

## Review Article

# Phytochemical Constituents and Pharmacological Activities of Plants from the Genus *Adiantum*: A Review

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## Abstract

*Adiantum* is a genus of ca. 200 species in the family Adiantaceae, distributed extensively across the world from cool temperate zones to hot tropical regions. A lot of *Adiantum* species have been used in traditional Chinese medicine to cure human and animal diseases including relief of internal heat or fever, enhancement of urination, removal of urinary calculus, and sundry other curative claims. Chemical studies have shown the presence of various classes of compounds, the main ones being triterpenoids, flavonoids, phenyl propanoids, steroids, alicyclic acids, lipids and long-chain compounds. The extract of this genus as well as pure compounds isolated from it have been demonstrated to possess multiple pharmacological activities such as analgesic, antinociceptive, anti-implantation, and antimicrobial activities. In this review, we have addressed the phytochemistry and pharmacological activities of the *Adiantum* species in order to collate existing information on this plant as well as highlight its multi-activity properties as a medicinal agent.

**Keywords:** *Adiantum* species, Adiantaceae, Phytochemical constituents, Pharmacological activities.

Received: 10 February 2011

Revised accepted: 13 September 2011

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## INTRODUCTION

*Adiantum* is a genus of ca. 200 species in the family Adiantaceae, distributed extensively over the world from cool temperate zones to hot tropical regions. As many as 30 species and 5 varieties are found in China [1]. Half of the species have been used in traditional Chinese medicine to cure human and animal diseases including relief of internal heat or fever, enhancement of urination, removal of urinary calculus, elimination of stasis to resolve swelling, relief of cough, cure of diarrhea and stoppage of bleeding, as well as treatment of urinary tract infection, calculus, hepatitis, hemorrhage, fractures, snakebite, burns and scald [2].

According to the literature, *Adiantum* species are a rich source of triterpenes with various structural skeletons. Besides, flavonoids, phenyl propanoids and sterols have been isolated from the genus *Adiantum* [3-14]. These compounds have been reported to show various bioactivities, such as analgesic, antinociceptive, anti-implantation, and antimicrobial activities. In this review, we summarize the current knowledge of the phytochemistry of the plants as well as the compounds that have been isolated from the genus *Adiantum*. The biological activities of this genus have also been addressed.

## PHYTOCHEMISTRY

Since the 1960s, 124 compounds, including terpenoids, flavonoids, phenyl propanoids, steroids, alicyclic acids, lipids and long-chain compounds have been reportedly isolated from the genus. Triterpenoids and flavonoids are the dominant constituents within the genus *Adiantum*.

### Terpenoids

Eighty-five triterpenoids were isolated from the genus *Adiantum* [3-5,15-52]. Most of the triterpenoids are pentacyclic and belong to the hopane and migrated hopane or closely related groups such as isohopane,

neohopene, fernane, isofernene, filicane, pteronane and adiane types. The presence of a large number of the nor-compounds is also a characteristic feature of this genus. Hopane-type triterpenoids, **1-9**, were isolated from various *Adiantum* species, such as *A. capillus-veneris*, *A. edgeworthii*, *A. monochlamys*, *A. caudatum*, *A. incisum*, *A. cuneatum*, *A. pedatum*, *A. tetraphyllum* and *A. lunulactum* (syn. *A. philippense*) (Table 1, Figure 1) [3,15-26]. Isohopane-type triterpenoid, **10**, was isolated from *A. lunulatum* [27], and neohopane-type triterpenoids, **11-16** were also isolated from the genus *Adiantum* (Table 2, Figure 2).

