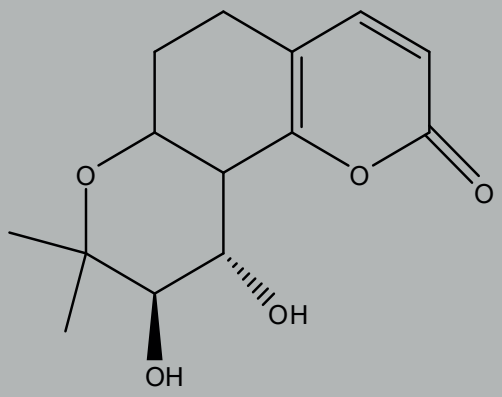
	Umbelliferone	*A.leptophyllum* Muell fruits	(Pers.)	F.	(35)



	Leptophyllidin	A.leptophyllum Muell fruits	(Pers.)	F.	(35) (36) (37)

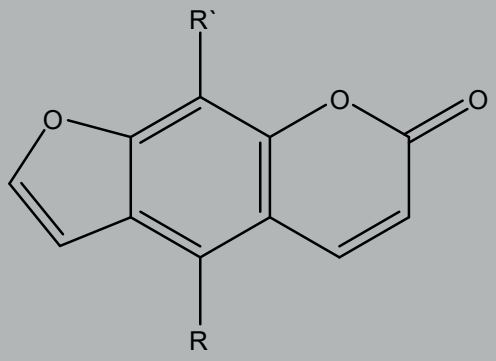
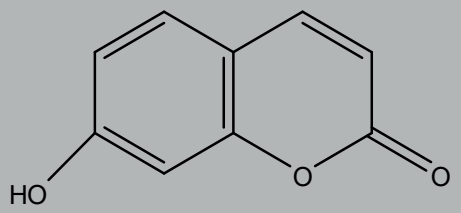
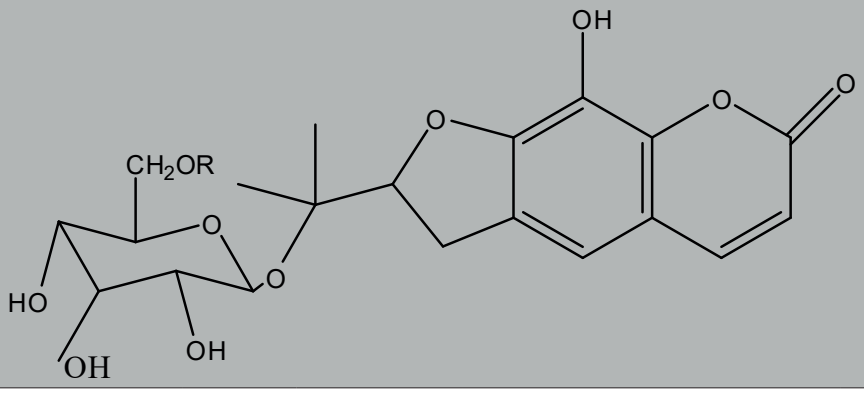


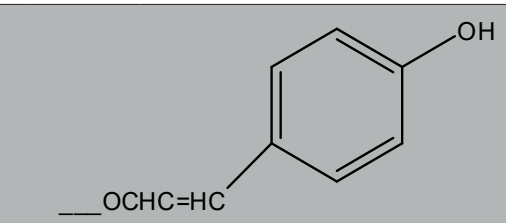
	Seselin	A.leptophyllum Muell fruits	(Pers.)	F.	(34) (35)



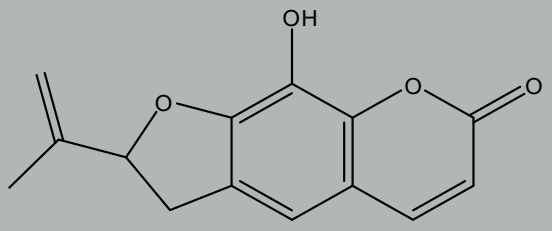
	Trans-khellactone	A.leptophyllum Muell fruits	(Pers.)	F.	(37)

