Chapter 9

# Phenolic Compounds in Genus *Smilax* (Sarsaparilla)

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Additional information is available at the end of the chapter

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**Abstract**

*Smilax* (Smilacaceae) is a genus of about 350 species, found in temperate, tropical and subtropical zones worldwide. The plants belonging to this genus are found throughout Asia, Europe, Oceania and the Americas. Species of the genus *Smilax* commonly called sarsaparilla are characterized as climbers, with long, thin thorny stem. The branches have tendrils which attach to other plants or objects and grow steadily upward. The roots of these plants have been used for centuries in Asia and the Americas as a tonic, diuretic and sudorific. The rhizome, roots, stems and leaves of sarsaparilla are used in traditional medicine. In the scientific literature, there are several reports on immunomodulatory properties, anticonvulsant, antibacterial, antifungal, anticancer, antidiabetic and antioxidant properties. However, there are no reports which explain the antioxidant activity of sarsaparilla extracts as a function of phenolic compound structures, such as flavonoids and phenylpropanoids. In this chapter, the relevance of phenolic chemical structure in antioxidant and anticancer activity of sarsaparilla extracts will be described. Special emphasis is placed on phenylpropanoid glycosides that consist of a sucrose core. These compounds are evidence of chemotaxonomy in the genus *Smilax*.

**Keywords:** *Smilax*, phenolic compounds, antioxidant activity, anticancer activity, phenylpropanoids, flavonoids

## 1. Introduction

The genus *Smilax* (Smilacaceae), commonly called sarsaparilla, consists of about 350 species. About 79 species are natives of China, 24 species are from India and 29 species are from Central America. The plants of this genus are climbers, have long, thin, thorny stems and have tendrils which attach to other plants or objects to climb steadily (**Figure 1**).

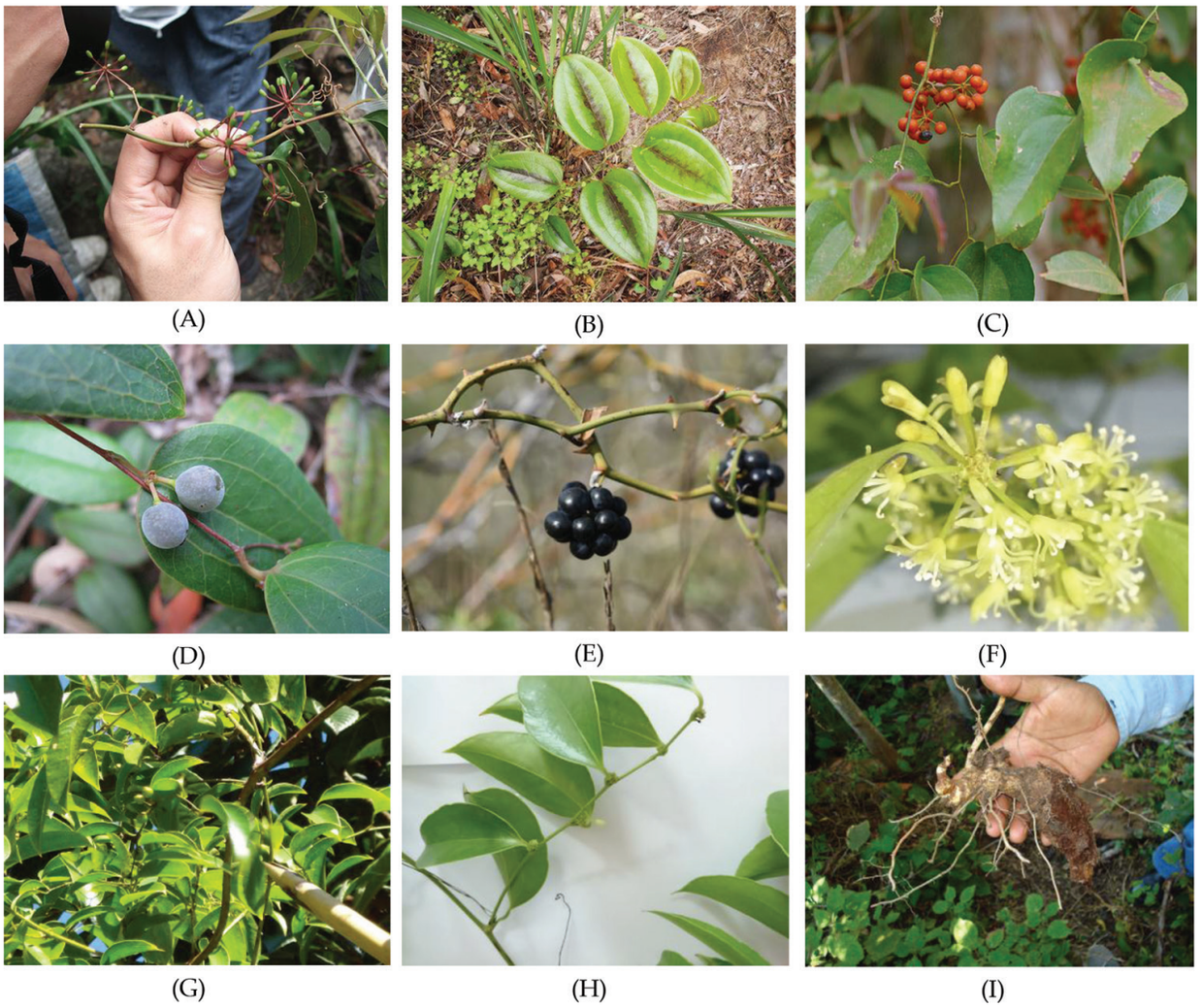


**Figure 1.** (A) *S. bracteata*, (B) *S. china*, (C) *S. fluminensis*, (D) *S. glyciphylla*, images from https://www.inaturalist.org/taxa. (E) *S. campestris*, image courtesy of Mauricio Bonifacino Ph.D. (Universidad de la República, Montevideo, Uruguay). (F)–(I) *S. domingensis*.

The rhizome, roots, stems and, occasionally, leaves of sarsaparilla are used as food and in traditional medicine. These plants are known to have immunomodulatory, antioxidant, antibacterial, antifungal and diuretic properties. Additionally, they are used for relief from climatery [1]. Also, the genus *Smilax* has pharmacological properties and is used to treat different types of cancer, diabetes, skin diseases, ulcers, as well as fever, gout and ophthalmic diseases [2].

In recent years, interest in the study of the genus *Smilax* has increased, mainly in Europe and Asia, due to the presence of phenolic compounds. Some species have also proven effective in the prevention and treatment of several cancers. In addition, extracts from the genus *Smilax* exhibit pro-apoptotic activity and antioxidant activity [3].

There are reports about the antioxidant property expressed as DPPH• radical scavenging activity of species of the genus *Smilax*, as *Smilax bockii* [4], *Smilax campestris* [5], *Smilax glabra* [6], *Smilax lanceifolia* [7], *Smilax perfoliata* [8], *Smilax riparia* [9], *Smilax scobinicaulis* [10] and *Smilax sebeana* [11]. This property is attributed to phenolic compounds such as stilbenes, flavones,

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flavanones, flavonols, smilasides, smiglasides and helionosides, among others. Phenolic compounds have a unique chemical structure for stabilizing free radicals in an aromatic system. Flavonoids and stilbenes have been identified as beneficial agents for the treatment of various diseases such as cardiovascular and neurodegenerative diseases, as well as cancers [12].

Therefore, this review will describe *Smilax* species that have been studied for their antioxidant and anticancer properties with special emphasis on reports of phenolic compounds such as smilasides, smiglasides and helionosides. These compounds are phenols with antioxidant activity and are constituted of a sucrose substituted with feruloyl and coumaril groups. These three groups of compounds are evidence of chemotaxonomy in genus *Smilax*.

## 2. Genus *Smilax*

The review is organized by species, and the principal uses in traditional medicine for every species discussed are described. The methods of extraction and purification of phenolic compounds are briefly mentioned. Also, the methods used to evaluate antioxidant and anticancer activities are discussed. Various reports make evident the diversity of the chemical structure of phenolic compounds and their relation to corresponding biological properties.

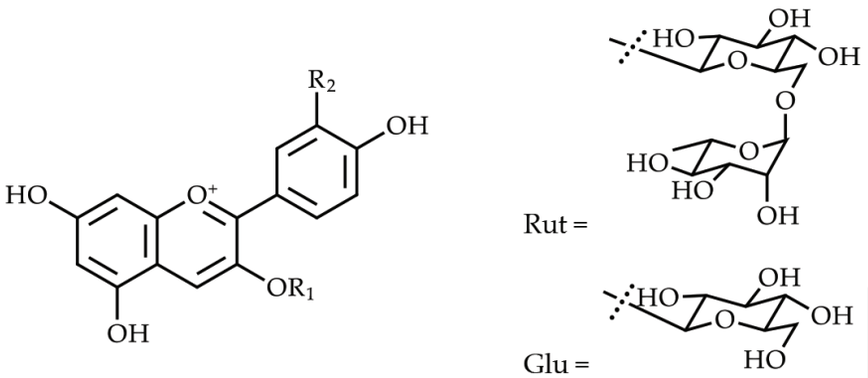
### 2.1. *Smilax aspera*

*Smilax aspera* has been used to treat diseases such as syphilis, rheumatism and diabetes, and as an antioxidant to reduce the discomforts of menopause [13].

Longo *et al*. isolated and identified anthocyanins from the skin of *S*. *aspera* berries [14]. The anthocyanins were extracted with 0.1% HCl (v/v) in methanol. Then, the extract was carried to clean process using solid phase extraction (SPE) of reverse phase C-18. This clean process allowed the removal of sugars, acids and other water-soluble compounds. Finally, the fraction, with a large quantity of phenolic compounds, was subjected to chromatographic purificationby High-Performance Liquid Chromatography-Diode Array Detector-Mass Spectrometry (HPLC-DAD-MS). The result of this study was the isolation and characterization of four anthocyanins: two pelargonidins (**1**, **3**) and two cyanidins (**2**, **4**) (**Figure 2**) [14]. The principal anthocyanin was identified as pelargonidin 3-*O*-rutinoside. The anthocyanins are responsible for the color of the *S*. *aspera* fruits.