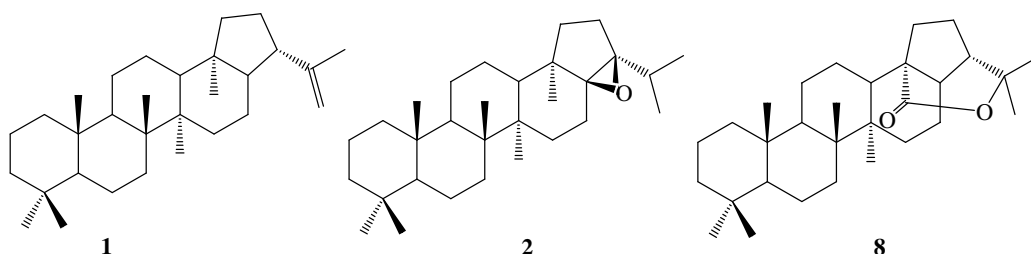
Other migrated hopane or closely related triterpenoids isolated from the genus *Adiantum* include norhopane-type triterpenoids, **17-29** (Table 3, Figure 3), fernane-type triterpenoids, **30-51** (Table 4, Figure 4), an isofernane-type triterpenoid, isofernene (**52**) isolated from *A. monochlamys* and *A. pedatum* [19,40], adiane-type triterpenoids, **53-57**, and filicane-type triterpenoids, **58-67** (Table 5, Figure 5), and a pteronane-type triterpenoid, pteron-14-en-7 $\alpha$ -ol obtained from *A. capillus-veneris* [16]. Secofilicanes **66** and **67** isolated from *A. cuneatum* are the first two secotriterpenoids that have been reported in ferns. Adipedatol (**28**) and filicenol (**61**) are the first two examples of the natural triterpenoids having the hemiketal and the conjugated aldehyde groups, respectively [23,28,35,40].

Other pentacyclics include lupane and norlupane triterpenoids lup-20(29)-en-28-ol, 24-norlupan-3-one and adiantulupanone isolated from *A. capillus-veneris*, *A. tetraphyllum* and *A. venustum* [3,47,48]. Oleanane triterpenoids olean-12-en-3-one and olean-18-en-3-one were isolated from *A. capillus-veneris* [15,25]. Noroleanane triterpenoids adininaonol and adiantuoleanone were isolated from *A. venustum* and *A. incisum* respectively [21,48]. Ursane triterpenoid urs-20-en-16-ol was isolated from *A. capillus-veneris* [47], and gammacerane triterpenoids tetrahyma-

**Table 1:** Hopane-type triterpenoids from the genus *Adiantum*

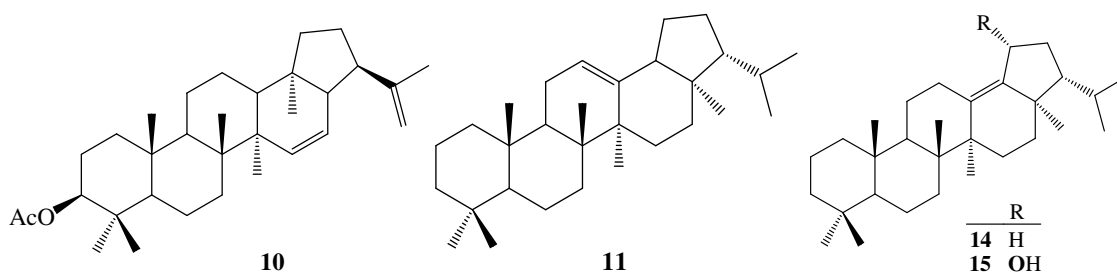
No.	Compound name	Source*	Ref.
1	Hop-22(29)-ene (= Diploptene)	A1~A3	15-19
2	17 $\beta$ ,21 $\beta$ -Epoxyhopane	A4	20
3	Adininaneone	A5	21
4	Hydroxyhopane (= Hopanol)	A1,A2,A6~A8	3,15-17, 22,23
5	Mollugogenol A	A9	24
6	6 $\alpha$ -Acetoxy-16 $\beta$ ,22-dihydroxy-3-ketohopane	A1,A9	24,25
7	17,29-Epoxyhopane	A1	16
8	Hopan-28,22-olide	A1	16
9	3 $\beta$ -Acetoxy-6 $\alpha$ -hydroxy-hop-15,17(21)-diene	A9	26

\* A1=*A. capillus-veneris*, A2=*A. edgeworthii*, A3=*A. monochlamys*, A4=*A. caudatum*, A5=*A. incisum*, A6=*A. cuneatum*, A7=*A. pedatum*, A8=*A. tetraphyllum*, A9=*A. lunulatum*

**Figure 1:** Selected hopane-type triterpenoids from the Genus *Adiantum***Table 2:** Isohopane and neohopane-type triterpenoids from the Genus *Adiantum*