Table 5. Coumarins reported in *Apium graveolens (L.)*

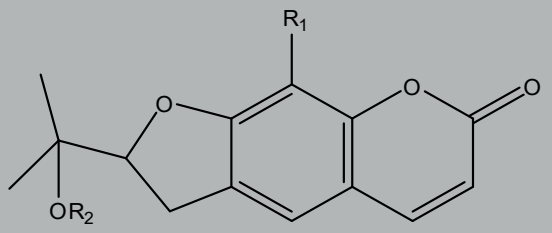
Chemical structure	Name	Source	Reference
			
R=R` =H	Psoralen	A.graveolens (L.) (celery)	(38)
		A.graveolens (L.)	(38)
		A.graveolens (L.)	(39)
		A.graveolens (L.) (Florida celery)	(40)
R=OCH3 ,R`=H	Bergapten	A.graveolens (L.) fruits	(41)
		A.graveolens (L.)	(38)
		A.graveolens (L.)	(38)
		A.graveolens L.(var. dulce and var.rapaceum)	(42) (39)
		A.graveolens (L.)	(43)
		A.graveolens (L.)	(40)
		A.graveolens (L.) (Florida celery)	
R=H, R`= OCH3	Xanthotoxin	A.graveolens (L.) (celery)	(38)
		A.graveolens (L.)	(38)
		A.graveolens (L.)	(39)
		A.graveolens (L.)	(41)
		A.graveolens (L.)	(40)
R=R`= OCH3	Isopimpinellin	A.graveolens (L.) fruits	(41)
		A.graveolens (L.) (celery)	(38)
		A.graveolens (L.)(celery)	(38)
		A.graveolens (L.) fruits	(42)
		A.graveolens (L.) (Florida celery)	(40)
R=OCH3,R`=OH	8-hydroxy-5-methoxy psoralen	A.graveolens (L.) fruits	(44)
R=OCH2CH=C(CH3)2,R`=H	Isoimperatorin	A.graveolens (L.) fruits	(41)
		A.graveolens (L.) fruits	(42)
	Umbelliferone	*A.graveolens (L.)* fruits	(44)
			



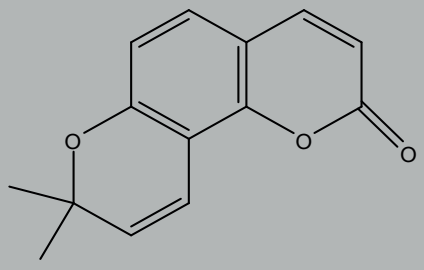
Apiumoside *A.graveolens (L.)* fruits [45]



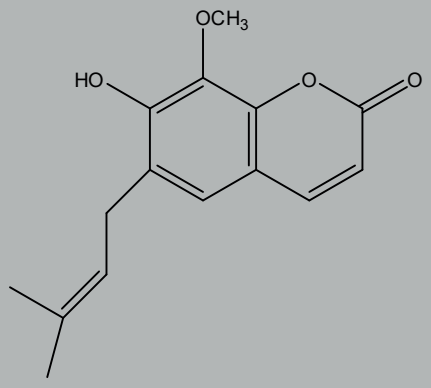
A p i u m e t i n *Apium graveolens (L.)* fruits [46]
(Leptophyllidin)



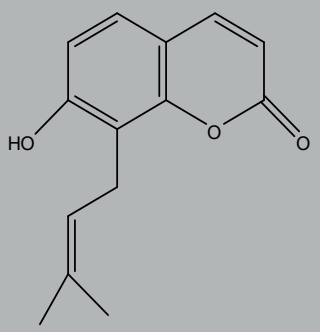
R1=OH, R2=H Rutaretin (leptophyllin) *Apium graveolens (L.)* fruits [46]