### 2.2. *Smilax bockii*

*S. bockii* is a plant used in traditional Chinese medicine with anti-inflammatory and antirheumatic properties. Xu *et al*. prepared a 70% aqueous ethanol extract from roots of *S*. *bockii* [4]. Then the extract was partitioned with chloroform, ethyl acetate and butanol successively. The butanol fraction was subjected to chromatographic purification leading to the separation of four flavonols (kaempferol (**5**), kaempferol-7-*O*-*β*-D-glucopyranoside (**6**), quercetin (**7**) and isorhamnetin (**8**), as well as three flavanone ((+)-dihydrokaempferol (**9**), engeletin (**10**) and iso-engeletin (**11**)), and a phenylpropanoid, caffeic acid *n*-butyl ester (**12**) (**Figure 3**). Additionally, the anti-inflammatory activities of a 70% aqueous ethanol extract and chloroform, ethyl acetate and butanol fractions were evaluated and the results showed the butanol fraction had a




| | $R_1$ | $R_2$ | Name |
|---|---|---|---|
| **1** | Rut | H | Pelargonidin 3-*O*-rutinoside |
| **2** | Rut | OH | Cyanidin 3-*O*-rutinoside |
| **3** | Glu | H | Pelargonidin 3-*O*-glucoside |
| **4** | Glu | OH | Cyanidin 3-*O*-glucoside |

**Figure 2.** Anthocyanin glycosides isolated from *S. aspera* fruits.

relevant inhibitory activity against TNF-$\alpha$-induced NF-κB activation with an IC50 value of 44.8 μg/mL. This activity can be attributed to phenolic compounds present in the butanol fraction.

### 2.3. *Smilax bracteata*

*S. bracteata* is a little-studied species. However, there are two representative chemical studies that describe the isolation and characterization of phenolic compounds. The first study was conducted by Li *et al*. who isolated and identified phenolic compounds from a methanol extract of *S. bracteata* rhizomes [15]. The air-dried and sliced rhizomes were extracted by maceration with methanol over 24 h. The extract was evaporated and re-dissolved in water and partitioned successively with dichloromethane, ethyl acetate and butanol. The butanol fraction was subjected to column chromatography and six new phenolic compounds were isolated and identified: two flavan-3-ol glucosides (**13**, **14**), one stilbene (**15**) (**Figure 4**) and three phenylpropanoid glycosides (**16**–**18**) (**Figure 5**). In the same study, Li *et al*. evaluated antioxidant activity of the six smilasides using the DPPH$^{\bullet}$ radical scavenging activity. The smilasides J to L (**22**–**24**) showed an antiradical activity similar to $\alpha$-tocopherol [15].

In a later study, Zhang *et al*. obtained a 95% aqueous ethanol extract from stems of *S. bracteata* [16]. The extract was concentrated and redissolved in water and successively extracted with hexane, dichloromethane and butanol. The dichloromethane fraction was purified with chromatography in several steps until smilasides G to L (**19**–**24**) were obtained (**Figure 5**).

### 2.4. *S. campestris*

*S. campestris* is commonly called sarsaparilla blanca [5]. Its roots and rhizomes have been used in folk medicine to treat skin diseases. An infusion from the leaves and aerial stems of *S.*

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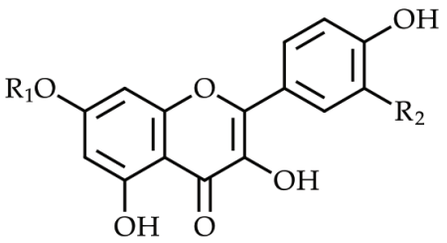
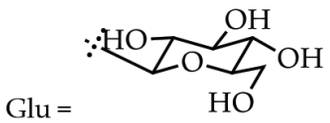
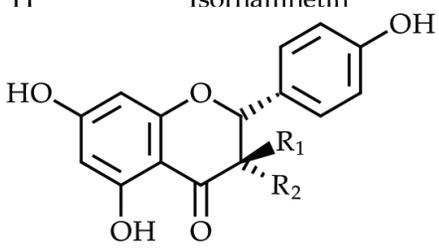
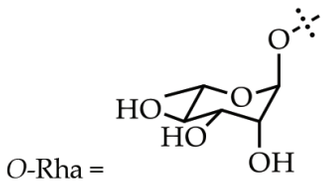


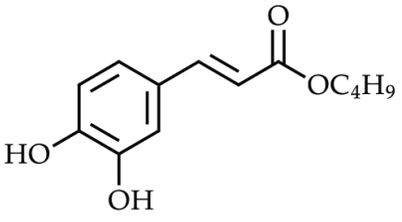




| | $R_1$ | $R_2$ | Name |
|---|---|---|---|
| **5** | H | OH | Kaempferol |
| **6** | Glu | H | Kaempferol-7-*O*-*β*-D-glucopyranoside |
| **7** | H | OH | Quercetin |
| **8** | H | OM | Isorhamnetin |



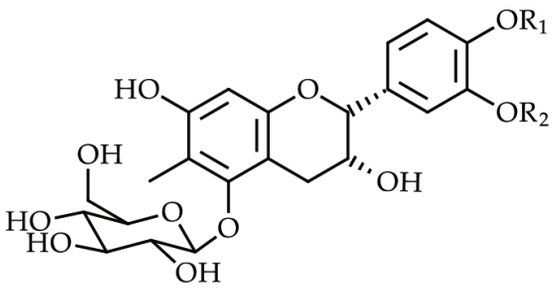

| | $R_1$ | $R_2$ | Name |
|---|---|---|---|
| **9** | H | OH | (+)-Dihydrokaempferol |
| **10** | H | *O*-Rha | Engeletin |
| **11** | *O*-Rha | OH | Isoengeletin |




**12** Caffeic acid *n*-butyl ester

**Figure 3.** Four flavonols (three aglycones and one glucoside), three flavanones (one aglycone and two glycosides) and one phenylpropanoid ester isolated from *S. bockii* roots.

*campestris* is used to relax the digestive system [5]. Rugna *et al*. reported antioxidant activity from 50% aqueous methanol extract from *S*. *campestris* rhizomes; the activity was expressed as total reactive potential (TRAP) [5]. Morais *et al*. obtained an ethanol extract by maceration and fractions from fresh stems of *S*. *campestris* [17]. The ethanol extract was concentrated, and the dried extract was re-dissolved in aqueous ethanol (7:3) and partitioned with hexane, dichloromethane, ethyl acetate and butanol. The antioxidant activity as DPPH• radical scavenging was evaluated for all fractions. The ethanol extract and butanol fraction exhibited a strong




| | $R_1$ | $R_2$ | Name |
|---|---|---|---|
| **13** | H | Me | (2*S*,3*S*)-5-*O*-*β*-D-glucopyranosyloxy-6-methyl-3′-methoxy-3,7,4′-trihydroxyflavan-3-ol |
| **14** | Me | H | (2*S*,3*S*)-5-*O*-*β*-D-glucopyranosyloxy-6-methyl-4′-methoxy-3,7,3′-trihydroxyflavan-3-ol |

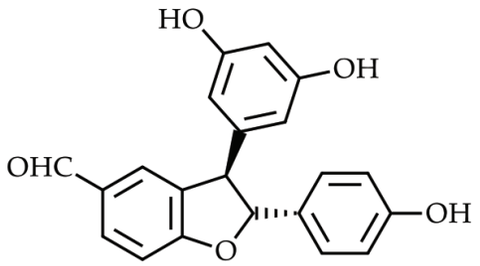



**Figure 4.** Two flavan-3-ol glycosides and one stilbene isolated from *S. bracteata* rhizomes.

antioxidant activity and was higher than Butylated hydroxytoluene (BHT), a commercial antioxidant. Also, Morais *et al*. reported that rutin (**25**) (**Figure 6**) and quercetin (**7**) (**Figure 3**) flavonol glycosides were the most abundant phenolic compounds present in ethanol extract and butanol fraction, respectively [17].

### 2.5. *Smilax china*

*S. china* is the most studied species of genus *Smilax*. Lee *et al*. evaluated antioxidant activity of *S. china* root using DPPH$^{\bullet}$ radical scavenging activity, cell viability, lipid peroxidation activity, superoxide dismutase (SOD) activity, catalase (CAT) activity and glutathione peroxidase (GPX) activity. These authors obtained a 70% aqueous methanol extract from the root of *S. china*. The extract was concentrated and partitioned with hexane, dichloromethane, ethyl acetate and butanol. The extract and its fractions were evaluated for antioxidant activity. The antiradical activity expressed as IC50 of the extract is about 8 μg/mL, while the ethyl acetate fraction exhibited the principal antiradical activity (IC50 approximately 5 μg/mL) [18]. Jeong *et al*. obtained several fractions with solvents of different polarity from *S. china* root and evaluated the antioxidant activity using DPPH$^{\bullet}$ radical scavenging activity, ABTS$^{\bullet+}$ radical scavenging activity, reducing power, ferric reducing/antioxidant power, ferric thiocyanate assay, malondialdehyde assay using mouse brain homogenates methods, and finally determined total phenols and phenolic composition [19]. The extraction was carried out with methanol at 70°C for 2 h. The methanol extract was evaporated to dryness. The dried extract was re-dissolved in water and the solution was consecutively partitioned with chloroform, ethyl acetate