No.	Compound name	Source*	Ref.
10	3 $\beta$ -Acetoxy-21 $\alpha$ H-hop-22(29)-ene	A9	27
11	Neohop-12-ene (= Neohopene)	A1~A3,A6,A7	15-18, 23, 28,29
12	Neohop-18-en-12 $\alpha$ -ol	A6	30
13	13-Epineohop-18-en-12 $\alpha$ -ol	A6	30
14	Neohop-13(18)-ene	A3,A4,A7	18, 20, 23,29
15	Neohop-13(18)-en-19 $\alpha$ -ol	A6	30
16	Neohopa-11,13(18)-diene	A3,A6,A7	18, 23, 28,29

\* A1=*A. capillus-veneris*, A2=*A. edgeworthii*, A3=*A. monochlamys*, A4=*A. caudatum*, A6=*A. cuneatum*, A7=*A. pedatum*, A9=*A. lunulatum*

**Fig 2:** Selected isohopane and neohopane-type triterpenoids from the Genus *Adiantum*

**Table 3:** Norhopane-type triterpenoids from the genus *Adiantum*

No.	Compound name	Source*	Ref.
17	Trisnorhopane	A1,A6	16,28
18	Isoglaucanone (= 17 $\alpha$ H-Trisnorhopan-21-one)	A1,A6,A7	15, 16, 23,28
19	Glaucanol A	A7	23
20	Glaucanol B acetate	A6	28
21	21-Hydroxy-30-norhopan-22-one (= 21-Hydroxyadiantone, Hydroxyadiantone)	A1,A3,A6,A7,A10,A11	15, 16, 18, 23, 28,31-33
22	Isodiantone	A1,A3~A7,A12	15,16,18,20,21, 23,28,33-38
23	Adiantone	A1~A7,A9,A10,A13	4,5,15-18, 20, 21,23, 28, 31, 36,37,39-41
24	19 $\alpha$ -Hydroxyadiantone	A2,A4	17,20
25	29-Norhopan-22-ol	A4	4
26	Isodiantol B [= (22S)-30- Norisohopan-22-ol, Isoadiantol]	A1,A3,A6,A7,A11	15,18, 22, 23,32
27	22,29 $\xi$ -Epoxy-30-norhopane-13 $\beta$ -ol	A9	39
28	Adipedatol	A7	23,40
29	Adipedatol Me ether	A7	40

\* A1= *A. capillus-veneris*, A2= *A. edgeworthii*, A3= *A. monochlamys*, A4 =*A. caudatum*, A5= *A. incisum*, A6= *A. cuneatum*, A7= *A. pedatum*, A9= *A. lunulatum*, A10= *A. venustum*, A11= *A. Emarginatum*

anol, epihakonanediol, ketohakonanol (= oxohakonanol) and hakonanediol were isolated from *A. monochlamys* [18]. Tetrahymanol and ketohakonanol were also isolated from *A. capillus-veneris*, *A. pedatum*, *A. emarginatum*, *A. cuneatum* and *A. incisum* [22,23,32,33,49].

Besides, tetracyclic triterpenoids have been isolated from *A. venustum*, including lanostane triterpenoids adiantulanosterol, lanost-20(22)-en-3,19-ether and adiantulanostene, as well as tirucallane triterpenes adiantutirucallenes A and B [48, 50-52].

