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REVIEW

Antiviral Activity of Compounds Isolated From Plants

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Abstract

This review presents 344 compounds isolated and identified from plants that previously demostrated antiviral activity. These compounds have been classified in appropiate chemical groups and data are reported on their pharmacological effect, mechanism of action, and other properties.

Keywords: Antiviral compounds, classes, structures, sources, activities.

Introduction

Research in molecular virology has opened new avenues in the knowledge and understanding of viral properties, the nature of the obligate parasitism of viruses and, to a certain extent, the mechanisms involved in viral diseases. On the other hand, the search for natural and man-made drugs to inhibit and cure viral infections in man and animals have been marred by failure. Even today, at a time when many of the molecular processes of viral replication in infected cells are fairly well understood, virtually no antiviral drugs are available for the cure of viral diseases. This is in contrast to the successful isolation of antibacterial drugs from natural sources that have revolutionized the treatment of many diseases in man and animals.

Viruses are intracellular obligate parasites of eukaryotic cells and they utilize a number of host metabolic processes, in addition to metabolic processes coded for by the virus itself. An effective antiviral drug must, therefore, interfere with virus-coded molecular processes without affecting any cellular metabolic processes. Unfortunately, many naturally occurrring substances, as well as synthetic drugs that have an inhibitory effect on virus replication, also have an inhibitory effect on molecular processes in both infected and uninfected tissues. Thus, the search for antiviral substances is severely hampered by the requirement for a drug with a very highly specialized inhibitory function which will not interfere with any specific metabolic pathway of the cell.

Many natural and synthetic drugs that were found to have antiviral activity when tested in cultured cells under *in vitro* conditions were considerably less effective when tested in virus-infected animal models. It became evident that transport of the drug to cells in the infected tissue is a major difficulty, especially when tissues become inflamed as a result of the viral infection. Since treatment of a virus infection is usually initiated when the symptoms are already obvious, introduction of a drug with antiviral activity at this stage is probably not sufficient to cure the infection if other elements such as lymphocytes and connective tissue have been activated and proceed to cause damage to the virus-infected tissue. Antiviral drugs, therefore, should be used in combination with anti-inflammatory drugs to suppress both the virus and tissue effects.

Plants represent a large, untapped, potential source of antiviral agents. Although there has been relatively few studies seeking antiviral agents from plants, those studies have revealed an unexpectedly frequent occurrence of antiviral activity in plants. Typically 20–30% of plants from tropical or temperate regions have been observed to possess antiviral activity.

A large number of compounds of varied chemical structures isolated from medicinal plants have been shown to possess antiviral activity. In this review, some compounds isolated from plants with antiviral activity are shown. This

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article is based on bibliographic research of Chemical Abstract from 1950–2000. It can be helpful in the search for antiviral substances from plants, and for individuals studying the mechanistic action and antiviral effects.

Alkaloids and nitrogenated compounds

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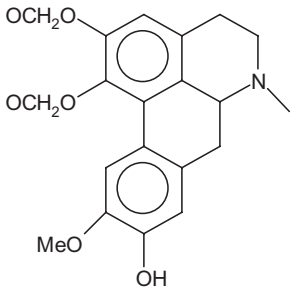

Actinophnine

Found in *Actinodaphne hookeri*; active against Herpes simplex virus type 1 (Montanha et al., 1995).

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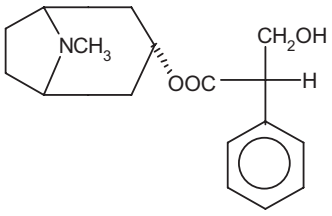

Atropine

Atropine was isolated from *Atropa belladona* L. (Solanaceae), inhibited the multiplication of enveloped viruses, no extracellular virucidal effect (Yamazaki & Tagaya, 1980).

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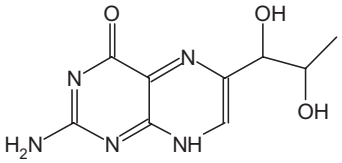

Biopterin

Biopterin was isolated from *Crithidia fasciculata*, has antiviral activity (Tschesche et al., 1962).

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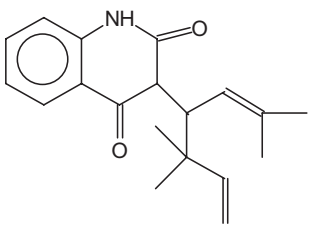

Buchapine

Isolated from *Euodia roxburghiana*; found to show inhibitory activity against HIV-1-reverse transcriptase (Manske & Brossi, 1985).

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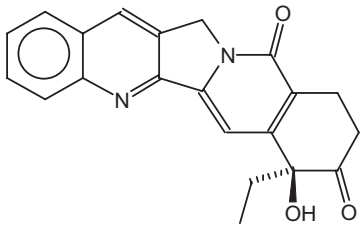

Camptothecin

Camptothecin and 10-methoxycamptothecin were isolated from leaves of *Ophiorrhiza mungos*; active against herpes virus (Tafur et al., 1976).

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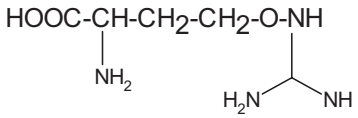

Canavanin

Canavanin inhibits influenza virus and Semliki Forest virus; isolated from *Carnavalia ensiformis* L. (Leguminosae) (Pilcher et al., 1955).

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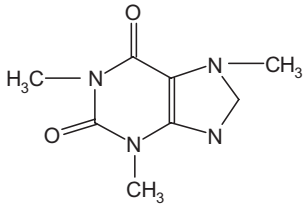

Caffeine

Caffeine suppressed the grown of Coxsackie-virus, Echonovirus, Herpes, Poliovirus, vaccinia and influenza virus; isolated from *Theobroma cacao* L. (Sterculiaceae) and *Coffea* sp. (Rubiaceae) (Yamazaki & Tagaya, 1980).

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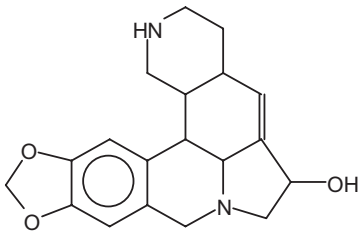

Caribine

The alkaloid caribine, found in *Hymenocallis arencola* (Amaryllidaceae), has antiviral activity (Manske & Brossi, 1987).

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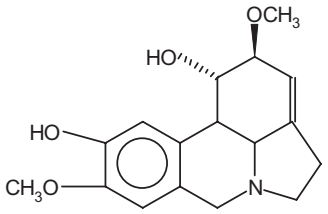

Carinatine

Found in the bulbs of *Zephyranthes carinata* (Armaryllidaceae); has an antiviral activity (Manske & Brossi, 1987).

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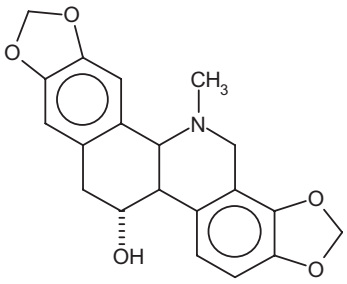

Chelidonine

Chelidonine is found in *Chelidonium majus* L. (Papaveraceae); has an effect on Herpes virus and is active against influenza virus (Manske & Brossi, 1987).

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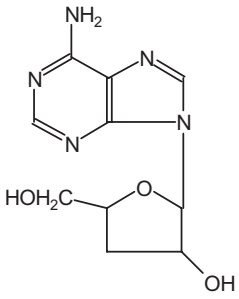

Cordycepin

Cordycepin is active against picornavirus, poliovirus, vaccinia, newcastle disease virus, Herpes simplex and influenza viruses; isolated from *Aspergillus nidulans* Eidam Wint. *Cordyceps militaris* (Kaij-a-Kamb et al., 1992).

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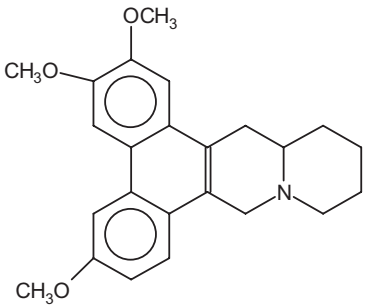

Cryptopleurine

Found in *Bochneria cylindrica* L. Sw. (Urticaceae) and *Cryptocarya pleurosperma* (Lauraceae); has antiviral activity against Herpes simplex type 1 (Cordell, 1981). and has extracellular virucidal activity (Manske & Brossi, 1989).

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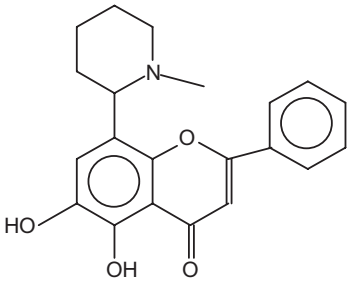

O-Demethyl-buchenavianine

The flavonoid alkaloid, *O*-demethyl-buchenavianine, isolated from *Buchenavia capitata*, produces partial protection against the cytopathic effect of HIV in cultured human lymphoblastoid cells (Vlietinck et al., 1997).

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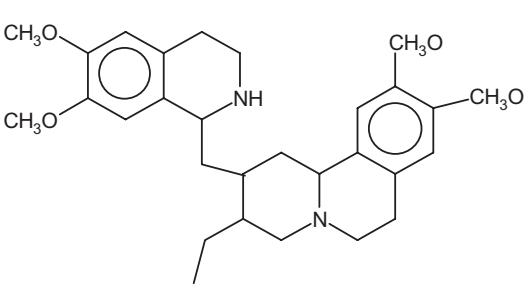

Emetine

Inhibits pseudorabies Semliki Forest and is active against Herpes virus; isolated from *Cephaelis ipecacuanha* A. Rich. (Rutaceae) (Hanish et al., 1966).

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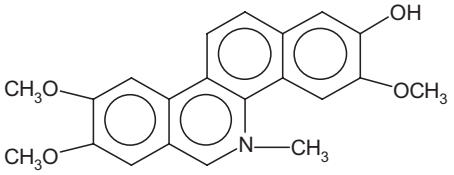

Fagaronine

Inhibits viral reverse transcriptase activity of retrovirus; isolated from *Fagara zanthoxyloides* Lam (Rutaceae) (Manske & Brossi, 1988).

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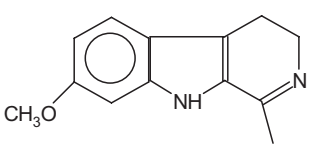

Harmaline

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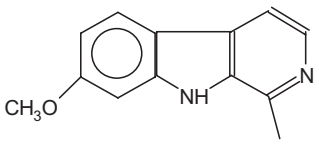

Harmine

Ocurrs in the seed of *Peganum harmala* (Zygophyllaceae). Harmine and harmaline were found to have antiviral effect against the DNA-containing herpes virus type 1 (HSV-1). The β-carboline alkaloids were not effective against RNA-containing influenza virus (Rashan, 1990).

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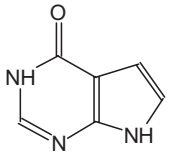

Hypoxanthine

Found in sugar beet, *Beta vulgaris* (Chenopodiaceae); has been used to treat viral diseases (Mifflin, 1981).

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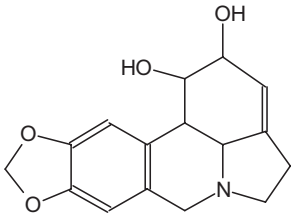

Lycorine

Lycorine, one of the principal alkaloids of the Amaryllidacea, exerts an antiviral effect on several RNA and DNA viruses; isolated from *Clivia miniata* (Amaryllidacea) (Leven et al., 1983).

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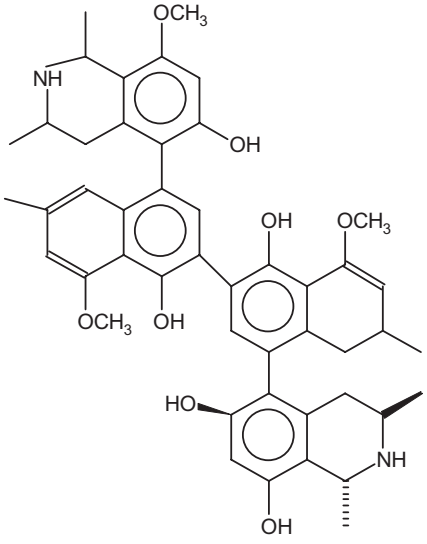

Michellamines D

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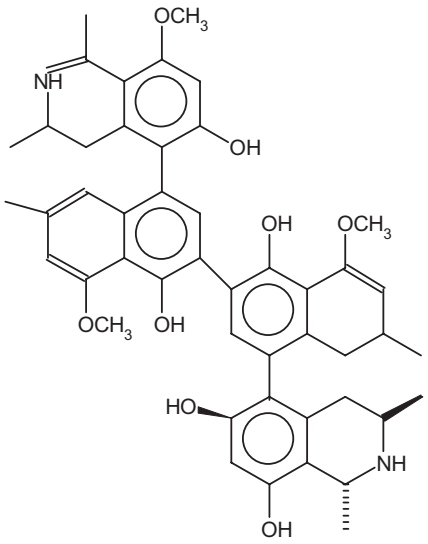

Michellamines F

The michellamines D and F, naphthyl-isoquinoline alkaloids, have been isolated from extracts of the tropical liana *Ancistrocladus korupensis* D. Thomas and Gereau (Ancistrocladaceae). Exhibited in vitro HIV-inhibitory activity (Halloch et al., 1997).

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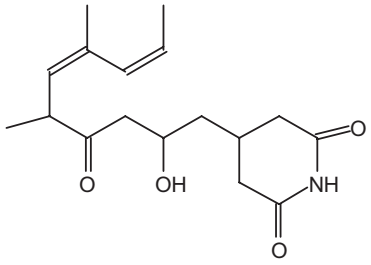

9-Methyl strptimidone

Is a secondary metabolite of *Streptomyces* species S-885 and is toxic to HeLa cells; has anti-polio activity at 0.02 µg/ml (Swallow et al., 1975).

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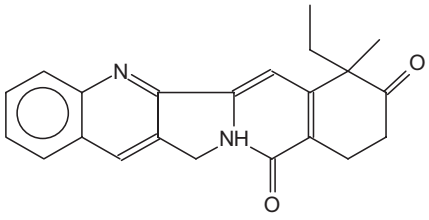
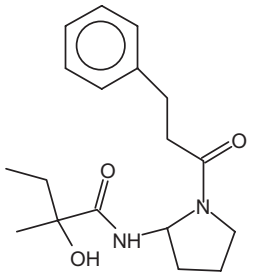


10-Methoxycamptothecin

This alkaloid was isolated from *Camptotheca acuminata* Descene (Nyssaceae); active against adenovirus, Herpes and vaccinia viruses. Produced inhibition of DNA and RNA synthesis (Clemens, 1977).

24



Odorinol

Odorinol, was isolated from *Aglaia roxburghiana* Miq. var. Beddomei (Meliaceae); active against Ranikhet disease virus (Phillipson & Zenk, 1980).

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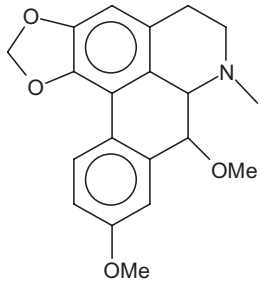

Oliverine

Found in *Polyathia oliveri*; acive against Herpes simplex virus type 1 (Montanha et al., 1995).

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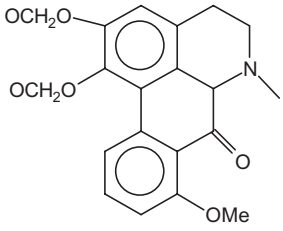

Oxostephanine

Found in *Stephania japonica*; acive against Herpes simplex virus type 1 (Montanha et al., 1995).

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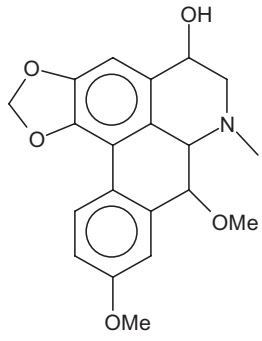

Pachystaudine

Found in *Pachypodanthium staudti*; acive against Herpes simplex virus type 1 (Montanha et al., 1995).

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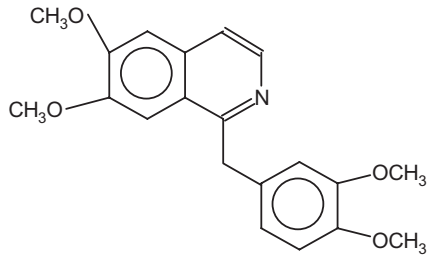

Papaverine

The benzylisoquinoline alkaloid papaverine has been shown to have a potent inhibitory effect on the replication of several viruses, including cytomegalovirus (CMV), measles and HIV. This compound found in the opium of *Papaver somniferum* (Papaveraceae) (Manske & Brossi, 1990).

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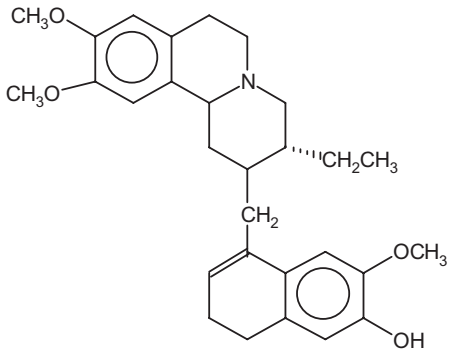

Psychotrine

Occurs in ipecacuanha root *Cephaelis acuminata* (Rubiaceae); active against HIV-1 (Manske & Brossi, 1985).

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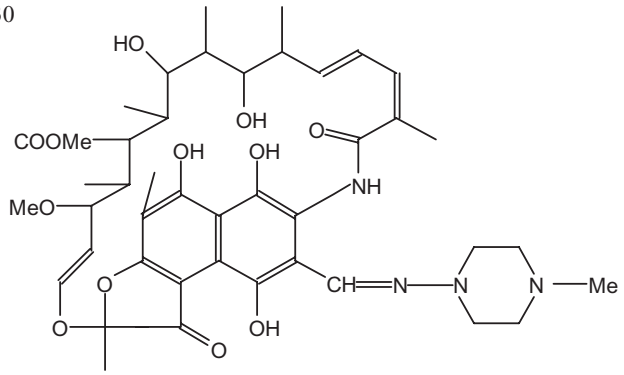

Rifampin

Produced by fermentation of *Streptomyces mediterranei*; active against vaccinia, pox, viruses (de Clercq, 1973).

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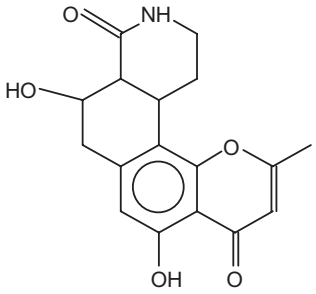

Schumannificine

This compound was isolated from the root bark of *Schumanniophyton magnificum*; activity against HIV and anti-Herpes simplex (anti-HSV) (Vlietinck et al., 1997).

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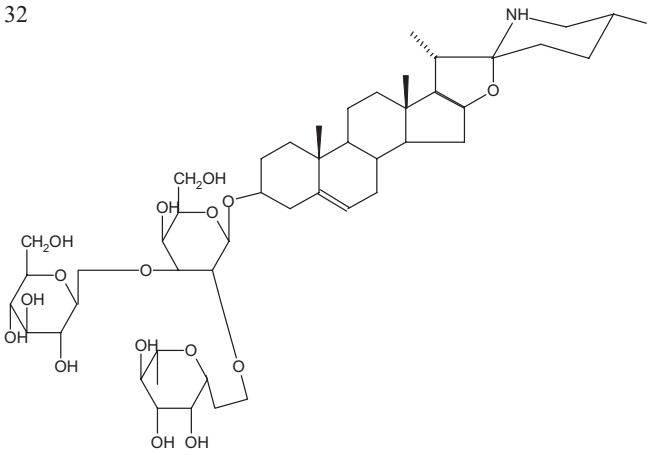
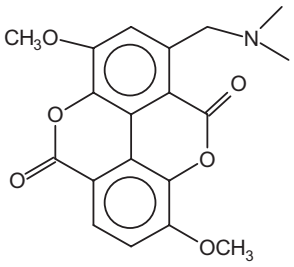


Solasonine

Solasonine is an steroidal glucoalkaloid isolated from the fruits of *Solanum nigrum* and *S. khasianum* (Solanaceae). Inhibited tobacco mosaic virus and sunnhemp rosette virus in inoculated test plants (Roychoudhury & Basu, 1983).

33



Taspine

Taspine inhibits RNA-directed DNA polymerase activity of avian myeloblastosis virus, Rauscher virus, and Simian sarcoma virus; isolated from *Croton lechleri* M. (Euphorbiaceae) (Manske & Brossi, 1990).