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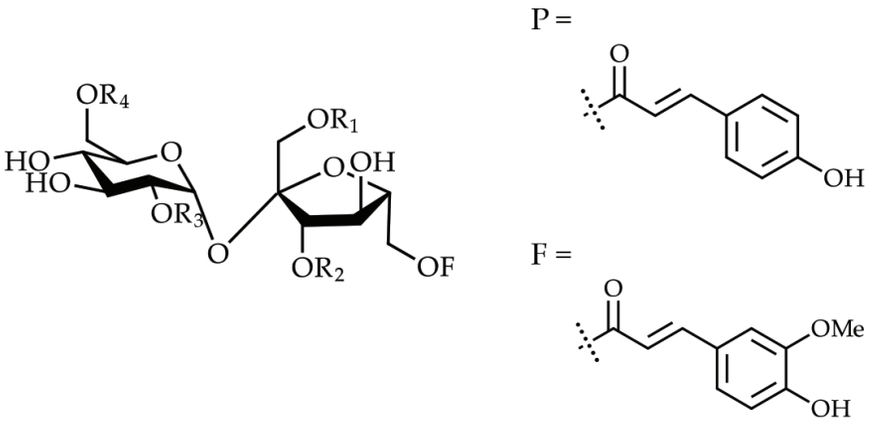
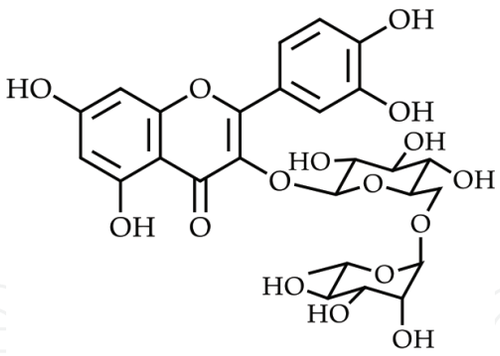



| | $R_1$ | $R_2$ | $R_3$ | $R_4$ | Name |
|---|---|---|---|---|---|
| **16** | P | H | H | H | (1-*O*-*p*-coumaroyl-6-*O*-feruloyl)-*β*-D-fructofuranosyl-(2→1)-*α*-D-glucopyranoside |
| **17** | P | F | H | H | (1-*O*-*p*-coumaroyl-3,6-di-*O*-feruloyl)-*β*-D-fructofuranosyl-(2→1)-*α*-D-glucopyranoside, smilaside C |
| **18** | H | H | H | COMe | (6-*O*-feruloyl)-*β*-D-fructofuranosyl-(2→1)-(6-*O*-acetyl)-*α*-D-glucopyranoside |
| **19** | P | P | H | H | (1,3-*O*-di-*p*-coumaroyl-6-*O*-feruloyl)-*β*-D-fructofuranosyl-(2→1)-*α*-D-glucopyranoside, smilaside G |
| **20** | P | P | COMe | H | (1,3-*O*-di-*p*-coumaroyl-6-*O*-feruloyl)-*β*-D-fructofuranosyl-(2→1)-(2-*O*-acetyl)-*α*-D-glucopyranoside, smilaside H |
| **21** | P | P | H | COMe | (1,3-*O*-di-*p*-coumaroyl-6-*O*-feruloyl)-*β*-D-fructofuranosyl-(2→1)-(6-*O*-acety)-*α*-D-glucopyranoside, smilaside I |
| **22** | F | P | H | H | (3-*O*-*p*-coumaroyl-1,6-*O*-diferuloyl)-*β*-D-fructofuranosyl-(2→1)-*α*-D-glucopyranoside, smilaside J |
| **23** | P | F | COMe | H | (1-*O*-*p*-coumaroyl-3,6-*O*-diferuloyl)-*β*-D-fructofuranosyl-(2→1)-(2-*O*-acety)-*α*-D-glucopyranoside, smilaside K |
| **24** | F | F | H | H | (1,3,6-*O*-triferuloyl)-*β*-D-fructofuranosyl-(2→1)-*α*-D-glucopyranoside, smilaside L |

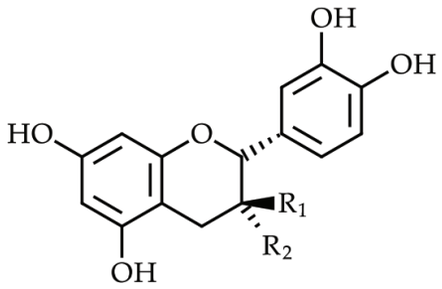
**Figure 5.** Phenylpropanoid glycosides with a sucrose core isolated from *S. bracteata* aerial parts.

and butanol. The results obtained by Jeong *et al*. show that the ethyl acetate fraction had the highest total phenol concentration, 401.62 ± 3.13 mg GAE/g of extract and the most abundant phenols were (+)-catechin (**26**) and (−)-epicatechin (**27**) (**Figure 7**) with a concentration of 135.26 ± 10.08 and 58.10 ± 0.51 mg/100 g, respectively. Consequently, this extract showed the most important antioxidant activity.



**25** Rutin

**Figure 6.** Chemical structure of rutin, a flavonol glycoside isolated from *S. campestris* rhizomes.



| | $R_1$ | $R_2$ | Name |
|---|---|---|---|
| **26** | OH | H | (+)-Catechin |
| **27** | H | OH | (-)-Epicatechin |

**Figure 7.** Two flavan-3-ol aglycones isolated from *S. china* roots.

Kuo *et al*. obtained a 70% aqueous ethanol extract from dried stems of *S. china*. The extracts were concentrated and suspended in water. The resulting suspension was partitioned with hexane and chloroform [20]. The chloroform fraction was purified by silica gel column chromatography. The purification conducted to isolate smilasides A to F (**Figures 5** and **8**), heloniosides A (**33**) and B (**34**) and smiglaside E (**35**) (**Figure 8**). The anticancer activity of smilasides A to F was evaluated *in vitro* and showed cytotoxic activity against cervical cancer cells (KB and HELA) and colon cancer cells (DLD-1).

Li *et al*. performed another study related to the evaluation of anticancer activity of *S. china* extracts with a high content of phenolic compounds [21]. Researchers in this study performed a bioassay-guided separation and purification of kaempferol-7-*O*-*β*-D-glucoside (**6**) from *S. china* rhizome. First, a 70% aqueous ethanol extract was obtained under reflux. Then the solvent was removed and residue was extracted with ethyl acetate, and butanol, sequentially, in a Soxhlet apparatus. Both ethyl acetate and butanol fractions were subjected to column chromatography separately. Several fractions with large amounts of flavonoid were obtained and each fraction was evaluated for *in vitro* anticancer activity. The human cells used in this study included liver cancer BEL-7402, cervical epithelial carcinoma HeLa, high metastatic lung

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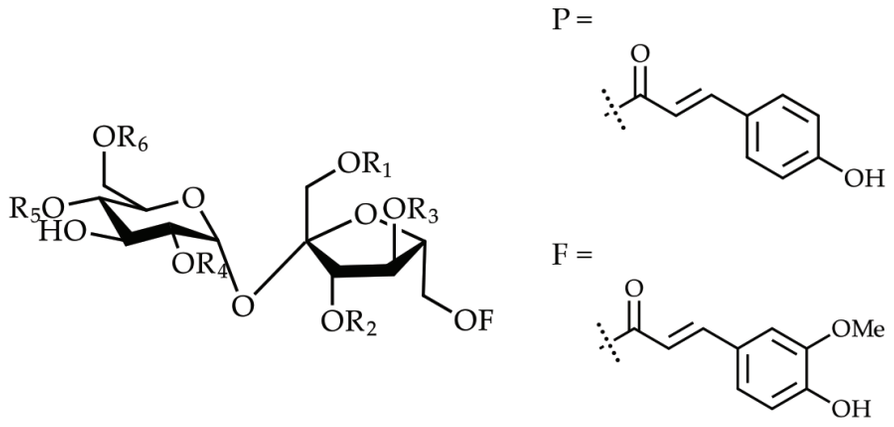
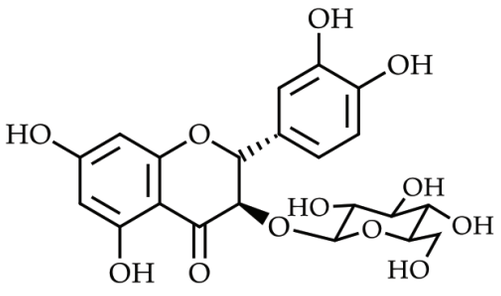



| | R1 | R2 | R3 | R4 | R5 | R6 | Name |
|---|---|---|---|---|---|---|---|
| **28** | H | F | H | H | COMe | COMe | (3,6-*O*-diferuloyl)-*β*-D-fructofuranosyl-(2→1)-(5,6-*O*-diacetyl)-*α*-D-glucopyranoside, smilaside A |
| **29** | H | F | H | COMe | H | H | (3,6-*O*-diferuloyl)-*β*-D-fructofuranosyl-(2→1)-(2-*O*-acetyl)-*α*-D-glucopyranoside, smilaside B |
| **30** | P | F | COMe | H | H | H | (4-*O*-acety-1-*O*-*p*-coumaroyl-3,6-*O*-diferuloyl)-*β*-D-fructofuranosyl-(2→1)-*α*-D-glucopyranoside, smilaside D |
| **31** | P | F | H | H | H | COMe | (1-*O*-*p*-coumaroyl-3,6-*O*-diferuloyl)-*β*-D-fructofuranosyl-(2→1)-(6-*O*-acetyl)-*α*-D-glucopyranoside, smilaside E |
| **32** | P | P | H | COMe | H | COMe | (1,3-*O*-di-*p*-coumaroyl-6-*O*-feruloyl)-*β*-D-fructofuranosyl-(2→1)-(2,6-*O*-diacetyl)*α*-D-glucopyranoside, smilaside F |
| **33** | H | F | H | H | H | H | (3,6-*O*-diferuloyl)-*β*-D-fructofuranosyl-(2→1)-*α*-D-glucopyranoside, helonioside A |
| **34** | H | F | H | H | H | COMe | (3,6-*O*-diferuloyl)-*β*-D-fructofuranosyl-(2→1)-(6-*O*-acetyl)-*α*-D-glucopyranoside, helonioside B |
| **35** | F | P | H | COMe | H | COMe | (3-*p*-*O*-coumaroyl-1,6-*O*-diferuloyl)-*β*-D-fructofuranosyl-(2→1)-(2,6-*O*-diacetyl)-*α*-D-glucopyranoside, smiglaside E |