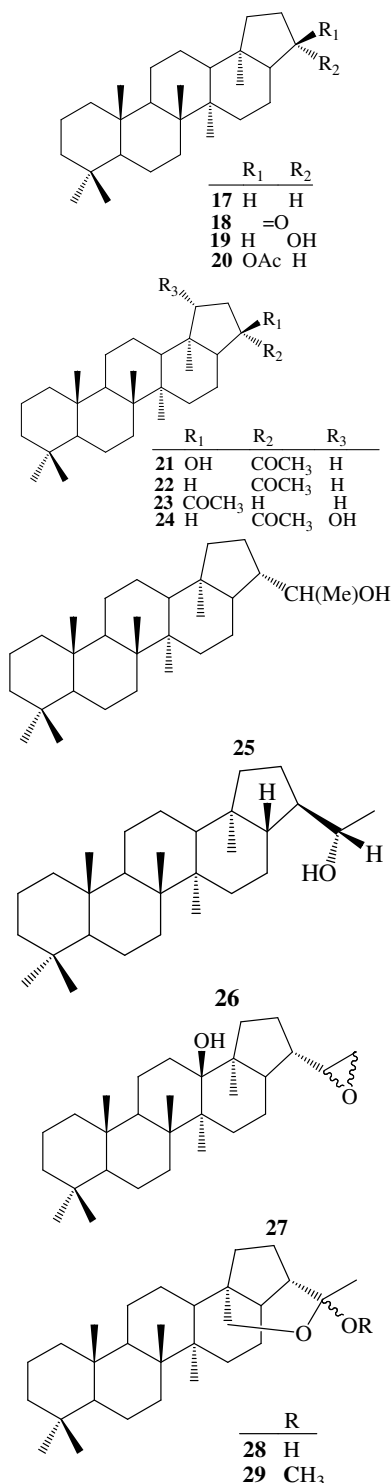
Diterpenoids, 8,13-epoxy-14-labden-19-oic acid has been isolated from *A. emarginatum* [32], and linear diterpenoids phytol and phyten-3(20)-1,2-diol were isolated from *A. tetraphyllum* [3]. Only one tetraterpenoid,  $\alpha$ -carotene monoepoxide was isolated from *A. venustum* [5].

### Flavonoids

Flavonoids (18 of them) have been isolated from the genus *Adiantum* [3-14]. Quercetin, kaempferol and their glycosides are the most common flavonols. Quercetin was isolated

from *A. tetraphyllum* [3] while hyperin and trifolin have been isolated from *A. monochlamys* and *A. malesianum* respectively [6,9]. Quercetin 3-*O*-(6"-malonyl)-*D*-galactoside, rutin, isoquercetin, querciturone, kaempferol 3-glucuronide, astragalol, kaempferol 3-sulphate, kaempferol 3,7-diglucoside, nicotiflorin and kaempferol 3-*O*-rutinoside sulfate were isolated from *A. capillus-veneris* [7,8,10,12,13]. Querciturone and kaempferol 3-glucuronide were also isolated from *A. cuneatum* [7]. Isoquercetin has also isolated from *A. monochlamys*, *A. caudatum*, *A. tetraphyllum*, *A. venustum* and *A. aethiopicum* [3-6] while astragalol was isolated from *A. monochlamys*, *A. cuneatum*, *A. venustum* and *A. aethiopicum* [5, 6,11].

Flavanone prunin was obtained from *A. monochlamys* and *A. aethiopicum* respectively [6]. Flavandiol, leucopelargonidin was isolated from *A. venustum* [5]. 2',4',6'-Trihydroxychalcone were isolated from *A. sulphureum* [14]. Flavone *C*-glucosides vitexin and isovitexin were isolated from *A. malesianum* [9].



**Figure 3:** Selected norhopane-type triterpenoids from the genus *Adiantum*

## Phenyl propanoids

Phenyl propanoids, 1-*p*-coumarylglucose 6-sulphate, 1-*p*-coumarylglucose 2-sulphate, 1-caFFEylglucose 3-sulphate, 1-caFFEylgalactose 6-sulphate and 1-caFFEylglucose were isolated from *A. capillus-veneris* [8,53] whereas 1-*p*-coumarylglucose 6-sulphate was also obtained from *A. pulverulentum* [54]. Coumarins methyl-*p*-coumarate and psoralen were isolated from *A. thalictroides var hirsutum* [4]. A coumarin dimer, daphnoretin was isolated from *A. capillus-veneris* [55].

## Steroids

$\beta$ -Sitosterol has been isolated from *A. capillus-veneris*, *A. caudatum*, *A. tetraphyllum* and *A. thalictroides var hirsutum* [3,4,36,40,56], daucosterol from *A. caudatum* [4], and stigmasterol and campesterol from *A. capillus-veneris* [56].

## Alicyclic acids

Alicyclic acids, shikimic acid and quinic acid were isolated from *A. capillus-veneris* [57].