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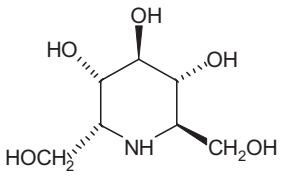

Homonojirimycin

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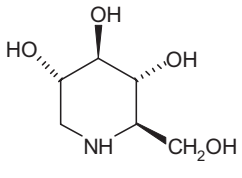

Deoxymanojirimycin

The alkaloids homonojirimycin and deoxymanojirimycin were isolated from *Omphalea diandra* (Euphorbiaceae). Homonojirimycin is an inhibitor of several α-glucosidases. Deoxymanojirimycin is an inhibitor of glycoprocessing mannosidase (Kite et al., 1988).

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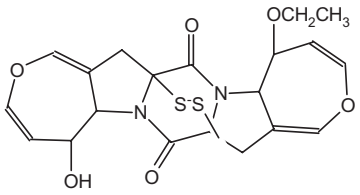

Aranotin

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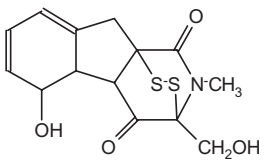

Gliotoxin

Aranotin and gliotoxin are inhibitors of coxsackievirus A 21, poliovirus, rhinovirus, influenza virus, para-influenza virus type 3; isolated from the *Arachniotus aureus* (Eidam) Schoeter and *Aspergillus terreus* (Becker, 1980; Miller et al., 1968).

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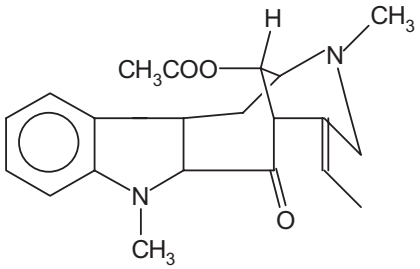
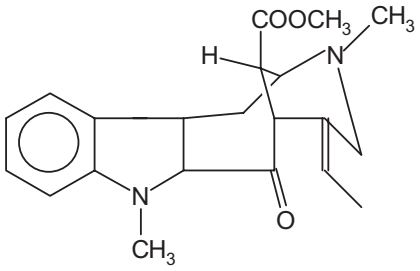


Ochropamine

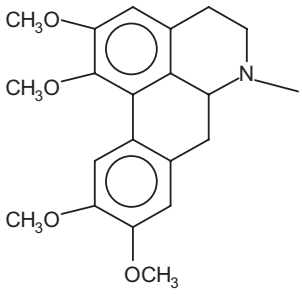
39



epi-16-Ochropamine

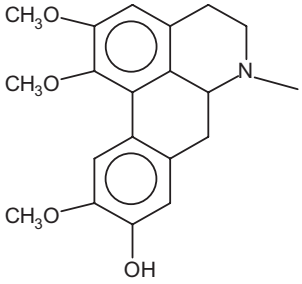
Active against influenza virus; isolated from *Cabucula erythrocarpa* Vatke Mar (Apocynaceae) (Manske & Brossi, 1990).

40



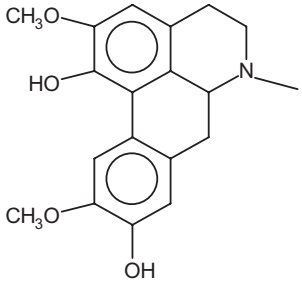
(+)-Glaucine fumarate

41



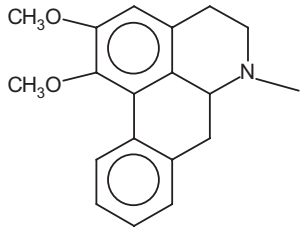
(+)-*N*-Methyllaurotetanine

42



(+)-Isoboldine

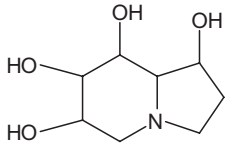
43



(−)-Nuciferine HCl

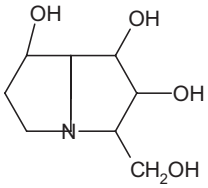
These aporphines were found to be active with selectivity indices >14, against Herpes simplex virus hominis type and RNA-picornaviridae (Boustie et al., 1998); found in 13 plant families, including *Corydalis cava, Glaucium flavum* (Papaveraceae), *Peumus boldo* (Momimiaceae).

44



Castanospermine

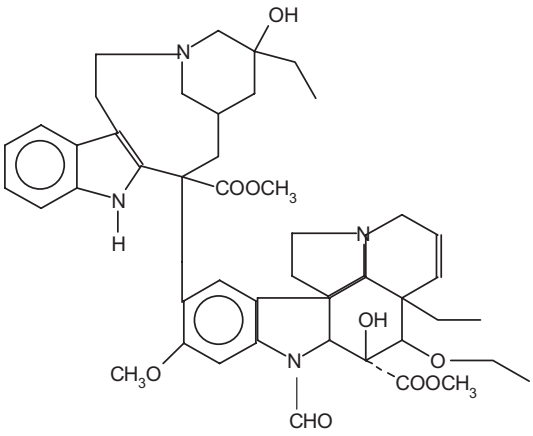
45



Australine

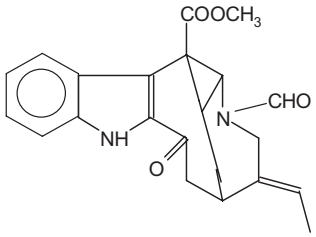
Castanospermine and australine are alkaloids found in seeds of *Castanospermum australe* (Leguminosae). Australian aborigenes use the seeds as food after soaking in water and roasting. Compounds reduce the ability of the human immunodeficiency virus (HIV) to infect cultured cells, and has potential for treating AIDS (Foder & Colasanti, 1985).

46



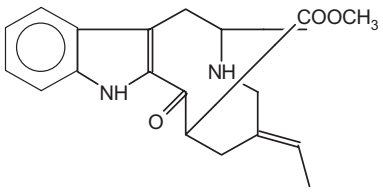
Leurocristina

47



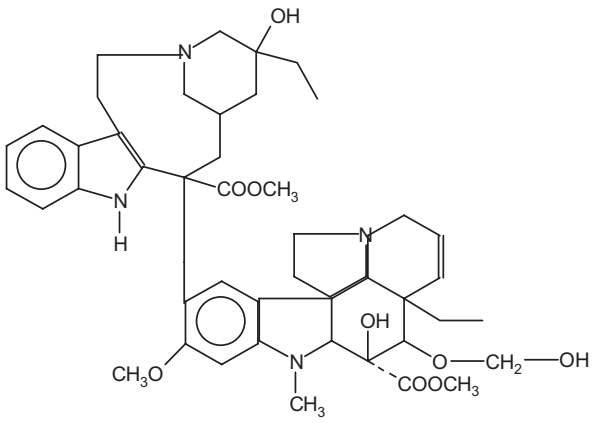
Periformyline

48



Perivine

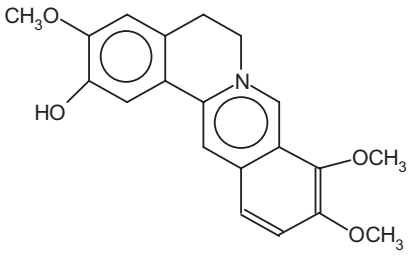
49



Vincaleucoblastine

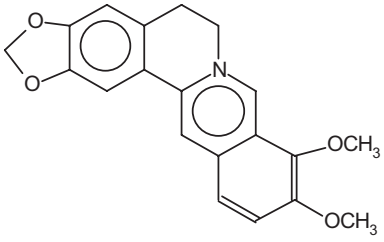
Four alkaloids were isolated from *Catharanthus roseus* L. G. Don. and *C. lanceus* Pich (Apocycaceae). Leurocristine is active against mengovirus extracellular virucidal, poliovirus, vaccinia, and influenza viruses (Farnsworth et al., 1968). Periformyline inhibits poliovirus type 3-Perivine is active against vaccinia, polio extracellular virucidal activity. Vincaleucoblastine possess extracellular virucidal activity against poliovirus vaccinia and influenza virus.

50



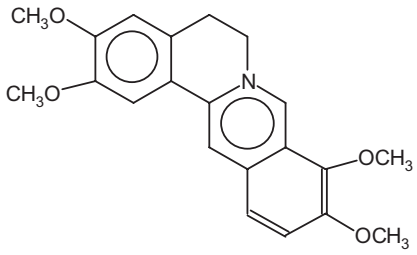
Columbamine

51



Berberine

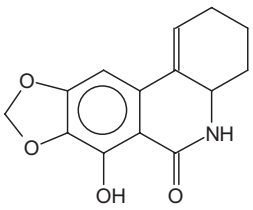
52



Palmitine

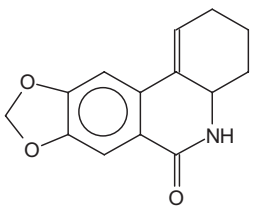
All these alkaloids are inhibitors against HIV-1; found in many plant families including Annonaceae (Coelocline), *Berberis vulgaris* (Berberidaceae) menispermaceae and Papaveraceae (Manske & Brossi, 1990).

53



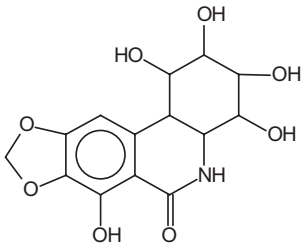
Narciclasine

54



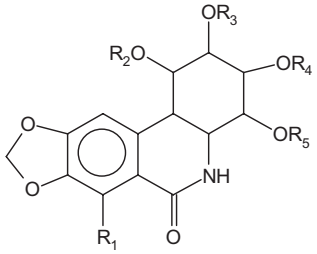
Lycoricidine

55



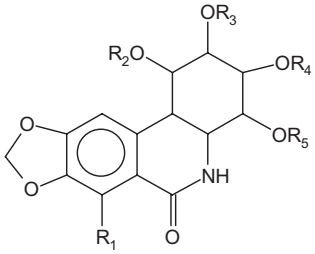
Pancratistatin

56



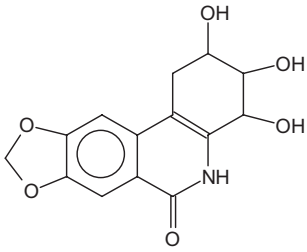
7-deoxypancratistatin

57



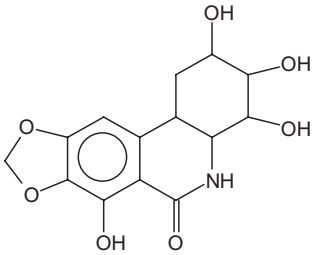
Acetatos
$R_1 = R_2 = R_4 = R_5 = H$,
$R_3 = Ac$
$R_1 = H$, $R_2 - R_5 = Ac$
$R_1 = R_2 = H$,
$R_3 = R_4 = R_5 = Ac$

58



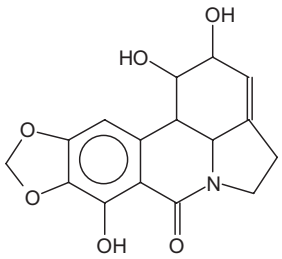
Isonarciclasine

59



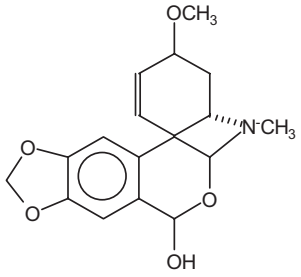
cis-Dihydronarciclasine

60



Lycorines

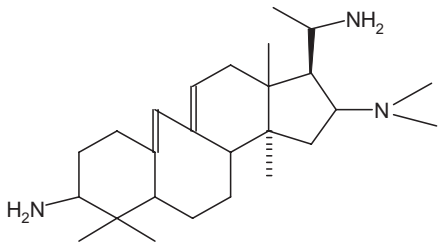
61



Pretazettine

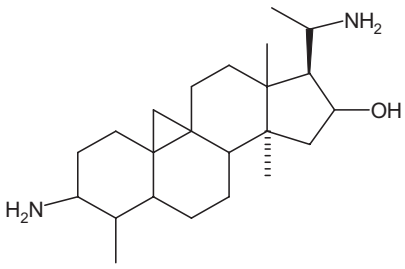
A series of isoquinoline alkaloids were isolated from *Narcissus poeticus* L. (Amaryllidaceae), exhibited consistent in vitro activity against flaviviruses and bunyaviruses (Gabrielsen et al., 1992). Lycorine was isolated from *Clivia mimiata* Regel (Amaryllidaceae). Poliomyelitis virus inhibition ocurred at 1 µg/ml (Ieven et al., 1982).

62



Buxamine E

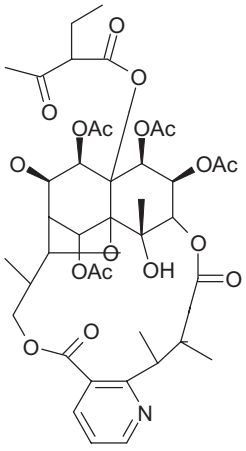
63



Cyclobuxamine H

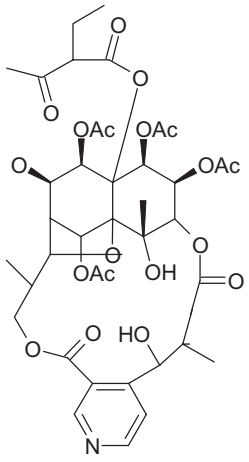
Occurs in *Buxus sempervirens*; shown to inhibit HIV-1 reverse transcriptase as well as TNF (Hiller, 1987).

64



Triptonines A

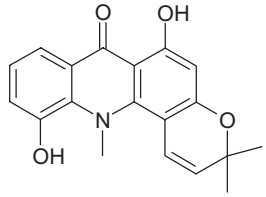
65



Triptonines B

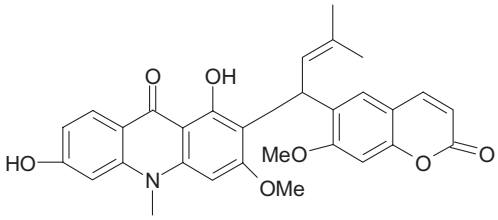
Sesquiterpene alkaloids were isolated from *Tripterygium hypoglaucum* and *Tripterygium wilfordii* (Celastraceae). These sesquiterpene pyridine alkaloids possesses Anti-HIV activity. The Triptonines B demonstrate potent anti-HIV with EC_{50} value of <0.10 µ/mL and an *in vitro* therapeutic value of >1000 (Duan et al., 2000).

66



5-hydroxynoracronycine

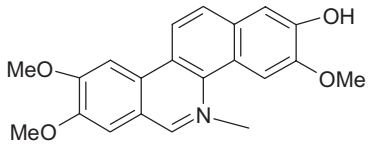
67



Acrimarine F

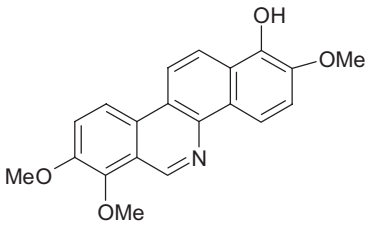
Acridone alkaloids were isolated from *Citrus* plants, showed remarkable inhibitory effects on Epstein-Barr virus activation (Takemura et al., 1995).

68



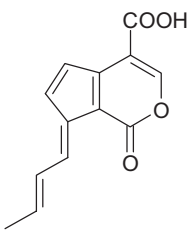
Fagaronine

69



Columbamine

70

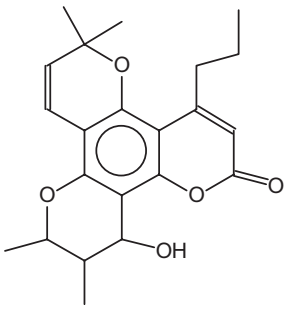


Fulvoplumierin

These compound are inhibitors of human immunodeficiency virus type 1 (HIV-1) reverse transcriptase. Found in *Plumeria rubra* L. (Apocynaceae) (Tan et al., 1991).

Coumarins

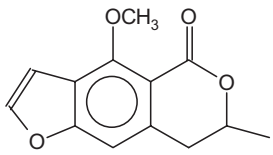
71



Calmolide A

Occur in the leaves of *Calophyllum lanigerum* (Gutiferae). It is active against HIV, (Murray et al., 1982).

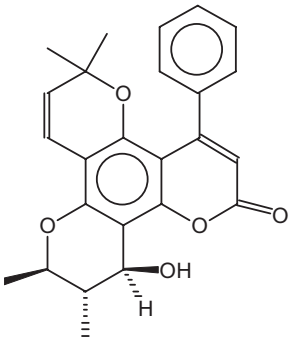
72



Coriandrin

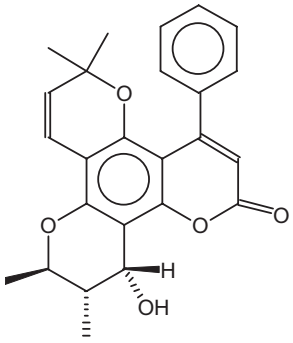
Found in *Coriandrum sativus.* It is active against HIV (Towers, 1989).

73



Inophyllum B

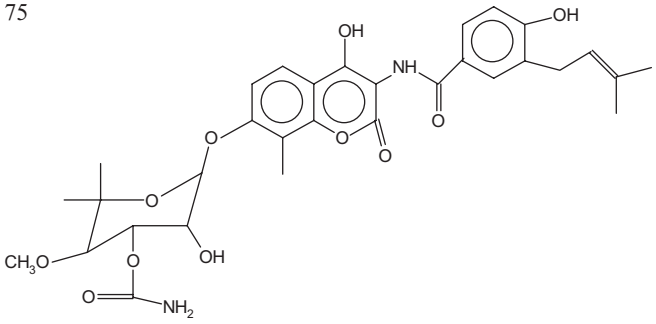
74



Inophyllum P

The coumarins inophyllum B and inophyllum P isolated from *Calophyllum inophyllum* Linn. (Guttiferae) were inhibitors of HIV-1 reverse transcriptase (Patil et al., 1993).

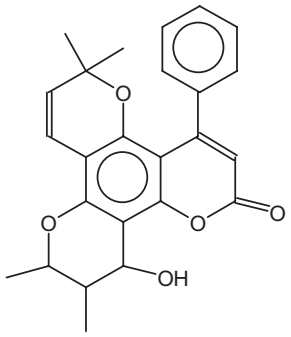
75



Novobiocin

Found in *Streptomyces spheroids* (Actinomycetales); has antiviral activity (Murray et al., 1982).

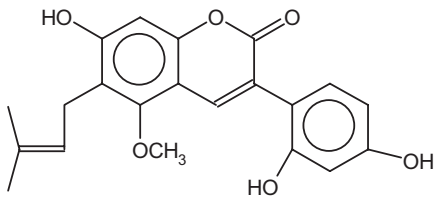
76



Soulatrolide

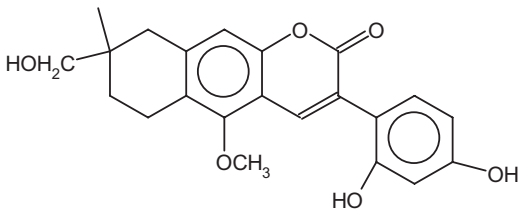
Occurs in the latex of *Calophyllum teysmanii* (Gutiferae); active against HIV (Murray et al., 1982).

77



Glycycoumarin

78

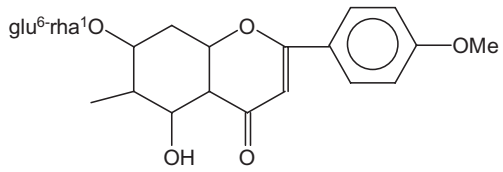


Licopyranocoumarin

Found in *Glycyrrhiza glabra* (Leguminosae). These compounds inhibit giant cell formation in HIV-infected cell cultures without any observable cytoxicity (Vlietinck et al., 1997).

Flavonoids

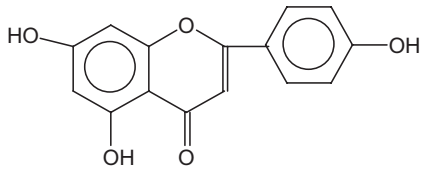
79



Acacetin 7-*O*-(6″-rhamnopyranosyl)β-D-glucopyranoside)

An active anti-HIV principle, acacetin 7-o-(6″-rhamnopyranosyl)β-D-glucopyra-noside), has been isolated from *Chrysanthemum morifolium* Ramar (Compositae) (Qi-hu et al., 1994).

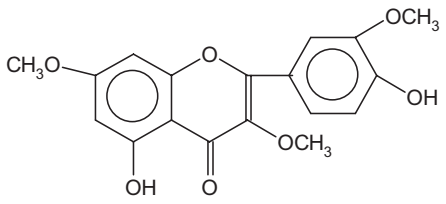
80



Apigenin

Widely distributed in the plant kingdom; active against Herpes virus (Beladi et al., 1977).