Seselin *Apium graveolens (L.)* fruits [41]



Apium graveolens (L.) fruits. [41]



Apium graveolens(L.) fruits. [41]

Fatty acids

The fixed oil of the fruits of *Apium graveolens L.* includes the fatty acids petroselinic, oleic, linoleic, myristic, palmitic, palmitoleic, stearic and myristoleic acids. [22]

The low polarity components from fruits of *Apium graveolens (L.)* include oleic acid (2,11 %) and palmitic acid (1,49 %).[47]

Miscellaneous

D-mannitol was identified from *Apium leptophyllum* (Pers.) F. Muell fruits.[35]

3-hydroxymethyl-6-methoxy-2,3-dihydro-1H-indol-2-ol and L-tryptophan was isolated from *Apium graveolens* Linn. fruits.[31]

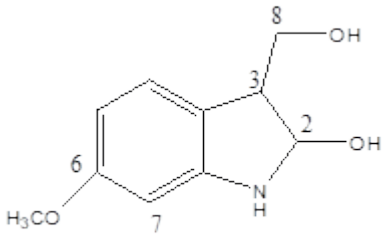
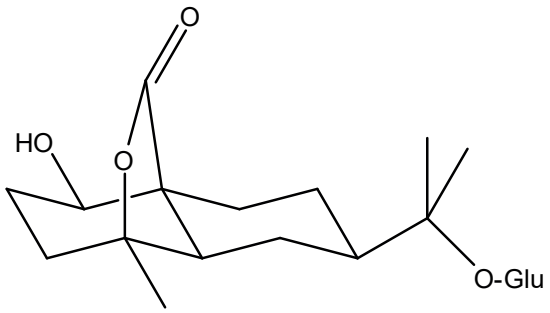


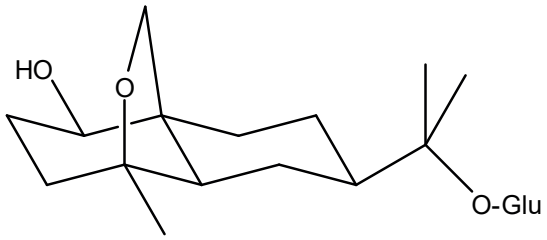
Figure 4. 3-hydroxymethyl-6- methoxy-2,3-dihydro-1H-indol-2-ol

Four compounds were isolated from fruits of *Apium graveolens L.* viz: p-hydroxybenzaldehyde, 3-hydroxy-4-isopropylbenzoic acid, vanillic acid and 4-hydroxy-2-isopropyl-5-methylphenyl-1-O-δ-D-glucopyranoside.[48]

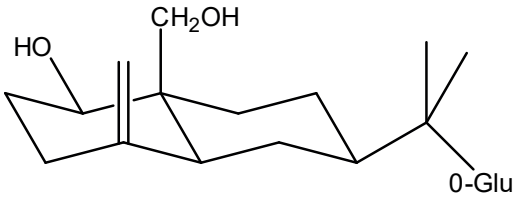
Five sesquiterpenoid glucosides (celeriosides A-E), , two norcarotenoid glucosides (citrosides A and B), a lignan glucoside ((7S,8R,8`R)-(+)-lariciresinol 9-O-ß-D- glucopyranoside.) and six aromatic compound glucosides identified as leonuriside A, 4-hydroxy-3,5-dimethoxybenzyl alcohol 4-O-ß-D-glucopyranoside, icariside F2, icariside D1, syringin, junipediol A 4-O-ß-D- glucopyranoside were isolated from the water-soluble portion of the methanol extract of fruit of *Apium graveolens L.*[49]