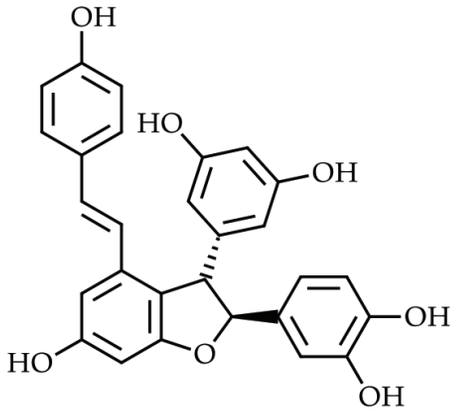
**Figure 8.** Phenylpropanoid glycosides with a sucrose core (five smilasides, two helionoside and one smiglaside) isolated from *S. china* stems.

carcinoma 95-D, melanoma A375, gastric cancer MKN-45, epithelial carcinoma A431, human acute leukemia HL60, normal embryonic kidney HEK293 and normal embryonic liver L-O2. Li *et al*. found eight extracts of *S. china* tubers with anticancer activity against HeLa cells. Also, a bioassay-guided isolation of the polled extract lead to the detection of kaempferol-7-*O*-*β*-D-glucoside (**6**). This flavonoid induces apoptosis as an anti-proliferative action related to radical scavenging activity [21]. Shao *et al*. developed a specific HPLC method for determination

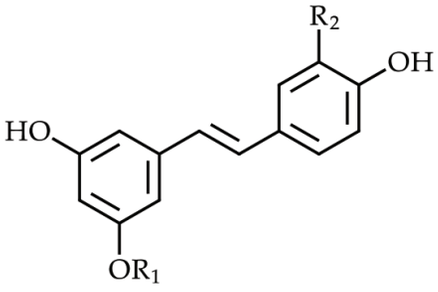
of the six major phenolic compounds active in *S. china*: taxifolin-3-*O*-glycoside (**36**), scirpusin A (**37**), piceid (**38**), oxyresveratrol (**39**), resveratrol (**40**) (**Figure 9**) and engeletin (**10**) (**Figure 3**). These compounds were extracted from the tuber of *S. china* with 95% aqueous ethanol and the concentrated extract was partitioned with petroleum ether, ethyl acetate and butanol. The ethyl acetate fraction was subjected to repeated silica gel chromatography. Finally, the purification of phenolic compounds was performed by HPLC [22]. Wu *et al*. also reported other study related to anticancer activity of phenolic compounds from *S. china* [12]. These authors obtained a 95% aqueous ethanol extract from the tuber of *S. china*, which was concentrated and suspended in water. The suspension was partitioned with petroleum ether, ethyl acetate and butanol. The ethyl acetate was the most bioactive fraction. This fraction was subjected to chromatographic purification. Three sub-fractions and six bioactive phenolic compounds bioactives: three flavonoids (kaempferol-7-*O*-*β*-D-glucoside (**6**), dihydrokaempferol (**9**) and dihydrokaempferol-3-*O*-*α*-L-rhamnoside (**10**)) and three stilbenoids (**37**, **39** and **40**), were isolated from the ethyl acetate fraction. These compounds were found to induce apoptosis in

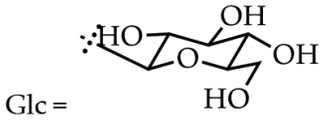


**36** Taxifolin-3-*O*-glucoside



**37** Scirpusin A





Glc =

| | $R_1$ | $R_2$ | Name |
|---|---|---|---|
| **38** | Glc | H | Piceid |
| **39** | H | OH | Oxyresveratrol (piceatannol) |
| **40** | H | H | Resveratrol |

**Figure 9.** One flavanonol (**36**) and four stilbenes (**37–40**) isolated from 95% ethanol extracts of *S. china* tubers.

anti-breast tumor cells MCF-7 and MDA-MB-231. The results showed that resveratrol and oxyresveratrol had the highest apoptosis rates [12].

### 2.6. *Smilax corbularia*

*S. corbularia* is used in traditional Thai medicine for the ailments treatment caused by the menopause, as well as for ovarian and breast cancer. For this reason, Wungsintaweekul *et al*. isolated and characterized the phenolic compounds of methanol extract from *S. corbularia* rhizome [23]. They also evaluated the cell proliferation stimulation of the isolated compounds against human cancer cell lines MCF-7 and T47D. The major compounds present in the rhizome of *S. corbularia* were rhamnosides dihydroflavonol derivatives, which represent 15% of methanol extract by weight. The results showed that the extract did not exhibit cytotoxicity against breast cancer cell lines MCF-7 and T47D. However, the flavanonol rhamnosides (engeletin (**10**) and isoengeletin (**11**)) (**Figure 3**); as well as, astilbin (**41**), isoastilbin (**42**), neoastilbin (**43**) and neoisoastilbin (**44**) (**Figure 10**), showed a suppressive effect on estradiol at concentration of 1 μM as evidenced by human breast cancer cell proliferation.

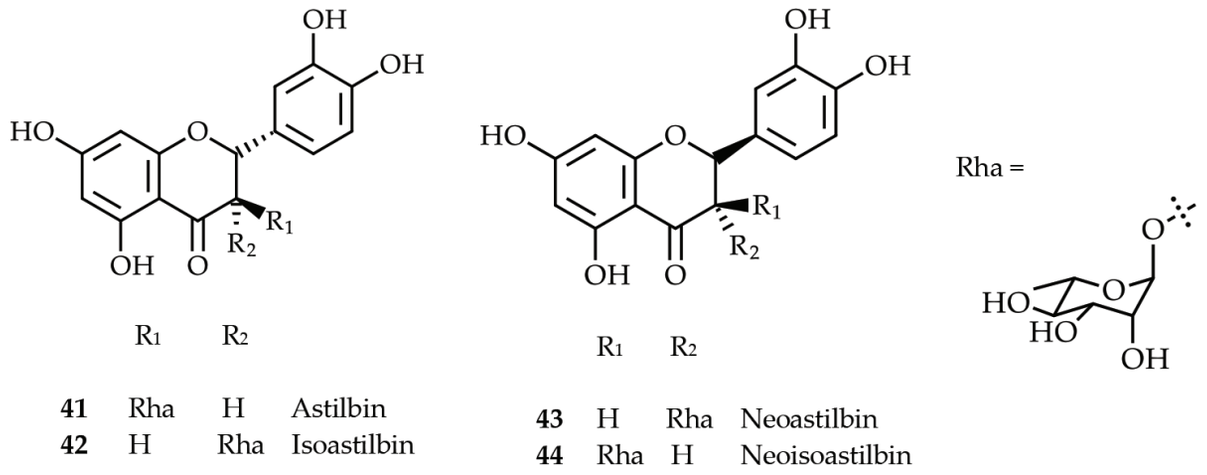



**Figure 10.** Flavononol rhamnosides (**41–44**) with activity against human breast cancer isolated from methanol extract of *S. corbularia* rhizomes.

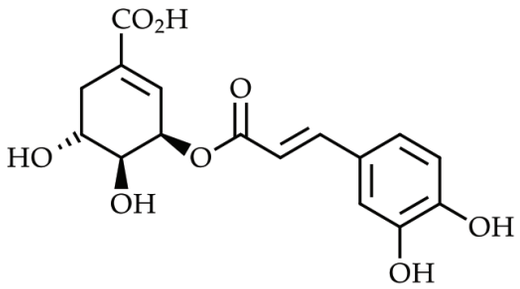
### 2.7. *Smilax domingensis*

*S. domingensis* is used in Central America by the pharmaceutical and cosmetics industries. The most representative studies of *S. domingensis* are related to cytotoxicity to cancer cells [24], inhibitory activity of estrogen [25] and antioxidant activity [26]. The chemical studies of *S. domingensis* only cover qualitative identification of flavonoids and anthocyanins using thin-layer chromatography (TLC) [27].

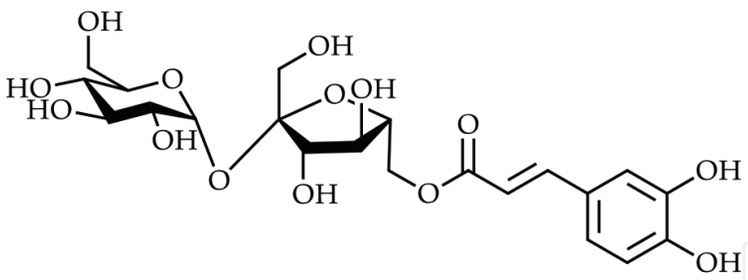
### 2.8. *Smilax excelsa*

*S. excelsa* is used in Turkey's traditional medicine to treat breast cancer, stomach pain and bloating [28]. Ozsoy *et al*. evaluated antioxidant activity of infusion, decoction, ethanol and ethyl acetate extracts from *S. excelsa* leaves using the inhibition of lipid peroxidation, metal

ion chelating, reducing power, DPPH• radical scavenging, superoxide, hydroxyl radicals and hydrogen peroxide [29]. Also, total phenols, total flavonoid and anthocyanin were quantified in the extracts. The content of total phenols and total flavonoid was found in the intervals of 8.8–35.7 GAE mg/g of dry matter and 0.61–28.7 catechin equivalents mg/g of dry matter, respectively. The extract with the highest content of total phenols was the infusion. The decoction and infusion showed major DPPH• radical scavenging. These results agree with the high content of phenols and flavonoids present in the infusion and decoction. On other hand, Khaligh *et al*. isolated and elucidated three phenol compounds (*trans*-resveratrol (**40**) (**Figure 9**), 5-*O*-caffeoylshikimic acid (**45**) and 6-*O*-caffeoyl-*β*-D-fructofuranosyl-(2→1)-*α*-D-glucopyranoside (**46**)) from ethyl acetate extract of *S. excelsa* (**Figure 11**) [30]. The extraction was a maceration performed at room temperature. After the solvent was removed, the extract was separated using silica gel column chromatography. In these study, also was evaluated the cytotoxicity of isolated compounds against human breast adenocarcinoma MCF-7cell lines. The 6-*O*-caffeoyl-*β*-D-fructofuranosyl-(2→1)-*α*-D-glucopyranoside showed a promising activity against MCF-7 cell lines [30].