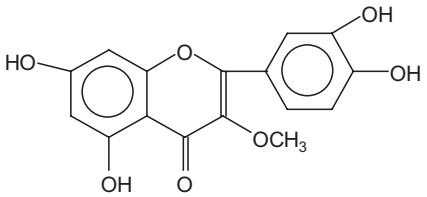
81



4′,5-Dihydroxy,3,3′,7-trimethoxyflavone

4′,5-Dihydroxy,3,3′,7-trimethoxyflavone, a potent anti-picornavirus agent, was isolated from Chinese medicinal herb, *Agastache rugosa* Kuntze (Labiadae) (Ishitsuka et al., 1982).

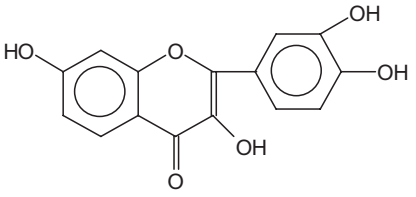
82



3,3′Dimethoxyquercetin

This methoxyflavone exhibiting remarkable activities against picornaviruses and vesicular stomatitis virus; isolated from *Euphorbia grantii* Oliv. (Euphorbiaceae) (Van Hoff et al., 1989) and *Veronia amygdalina* Del. (Compositae) (Rwangabo et al., 1986).

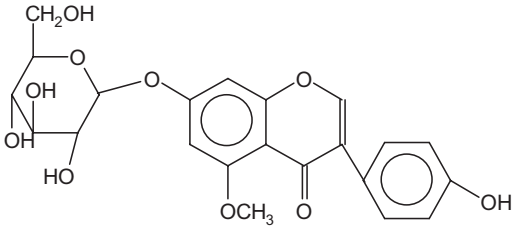
83



Fisetin

Fisetin was isolated from *Rhus* spp. (Anacardiaceae), inactivates pseudorabies virus (Beladi et al., 1977).

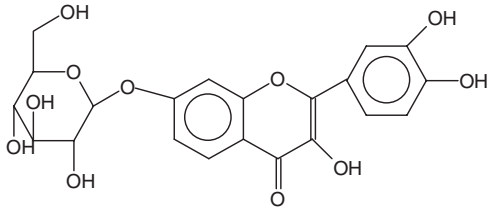
84



O-Glucosyl-7-methyl-5-genistein

Occurs in *Ulex europaeus* L. (Leguminosae); active against herpes virus (Swallow et al., 1975).

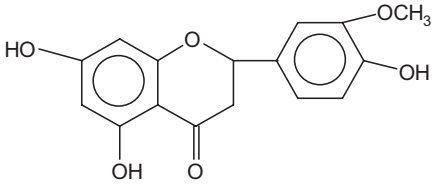
85



Glycosil-7-*O*-luteolin

An antiviral substance against herpes and poliomelytis viruses was isolated from *Matricaria inodora* L. (Compositae) methanol extract and shown to have the structure glycosil-7-*O*-luteolin (Suganda et al., 1984).

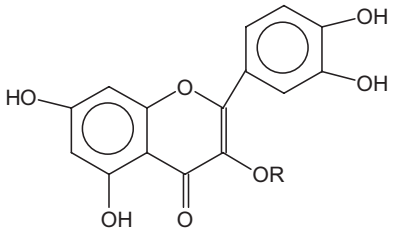
86



Hesperetin

Occurs in *Citrus* spp. (Rutaceae) predominant in lemons and sweet oranges; weak activity against vesicular stomatitis virus (Harborne, 1988).

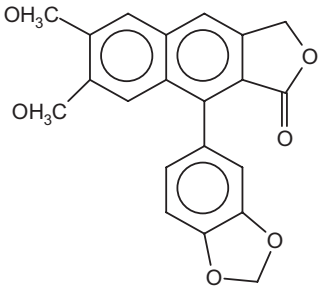
87



Isoquercitrin

The antiviral agent isoquercitrin was isolated from *Waldsteinia fragarioides* Michx. (Rosaceae); activity against Herpes simplex type 1 virus (Karam & Shier, 1992).

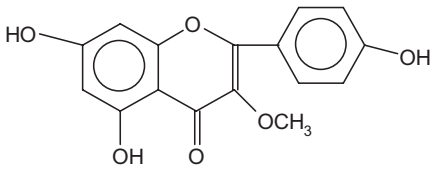
88



Justicidin B

Found in *Phyllanthus acuminatus* (Euphorbiaceae); antiviral activity against murine, cytomegalovirus and Sindbis virus (Inghman, 1983).

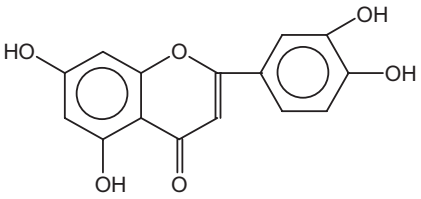
89



Kaemferol 3-methyl ether; Isokaempferide

Found in *Solanum sarrachoides* (Solanaceae); antiviral activity (Harborne, 1988).

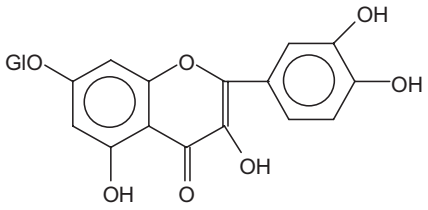
90



Luteolin

Luteolin is widely distributed in the plant kingdom; activity against pseudorabies virus (Beladi et al., 1977).

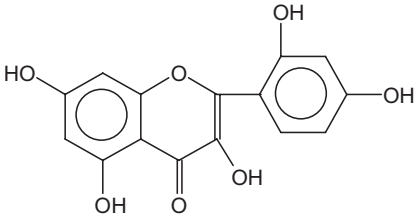
91



Luteolin-7-*O*-glucoside

The flavone, luteolin–7-*O*-glucoside was isolated from *Matricaria inodora* L. (Compositae); active against herpes virus and poliovirus (Beladi et al., 1977).

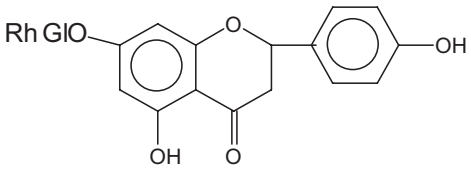
92



Morin

The flavone, morin, was isolated from *Chlorophora tinctoria* L. Gaud (Moraceae); activity against pseudorabies virus (Beladi et al., 1977).

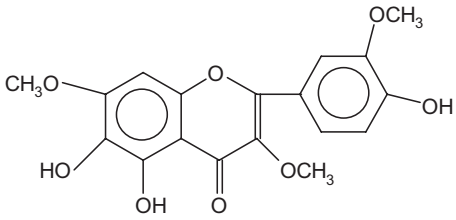
93



Naringin

Naringin; weak activity against vesicular stomatitis virus; isolated from *Citrus paradisi* Macfad. (Rutaceae) (Wacker & Eilmes, 1978).

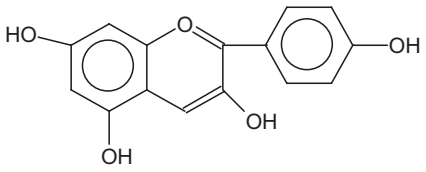
94



Pachypodol

Pachypodol (quercetin 3,7,3′-trimethyl ether) was isolated from *Begonia glabra* (Begoniaceae); antiviral activity (Cody et al., 1986).

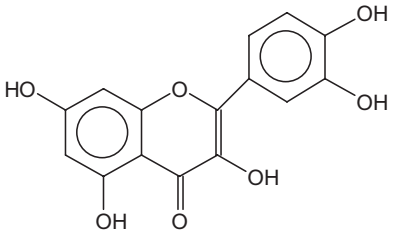
95



Pelargonidin

Pelargonidin, virucidal for several enveloped viruses; isolated from *Pelargonium* sp. (Geraniaceae) (Beladi et al., 1977).

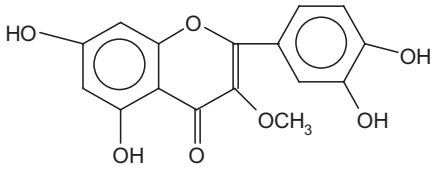
96



Quercetin

Infectivity of potato virus X (PVX) was strongly inhibited (80%) by a low concentration (<1 μg/ml^{-1}) of quercetin isolated from *Chenopodium quinoa* (Quenopodiaceae) (French & Towers, 1992).

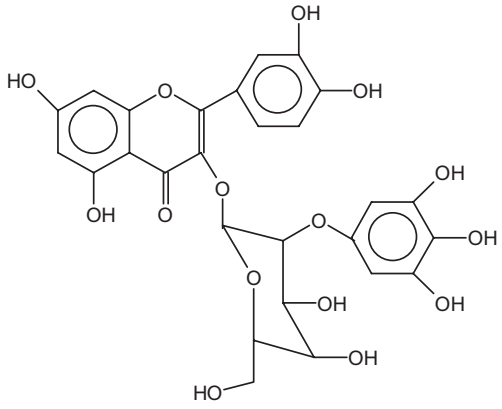
97



Quercetin 3-methyl ether

Found as the aglycone in the leaves of Compositae and other families; antiviral activity (Cody et al., 1986).

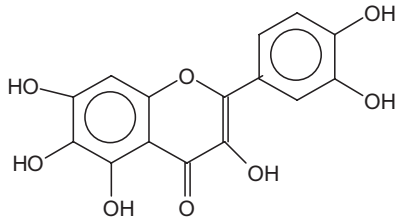
98



Quercetin 3-*O*-(2″-galloyl)-β-D-galactopyranoside

From an ethyl acetate extract of the leaves of *Acer okamotoanum* Nakai (Aceraceae) was isolated a flavonol glycoside gallate ester [quercetin 3-*O*-(2″-galloyl)-β-D-galactopyranoside]; inhibits HIV-1 integrase (Kim et al., 1998).

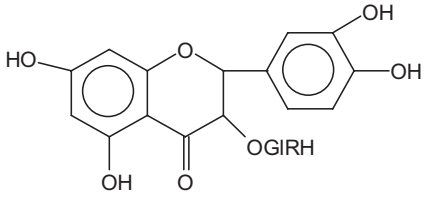
99



Quercetagetin

Found in the flowers of many spp. of Compositae; shown to inhibit in vitro RTs of certain retroviruses including Rauscher murine leukemia (RLV) and HIV, as well as cellular DNA polymerases (Cody et al., 1986).

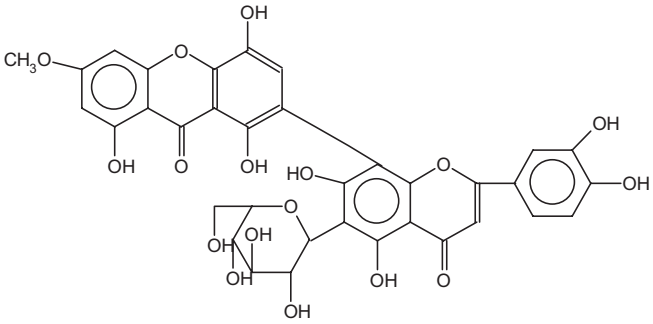
100



Rutin

Found in many plants, especially *Fagopyrum esculentum* Moench (Polygonaceae); virucidal for pseudorabies; weak activity against vesicular stomatitis virus (Beladi et al., 1977).

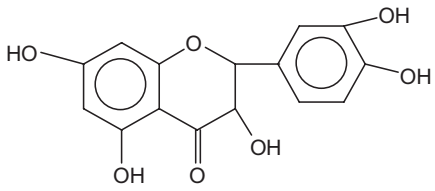
101



Swertifrancheside

This flavonone-xanthone, isolated from the lichen *Swertia franchetiana*, is a potent inhibitor of the DNA polymerase activity of human immunodeficiency virus-1 reverse transcriptase (HIV-1 RT) (Pengsuparp et al., 1995).

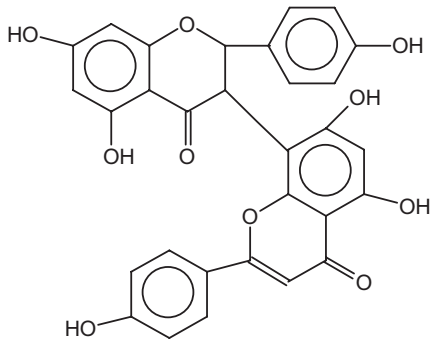
102



Taxifolin

Widespread occurence in many Coniferae; in *Acacia catechu* (Leguminosae); antiviral activity (Harborne, 1988).

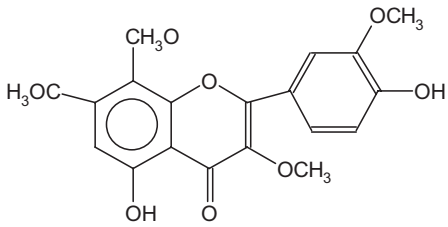
103



Volkensiflavone

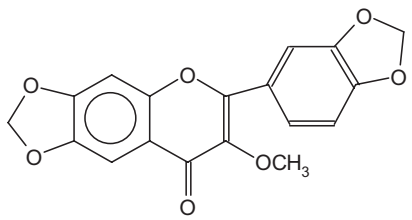
Found in *Rhus succedania* L. (Anacardaceae); active against influenza B virus (Lin et al., 1997; Lin et al., 1999).

104



Ternatin

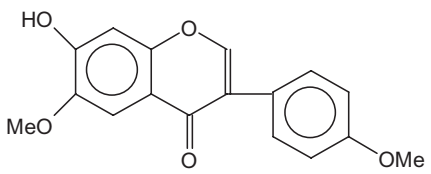
105



Melaternatin

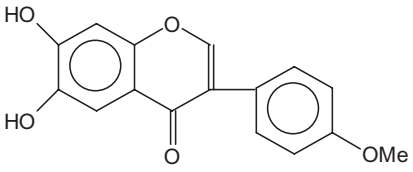
Two 3-methoxyflavones isolated from the *Evodia madagascariensis* Baker (Rutaceae), ternatin and meliternatin; inhibited the cytopathic effect caused by HSV-1, HSV-2, adenovirus type 2, poliovirus type 2 and VSV type 2 and reduced the viruses infectivity on the multistep virus replication (Simoes et al., 1990).

106



Afromosin

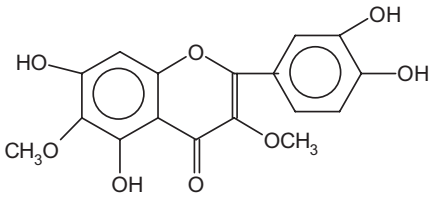
107



Formononetin

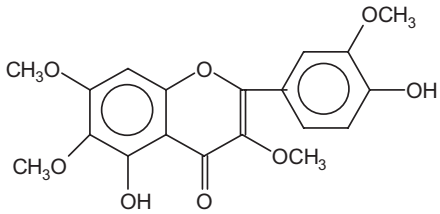
The isoflavonoids afromosin and formononetin were isolated from *Wisteria brachybotrys* Sieb (Leguminosae); significant inhibitory effects on the Epstein-Barr virus early antigen (EBV-EA) activation (Konoshima et al., 1989).

108



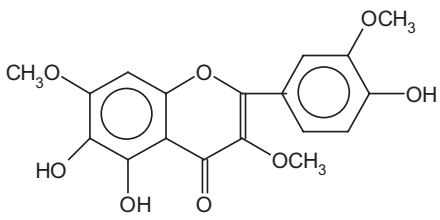
Axillarin

109



Chrysosphenol B

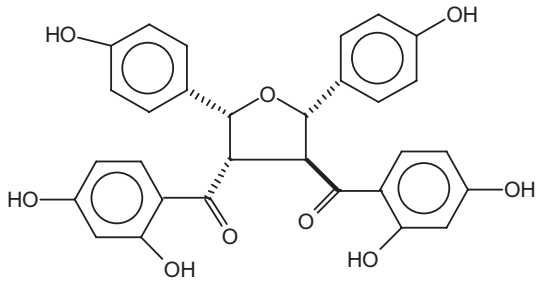
110



Chrysosplenol C

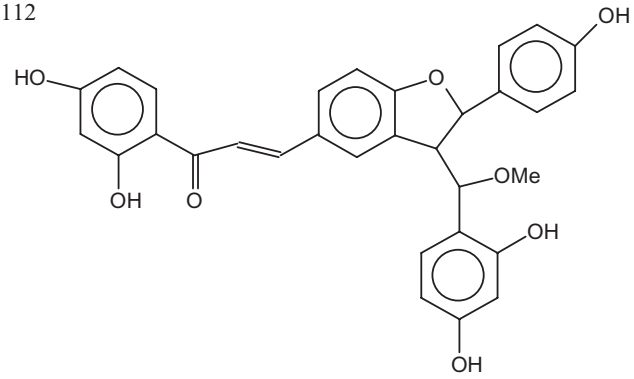
Axillarin, chrysosplenol B and chrysosplenol C are contained in *Chrysosplenium tosaense* (Saxifragaceae); antiviral activity, especially against rhinovirus (Tsuchiya et al., 1985).

111



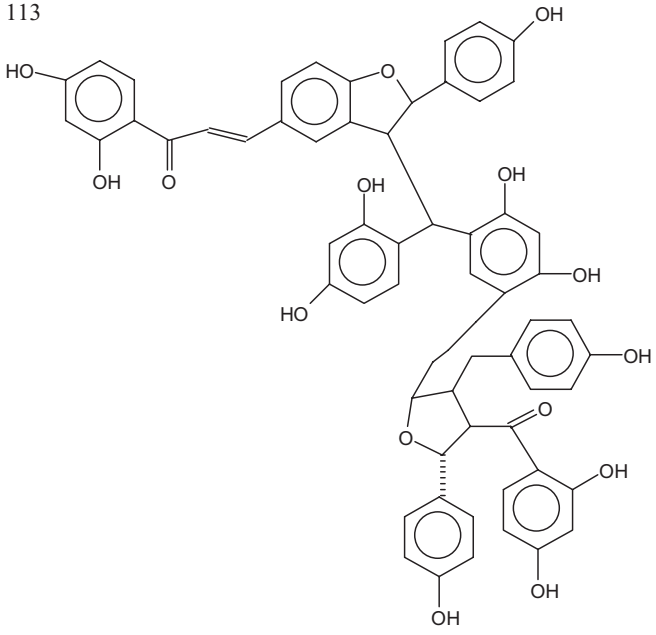
Lophirone F

112



Azobechalcone

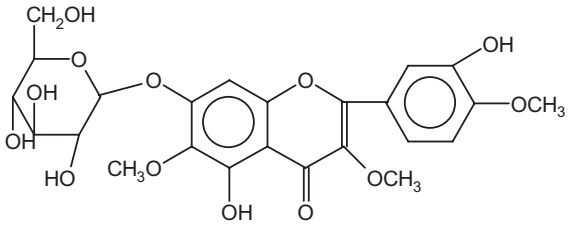
113



Isolophirachalcone

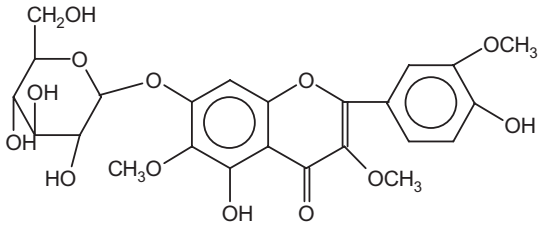
Three flavonoids were isolated from *Lophira alata* (Orchnaceae); inhibitory activity against Epsein-Barr virus (EBV) early antigen (EA) induction test (Murakami et al., 1992).

114



Centaurein

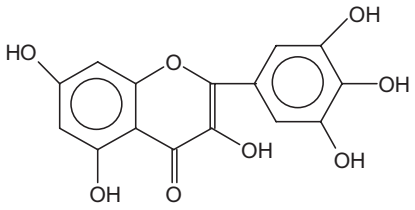
115



Jacein

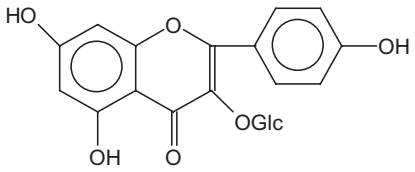
Found in *Centaurea nigra* L. (Compositae); antiviral activity on herpes virus and poliovirus (Kaij-a-Kamb et al., 1992).

116



5,7,3,3′,4,5-Hexahydroxyflavone

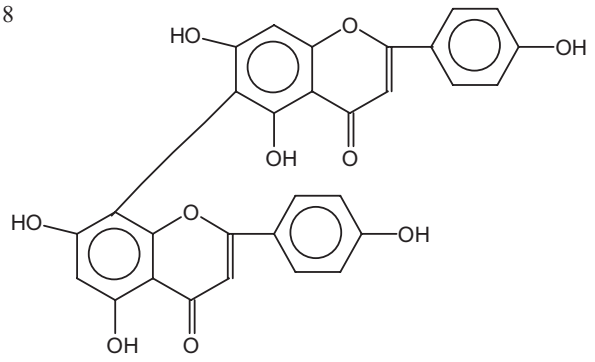
117



5,7,4′-Trihydroxy-3-glycosylflavone

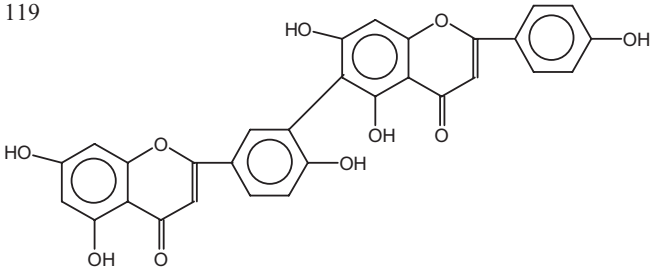
These flavones caused inhibition of HIV-1 infection at non-toxic concentrations; isolated from *Befaria cinnamomea* (Ericacea) (Mahmood et al., 1993).