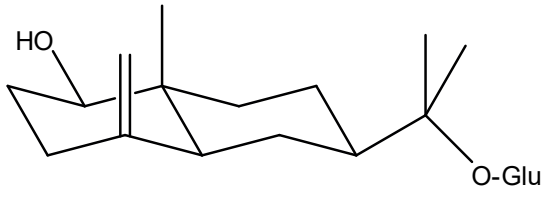
Celerioside A



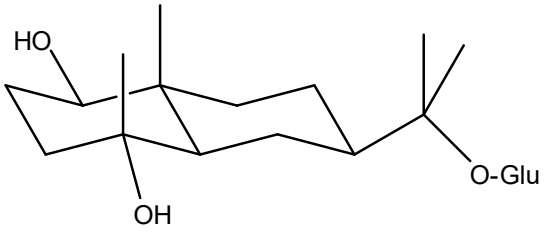
Celerioside B



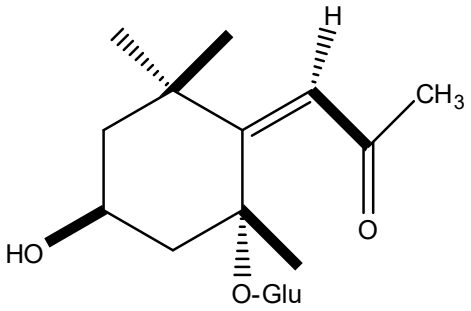
Celerioside C



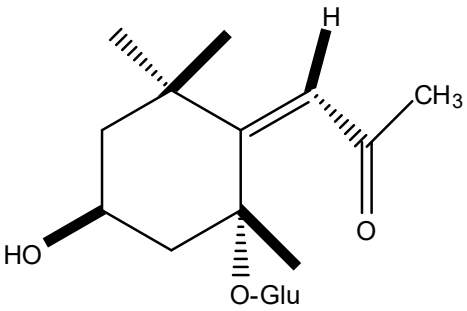
Celerioside D



Celerioside E



Citroside A



Citroside B

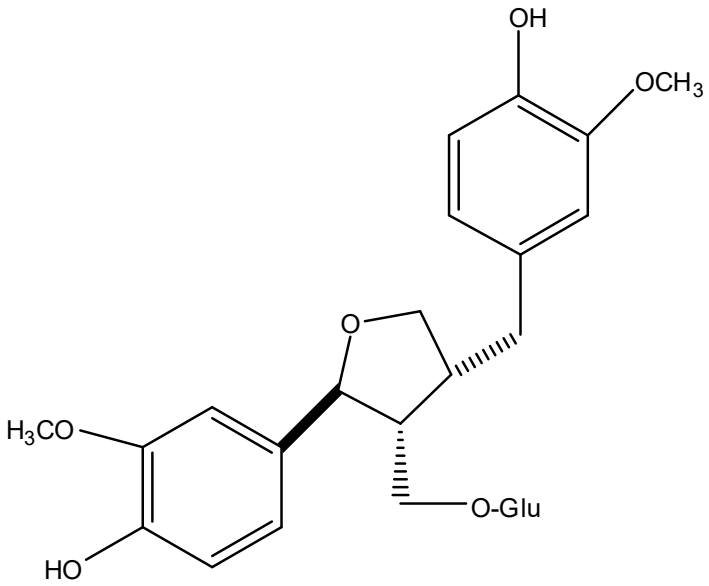
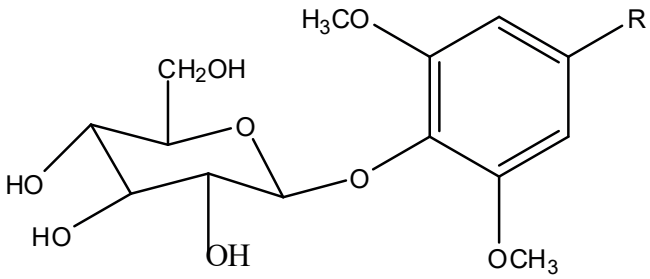
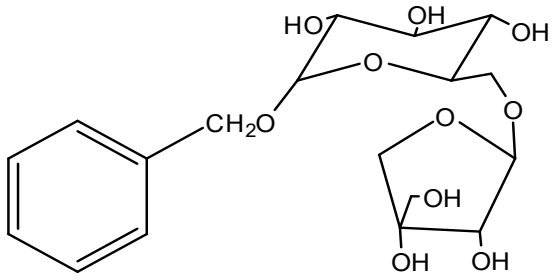