**45** 5-*O*-Caffeoylshikimic acid




**46** 6-*O*-Caffeoyl-*β*-D-fructofuranosyl-(2→1)-*α*-D-glucopyranoside

**Figure 11.** Two phenylpropanoids (**45** and **46**) derivates of caffeic acid with activity against human breast cancer.

### 2.9. *Smilax fluminensis*

*S. fluminensis* has a wide geographical distribution in Brazil, and propagation studies have shown it to grow relatively easily. Hence, it is a promising species for growing demand from the pharmaceutical industry [31, 32] have published the only chemical study of *S. fluminensis* thus far. They obtained extracts from leaves and isolated phenolic compounds. Two flavonol glycosides were isolated and characterized, rutin (**25**) (**Figure 6**) and quercetin-3-*O*-*β*-D-galactopyranoside (**47**) (**Figure 12**).

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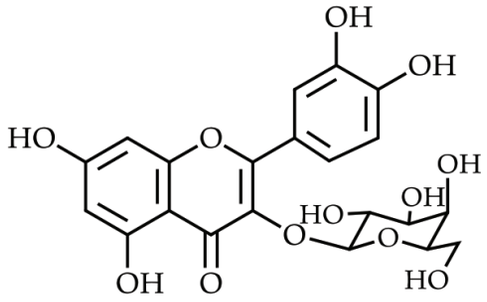

**47** Quercetin-3-*O*-*β*-D-galactopyranoside

**Figure 12.** Flavonol glycoside (**47**) isolated from branches of *S. fluminensis*.

### 2.10. *Smilax glabra*

The second most-studied species, after *S. china* is *S. glabra*. This species has been used in Chinese folk medicine for the treatment of acute bacterial dysentery, syphilis, acute and chronic nephritis [33], hyperinsulinemia [34] and cancer [35]. She *et al*. evaluated the effect of aqueous extract of *S. glabra* on cancer cell adhesion, migration and invasion of HepG2, MDA-MB-231 and T24 cells *in vitro* and the metastasis suppression of MDA-MB-231 cells *in vivo* [36]. Gao *et al*. showed 95% aqueous ethanol extracts of *S. glabra* rhizomes to be effective against cancer via mitochondrial apoptosis in human breast cancer MCF7, colon carcinoma HT-29 and gastric cancer cell line BGC-823 [3]. The results obtained by these authors point out that the aqueous extract of *S. glabra* possibly promotes cell adhesion by increasing the size and strength of focal adhesions and inhibits the invasion of HepG2, MDA-MB-231 and T24 cells.

Xia *et al*. performed an evaluation of the protective effect of 60% aqueous ethanol extract of *S. glabra* rhizome against lead-induced oxidative stress in rats and quantified total phenols and total flavonoids [37]. The results of this study proved that the extract of *S. glabra* could minimize damages caused by the lead. The protective effect can be attributed to high concentrations of total phenols and total flavonoids in the extract. Total phenols reported were 262 ± 12.7 mg gallic acid equivalents (GAE)/g dry weight of the extract and total flavonoids were 203.4 ± 9.1 mg rutin equivalents/g dry weight of the extract [37].

Trinh *et al*. evaluated the antioxidant activity of 95% aqueous ethanol extract of *S. glabra* roots. They obtained two fractions from a partitioning with hexane and ethyl acetate, and astilbin (**41**) (**Figure 10**) isolated from the ethyl acetate fraction [38]. The fractions were obtained from 95% aqueous ethanol previously dried. The extract was suspended in 50% aqueous ethanol and partitioned with hexane and ethyl acetate. The extract, hexane and ethyl acetate fractions, and **41** were subjected to evaluation of DPPH• radical scavenging activity, thiobarbituric acid-reactive species (TBARS) and 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) cell viability assay for hepatoprotective effect via $H_2O_2$-injured mouse hepatocytes. The astilbin was isolated from the ethyl acetate fraction. The results of this study showed the ethyl acetate fraction has the principal antioxidant activity and MTT, attributed to the presence of astilbin, the main phenolic compound present in *S. glabra* rhizome [38]. Astilbin (**41**), a rhamnosyl flavanonol, besides exhibiting antioxidant activity, has coenzyme

A reductase-inhibiting [39], aldose reductase-inhibiting [40], hepatoprotective [41], anti-oedemaogenic [42] and anti-arthritis [43] activities.

Zhang *et al*. obtained two aqueous and methanolic extracts, from *S*. *glabra* rhizomes and evaluated their antioxidant activity using DPPH• radical scavenging, ABTS radical cation scavenging, reducing power, superoxide anion radical scavenging activity and antioxidant activity in a linoleic acid emulsion system. They carried out quantification of total phenols [44]. The results showed that the methanol extract had the highest content of total phenols (152.28 ± 10.57 mg GAE/g of extract) and astilbin (245.65 ± 8.21 mg/g of extract). In general, the methanol extract has more antioxidant activity than aqueous extract and this behavior is attributed to the presence of **41** in the methanol extract [44]. Lu *et al*. evaluated antioxidant and anti-inflammatory activities of 70% aqueous ethanol extract from *S*. *glabra* rhizomes [45]. The methods used to evaluate antioxidant activity were DPPH• radical scavenging, ABTS radical cation scavenging and reducing power. Anti-inflammatory activity was evaluated with MTT cell viability, measuring of nitric oxide/nitrite and enzyme-linked immunosorbent assay for IL-6 and TNF-$\alpha$ cytokines detection. The study also involved quantification of total phenols and total flavonoids. This was done by separation and identification of major phenols using ultrahigh pressure liquid chromatography coupled to electrospray mass spectrometry (U-HPLC-ESI-MS). The results obtained showed the 70% aqueous ethanol extract of *S*. *glabra* rhizome has a radical scavenging on DPPH• statistically equal to ascorbic acid ($P > 0.05$). The results regarding anti-inflammatory activity showed that accumulation of NO, IL-6, and TNF-$\alpha$ in lipopolysaccharides (LPS)-stimulated groups was higher than the group used as the positive control. Dexamethasone was employed as a positive control. Finally, 17 phenolic compounds were isolated and identified from the 70% aqueous ethanol extract of *S*. *glabra* rhizome, including engeletin (**10**) and isoengeletin (**11**) (**Figure 3**); astilbin (**41**), isoastilbin (**42**), neoastilbin (**43**), neoisoastilbin (**44**) (**Figure 10**); and 5-*O*-caffeoylshikimic acid (**45)** (**Figure 11**).

Moreover, there have been several chemical studies to isolate and characterize phenolic compounds from different parts of *S*. *glabra*. Chen *et al*. obtained a methanol extract of *S*. *glabra* rhizome. After solvent removal, the dry extract was suspended in water and partitioned with ether petroleum and ethyl acetate. The ethyl acetate extract was purified by chromatographic column to separate the phenolic compounds. The compounds isolated were five flavonoids (engeletin (**10**), astilbin (**41**), smitilbin (**48**), taxifolin or dihydroquercetin (**49**) and eucryphin (**50**), **Figure 13**), and two phenylpropanoids, resveratrol (**40**) and 5-*O*-caffeoylshikimic acid (**45**) [33]. Cheng *et al*. isolated new five phenylpropanoid glycosides, containing a sucrose core, smiglasides A–E (**35**, **51**–**54**, (**Figures 8** and **13**) from *S*. *glabra* rhizomes, [46]. The extraction and isolation procedures were followed exactly as was described by Chen *et al*. [33].

Xu *et al*. conducted a comprehensive chemical study of *S*. *glabra* rhizomes [47]. The air-dried and powdered rhizomes of *S*. *glabra* were extracted with 95% aqueous ethanol and 50% aqueous ethanol under reflux, consecutively. The extracts were combined and evaporated until to dryness and the residue was suspended in water and partitioned with petroleum ether, ethyl acetate and butanol. The ethyl acetate and butanol fractions were subjected to chromatographic separation. The purification allowed to the isolation 13 flavanones (dihydrokaempferol (**9**), engeletin (**10**), astilbin (**41**), isoastilbin (**42**), neoastilbin (**43**), neoisoastilbin

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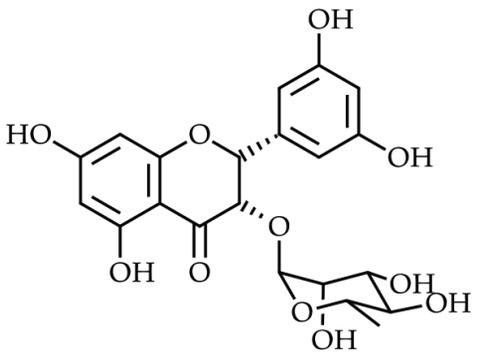
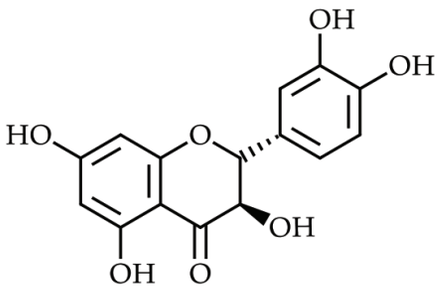
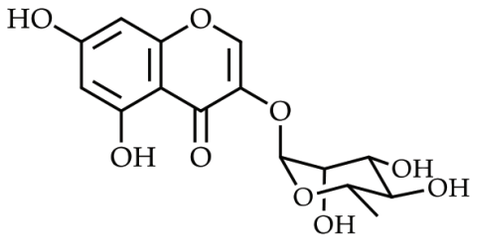