## Lipids

The betaine lipid diacylglyceryl-*O*-4'-(*N,N,N*-trimethyl)homoserine was isolated from *A. capillus-veneris* [58]. Positional analysis of the fatty acids by lipase treatment showed that palmitic acid is esterified at position 1, and linoleic, linolenic, and arachidonic acids at position 2 of the glycerol moiety of the lipid. Although the trimethylhomoserine lipid has been found in some algal species, this is the first report that it exists in a vascular plant [58].

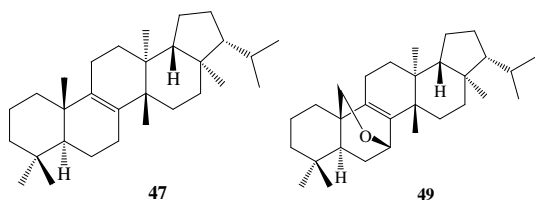
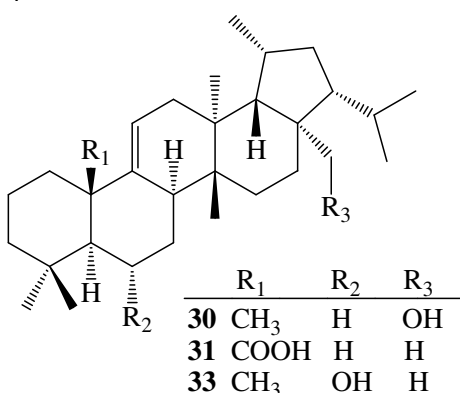
## Other long-chain compounds

16-hentriacontanone and hentriacontane were isolated from *A. caudatum* [36]. Besides, arachidonic acid was found in *A. pedatum*[59]. The essential oil in the roots of *A. flabellulatum* contained *n*-decanoic acid

**Table 4:** Fernane-type triterpenoids from the genus *Adiantum*

No.	Compound name	Source*	Ref.
30	Fern-9(11)-en-28-ol	A1,A4,A9	15,16,20,39
31	Fern-9(11)-en-25-oic acid	A2,A9,A10	17, 39,42
32	Fern-9(11)-en-25-ol	A6	30
33	Fern-9(11)-en-6 $\alpha$ -ol	A9	39
34	Fern-9(11)-en-3 $\alpha$ -ol	A1	16
35	Fern-9(11)-en-12 $\beta$ -ol	A1	15
36	Fern-9(11)-en-12-one	A1	15,16
37	Fern-9(11)-ene (= Fernene, Davallene)	A1~A4,A6,A7,A9	15-18,20,23,28, 37, 39,40, 43
38	19 $\alpha$ -Hydroxyfern-9(11)-ene	A4	20
39	23-Hydroxyfernene	A5,A7	21,23
40	Fern-7-en-3 $\alpha$ -ol	A1	16
41	Fern-7-en-25-ol	A6	30
42	Fern-7-ene= 7-fernene	A1~A4,A6,A7	15-20,23,28,40
43	19 $\alpha$ -Hydroxyfern-7-ene	A4	20
44	25-Norfern-7-en-10 $\beta$ -yl formate	A6	28
45	Ferna-7,9(11)-diene	A1,A3,A4,A7	15,16, 18,20,23,29
46	19 $\alpha$ -Hydroxyferna-7,9(11)-diene	A4	20
47	Fern-8-ene	A3,A4,A7	18, 20,23
48	7 $\alpha$ ,8 $\alpha$ -Epoxyfernan-25-ol	A6	22,44
49	7 $\beta$ ,25-Epoxyfern-8-ene	A6	28
50	7 $\beta$ ,25-Epoxyfern-9(11)-en-8 $\alpha$ -ol	A6	22,43
51	8 $\alpha$ -Hydroxyfernan-25,7 $\beta$ -olide	A4	20

A1= *A. capillus-veneris*, A2= *A. edgeworthii*, A3= *A. monochlamys*, A4= *A. caudatum*, A5= *A. incisum*, A6= *A. cuneatum*, A7= *A. pedatum*

**Figure 4:** Selected fernane-type triterpenoids from the genus *Adiantum*

(11.44%), 6,10,14-trimethyl-2-pentadecanone (11.23 %), and nonanoic acid (6.15 %), whereas the essential oil in the leaves of *A. flabellulatum* contained *n*-decanoic acid (11.77 %) and nonanoic acid (4.01 %) [60]. The essential oil from the leaves of *A. edgeworthii* contained *n*-nonanal as the chief constituent [61].