118



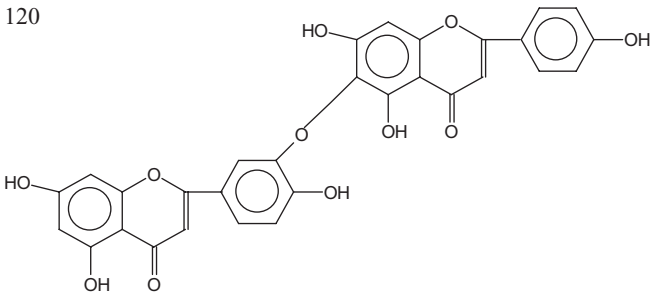
Agathisflavone

119



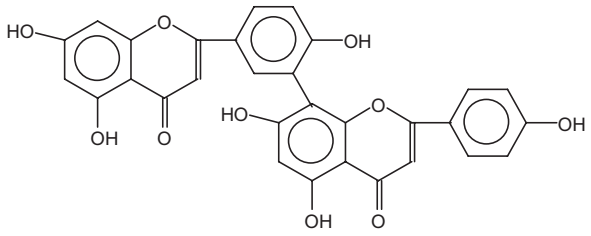
Robustaflavone

120



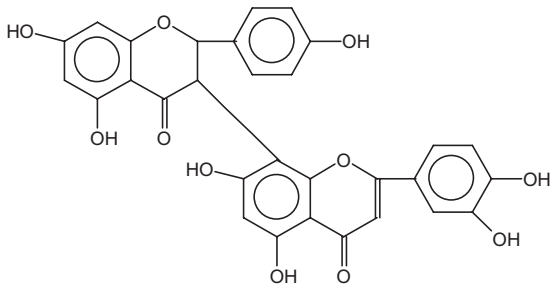
Hinokiflavone

121



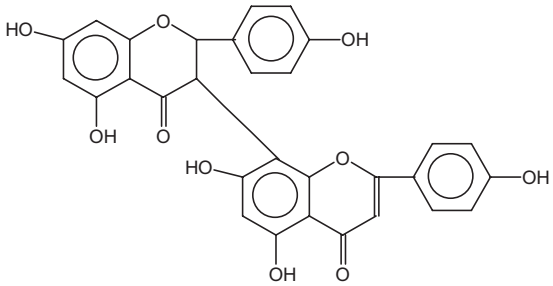
Amentoflavone

122



Morelloflavone

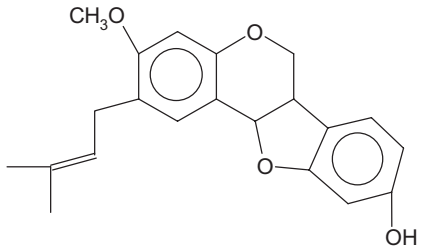
123



GB1-a

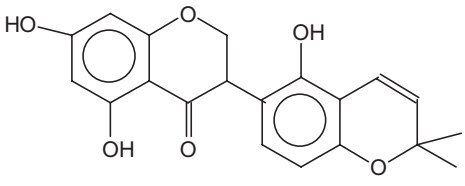
Biflavonoids robustaflavone and hinokiflavone have activity against HIV-1 reverse transcriptase (RT), with IC_{50} values of 65 µM. The other compounds were moderately active against HIV-1; isolated from *Rhus succedanea* L. (Anacardiaceae) and *Garcinia multiflora* Champ (Guttiferae) (Lin et al., 1997).

124



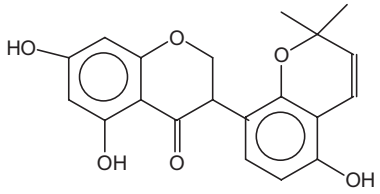
3-*O*-Methylcalopocarpin

125



Licoisoflavanone

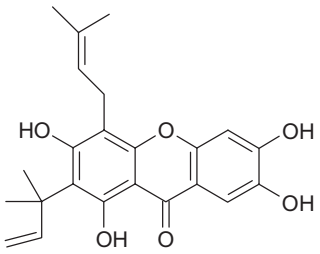
126



Glyasperin

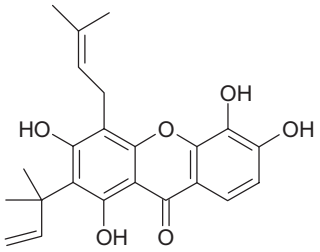
Found in *Erythrina lysistemon* Hutch (Leguminosae). These compounds were active against HIV (McKee et al., 1997).

127



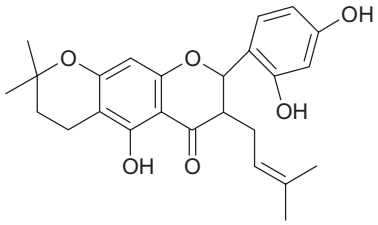
Macluraxanthone B

128



Macluraxanthone C

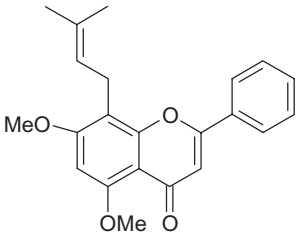
129



Dihydrocudraflavone B

HIV-inhibitory prenylated xanthones and flavones from *Maclura tinctoria* known as "Osage orange". These xanthones and flavones were moderately active against HIV-1 (Groweiss et al., 2000).

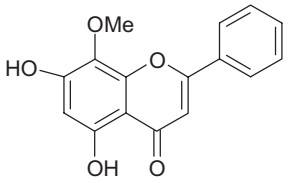
130



7-*O*-Methyl-glabranine

Found in *Tephrosia madrensis*; has antiviral effect on the dengue virus (Sanchez et al., 2000).

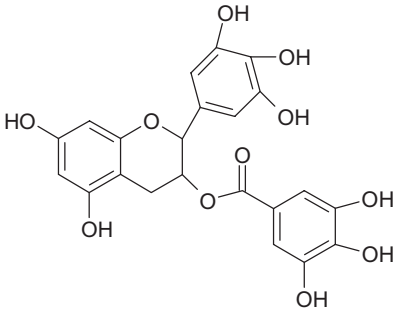
131



Wogonin

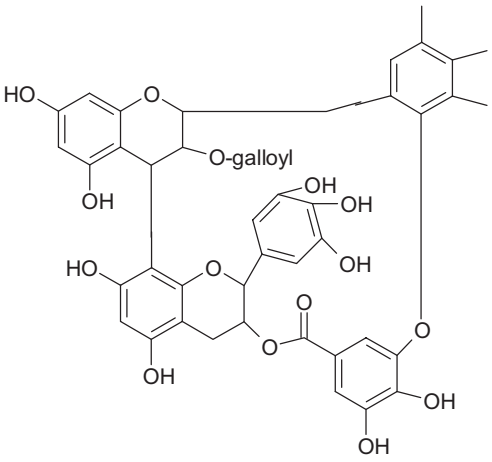
Wogonin was isolated from *Scutellaria baicalensis* (Labiatae), and can suppress HBV surface antigen production without evidence of cytotoxicity. The relaxed circular and the linear forms of HBV DNA are significantly reduced in the wogonin-treated group (Huang et al., 2000).

132



Samarangenin B

133

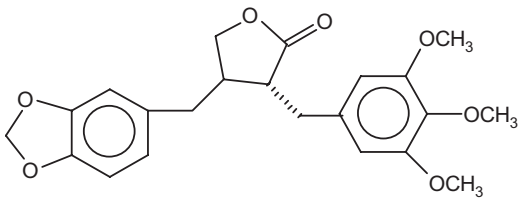


Myricetin

Flavonoids and a new flavanone were isolated from the root of *Limonium sinense* (Plumbaginaceae). Both compounds exhibited potent inhibitory activities in HSV-1 replication (Lin et al., 2000).

Lignans

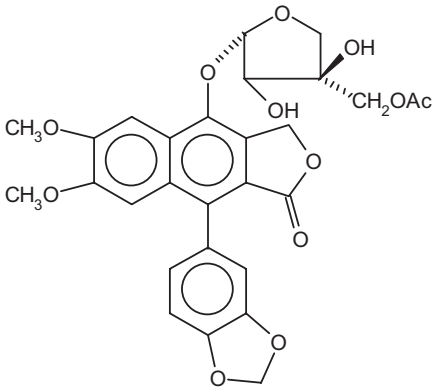
134



Dihydroanhydropodorhizol

Occurs in the leaves and stems of *Bursera schletchtendalii* (Burseraceae); weak antiviral activity against Herpes simplex type-1 (Ayres & Loike, 1990).

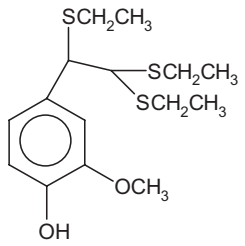
135



Diphyllin apioside-5-acetate

The lignans justicidin A and B, diphyllin, diphyllin apioside and diphyllin apioside-5-acetate were isolated from aerial parts of *Justicia procumbens* var. *leucantha* (Acanthaceae); strong antiviral activity against vesicular stomatitis virus and low cytotoxicity against rabbit lung cells (RL-33) (Asano et al., 1996).

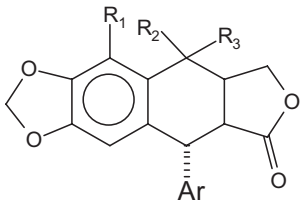
136



Lignine guaiacyl derivative

Found in *Pinus nigra* Arnold (Pinaceae); anti-HIV activity (Eberhardt & Young, 1996).

137



$R_1 = R_2 = R_3 = H$
Deoxypodophyllotoxin

138 $R_1 = R_2 = H, R_3 = OH$
4′-Dimethylpodophyllotoxin

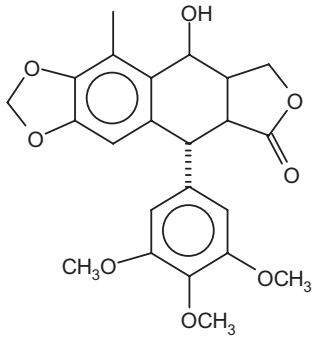
139 $R_1 = R_2 = H, R_3 = OAc$
Podophyllotoxin acetate

140 $R_1 = H, R_2 = OAc, R_3 = H$
Epidophyllotoxin acetate

141 $R_1 = OMe, R_2 = R_3 = H$
β-Peltatin A methyl ether

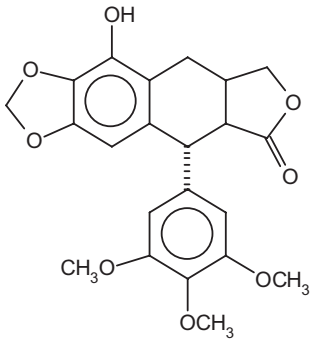
Five cyclolignans were isolated from *Juniperus sabina* (Cupressaceae); antiviral assays were performed on Herpes simplex virus type infecting fibroblasts of monkey kidney (HSV-1/CV-1) and on vesicular stomatitis virus infecting fibroblasts of hamster kidney (VSV/BHK). All the *trans*-tetralinelactones showed an antiviral effect (Feliciano et al., 1993).

142



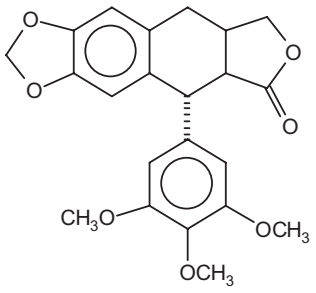
Podophyllotoxin

143



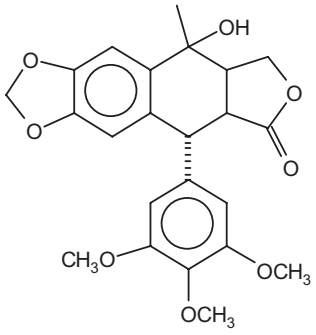
β-Peltatin

144



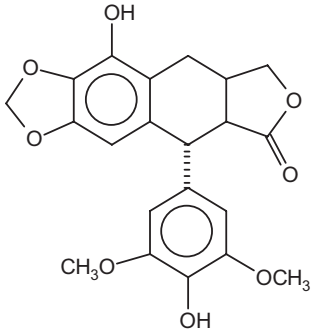
Deoxypodophyllotoxin

145



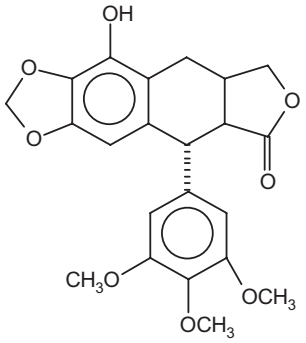
Picropodophyllotoxin

146



α-Peltatin

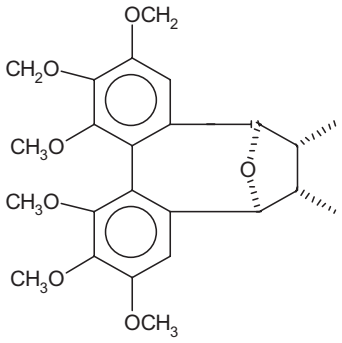
147



β-Pelatin

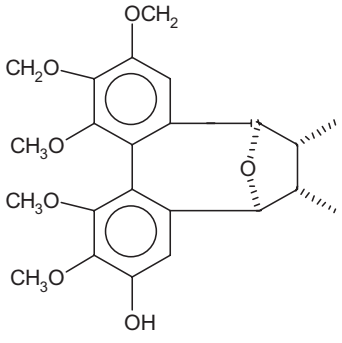
The antiviral activity of an aqueous extract of *Podophyllum peltatum* (Berberidaceae) was investigated. The extract was fractionated and podophyllotoxin was found to be the most active component in inhibiting the replication of measles and Herpes simplex type 1 viruses (McKee et al., 1997). α- and β-Pelatin were also isolated from *Podophyllum peltatum* L. These compounds have moderate activity against Herpes virus, measles (Bedows & Hatfield, 1982).

148



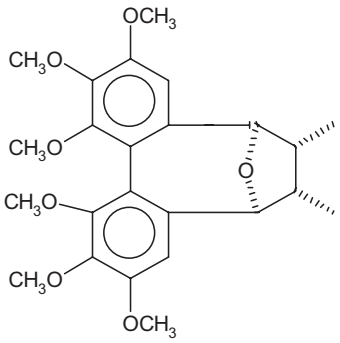
Kadsulignan L

149



Kadsulignan M

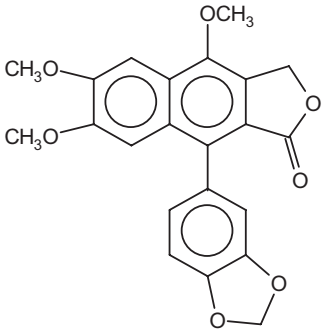
150



Kadsulignan N

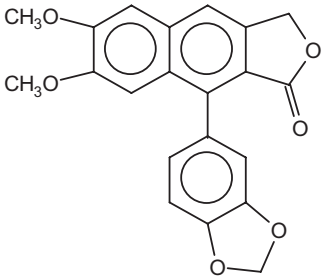
These lignans were isolated from the seeds of *Kadsura coccinea* (Schisandraceae); anti-HIV activity in vitro (Liu & Li, 1995).

151



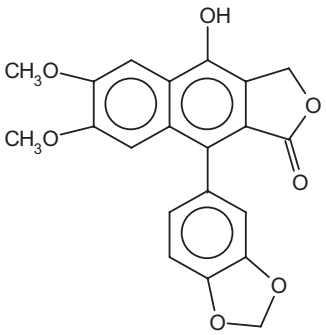
Justicidins A

152



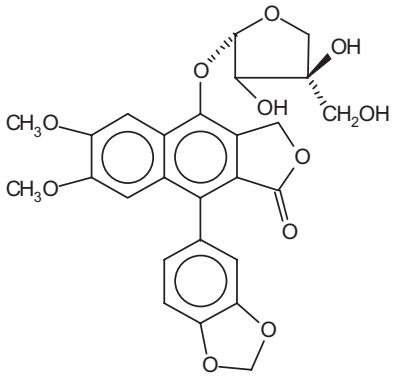
Justicidins B

153



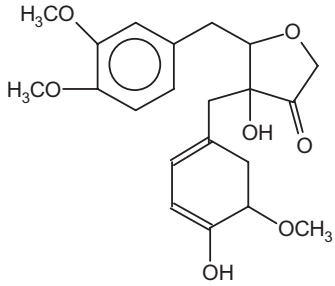
Diphyllin

154



Actigenin

155

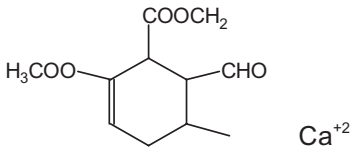


Trachelogenin

These lignanolides of the dibenzylbutyrolactone type were isolated from *Forsythia intermedia* and *Ipomoea cairica* (Convolvulaceae), respectively; shown to inhibit replication of HIV-1 in infected human cell systems (Vlietinck et al., 1998).

Miscellaneous compounds

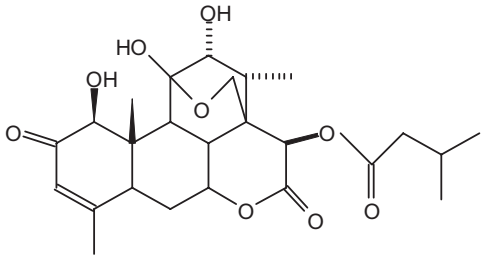
156



Calcium elenolate

Found in *Olea europaea* L. (Oleaceae); exhibit in vitro antiviral activiy against viruses (Swallow et al., 1975).

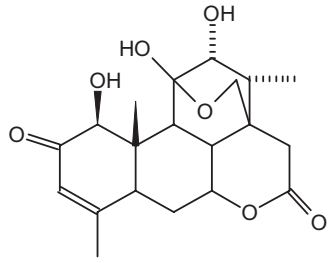
157



Castelanone

Castelanone is a nortriterpenoid with a quassinoid skeletal type occurs in the root bark of *Castela tweediei* (Simaroubaceae); exhibits in vitro antiviral activiy against the oncogenic Rous sarcoma virus (Rembold, 1989).

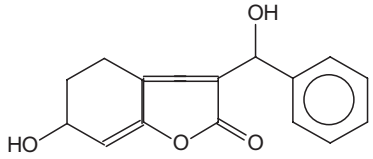
158



Chaparrinone

Found in the seeds of *Quassia undulata* (Simaroubaceae); exhibits *in vitro* antiviral activiy against the oncogenic Rous sarcoma virus (Rembold, 1989).

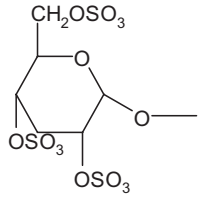
159



Cochinolide

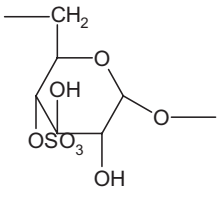
A γ-alkylidene bicyclic butenolide designated as cochinolide was isolated from the root bark of *Homalium cochinchinesis* (Flacoutiaceae); moderate antiviral activities against HSV-1 and -2 (Ishikawa et al., 1998).

160



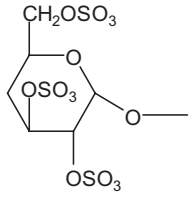
Curdlan sulphate

161



Dextran sulphate

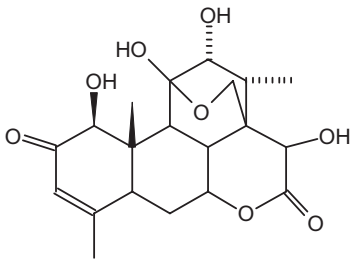
162



Dextrin sulphate

Various sulphated polysaccharides have been found to be the anti-HIV active substances of many antivirally active plant extracts. Dextran sulphate occurs in *Viola yedoensis* (Violaceae). Dextrin sulphate was isolated from *Prunella vulgaris* and Curdlan sulphate from *Alternanthera philoxeroides* (Amarantaceae). The inhibitory effect on viral binding, viral replication and syncytium formation appear to be mediated by a specific interaction with the V3 region of gp 120 (Vlietinck et al., 1998).