Figure 5. Celeriosides

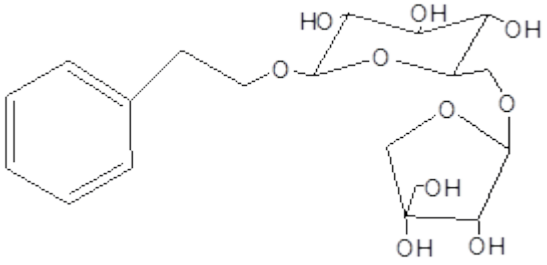
(7S,8R,8`R)-(+)-lariciresinol 9-O-β-D-glucopyranoside.



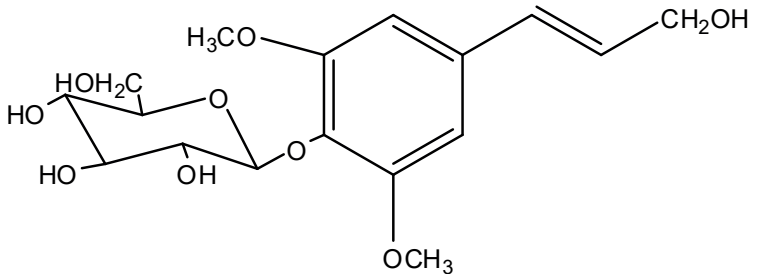
R=OH Leonuriside A
R=CH_2OH 4-hydroxy-3,5-dimethoxybenzyl alcohol 4-O-β-D-glucopyranoside



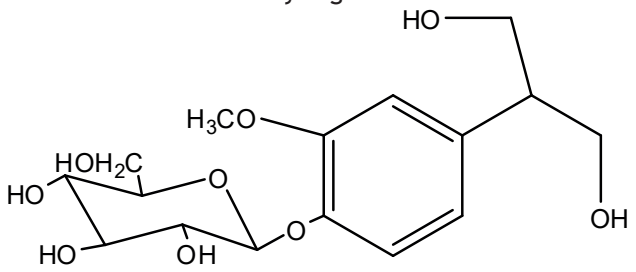
Icariside F_2



Icariside D_1



Syringin



Junipediol A 4-O-β-D-glucopyranoside

Figure 6. Miscellaneous compounds of fruit of *Apium graveolens* L

Myristicic acid was isolated and identified from the ether extract of celery fruits.[44]

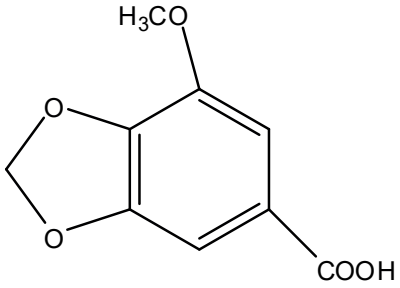
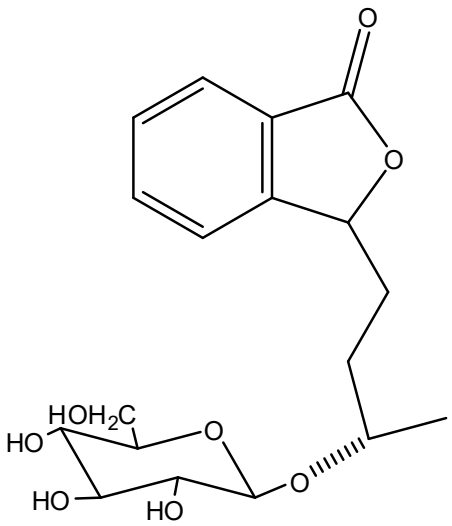