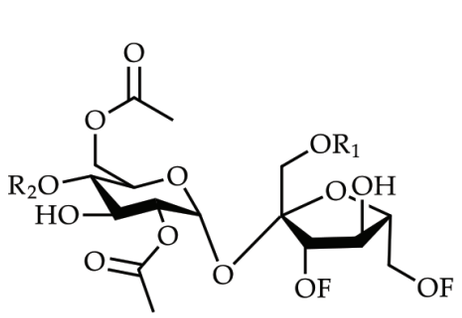
**48** Smitilbin

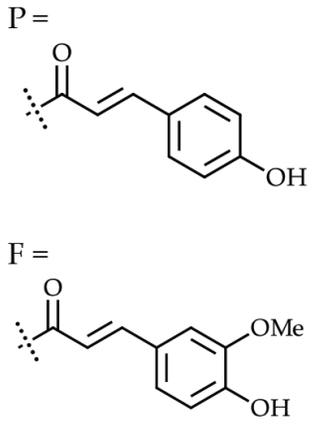


**49** Taxifolin



**50** Eucryphin





| | $R_1$ | $R_2$ | Name |
|---|---|---|---|
| **51** | F | COMe | (1,3,6-*O*-triferuloyl)-*β*-D-fructofuranosyl-(2→1)-(2,4,6-*O*-triacetyl)-*α*-D-glucopyranoside, smiglaside A |
| **52** | F | H | (1,3,6-*O*-triferuloyl)-*β*-D-fructofuranosyl-(2→1)-(2,6-*O*-diacetyl)-*α*-D-glucopyranoside, smiglaside B |
| **53** | H | COMe | (3,6-*O*-diferuloyl)-*β*-D-fructofuranosyl-(2→1)-(2,4,6-*O*-triacetyl)-*α*-D-glucopyranoside, smiglaside C |
| **54** | P | COMe | (1-*O*-*p*-coumaroyl-3,6-*O*-diferuloyl)-*β*-D-fructofuranosyl-(2→1)-(2,4,6-*O*-triacetyl)-*α*-D-glucopyranoside, smiglaside D |

**Figure 13.** Flavonoids and smiglasides isolated from *S. glabra* rhizome.

(**44**), taxifolin (**49**), naringenin (**55**), sakuranetin (**56**), arthromerin B (**57**), sinesin (**58**), (2*R*,3*R*)-taxifolin-3′-*O*-*β*-D-glucopyranoside (**59**) and (2*S*,3*S*)-glucodistylin (**60**); 3 flavanes: (+)-catechin

(**26**), (−)-epicatechin (**27**) and cinchonain 1b (**60**)); 2 flavanones (luteolin (**62**) and apigenin (**63**)); two flavonols (quercetin (**7**) and myricetin (**64**)); 1 chalcone, kukulkanin B (**65**); 3 stilbenes (piceid (**38**), piceatannol (**39**), and resveratrol (**40**)); 6 phenylpropanoids (5-*O*-caffeoylshikimic acid (**45**), caffeic acid (**66**), 3-*O*-*p*-coumaroylshikimic acid (**67**), smiglycerol (**68**), juncusyl ester B (**69**) and 1-*O*-p-coumarylglycerol (**70**), **Figure 14**). It is noteworthy that in this study no smiglasides were detected, despite an intensive separation of phenolic compounds having conducted. One explanation for these results is that possibly the high temperatures used for extraction caused smiglasides degradation.

### 2.11. *Smilax glycyphylla*

*S*. *glycyphylla* is a plant endemic to Australia and its leaves and fruits have a sweet taste like honey grass. The sweet principle of *S*. *glycyphylla* is called glycyphyllin A (**71**) and identified as a phenol compound with a structure of dihydrochalcone, phloretin-2′-*α*-L-rhamnose [48]. Cox *et al*. evaluated aqueous extracts of leaves and stems of *S. glyciphylla* [49]. The methods used to evaluate antioxidant activity were lipid peroxidation using thiobarbituric acid reactive substances (TBARS), superoxide quenching by coupling superoxide generation to the reduction of nitroblue tetrazolium (NBT), inhibition of deoxyribose-driven fenton degradation and total radical-antioxidant potential (TRAP) using free radicals derived from ABTS (2,2′-azinobis(3-ethylbenzothiazoline 6-sulphonate). The results showed that *S*. *glycyphylla* extract inhibited deoxyribose degradation. The total radical-antioxidant potential was seven times that the trolox a water-soluble analog of vitamin E with a high antioxidant activity.

Huang *et al*. performed a study of phenolic profile and antioxidant activity of *S*. *glycyphylla* leaves [50]. The leaves of *S*. *glycyphylla* previously dried and blended were extracted with 80% aqueous ethanol. Then, the extract was concentrated and partitioned with hexane and butanol, consecutively. The butanol fraction was subjected to chromatographic separation. The separation produced eight phenolic compounds such as the glycyphyllin A previously mentioned, two new dihydrochalcones (glycyphyllin B (**72**) and C (**73**)) and five flavonoids (catechin (**26**), (2*R*,3*R*)-dihydrokaempferol-3-*O*-*β*-D-glucopyranoside (**57**), kaempferol-3-*O*-*β*-D-glucopyranoside (**74**), quercetin-3-*O*-*β*-D-glucopyranoside (**75**) and kaempferol-3-*O*-*β*-neohesperidoside (**76**), **Figures 14** and **15**). The antioxidant activity of pure compounds was evaluated using ferric reducing ability of plasma (FRAP) and DPPH$^{\bullet}$ radical scavenging. The flavonoids showed a good antioxidant activity; contrary to this, the dihydrochalcones showed weak antioxidant activity [50].

### 2.12. *Smilax lanceaefolia*

The root of *S*. *lanceifolia* prepared as a decoction is used in traditional Indian medicine to soothe stomach pain and rheumatism. The boiled extract is used to expel gallbladder and kidney stones. It was also found that the aqueous extract of *S*. *lanceifolia* contains compounds with a high affinity for binding proteins, specifically by active sites joining reverse transcriptase. Therefore, it can be used to inhibit proliferation of retroviruses-agents in viral diseases such as AIDS and T-cell leukemia [51]. Laintojam and Kongbrailatpam performed a study on the chemical constituents and antioxidant activiy of *S*. *lanceifolia* roots extracts [7]. The extracts were obtained from petroleum ether, chloroform and methanol, successively. Antioxidant

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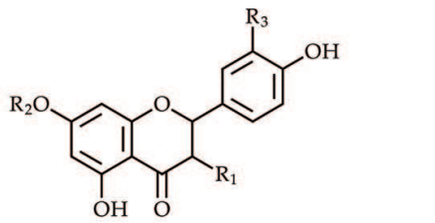
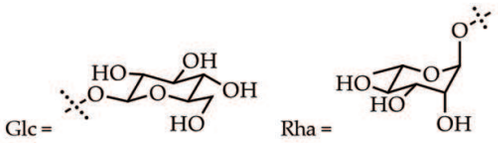
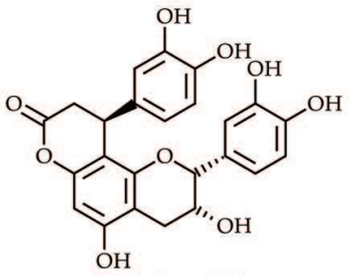
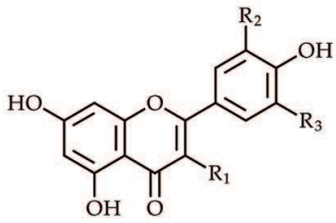


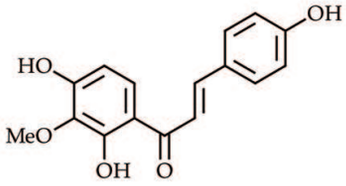

| | $R_1$ | $R_2$ | $R_3$ | Name |
|---|---|---|---|---|
| **55** | H | H | H | Naringenin |
| **56** | H | Me | H | (2*S*)-Sukaranetin |
| **57** | Glc | H | H | (2*R*,3*R*)-Arthromerin B |
| **58** | OH | Glc | H | (2*R*,3*R*)-Sinensin |
| **59** | OH | H | Glc | (2*R*,3*R*)-Taxifolin-3′-*O*-*β*-D-glucopyranoside |
| **60** | Glc | H | OH | (2*S*,3*S*)-Glucodistylin |



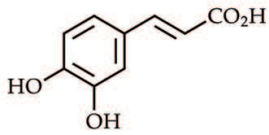

**61** Cinchonain Ib



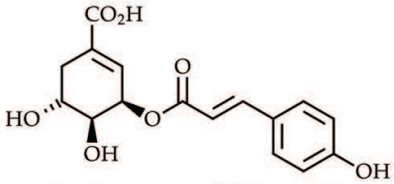

| | $R_1$ | $R_2$ | $R_3$ | Name |
|---|---|---|---|---|
| **62** | H | OH | H | Luteolin |
| **63** | H | H | H | Apigenin |
| **64** | OH | OH | OH | Myricetin |