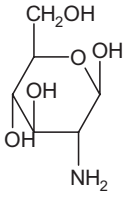
163



Glaucarubolone

Found in the seeds of *Quassia simarouba* (Simaroubaceae); exhibits in vitro antiviral activiy against the oncogenic Rous sarcoma virus (Rembold, 1989).

164



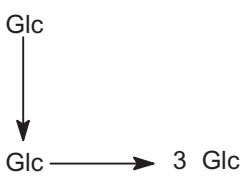
D-glucosamine

Glucosamine inhibited the formation of infectious fowl plague, Sindbis and Semliki Forest virus. Affect glycolipid and glycoprotein synthesis of enveloped virus, has effect on RNA viruses, HSV, pox virus, NDV-inhibits para influenza 3, RDV, measles. The glucosamine was isolated from *Dahlis* sp. (Compositae), *Glycine max* (L.) Merr (Leguminosae) and *Phaeseolus aureus* Roxb. (Leguminosae) (Kaluza et al., 1972).

165

Glucans 1

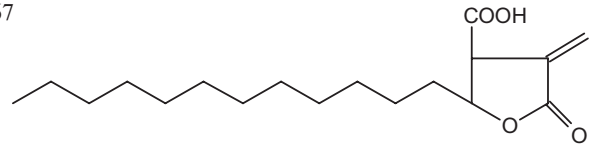
166



Glucans 2

Found in *Nicotania tabacum* (Solanaceae), exhibit inhibition of the initiation of virus infection on *Nicotania tabacum* (Rouhier et al., 1995).

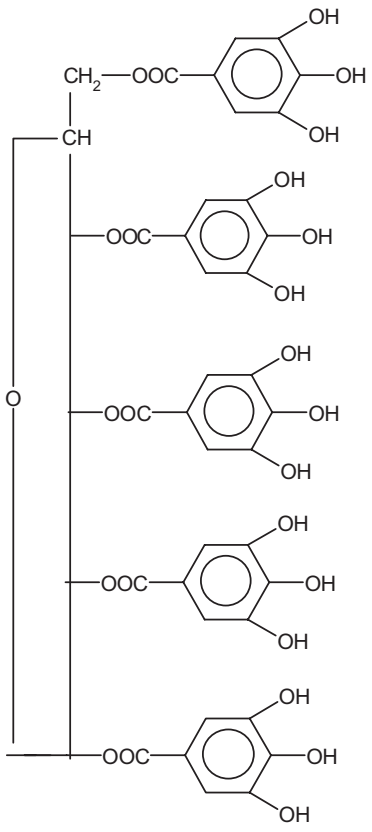
167



α-Methylene-γ-lactone

This lactone isolated from the lichen *Cetraria islandica*, is a potent inhibitor of the DNA polymerase activity of human immunodeficiency virus-1 reverse transcriptase (HIV-1 RT) (Pengsuparp et al., 1995).

168

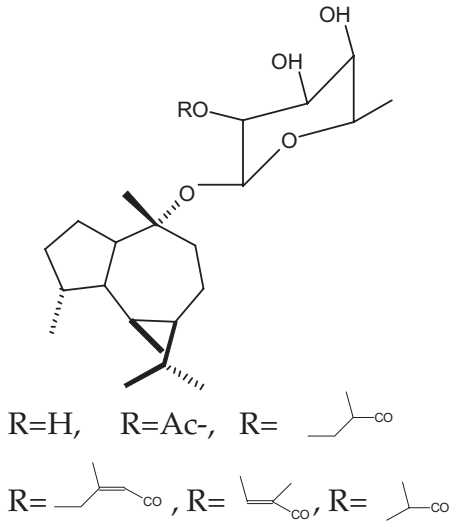


Pentagalloylglucose

Found in *Paeonia albiflora* Pallas (Paeoniaceae); active against Herpes virus (Kaij-a-Kamb et al., 1992).

Monoterpenoids, diterpenoids and sesquiterpenoids

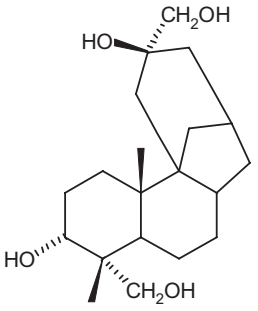
169



Alloaromadendrol glycosides

The six sesquiterpene glycosides, based on the alloaromadendrane skeleton, were isolated from *Calendula arvensis* L. (Compositae); active against two RNA-viruses: a minus-strand RNA virus, vesicular stomatitis virus (VSV), and a plus-strand RNA virus, rhinovirus (HRV type 1B). The compounds were found to be active mainly against VSV (Tommasi et al., 1990).

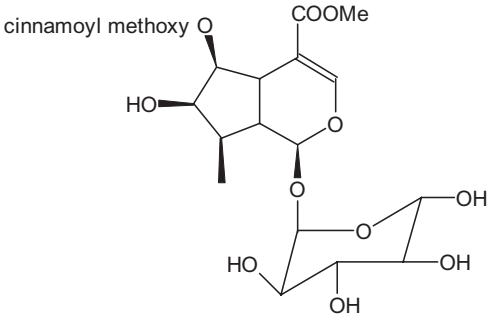
170



Aphidicolin

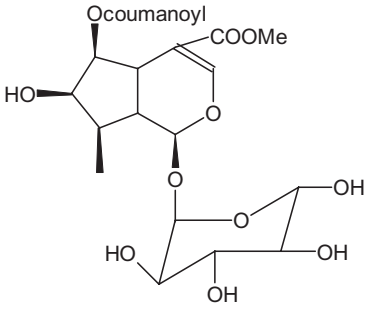
Aphidicolin is an diterpene isolated from the fungus *Cephalosporium aphidicola*; inhibition of Herpes simplex strains 1 and 2 (Hanson, 1972).

171



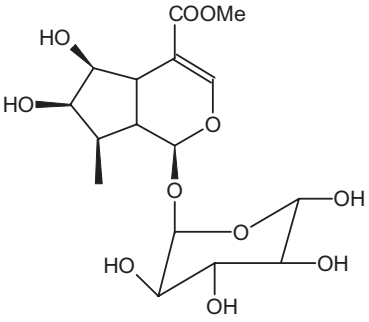
Arbotristosides A

172



Arbotristosides B

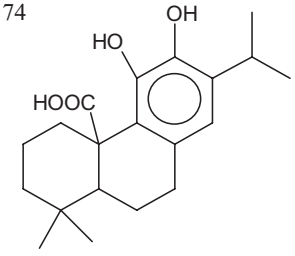
173



Arbotristosides C

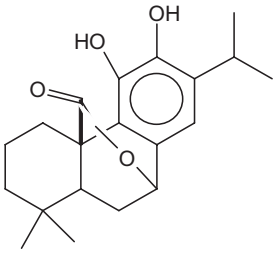
The seed of *Nyctanhes arbor-tristis* (Verbenaceae) has led to the isolated of iridoid glucosides, arbotristosides A, B and C; are significantly active against EMCV and SFV with an increase in average survival time of the infected animals (Rathore et al., 1990).

174



Carnosolic acid

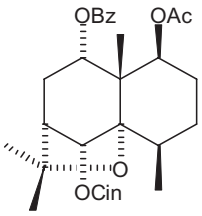
175



Carnosol

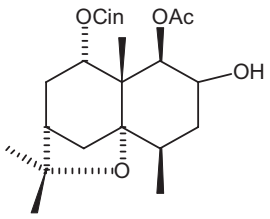
The diterpenes carnosolic acid and carnosol were isolated from *Rosmarinus officinalis* L. (Labiatae); effective HIV protease inhibitors. Carnosolic acid showed the strongest inhibitory effect (IC_{90} = 0.08 µg/ml). The cytotoxic TC_{90} on H9 lymphocytes was 0.36 µg/ml, which is very close to the effective antiviral dose (Paris et al., 1993).

176



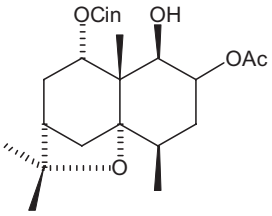
Celafolin A-1

177



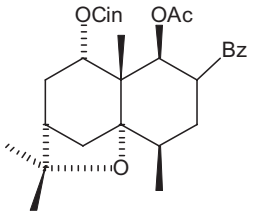
Celaforin B-2

178



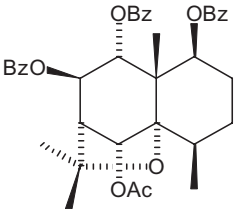
Celaforin B-3

179



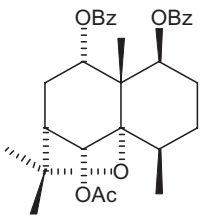
Celaforin C-1

180



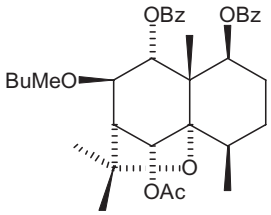
Celaforin D-1

181



Celaforin D-2

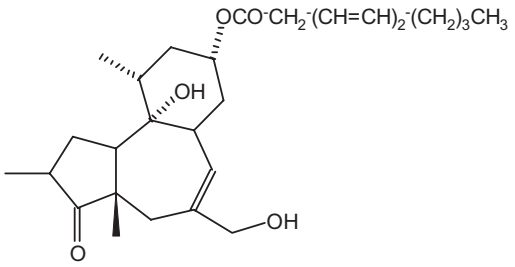
182



Celaforin D-3

Esters of eight sesquiterpenoids polyalcohols have been isolated from *Celastrus stephanotiifolius* Makino (Celastraceae); all compounds inhibit Epstein-Barr virus early antigen activation significantly at low doses (Takaishi et al., 1993).

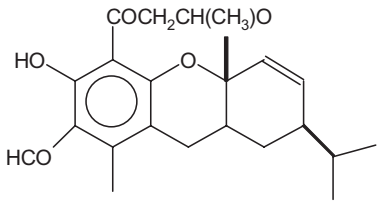
183



12-Deoxyphorbol-13(3E,5E-decadienoate)

This phorbol ester was isolated as the anti-HIV principle of *Excoecaria agallocha* (Euphorbiaceae) (Erickson et al., 1995).

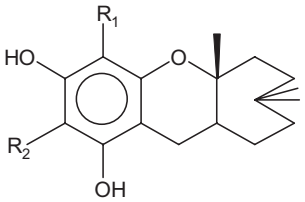
184



Euglobal T1

From the juvenile leaves of *Eucalyptus tereticornis* Sm. (Myrtaceae), a new euglobal having a phlorophene-monoterpene structure, euglobal Tl, has been isolated; inhibition of Epstein-Barr virus activation (Kokumal et al., 1991).

185

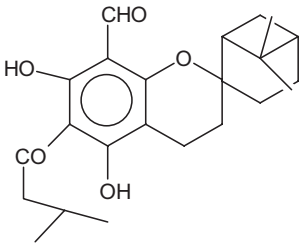


$R_1 = COCH_2CH(CH_3)_2$,
$R_2 = CHO$
Euglobal 1

186

$R_1 = CHO$,
$R_2 = COCH_2CH(CH_3)_2$
Euglobal 2

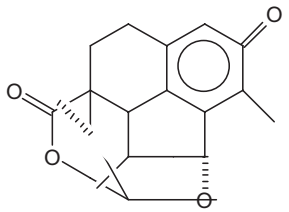
187



Euglobal 3

These euglobals, with acylphloroglucinol monoterpene structures, were isolated from *Eucalyptus grandis*; inhibited Epstein-Barr virus activation (Myrtaceae) (Takasaki et al., 1990).

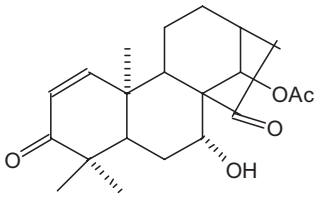
188



Halnanolide

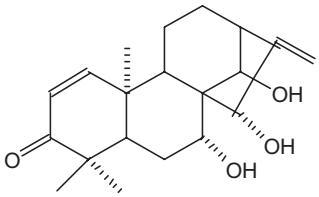
Halnanolide is active in tissue culture against plaque formation by influenza virus A (WS), Newcastle diseases virus, Japanese B encephalitis virus (AZ), and vaccina virus (Cracker & Simon, 1986), isolated from *Banisteria caapi* (Malpighaceae).

189



Liangshanin B

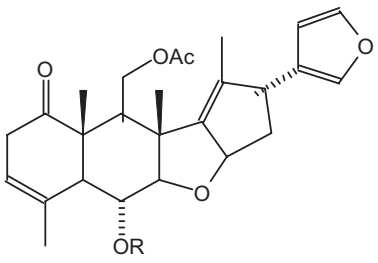
190



Liangshanin D

The leaves of *Rabdosia liangshanica* C.Y. (Labiatae) are quite rich in diterpenoids. The liangshanin B and liangshanin D show inhibitory activity against the hepatitis virus (Fenglei et al., 1989).

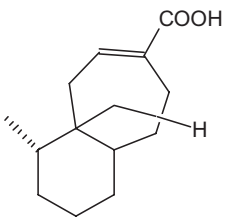
191



Nimbinen

Limonoids found in plants of the order Rutales; has antiviral activity (Champagne et al., 1992).

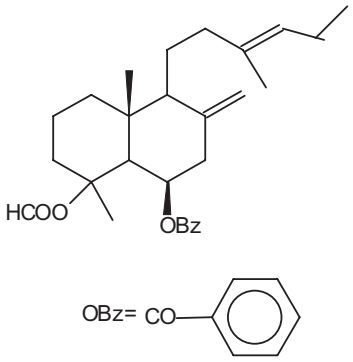
192



Sclerocarpic acid

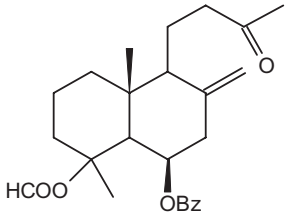
This sesquiterpene was isolated from the bark of *Glyptopetalum sclerocarpum* (Celastraceae); exhibited antiviral activity against Herpes simplex virus type 1 and 2 (Sotanaphun et al., 1999).

193



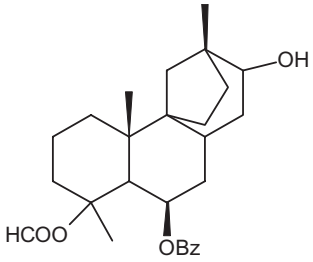
Scoparic acid A

194



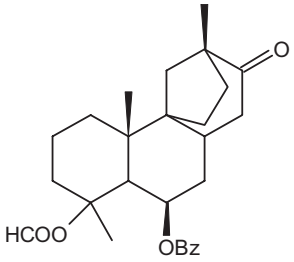
Scoparic acid B

195



Scoparic acid C

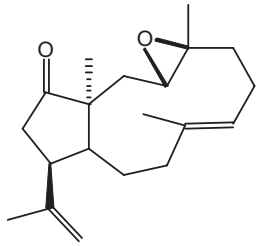
196



Scopadulcis acid B

These compounds inhibit the viral replication of Herpes simplex virus type 1; isolated from *Scoparia dulcis* (Scrophulariaceae) (Hayashi et al., 1988; Hayashi et al., 1990).

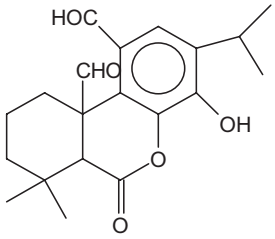
197



Dolabellane

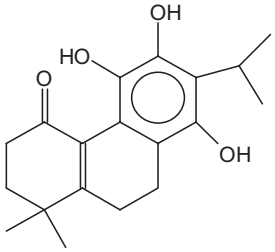
Found in *Dolabella californica* (Dictyotaceae); active against influenza and adenovirus viruses (Piatelli & Tringali, 1995).

198



Safficinolide

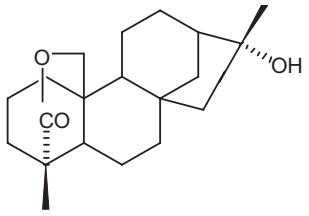
199



Sageone

These diterpenoids showed antiviral activity against VSV (vesicular stomatitis virus); isolated from the aerial parts of *Salvia officinalis* (Labiatae) (Tada et al., 1994).

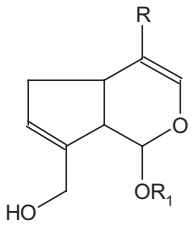
200



Tripterifordin

A kaurane-type diterpene lactone, tripterifordin, has been isolated from the roots of *Triterygium wilfordii* Hook (Celastraceae); shows anti-HIV replication activity in H9 lymphocytes cells with an EC_{50} of 1 µg/ml (Chen et al., 1992).

201



R = CH =, R_1 = β-D-glucopyranosyl
Arennoside

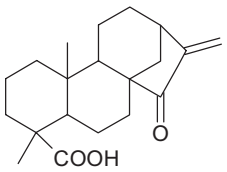
202 R = COOH =, R_1 = β-D-glucopyranosyl
Geniposidic acid

203 R = COOMe =, R_1 = β-D-glucopyranosyl
Geniposidic

204 Gardenoside

The callus and cell suspension cultures of *Genipa americana* L. (Rubiaceae) produce four iridoids glucosides. Tarennoside is most active, and the activity decreases with the progress of the metabolism. The activity of geniposide is lower than that geniposidic acid (Ueda & Iwahashi, 1991).

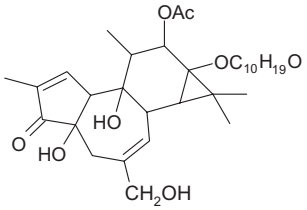
205



Xylopinic acid

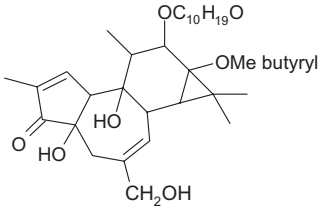
Kaurane diterpene was isolated from fruits of *Xylopia sp*. The HIV-inhibitory activity on infected CEM-SS cells revealed an EC_{50} of 0.9 µg/mL (Fuller et al., 1996).

206



12-*O*-Acetylphorbol-13-decanoate

207

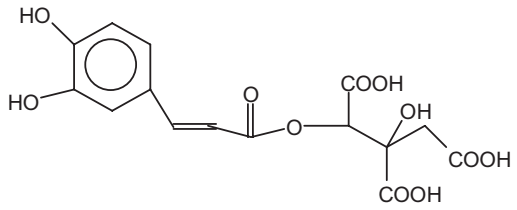


12-*O*-Decanoylphorbol-13-(2-methyl butyrate)

Found in the seeds of *Croton tiglium* (Euphorbiaceae); effectively inhibited the cytopathic effect of HIV-1 (El-Mekkawy et al., 2000).

Phenolic

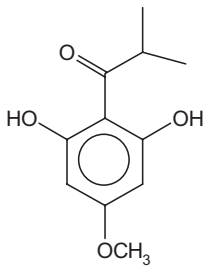
208



2-*O*-Caffeoyl-(+)-allohydroxycitric acid

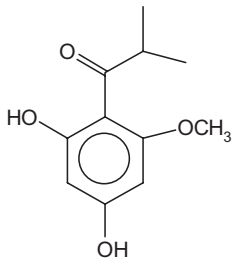
The caffeoyl ester 2-*O*-caffeoyl-(+)-allohydroxycitric acid, with antiviral propierties against Coxsackie and Herpes simplex viruses, was isolated from *Spondias mombin* (Anacardiaceae) (Corthout et al., 1992).

209



2,6-Dihydroxymethoxyisobutylrophenone

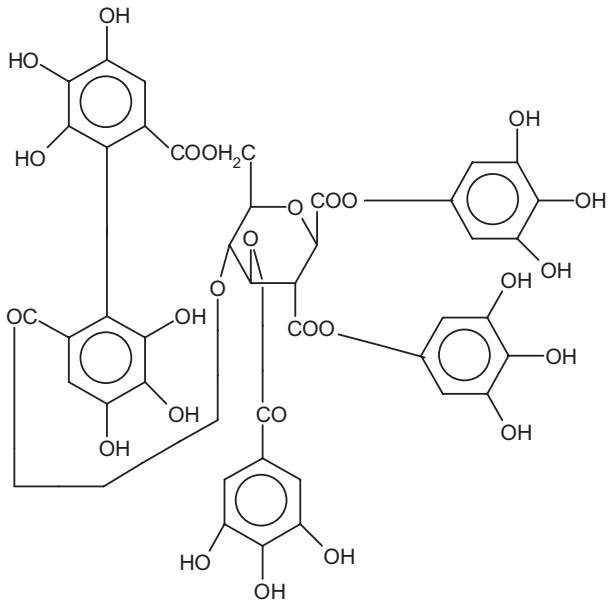
210



4,6-Dihydroxymethoxyisobutylrophenone

Bioassay-guided fractionation has led to the isolation and structural identification of the compounds 2,6-dihydroxy-methoxyisobutylrophenone and 4,6-dihydroxy-methoxyisobutylrophenone responsible for antiviral activity. Both were isolated from *Kunzea ericoides* A. Rich. (Myrtaceae) (Bloor, 1992).