Figure 7. Myristicic acid

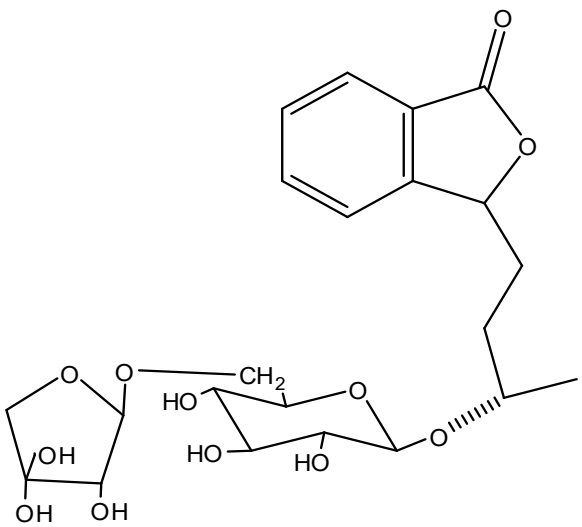
A new brassinosteroid was detected in fruits of *Apium graveolens (L.)* and it was shown to be 2-deoxybrassinolide by gas chromatography-mass spectral analysis.[50]

Columbianetin was found to be a phytoalexin associated with celery resistance to pathogens during storage.[51]

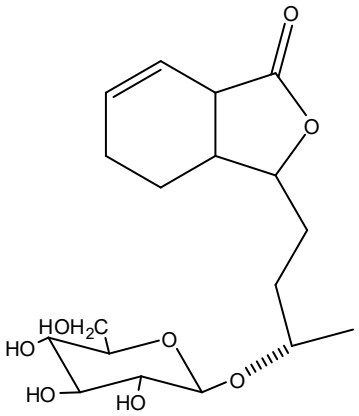
Three phthalide glycosides celephthalide A, B and C were isolated from water soluble portion of the methanol extract of celery fruit.[49]



Celephthalide A



Celephthalide B



Celephthalide C

Figure 8. Celephthalides

The fruits of *Apium leptophyllum* (pers.) F. Muell were found to contain an acid namely 2,3-dihydro-2-methyl-6- hydroxybenzofuran-5- carboxylic acid.[52]

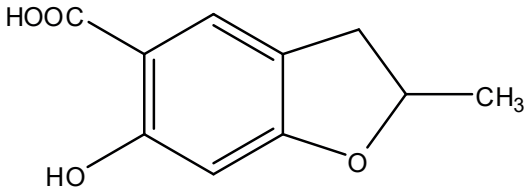


Figure 9. 2,3-dihydro-2- methyl-6- hydroxybenzofuran-5- carboxylic acid

Biological activities of the different plants of genus *Apium*

Antimicrobial activity

The antimicrobial study for the essential oil of aerial parts of *Apium leptophylum* (Pers.) F. Muell revealed a strong activity against *Candida albicans* , moderate activity against gram negative cocci and rods and gram positive cocci. The microorganisms used were; *staphylococcus aureus, sarcina lutea, Bacillus subtilis, Escherishia coli and Neisseria* sp.[11] Isolation of antifungal compounds from methanolic extract of *Apium graveolens (L.)* seeds was reported.[20] Polyacetylenes isolated from celery have shown to be highly toxic towards fungi and bacteria.[53]

Insecticidal activity

The essential oil of celery was tested in its vapour form. It has repellent, toxic and reproduction inhibitory effects against *Acanthoscelides obtectus*.[54]

The methanolic extract of *Apium graveolens (L.)* fruits revealed mosquitocidal and nematicidal effect.[20]

Larvicidal and adulticidal potency of ethanolic preparation of hexane-extracted *Apium graveolens (L.)* was investigated.[55]

The essential oil of celery exerted larvicidal activity against two mosquito species, *Anopheles dirus* , the major malaria vector in Thailand and *Aedes aegypti* , the main vector of dengue hemorrhagic fever in Urban areas.[56]