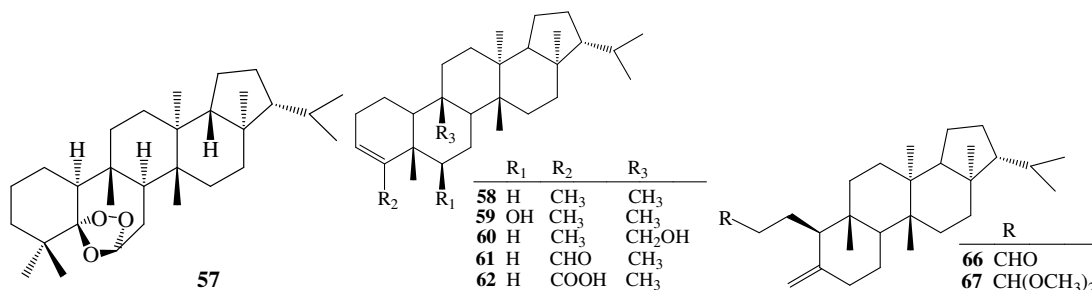
### Other constituents

A saponin glycoside was isolated from *A. capillus-veneris*. Study of the hydrolytic products of the saponin revealed a triterpenoid hydroxyhopanone aglycon and the sugar components: galactose, xylose and rhamnose. *A. capillus-veneris* was also contained protein [62]. The essential oil in the roots of *A. flabellulatum* contained diethyl phthalate [60]. The essential oil in the leaves of *A. flabellulatum* contained 2-isopropenyl-4 $\alpha$ ,8-dimethyl-1,2,3,4,4 $\alpha$ ,5,6,7-octahydrona-

**Table 5:** Adiane and filicane-type triterpenoids from the genus *Adiantum*

No.	Compound name	Source*	Ref.
53	Adian-5-en-3 $\alpha$ -ol (=Adiantol)	A1,A6	16,35
54	Adian-5-ene (=Adianene)	A1	16
55	Adian-5-en-25-ol	A6	30
56	Adian-5(10)-en-3 $\alpha$ -ol	A1	16
57	Adianene ozonide (= Adian-5-ene ozonide)	A3	18,45
58	Filic-3-ene (= 3-Filicene, Filicene)	A1~A4,A6,A7,A10	4,5,15-20, 23, 28, 32,40
59	Filicenol A	A3	18
60	Filicenol B	A3,A9	18,39
61	Filicenal	A6,A7	23, 28, 35,40
62	Filicenoic acid	A7	23
63	4 $\alpha$ -Hydroxyfilican-3-one	A1	15
64	3 $\alpha$ -Hydroxy-4 $\alpha$ -methoxyfilicane	A4	20
65	Adiantoxide = 3 $\alpha$ ,4 $\alpha$ -Epoxyfilicane	A1	15, 16,46
66	4,23-Bisnor-3,4-secofilic-5(24)- en-3-al	A6	22,44
67	4,23-Bisnor-3,3-dimethoxy-3,4- secofilic-5(24)-ene	A6	22,44

A1= *A. capillus-veneris*, A2= *A. edgeworthii*, A3= *A. monochlamys*, A4= *A. caudatum*, A6= *A. cuneatum*, A7= *A. pedatum*

**Figure 5:** Selected adiane and filicane-type triterpenoids from the genus *Adiantum*

phthalene (10.63%), [1*R*-(1 $\alpha$ ,7 $\beta$ ,8 $\alpha$ )]-1,2,3,5,6,7,8,8a-octahydro-1,8a-dimethyl-7-(1-methylethenyl)-naphthalene (9.88%),  $\alpha$ -panasinsen (8.11%), 4-tetradecyne (6.63%), and  $\beta$ -pinene (5.16%) [60]. The essential oil from the roots of *A. edgeworthii* contained 2,6-di-tert-butyl *p*-cresol as the chief constituent [61].

## PHARMACOLOGICAL ACTIVITIES

The extract of the *Adiantum* species as well as pure compounds isolated from them, have

been demonstrated to possess multiple pharmacological activities including analgesic, antinociceptive, anti-implantation, and antimicrobial activities.