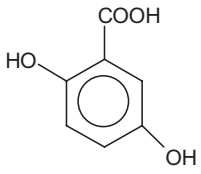
211



Eugenin or Ellagitanin

Eugenin is active against Herpes virus; isolated from buds of *Syzyium aromatica* Merr (Myrtaceae) (Takeshi & Tanaka, 1981). Also isolated from *Paeonia suffruticosa* (Paeoniaceae) (Takeshi & Tanaka, 1982).

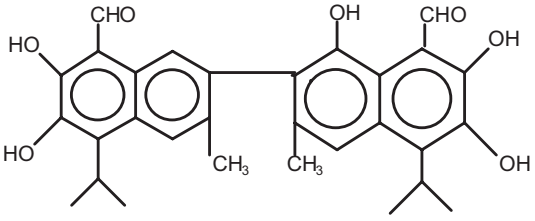
212



Gentisic acid

The gentisic acid was isolated from leaves and roots of *Citrus cultivars* (Rutaceae), in the fruit peels of *Vitus vinifera* (Vitaceae); antiviral activity (Van Sumere, 1989).

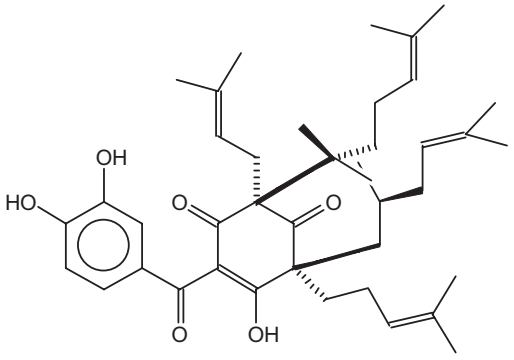
213



Gossypol

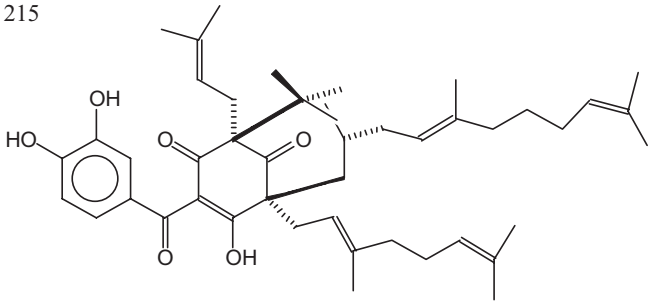
Gossypol, was isolated from the fruit of *Gossypium herbaceum* L. (Malvaceae); virucidal for Herpes para-influenza 3 and influenza viruses (Harborne & Baxter, 1993).

214



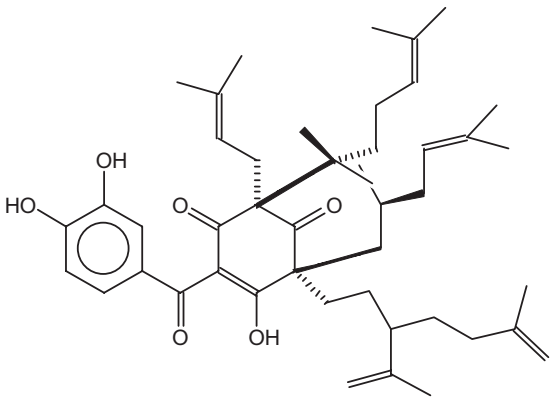
Guttiferone A

215



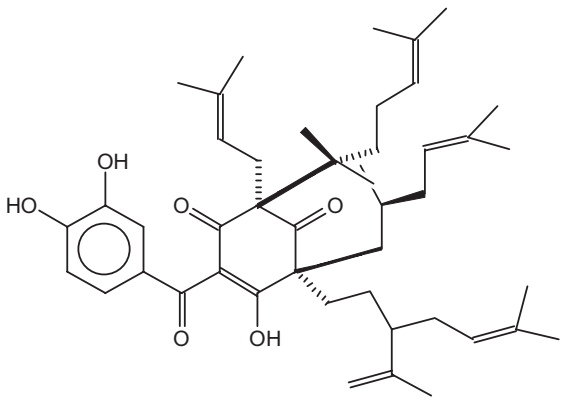
Guttiferone B

216



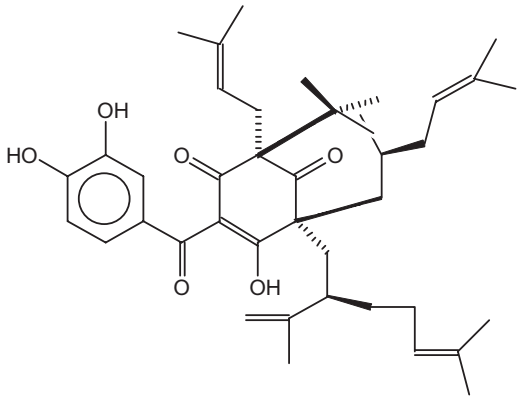
Guttiferone C

217



Guttiferone D

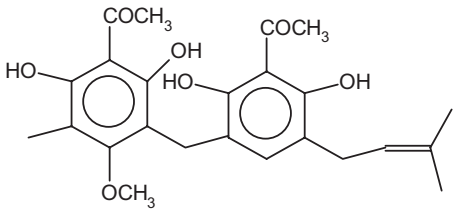
218



Guttiferone E

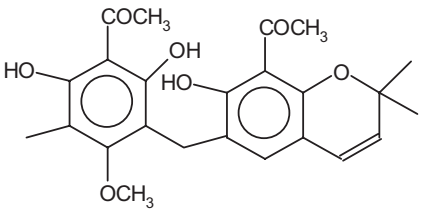
Extracts from species of the tropical plant genera *Symphonia globulifera, Garcinia livinstonei, Garcinia ovalifolia* and *Clusia rosea* (Guttiferae), have yielded a series of polyisoprenylated benzophenone derivatves named guttiferones A, B, C, D and E. These compounds inhibit the cytopathic effects of in vitro HIV infection (Gustafson et al., 1992).

219



Mallotojaponin

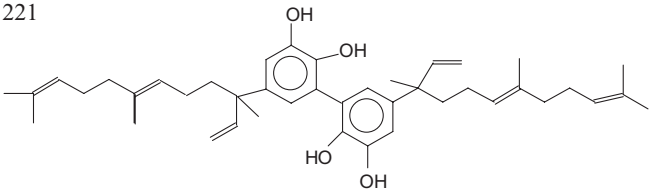
220



Mallotochromene

Mallotojaponin and mallotochromene are phoroglucinol derivatives isolated from the pericarps of *Mallotus japonicum*; anti-HIV RT activity (Van Sumere, 1989).

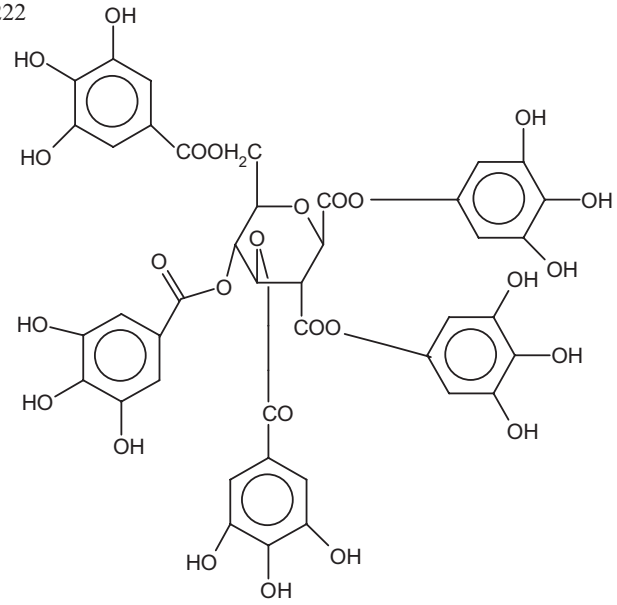
221



Peltalol A

The prenylated catechol dimers, namely peltatol A, has been isolated from the tropical shrub *Pothomorpha peltata* (Piperaceae). This compound inhibits HIV-1 induced cell killing at subtoxic concentrations of 1–10 µg/ml (Van Sumere, 1989).

222



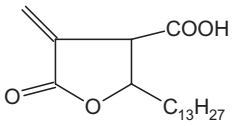
Pentagalloyl-β-D-glucose

Pentagalloyl-β-D-glucose is an tannin, with the skeletal type gallotannin, occurs in the leaves of *Nuphar japonicum* (Nymphaeaceae). This compound exhibited antiviral activity against human immunodeficiency virus (Porter, 1989).

223 Polyphenolic complex

A polyphenolic complex isolated from the Bulgarian medicinal plant *Geranium sanguineum* L. (Geranaceae) inactivated the neuraminidase activity of different influenza virus strains-A/PR8 (HINI), A/Krasnodar (H2N2), A/Hong Kong (H3N2), B/Lee. The effect was dependent on the dose of the substance, the time of treatment and the temperature of the reaction. The inhibition of the neuraminidase activity correspond to a decrease of the hemagglutination and the infectionss titres and was reversible (Serkedjieva et al., 1992).

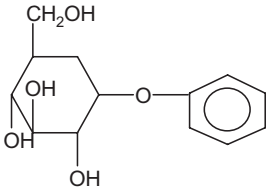
224



Protolichesterinic acid

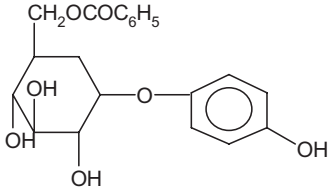
This aliphatic α-methylene-γ-lactone was isolated from the lichen *Cetraria islandica*. It is active against HIV RT (Van Sumere, 1989).

225



Salicin

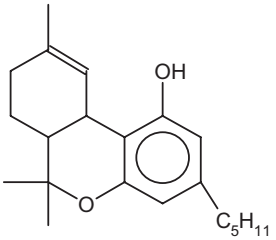
226



Salireposide

Salicin and salireposide were found to be active at 25 µg/ml against poliomyelitis and Semliki forest virus. Both compounds were isolated from *Populus trichocarpa* (Salicaceae) (Van Hoff et al., 1989).

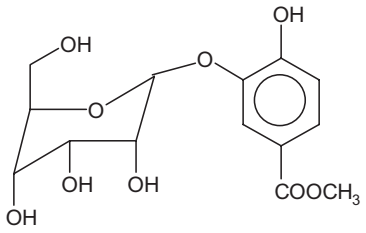
227



Δ-9-Tetrahydrocannabinol

The Δ-9-tetrahydrocannabinol was isolated from *Cannabis sativa* L. (Cannabaceae); active against Herpes simplex type 1 (HSV-1) and Herpes simplex type 2 (HSV-2) (Blevins & Dumic, 1980).

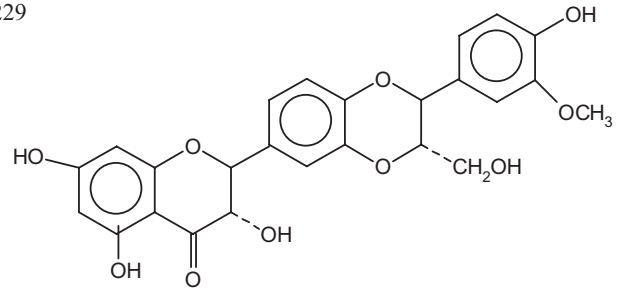
228



Woodorien

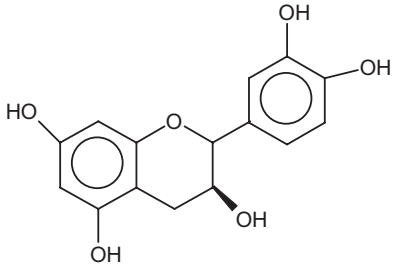
Found in the rhizomes of *Woodwardia orientalis* SW reduces the plaque forming ability of Herpes simplex virus type 1 (HSV-1) and poliovirus (Xu et al., 1993).

229



Silymarin

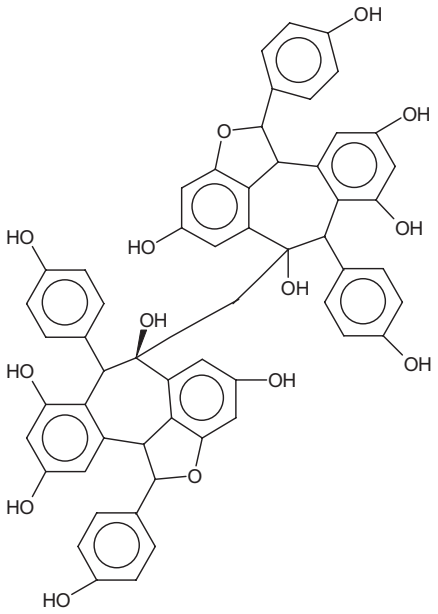
230



Cyanidol

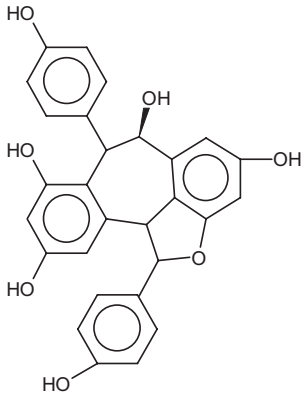
Two compounds have been used in treatment of acute viral hepatitis; isolated from *Silybum marianum* (Compositae) (Swallow et al., 1975).

231



Dibalanocarpol

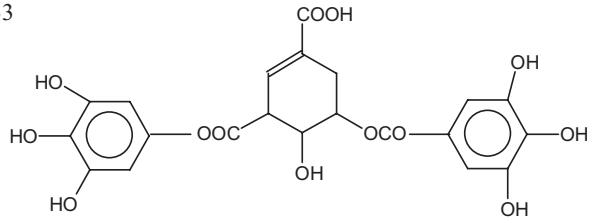
232



Balanocarpol

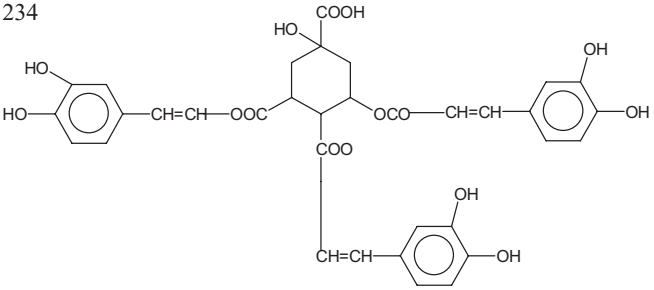
The oligostilbenes dibalanocarpol and balanocarpol were isolated from *Hopea malibato* Foxw (Dipterocarpaceae); exhibited very modest HIV-inhibitory activity (Hatano et al., 1988).

233



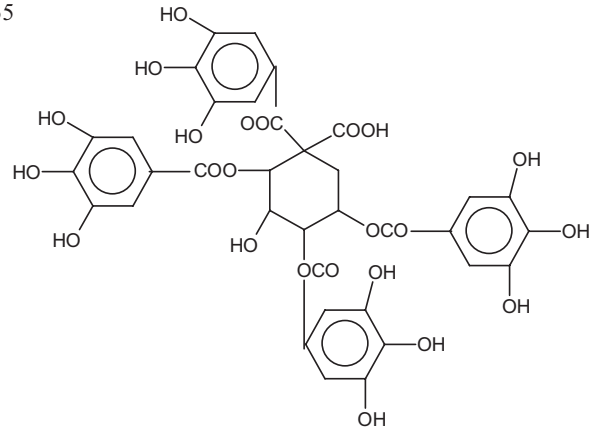
3,5-di-*O*-Galloylquinic acid

234



3,4,5-tri-*O*-Caffeoylquinic acid

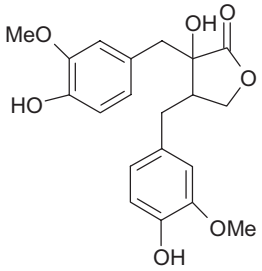
235



1,3,4-tri-*O*-Galloylquinic acid

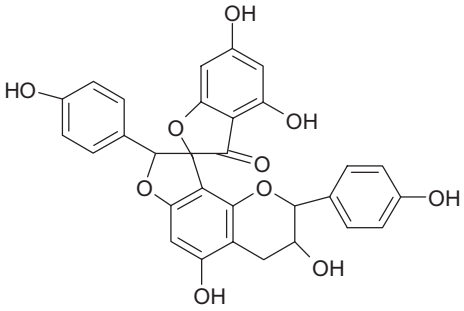
Galloylquinic acid and caffeoylquinic acid, isolated from *Guiera senegalensis* and *Securidata longipedunculata*, respectively, are selective inhibitors of HIV (Van Sumere, 1989).

236



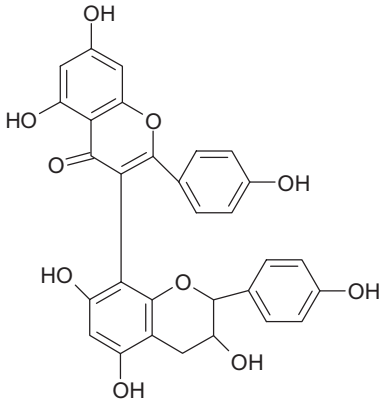
(+)-Nortrachelogenin

237



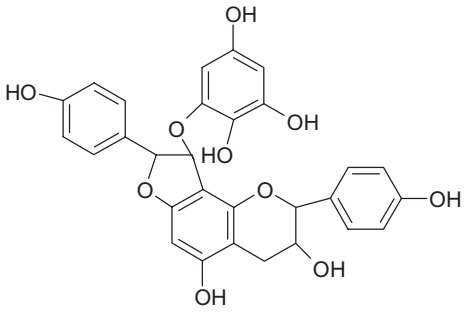
Genkwanol A

238



Wilkstrol B

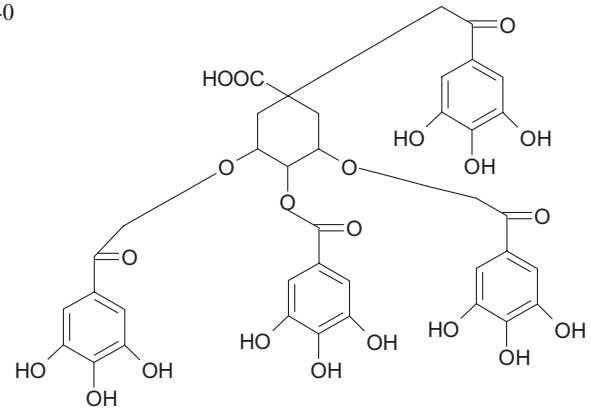
239



Daphnodorin B

Compounds moderately active against HIV-1 *in vitro*; also showed antifungal, antimitotic activities agents, were isolated from the roots of *Wikstroemia indica* C. A. Meyer (Thymelaeaceae) (Hu et al., 2000).

240

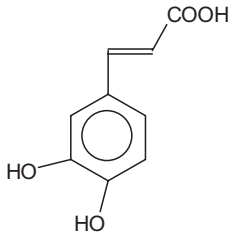


1,3,4,5-tetra-*O*-Galloylquinic acid

Protected target cells from the cytopathic effects of HIV-1 and HIV-2, also exhibited potent inhibition of cellular DNA polymerases, as well as of the reverse transcriptases of HIV-1 and HIV-2. Found in *Lepidobotrys staudtii* Engl. (Lepidobotryaceae), (Bokesch et al., 1996).

Phenylpropanoids

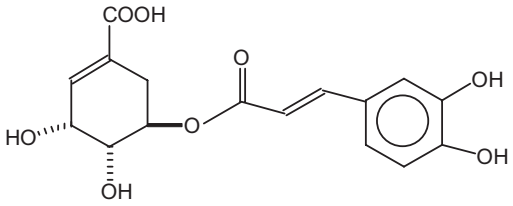
241



Caffeic acid

A compound with widespread occurrence, was isolated from *Coffea arabica* (Rubiaceae); show weak activity against influenza virus, is active against Herpes simplex, vaccinia and polio viruses (Molgaard & Ravn, 1988).

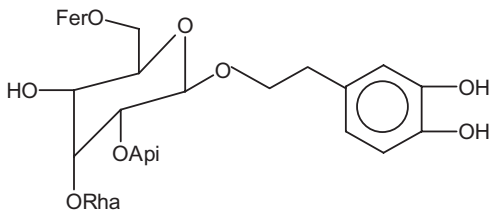
242



Chlorogenic acid

Widely distributed in the plant kingdom, first found in green coffee beans, *Coffea arabica* (Rubiaceae). This compound inactivates some poliovirus (Molgaard & Ravn, 1988).