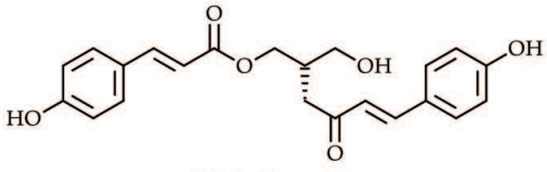

**65** Kukulkanin B



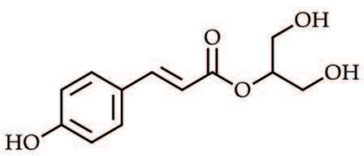

**66** Caffeic acid



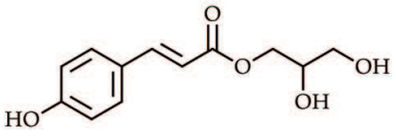

**67** *O*-*p*-coumaroylshikimic acid




**68** Smiglycerol

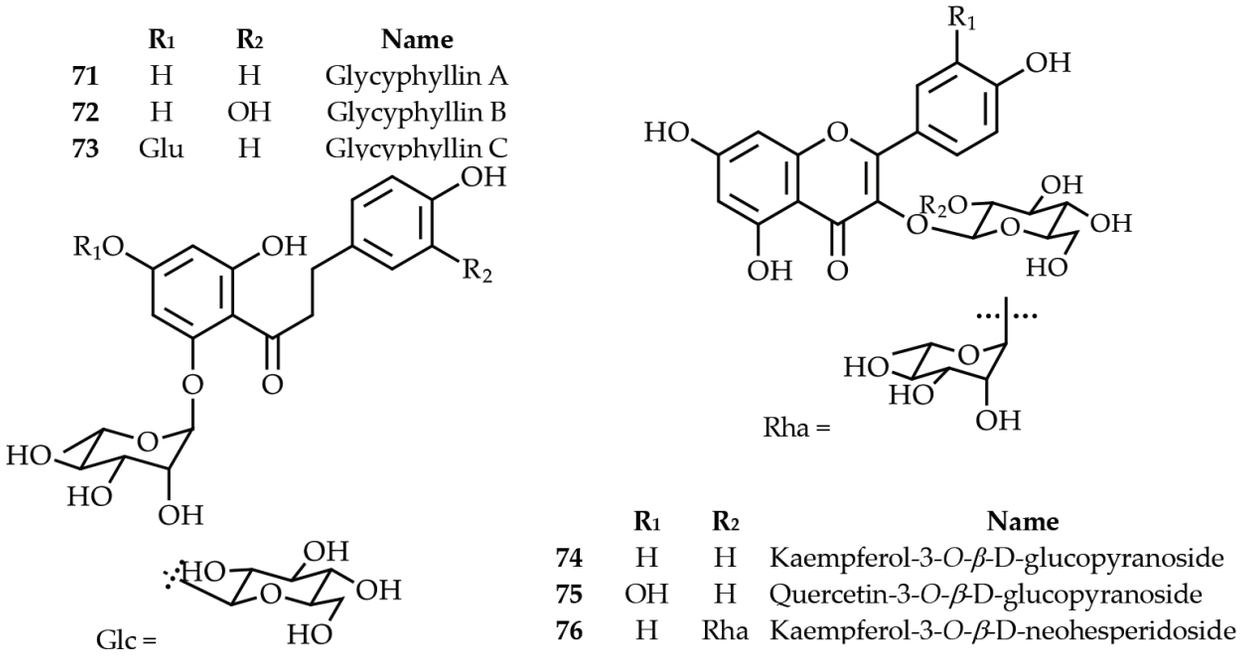



**69** Juncusyl ester B




**70** 1-*O*-*p*-coumarylglycerol

**Figure 14.** Flavonoids and phenylpropanoids isolated from *S. glabra* rhizome.




| | R1 | R2 | Name |
|---|---|---|---|
| **71** | H | H | Glycyphyllin A |
| **72** | H | OH | Glycyphyllin B |
| **73** | Glu | H | Glycyphyllin C |

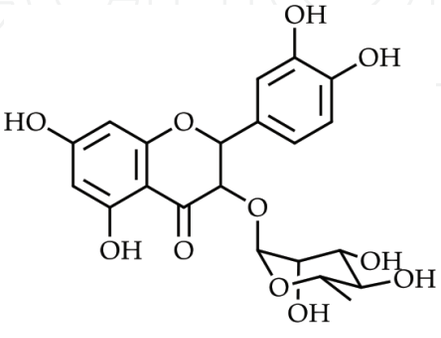
| | R1 | R2 | Name |
|---|---|---|---|
| **74** | H | H | Kaempferol-3-*O*-*β*-D-glucopyranoside |
| **75** | OH | H | Quercetin-3-*O*-*β*-D-glucopyranoside |
| **76** | H | Rha | Kaempferol-3-*O*-*β*-D-neohesperidoside |

**Figure 15.** Phenolic compounds isolated from 80% ethanol extract of *S. glycyphylla* leaves.

activity of the extracts was evaluated by DPPH$^{\bullet}$ radical scavenging and it was found that the methanol extract had the principal antiradical activity attributed to phenolic compounds. The only compound isolated from methanol extract was flavanonol glycoside, quercitrin (**77**, **Figure 16**) [7].

### 2.13. *Smilax riparia*

The roots and rhizomes of *S. riparia*, commonly called "Niu-Wei-Cai" in China, are used in traditional Chinese medicine as diuretics, treatments for inflammation and cancer [52], and in some cases as food [53]. Sun *et al*. isolated three phenylpropanoid glycosides (the smilasides M (**78**) and N (**79**), and 2′,6′-diacetyl-3,6-diferuloylsucrose (**80**), **Figure 16**) from a 95% aqueous ethanol extract of *S. riparia* roots and rhizomes. The concentrated extract was suspended

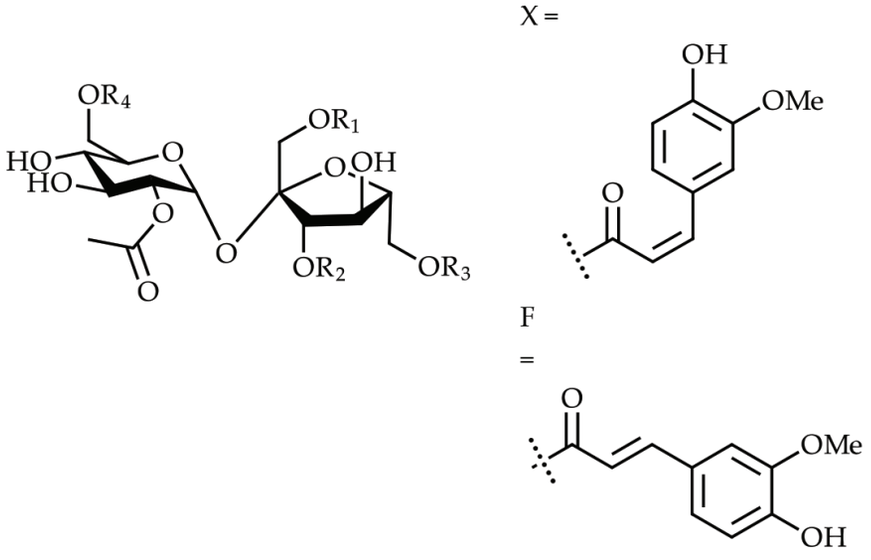



**77** Quercitrin

**Figure 16.** Flavanonol glycoside from methanol extract of *S. lanceifolia* roots.

in water and subjected to D101 macroporous resin column chromatography and eluted with water and 30% and 70% ethanol, successively. The fraction eluted with 70% ethanol was suspended in water and partitioned with chloroform, ethyl acetate and butanol. The ethyl acetate fraction was chromatographed over a silica gel column, followed by thin-layer chromatography (TLC) and finally, the fractions were subjected to C18 reversed-phase silica gel column to obtain the afore-mentioned compounds, [54].

Wang *et al*. isolated five phenylpropanoids with a sucrose core (helonioside B (**18**), smiglaside A (**51**), smiglaside B (**52**), and smilaside P (**81**), **Figures 5**, **13** and **17**) [55]. The phenylpropanoid compounds were obtained from a 95% aqueous ethanol extract of *S. riparia* roots and rhizomes. The extract was subjected to macroporous resin HPD-600 and eluted with 95% aqueous ethanol and ethyl acetate. Subsequently, the ethyl acetate fraction was subjected to silica gel column chromatography, and from this fraction were obtained the phenylpropanoids compounds. The five compounds were subjected to cytotoxicity test against human promyelocytic leukemia (HL-60), human hepatocellular carcinoma (SMMC-7721), human lung cancer (A-549), human breast cancer (MCF-7) and human colon cancer (SW480) using 3-(4,5-dimethylthiazol-2-yl)-5-(3-carboxymethoxy-phenyl)-2-(4-sulfophenyl)-2H-tetrazolium (MTS). The five compounds were evaluated for anticancer activity. Antioxidant activity was also evaluated using DPPH$^{\bullet}$ radical scavenging activity. The results showed the phenylpropanoid compounds with three feruloyl and acetyl groups exhibited the primary antitumoral and antioxidant activities. The proposed explanation of these results was that the feruloyl and




| | R1 | R2 | R3 | R4 | Name |
|---|---|---|---|---|---|
| **78** | H | X | F | COMe | 2′,6′-diacetyl-3-*Z*-feruloyl-6-feruloylsucrose, smilaside M |
| **79** | H | F | X | COMe | 2′,6′-diacetyl-3-feruloyl-6-*Z*-feruloylsucrose, smilaside N |
| **80** | H | F | F | COMe | 2′,6′-diacetyl-3,6-diferuloylsucrose |
| **81** | F | F | F | H | Smilaside P |

**Figure 17.** Phenylpropanoids from 95% ethanol extract of *S. riparia* roots and rhizomes.

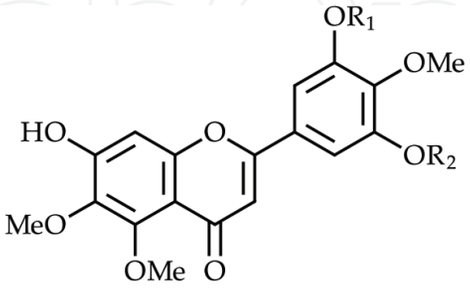
acetyl groups confer a minor polarity to the compounds with the most activity and are key to inducing antitumoral activity [55].

### 2.14. *Smilax scobinicaulis*

The roots of *S. scobinicaulis*, also called "Hei Ci Ba Quia" in Chinese, are used in traditional Chinese medicine for the treatment of arthritis, gout and inflammatory diseases [10]. Zhang *et al*. studied the chemical composition of *S*. *scobinicaulis*. These researchers first obtained a 95% aqueous ethanol extract from *S*. *scobinicaulis* roots and rhizomes. The extract was concentrated, suspended in water and partitioned with petroleum ether, ethyl acetate and butanol, successively. The ethyl acetate fraction was subjected to column chromatography. The purification was done to isolate and characterize two new flavones (7,3′,5′-trihydroxy-5,6,4′-trimethoxyflavone (**82**) and 7-hydroxy-5,6,3′,5′-pentamethoxyflavone (**83**), **Figure 18**). The new flavones were evaluated for cell proliferation and viability assay against human breast adenocarcinoma (MCF-7) and human lung carcinoma (H520). The results showed a weak activity for **82**, but 7-hydroxy-5,6,3′,5′-pentamethoxyflavone, **83** was inactive [10].