### Analgesic activity

Hexane fraction from *A. cuneatum* as well as filicene (58) and filicenal (61), given intraperitoneally, exhibited potent analgesic activity when evaluated in two models of pain in mice - writhing test and formalin-induced pain. 58 presented an ID<sub>50</sub> value of 19.5

$\mu\text{mol/kg}$  body weight (writhing test), being about 7-fold more active than some reference drugs, such as acetyl salicylic acid and acetaminophen, with the dose of 73.0-247.0, and 140-250  $\mu\text{mol/kg}$  respectively. It also inhibited both phases (neurogenic and inflammatory) of the formalin test at 10 mg/kg (24  $\mu\text{mol/kg}$ ). The results confirm and justify the popular use of this plant for the treatment of sorrowful conditions [35]. Ethanol extract of *A. venustum* demonstrated good analgesic activity with 100 mg/kg when compared with 50 mg/kg [63].

### Anti-inflammatory activity

The chronic anti-inflammatory activity of the ethanol extract of *A. venustum* has been evaluated by carrageen-induced paw edema method. The results, at the two dose levels tested in rats, indicate significant anti-inflammatory activity. Maximum inhibition of inflammation was 71.15 % recorded with 100 mg/kg of plant extract. A further decrease in dose level (50 mg/kg) produced an even greater decrease in anti-inflammatory activity [63].

### Antinociceptive activity

When evaluated against acetic acid-induced abdominal constrictions, filicene (**58**) (10, 30 and 60 mg/kg, i.p.) produced dose-related inhibition of the number of constrictions, being several times more potent, with  $\text{ID}_{50}$  of 9.17 mg/kg (6.27 - 13.18 mg/kg), than acetaminophen which had an  $\text{ID}_{50}$  of 18.8 mg/kg (15.7 - 22.6 mg/kg), diclofenac ( $\text{ID}_{50}$  12.1, range 9.40-15.6 mg/kg) and acetylsalicylic acid ( $\text{ID}_{50}$  24.0, range 13.1-43.8 mg/kg); the dose was the same as those used for the standard drugs. **58** also produced dose-related inhibition of the pain caused by capsaicin and glutamate, with mean  $\text{ID}_{50}$  values of 11.7 (range 8.51 - 16.0) and < 10 mg/kg, respectively. Its antinociceptive action was significantly reversed by atropine, haloperidol, GABAA and GABAB antagonists (bicuculline and phaclofen, respectively.), but was not

affected by L-arginine-nitric oxide, serotonin, adrenalin and the opioid systems [64].

### Anti-implantation activity

Petroleum ether extracts of *A. capillus* and isoadiantone (**22**) were reported to be active as inhibitors of postcoital implantation in rats [38].

### Antimicrobial activity

The methanol extract of *A. capillus-veneris*, *A. peruvianum*, *A. venustum* and *A. caudatum* have been tested for their antimicrobial activity against five Gram positive, six Gram negative (including multiresistant *Staphylococcus aureus*) bacterial and eight fungal strains using standard microdilution assay. Maximum activity was exhibited by *A. venustum* followed by *A. capillus-veneris*, *A. peruvianum* and *A. caudatum*. The extract of *A. capillus-veneris* had very low MIC value (0.48  $\mu\text{g/mL}$ ) against *Escherichia coli*, whereas *A. venustum* extract activity against *Aspergillus terreus* showed an MIC of 0.97  $\mu\text{g/mL}$ . Total phenolic constituents of *A. venustum*, *A. capillus-veneris*, *A. peruvianum* and *A. caudatum* were 0.81, 0.83, 0.71 and 0.52 % w/w (gallic acid equivalent), respectively, implying that the observed activity may be related to the content of phenolics [65].

Pradeep *et al* reported that aqueous and alcohol extracts of *A. capillus-veneris* and *A. incisum* were effective against *A. tumefaciens*; aqueous and alcohol extracts of *A. capillus-veneris* and *A. lunulatum* against *E. coli* and *S. typhi*; alcohol extract of *A. incisum* against *Salmonella arizonae*; aqueous and alcohol extracts of *A. capillus-veneris* and *A. incisum*, and alcohol extract of *A. lunulatum* against *S. aureus* [66].