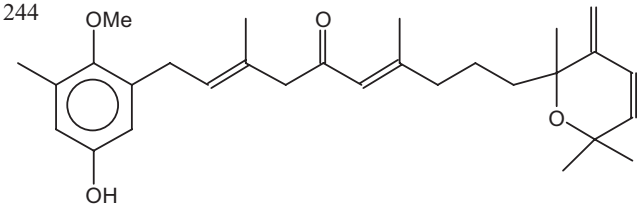
243



3-Methyl-but-2-enyl caffeate

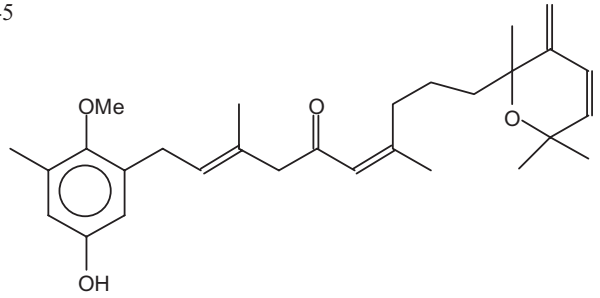
3-Methyl-but-2-enyl caffeate isolated from *Populus nigra* L. (Salicaceae), was found to reduce the viral titer by 3 $\log_{10}$ and viral DNA synthesis by 32-fold (Amoros et al., 1994).

244



Usneoidone E

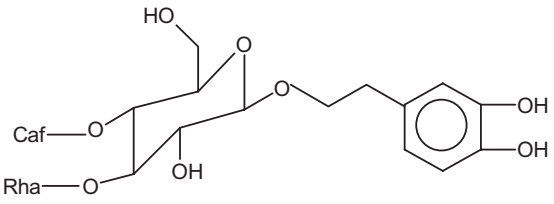
245



Usneoidone Z

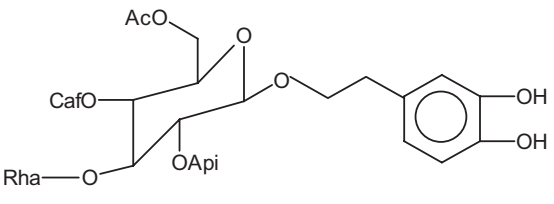
Two meroterpenes have been isolated from the brown seaweed *Cystoseira usneoides* (Phaeophyceae), usneoidone E and Z. Both compounds exhibit antiviral activity (Urones et al., 1992).

246



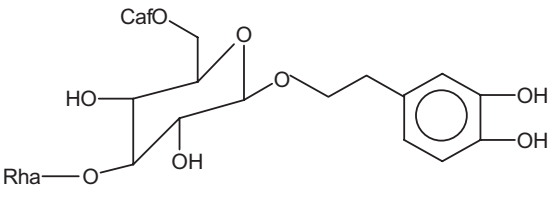
Verbacoside

247



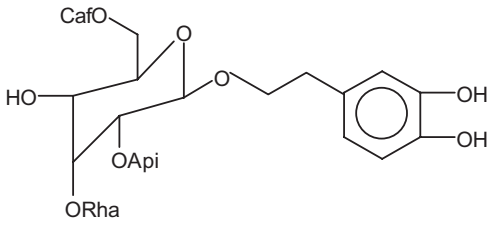
Isoverbacoside

248



Luteoside A

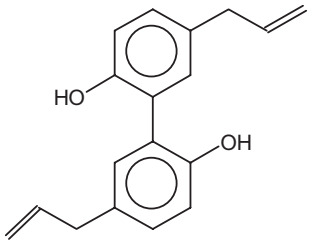
249



Luteoside B

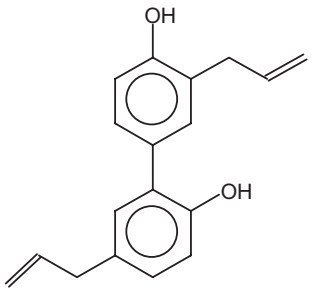
These phenylpropanoid glycosides were isolated from the roots of the medicinal plant *Markhamia lutea* Seemann ex Baillor (Bignoniaceae). All five phenylpropanoid glycosides exhibited potent *in vitro* activity against respiratory syncytial virus (Kerman et al., 1998).

250



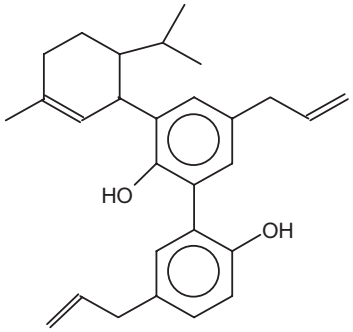
Magnolol

251



Honokiol

252

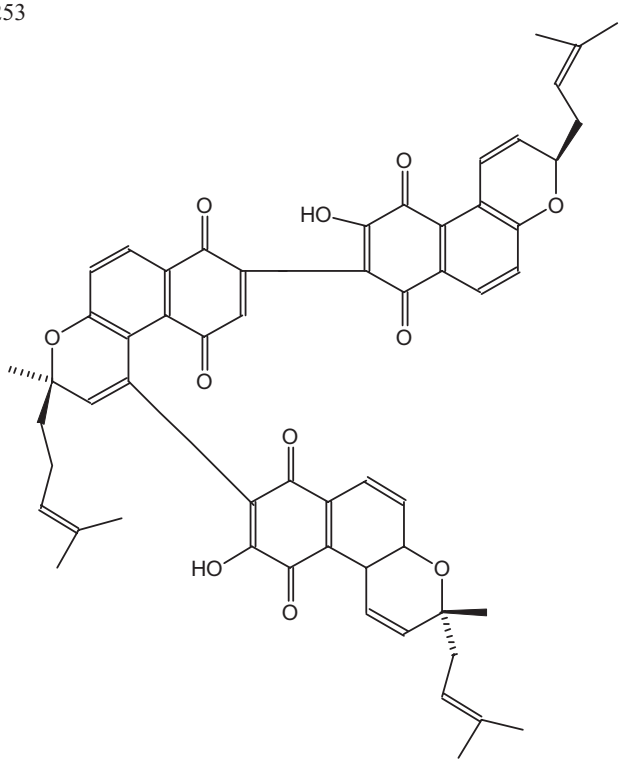


Monoterpenylmagnolol

Three neolignans, known as magnolol, honokiol and monoterpenylmagnolol, were isolated from the bark of *Magnolia officinalis* Rehd. et Wils (Magnoliaceae); inhibitors of Epstein-Barr virus early antigen (EBV-EA) activation induced by 12-*O*-tetradecanoyl-phorbol-13-acetate (TPA) (Konoshima & Kozuka, 1991[a]).

Quinones

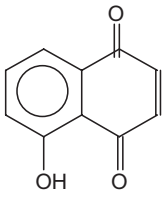
253



Conocurvone

Several organic extracts of the plant *Conospermun incurvum* (Proteaceae) inhibited the killing of T4-lymphoblastoid cell line (CEM-SS) by HIV-1_{RF}. Conocurvone is an anti-HIV agent (Decostered et al., 1993).

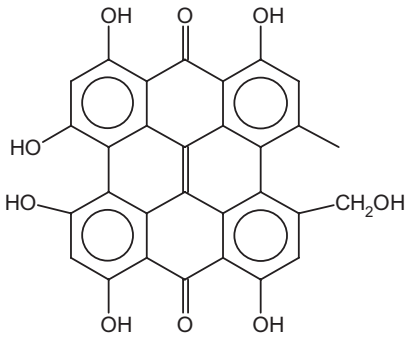
254



Juglone

Found in the stem bark of *Juglans nigra* (Juglandaceae); antiviral effect against HSV-1 virus (Berg & Labiade, 1989). The pseudohypericin is an bianthraquinone with antiretroviral activity; isolated from *Hypericum triquetrifolium* (Hypericaceae) (Berg & Labiade, 1989).

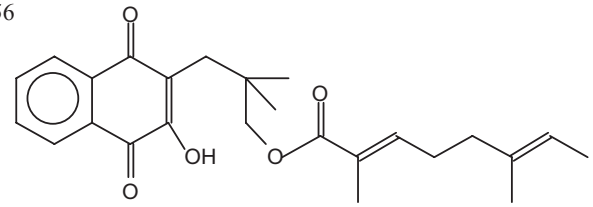
255



Pseudohypericin

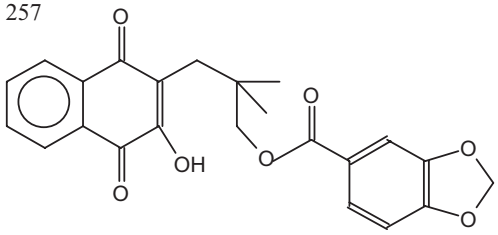
The pseudohypericin is an bianthraquinone with antiretroviral acivity; isolated from *Hypericum triquetrifolium* (Hypericaceae) (Berg & Labiade, 1989).

256



Rhinacanthin C

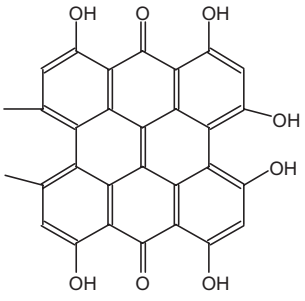
257



Rhinacanthin D

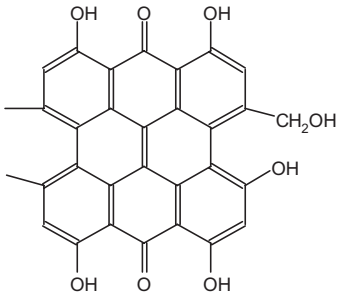
The naphthoquinones, rhinacanthin C and D, exhibit inhibitory activity against cytomegalovirus (CMV), with EC_{50} values of 0.02 µg/ml (Sendl et al., 1996). These compounds were isolated from the shrub *Rhinacanthus nasutus* (L) Kurz (Acanthaceae).

258



Hypericin

259

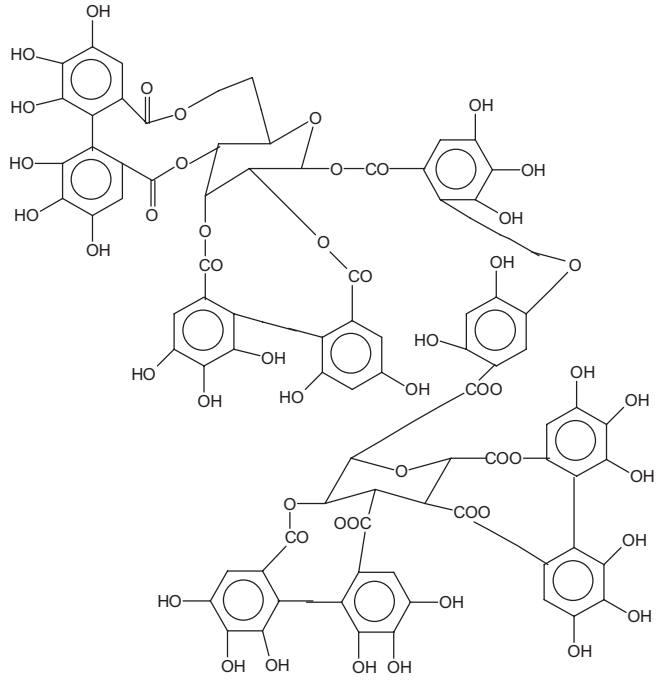


Pseudohypericin

Hypericin and pseudohypericin are photodinamic pigments (condensed anthraquinone) present in *Hypericum perforatum* (Hypericaceae). At 10 µg/ml, hypericin was cytotoxic to CEM cells under both light dark conditions (Hudson et al., 1993). Pseudohypericin is highly effective in preventing viral-induced manifestations that follow infection with a variety of retroviruses *in vitro* and *in vivo.*

Tannins

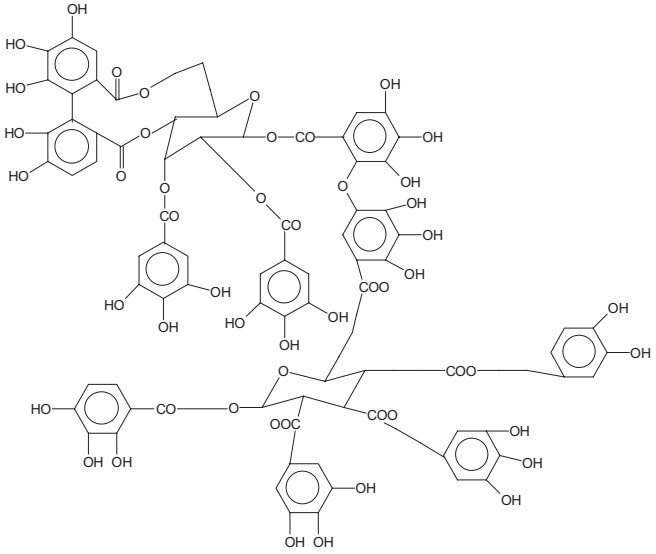
260



Agrimoniin

Found in roots of *Agrimonia pilosa* (Rosae); potent inhibitor of RT from avian myeloblastosis virus (AMV) due to interference of the template-primer-enzyme nucleotide complex (Porter, 1989).

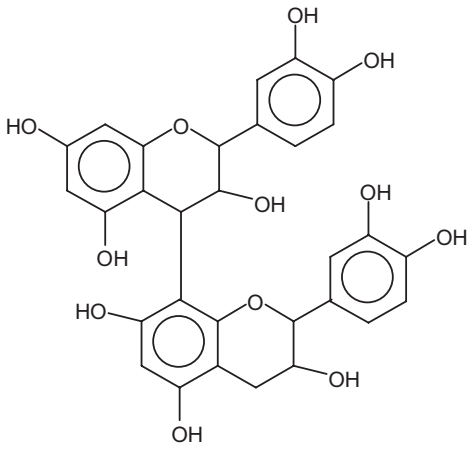
261



Coriariin A

Occurs in the leaves of *Coriaria japonica* (Coriariaceae); active against HIV (Porter, 1989).

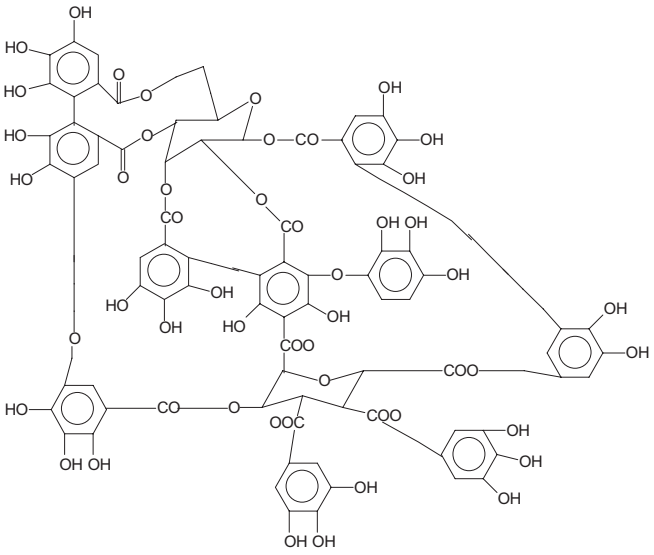
262



Procyanidin B_2

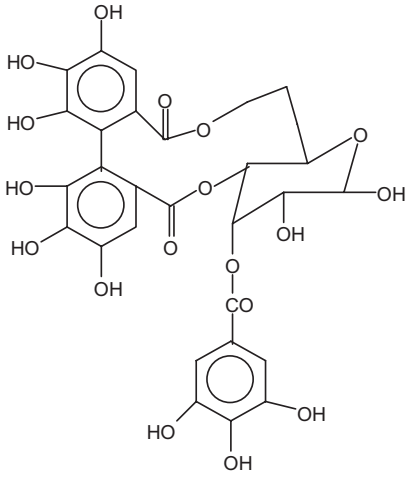
Found in the leaves of the raspberry, *Rubus idaeus* (Rosaseae); active against HIV (Porter, 1989).

263



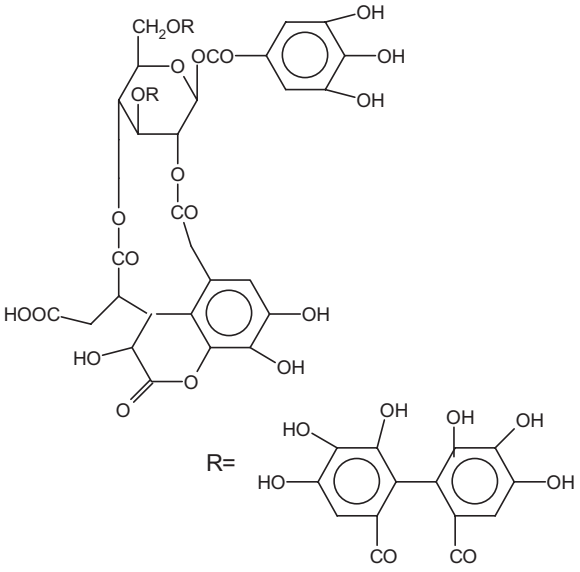
Camellin B

264



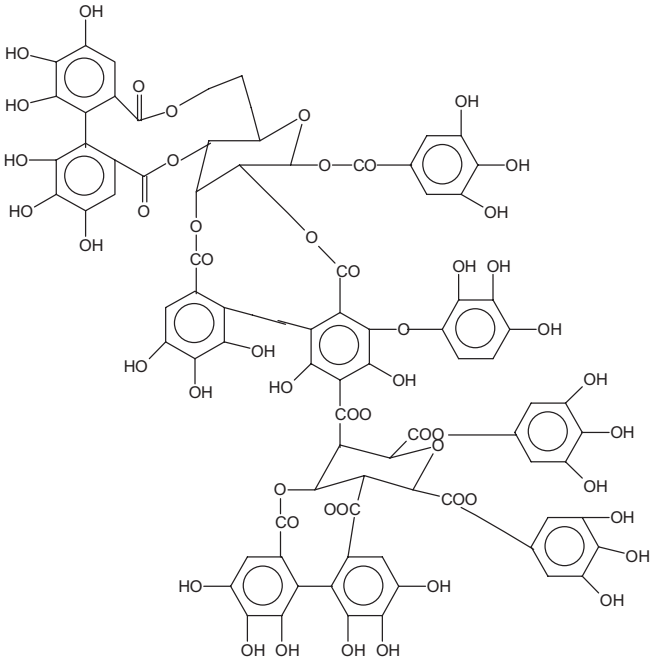
Gemin D

265



Chebulagic acid

266

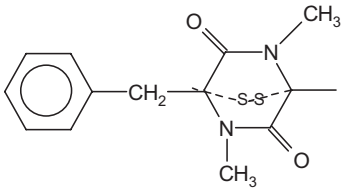


Nobotanin B

Chebulagic acid was isolated from *Terminalia chebula* (Combretaceae), gemin D from *Geum japonicum* (Rosae), nobotanin B from *Tibouchina semicandra* (Melastomaceae). These hydrolysable tannins did not completely inhibit HIV binding. It was subsequently found that the dimeric hydrolysable tannins are potent inhibitors of poly(ADP-ribose) glucohydrolase, an enzyme that plays a regulatory role in gene transcription (Vlietinck et al., 1998).

Thiophenes and polyacetylenes

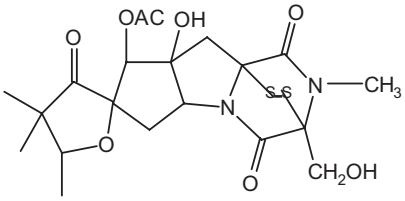
267



Hyalodendrin A

Found in *Penicillium turbatum*; activity against polio and Coxsackie viruses (Becher, 1976).

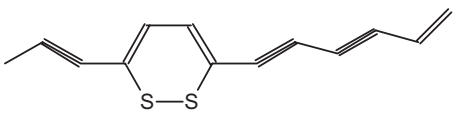
268



Sidoresmin A

Formed on fermentation of *Sirodesmiun diversum*; very high activity against rhinoviruses in vitro; active at 0.01 µg/ml, not toxic at 0.4 µg/ml (Swallow et al., 1975).

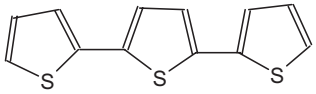
269



Thiarubine-A

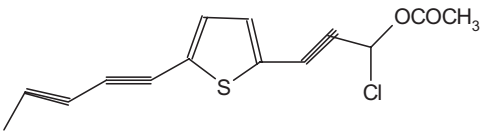
The polyine, thiarubine-A, was isolated from *Chaenactis douglasii* (Compositae). Two mammalian viruses, murine cytomegalovirus and Sindbis virus, both of which possess membranes, were extremely sensitive to the compound, but only in the presence of UV-A radiation (Hudson et al., 1986a).

270



α-Terthienyl (α-T)

271



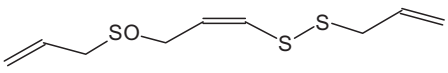
ACBP-thiophene

Phenylheptatriyne was isolated from *Bidens pilosa* (Compositae), thiophene-A from *Chaenactis douglasii* (Compositae). α-Terthienyl and ACBP-thiophene from *Tagetes patula* (Compositae). The four compounds possess activity against Sindbis virus (Hudson et al., 1986b).