### 2.15. *Smilax sebeana*

*S. sebeana* is used in traditional Japanese and Chinese medicine to treat syphilis, arthritis and gout [11]. Ao *et al*. evaluated antioxidant activity in isolated phenolic compounds from methanol extracts of *S*. *sebeana* rhizomes and roots [11]. The methanol extract was obtained from maceration of fresh rhizomes and roots with methanol at room temperature. The methanol extract was concentrated, suspended in water and partitioned with hexane, ethyl acetate and butanol, successively. The ethyl acetate fraction was purified in two steps. First, it was subjected to column chromatography packed with sephadex LH-20. Some of the fractions collected were selected to evaluate by HPLC to evaluate their components. Finally, the fractions with similar composition were pooled and purified by preparative HPLC. Also, the total phenol content and antioxidant activity expressed by DPPH radical scavenging were evaluated for methanol, ethyl acetate and butanol fractions. The major content of total phenols was




| | $R_1$ | $R_2$ | Name |
|---|---|---|---|
| **82** | H | H | 7,3′,5′-trihydroxy-5,6,4′-trimethoxyflavone |
| **83** | Me | Me | 7-hydroxy-5,6,3′,5′-pentamethoxyflavone |

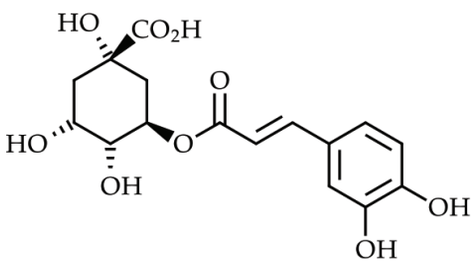
**Figure 18.** Flavones from 95% ethanol extract of *S*. *scobinicaulis* roots.

http://dx.doi.org/10.5772/66896

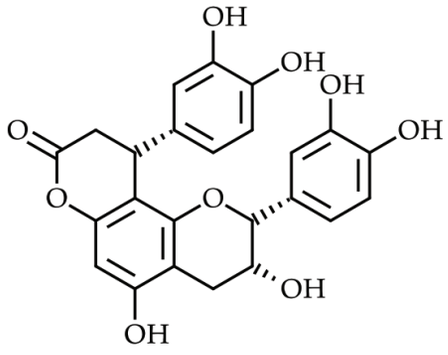
found in the ethyl acetate fraction, 238.5 mg catechin/g extract. This fraction also showed the principal DPPH• radical scavenging activity, $IC_{50}$ of approximately 10.4 μg/mL. The compounds isolated from the ethyl acetate fraction were one phenylpropanoid (chlorogenic acid (**84**), **Figure 19**) and three cinchonain (1b (**61**), 1a (**85**) and 11a (**86**), **Figures 14** and **19**) [11].

### 2.16. *Smilax trinervula*

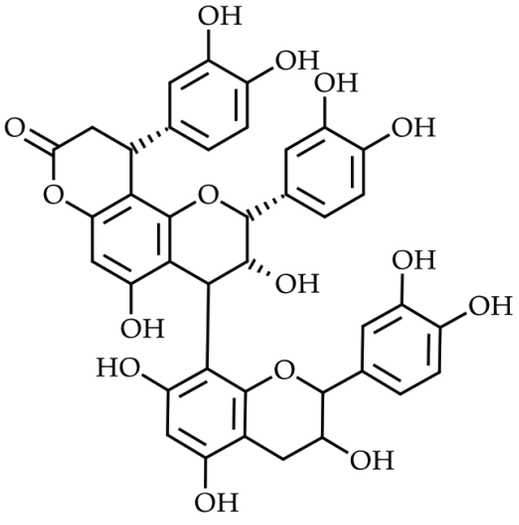
*S. trinervula* is a plant used in traditional Chinese medicine. The rhizomes and roots are sources of the Chinese drug "Ba-Quia" used as a diuretic and to treat pelvic inflammation [56]. Shu *et al*. carried out the first chemical designed to isolate phenolic compounds from rhizomes of *S. trinervula*. These researchers obtained a 70% aqueous ethanol extract and removed the solvent [56]. The extract was partitioned with ethyl acetate and butanol. The butanol fraction was subjected to macroporous resin column chromatography. The fractions obtained from this separation were subjected to repeated silica gel and sephadex LH-20 column chromatography. Finally, the fractions were subjected to semipreparative HPLC. From this separation process were isolated eight phenolic compounds, three phenylpropanoids and five neolignans. These




**84** Chlorogenic acid

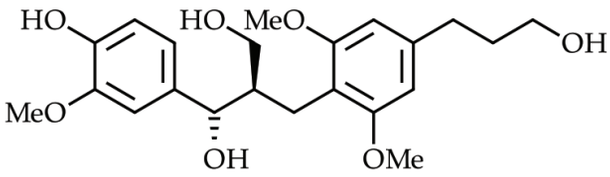



**85** Cinchonain Ia

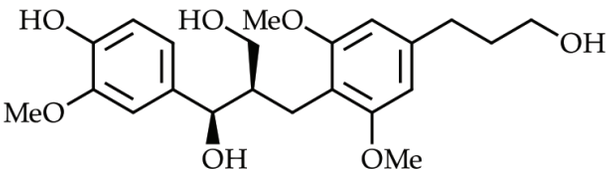



**86** Cinchonain 11a

**Figure 19.** Phenolic compounds from methanol extract of *S. sebeana* rhizomes and roots.




**87** (7*S*,8*R*)-4,7,9,9′-tetrahydroxy-3,3′-dimethoxy-8-*O*-4′-neolignan




**88** (7*R*,8*R*)-4,7,9,9′-tetrahydroxy-3,3′-dimethoxy-8-*O*-4′-neolignan

**Figure 20.** Two neolignans (**87** and **88**) with colon anticancer activity isolated of 70% ethanol extract from *S. trinervula* rhizomes.

compounds were evaluated against five human cell lines (SH-SY5Y, SGC-7901, HCT-116, Lovo and Vero) using the MTT method. The anticancer evaluation showed (7*S*,8*R*)-4,7,9,9′-tetrahydroxy-3,3′-dimethoxy-8-*O*-4′-neolignan (**87**) and (7*R*,8*R*)-4,7,9,9′-tetrahydroxy-3,3′-dimethoxy-8-*O*-4′-neolignan (**88**) (**Figure 20**) had cytotoxic activity against Lovo [56].

## 3. Conclusions

The polar extracts of *Smilax* species have high concentrations of phenolic compounds with high antioxidant activity. The main investigations of *Smilax* species are oriented to evaluate cytotoxicity against human cancer of cervical, lung, breast adenocarcinoma, liver and colon. The results of this review chapter showed flavonol, astilbin and phenylpropanoids binding to the sucrose nucleus (three moieties of ferulic acids and acetyl group to maximize activity) have a high potential as anticancer compounds. The anticancer activity with high concentrations of phenol compounds is attributed to antioxidant activity that induces cell apoptosis. The flavonols and phenylpropanoids can be isolated from ethyl acetate fractions obtained from a 95% aqueous ethanol extract of rhizomes and roots. Also, areal parts of *Smilax* plants contain phenolic compounds, for example, leaves and fruits. **Table 1** shows a resume of total phenols content and DPPH$^{\bullet}$ radical scavenging activity of extracts and fractions obtained from five *Smilax* species. The leaves and fruits of *Smilax* plants contain phenolic compounds. The fruits are also a source of anthocyanins. The chemical studies based on isolation and evaluation of phenolic compounds are few and do not cover more than 10% of the total *Smilax* species. Most studies have been carried out on species that grow in Asia. Hence, it is necessary continue studying the phenolic compound content of *Smilax* species, as well as evaluating their antioxidant, antidiabetic and anticancer properties.

| **Specie (part of plant)**<br>**Extract/fraction** | **Total phenols (mg GAE/g dm)** | **DPPH•**<br>**Radical scavenging activity**<br>**$IC_{50}$ (μg/mL)** |
|---|---|---|
| ***S. campestris*** (aerial) | | Ref. [17] |
| Ethanol extract | – | 13.6 |
| Hexane fraction | – | 405.5 |
| Dichloromethane fraction | – | 298.9 |
| Ethyl acetate fraction | – | 108.9 |
| Butanol fraction | – | 2.1 |
| ***S. china*** (*roots*) | Ref. [19] | Ref. [19] |
| Methanol extract | – | – |
| Chloroform fraction | 142.6 | 302.2 |
| Ethyl acetate fraction | 401.6 | 85.5 |
| Butanol fraction | 206.8 | 210.9 |
| Water fraction | 97.3 | 224.9 |
| ***S. excelsa*** (leaves) | Ref. [29] | Ref. [29] |
| Water extract | 30.6 | 1190 |
| Infusion | 35.7 | 1240 |
| Ethanol extract | 30.1 | 1490 |
| Ethyl acetate extract | 8.8 | 2660 |
| ***S. glabra*** (rhizomes) | Ref. [44] | Ref. [44] |
| Water extract | 29.41 | 236 |
| Ethanol fraction[a] | 109.8 | 58 |
| Methanol extract | 152.3 | 43 |
| ***S. riparia*** (rhizomes and roots) | | Ref. [55] |
| 95% ethanol extract | – | 2520 |
| 95% ethanol fraction | – | 1460 |
| Ethyl acetate fraction | – | 1330 |
| Methanol fraction | – | 1000 |

GAE mg: milligrams of gallic acid equivalent, dm: dry matter, $IC_{50}$: extract concentration necessary to decrease 50% the initial concentration of DPPH•. The fractions were obtained from a partition of corresponding extract.This fraction was obtained from water extract.

**Table 1.** Total phenols, antioxidant activity expressed as DPPH radical scavenging activity of *Smilax* genus species.

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## Conflict of interest

The authors have no conflict of interest to declare and are responsible for the content and writing of the manuscript.

## Ethical approval

This chapter does not contain any studies with human participants or animals performed by any of the authors.

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