The methanol extract of *A. trapiziforme* inhibited the growth of *Bacillus megaterium* and *Staphylococcus aureus* B-43-5. Older plants showed more pronounced activity than



young ones and fertile fronds had greater activity than vegetative ones [67].

Using disk susceptibility tests, the antibacterial activity of adiantone (**23**), 22,29 $\xi$ -Epoxy-30-norhopane-13 $\beta$ -ol (**27**), fern-9(11)-en-28-ol (**30**), fern-9(11)-en-25-oic acid (**31**), fern-9(11)-en-6 $\alpha$ -ol (**33**), fern-9(11)-ene (**37**), filicenol B (**60**) and 6-oxofer-9(11)-ene were assayed against Gram negative bacteria *Escherichia coli* (ATCC 25922), *Pseudomonas aeruginosa* (ATCC 25619), *Salmonella typhi* (ATCC 23564) and Gram positive bacteria *Bacillus sphaericus* (ATCC 14577), *Bacillus subtilis* (ATCC 6051), and *Staphylococcus aureus* (ATCC 9144) [39]. Compounds **23**, **31**, and **37** were highly active against *S. typhi* and moderately active against *P. aeruginosa*, while compound **27** showed moderate activity against *S. typhi*. The other compounds did not show significant activity against the tested bacterial strains. Interestingly, Gram negative bacteria, except *E. coli*, were highly susceptible to compounds **23**, **31** and **37** and comparable with the positive control, kanamycin[39].

Alcohol extracts of the rhizome of *A. capillus-veneris* effectively inhibited the proliferation and metabolism activity of rifampicin-resistant pulmonary tuberculosis cells [68].

### Antiviral activity

Using vesicular stomatitis virus in monkey cell cultures as test organism, the extracts of *A. capillus-veneris* was found to exhibit antiviral activity [69].

### Agglutinating activity

Lectin from the leaves of *A. flabellulatum* had a characteristic of glycoproteins, exhibiting agglutinating activity on rabbit erythrocytes, as well as human erythrocytes of A, B, or O groups, but had no activity on turtle erythrocytes. It agglutinated cells of unicellular alga (*Chlorella pyrenoidosa*), natural or heat-treated cells of yeast (*Saccharomyces cerevisiae*) and heat-treated

cells of *Bacillus subtilis* [70]. Its' highest agglutinating activity on chicken's red blood cell reached 2<sup>10</sup>. In addition, it was specific for not only some marine algae, as well as bacterial, yeast and tumor cells but also for two species of plant harmful germ and bacteria, *Helminthosporium turcicum* and *Pseudomonas solanacoarum* [71].

### Insect-molting hormone activity

Leaf material from 64 New Zealand ferns was examined for insect molting hormone activity by using the housefly larvae for bioassay. Activity was found in most species including the genera *Adiantum* [72].

### Other activities

Total flavonoids from *A. capiuaris-veneris* showed high scavenging activity on hydroxyl radicals [73]. El-Tantawy *et al* determined the antidiabetic and diuretic effects of the alcohol and aqueous extracts of *A. capillus-veneris* as well as the isolated mucilage [55]. Melos *et al* evaluated the allelopathic potentials of the crude ethanol extract of *A. tetraphyllum* and its fractions against *Lactuca sativa* (lettuce) and *Allium cepa* (onion) seeds [3]. The average time of germination of lettuce and onion seeds, when subjected to the crude ethanol extract as well as hexane and AcOEt fractions of *A. tetraphyllum*, respectively, at a concentration of 1000 mg/L, was significantly ( $p < 0,05$ ) longer than that for the control.

## CONCLUSION

Chemical studies on *Adiantum* species have revealed that the typical constituents of this genus are terpenoids and flavonoids. Among them, some exhibit strong bioactivities, especially analgesic, antinociceptive, anti-implantation, and antimicrobial activities. Further phytochemical and biological studies should be carried out on this genus in order to elucidate their active principles and mechanisms of action of the active constituents.

## ACKNOWLEDGEMENT

The work was supported by a grant (No. 2005DFA30670) for international collaborative research by Ministry of Science and Technology, China and a grant (No. 2009CC018) from Yunnan Province of China for basic research in social development.

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