Cytotoxic activity

Celery was included among cytotoxic herbal formulations used in the traditional medicine of ancient Persia as abortifacients.[57]

The cytotoxicity of the polyacetylenes isolated from celery against five different cell lines was evaluated by the annexin V-PI assay. Falcarinol was found the most active against acute lymphoblastic leukemia with IC_{50} 3,5 µ mol/L.[33]

Anti-inflammatory activity

Celery was assessed for its anti-inflammatory activity on intact rats by measuring the suppression of carrageenan-induced paw edema.[58] The anti-nociceptive and anti-inflammatory effects of ethanolic extract of celery was studied by using the acetic acid induced writhing and hot plate test in mice.[59]

The anti-inflammatory activity af apiin isolated from *Apium graveolens (L.)* leaves was studied.[29]

The mol. docking of isocnidilide was carried out for antibacterial (DNA gyrase) antioxidant (tyrosinase), and anti-inflammatory (cyclooxygenase-2) activities. The docking simulation results were involved hydrophilic interactions and demonstrated high binding affinity of isocnidilide for anti-inflammatory protein (cycloxygenase-2). The presence of isocnidilide makes *A. graveolens* oil a potential anti-inflammatory and antimicrobial agent.[23]

Antioxidant activity

Celery fruits exhibited good antioxidant activity, cyclooxygenase and topoisomerase inhibitory effects.[60]

Both root and leaves extracts of of celery are good scavengers of OH and DPPH radicals.[61]

Total phenol, antioxidant and free radical scavenging activities of celery were studied.[62] The therapeutic potential of Apium leptophyllum Pers. Fruits, total phenolic as well as flavonoidal contents and antioxidant values were evaluated. A. leptophyllum was found to be dose dependent inhibition against these free radicals.[63]

Hepatoprotective activity

The antihepatotoxic effect of methanolic extract of the fruits of *Apium graveolens (L.)* was reported.[64]

The chemopreventive activity of methanolic extract of *Apium graveolens (L.)* fruits has been investigated on chemically induced hepatocarcinogenesis.[65]

Vasodilatory action

The effect of apigenin isolated from celery on the contraction of rat thoracic aorta was studied.[26]

Apium graveolens L. (celery) seed has been used for hypertension. vasorelaxant effect of celery seed extract was investigated in isolated rat aorta.[66]

Anti-hyperlipidemic effect

The hypolipidemic effect of the extract of *Apium graveolens* L. root (AGRE)in hyperlipidemia rats was studied [67,68]

Treatment of urinary tract infections

The antiadhesive activity of extract, fractions and purified compoundds was assessed by flow cytometry, evaluating the adhesion of fluorescent-labeled uropathogenic bacteria to T24 bladder cells.[69]

Effect on spermatogenesis

Apium graveolens L. (celery) has been widely used in traditional medicine for treatment of various disorders including impotency the effects of aq. ext. of A. graveolens on testicular tissue and spermatogenesis in healthy male rats were investigated. celery leaf ext. may improve spermatogenesis process and also be useful for some sperm fertility parameters.[70]

CONCLUSIONS

Family Apiaceae (Umbelliferae) is a unique family in the flowering plants due to its characteristic inflorescences and fruits besides the distinctive chemistry reflected in odor, flavor and even toxicity of many of its members. Several umbellifers were known to the ancient Chinese and Mexican Indian civilizations, as well as, to the Egyptians, Greeks and Romans of the Mediterranean basin.

Plants of the family Apiaceae are usually used medicinally as a cure for gastrointestinal complaints, cardiovascular ailments, they are also used as antispasmodics, sedatives and a source of resins, gum resins, flavouring agents, foods and even poisons.

Subfamily Apioideae comprises numerous members reputed for their high content of coumarins, flavonoids and volatile oils.

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CONFLICT OF INTEREST

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