272 Allyl methyl tiosulfinate

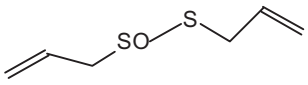
273 Methyl allyl tiosulfinate

274



Ajoene

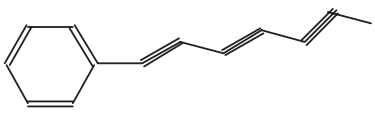
275



Allicin

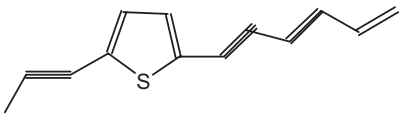
Garlic is known to be of therapeutic value in the treatment of infectious diseases caused by bacteria, fungi, viruses and protozoa. Four compounds isolated from *Allium sativa* L. (Liliaceae) were investigated in vitro for their virucidal effects against Herpes simplex virus, parainfluenza virus type 3, vaccinia virus, vesicular stomatitis virus and human rhinovirus type 2. All compounds were virucidal to each virus type. The antiviral activity decreased in the order of ajoene > allicin > allyl methyl tiosulfinate > methyl allyl tiosulfinate (Weber et al., 1992).

276



Phenylheptatriyne (PHT)

277



Thiophene-A

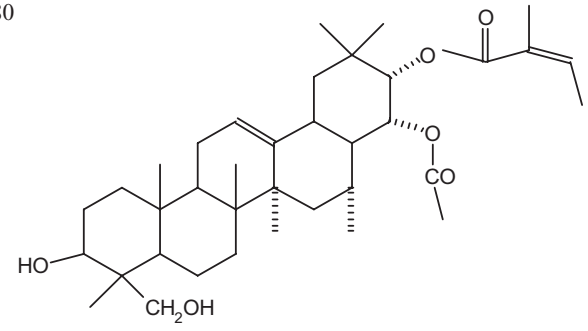
278 CH_3-SO_2-$(CH_2)_4$-NCS
Erysolin

279 CH_3-SO-CH=CH-$(CH_{2-})_2$-NCS
Sulforaphen

Found in *Cardaria draba* L. Desv. (Cruciferae); antiviral activity against mengovirus and newcastle disease virus (Kaij-a-Kamb et al., 1992).

Triterpenoids

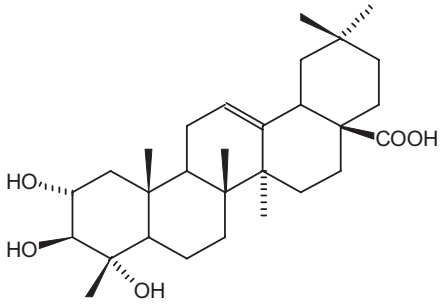
280



β-Aescin

Triterpenoid was isolated from *Aesculus hippocastranum* L. (Hippocastanaceae); active against influenza viruses (Hiller, 1987).

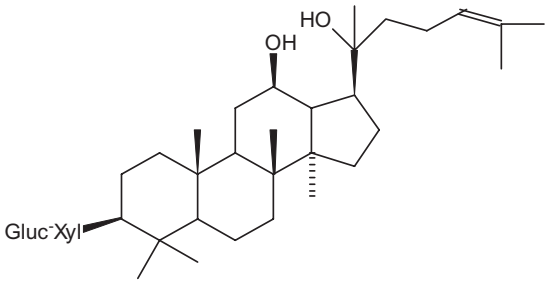
281



Arjunolic acid

Is an oleanene-type triterpene isolated from the rhizome of *Cochlospermun tinctorium* A. Rich. (Cocholospermaceae); exhibited complete inhibition on EBV-EA activation in Raji cells induced by 12-*O*-tetradecanoyl-phorbol-13-acetate (TPA) (Diallo et al., 1989).

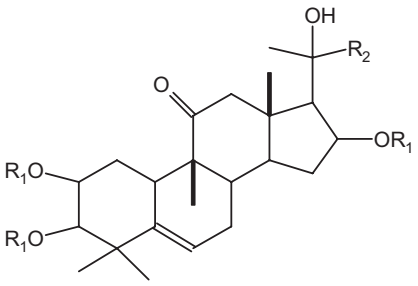
282



Chikusetsusaponin

Isolated from the rhizomes of *Panax japonicus* C.A. Mayer; anti-HIV activity (Hasegawa et al., 1994).

283

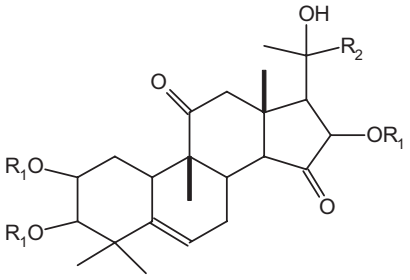


R_1 = H, R_2 = COCH═$CHC(CH_3)_2OH$
Cucurbitacin F

284 R_1 = H, R_2 = COCH-$CHC(CH_3)_2OH$
23,24-Dihydrocucurbitacin F

285 R_1 = H, R_2 = COCH-$CHC(CH_3)_2OH$
15-oxo-23, 24-Cucurbitacin F

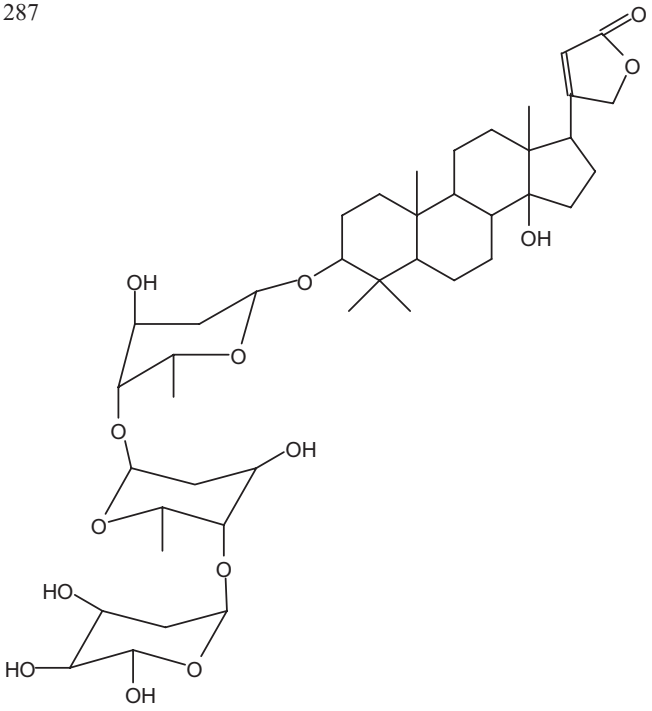
286



R_1 = H, R_2 = COCH=$CHC(CH_3)_2OH$
15-oxo-Cucurbitacin F

These compounds were inhibitors of Epstein-Barr virus early antigen activation induced by 12-*O*-tetradecanoylphorbol-13-acetate; isolated from *Cowania mexicana* (Rosaceae) (Konoshima et al., 1993).

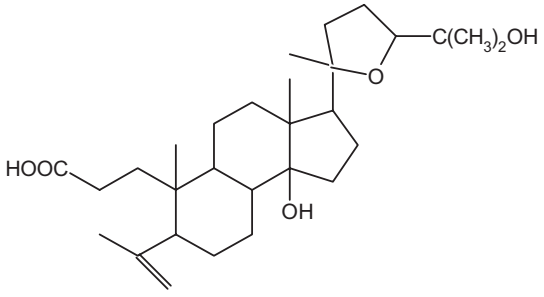
287



Digitoxin

Digitoxin, was isolated from *Digitalis purpurea* L. (Scrophulariaceae); inhibits poliovirus replication (Koch & Gyorgy, 1969).

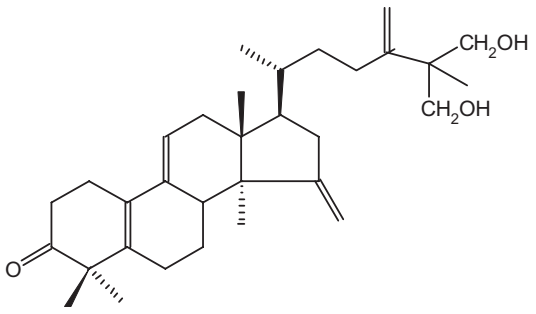
288



Eichlerianic acid

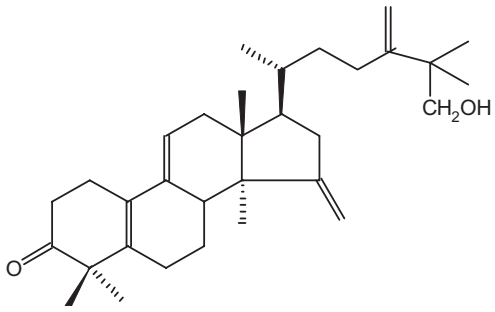
Eichlerianic acid was isolated from *Cowania mexicana* (Rosae); is active against Herpes virus type 1 (Hiller, 1987).

289



Ganoderiol F

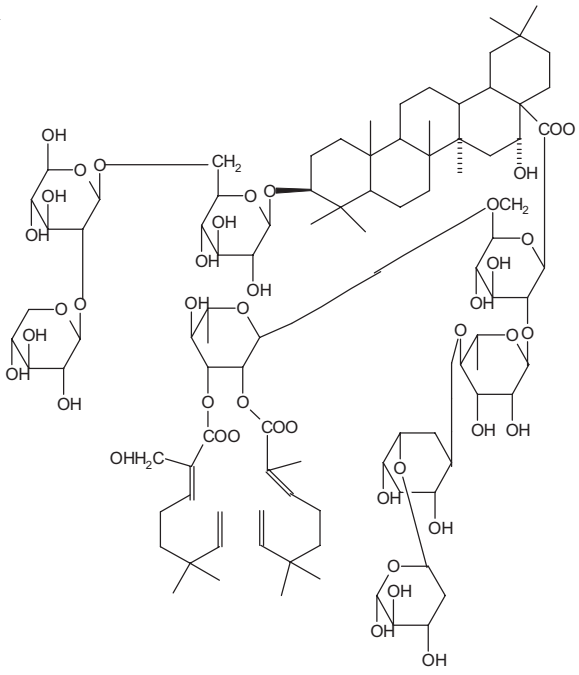
290



Ganodermanontriol

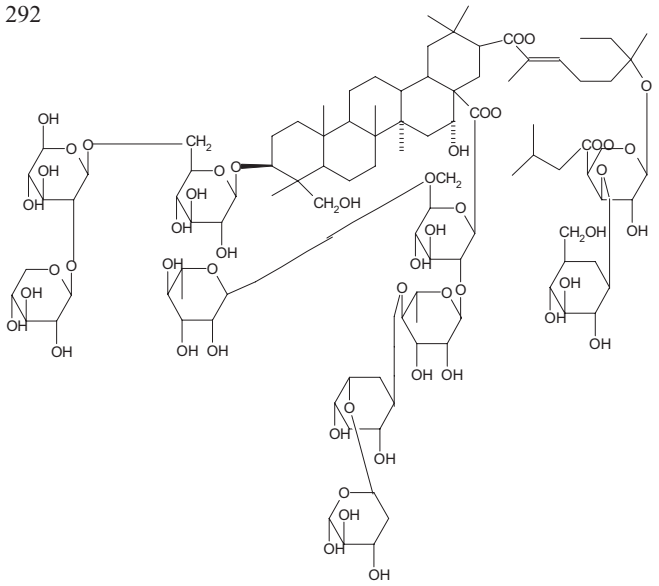
The highly oxygenated triterpene ganoderiol F and ganodermanontriol have been isolated from the fruits of *Ganoderma lucidum* (Polyporaceae); active as anti-HIV-1 agents with an inhibitory concentration of 7.8 $\mu g\,ml^{-1}$ (Et-Mekkawy et al., 1998).

291



Gleditsia saponin C

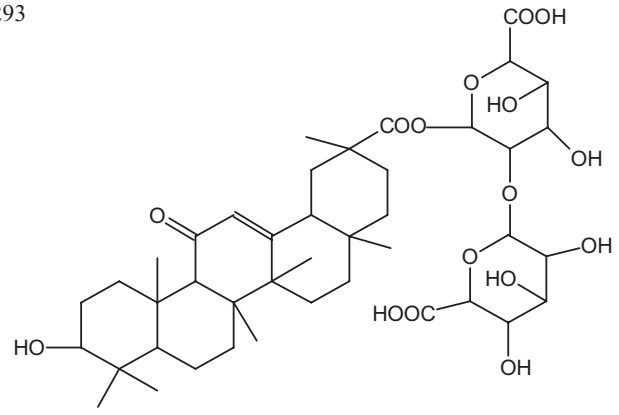
292



Gymnocladus saponin G

Gleditsia saponin C and gymnocladus saponin G were isolated from *Gleditsia japonica* Miquel (Leguminosae) and *Gymnocladus chinensis* Baillon (Leguminosae), respectively; inhibitory effects against HIV replication in H-9 cells (Konoshima et al., 1995).

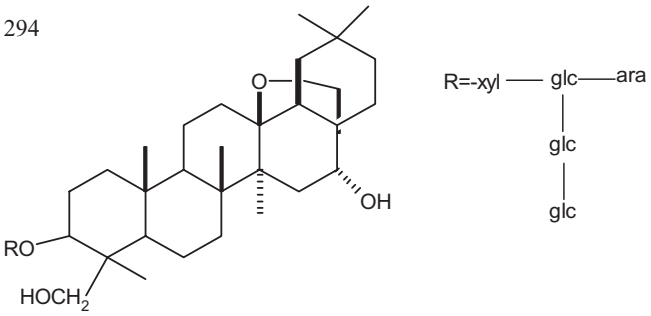
293



Glycyrrhizic acid

This triterpene was isolated from *Glycyrrhiza glabrata* L. (Leguminosae); active against herpes simplex type 1, vaccinia, newcastle disease virus and vesicular stomatitis virus (Hatano et al., 1988).

294



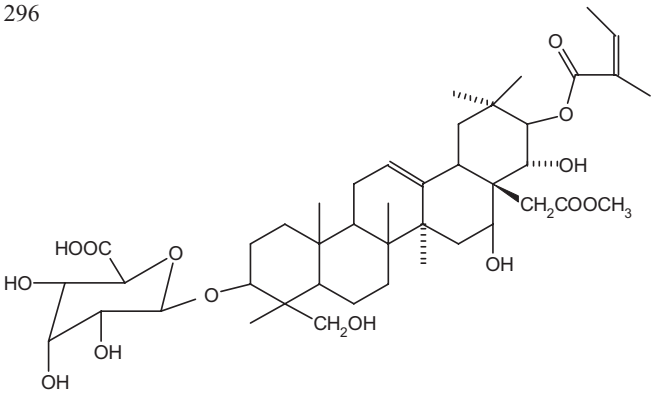
3-*O*-Glucose(1→3) [arabinose 1→4]-glucose-xyloside of 23-hydroxy-protoprimulagenin A.

295

3-*O*-Glucose(1→3) [arabinose 1→4]-glucose-xyloside of 23-hydroxyproto-primulagenin A.

With an additional glucose, two saponins were isolated from *Anagallis arvensis* (Primulaceae); *in vitro* antiviral activity against Herpes simplex virus type 1 and poliovirus (Amoros & Girre, 1987).

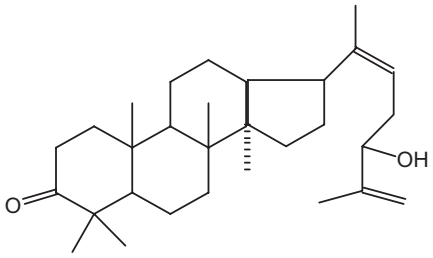
296



Gymnemic acid

Occurs in the leaves of *Gymnema sylvestre* (Asclepiadaceae); in vitro anti-influenzal activity (Rao et al., 1974).

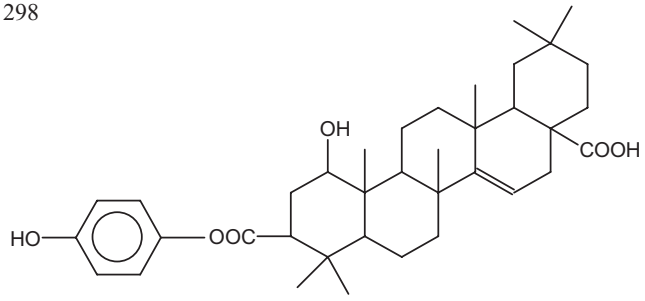
297



24-Hydroxydammaran-20,25-dien-3-one

This triterpene was isolated from *Chisocheton macrophyllus* leaves; inhibitory effects of Epstein-Barr virus activation (Inada et al., 1993).

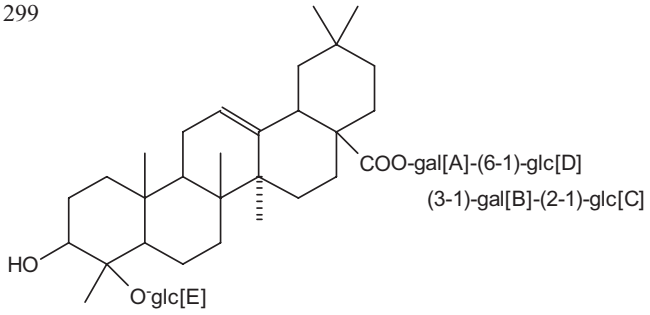
298



1β-Hydroxyaleuritolic acid 3-*p*-hydroxy-benzoate

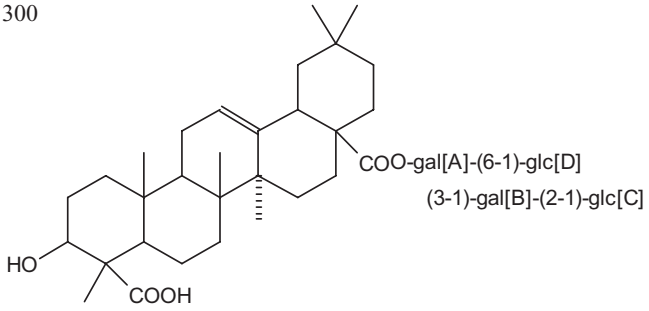
This triterpene isolated from *Maprounnea africana*; potent inhibitor of the DNA polymerase activity of human immunodeficiency virus-1 reverse transcriptase (HIV-1RT) (Pengsuparp et al., 1995).

299



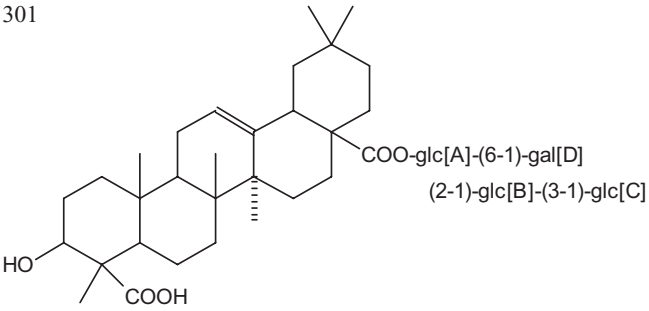
(3β-hydroxyolean-12-en-23,28 dioic acid 23-o-[β-D-glucopyranosyl-28-o-[β-D-glucopyranosyl(1→3)] β-D-gluco-pyranosyl(1→6)] β-D-galactopy-ranoside

300



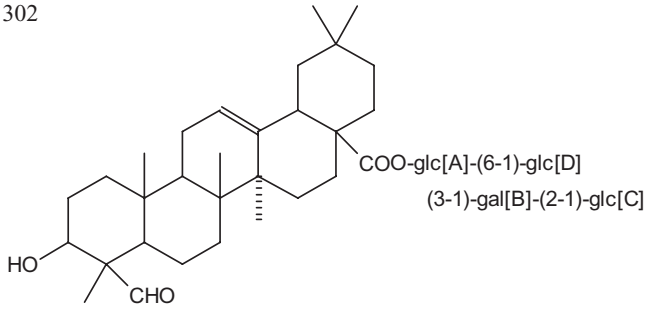
(3β-hydroxyolean-12-en-23,28 dioic acid 28-o-[β-D-glucopyranosyl-(1→2)][β-D-galactopyranosyl(1→3)] β-D-galactopyranosyl(1→6)] β-D-glucopyranoside

301



(3β-hydroxyolean-12-en-23,28-dioic acid 28-o-[β-D-glucopyranosyl-(1→2) [β-D-galactopyranosyl(1→6)] β-D-glucopy-ranoside

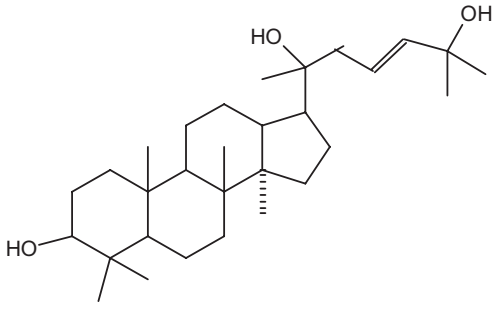
302



(3β-hydroxyolean-12-en-23,oxo-28oic acid 28-o-[β-D-glucopyranosyl-(1→2)][β-D-galactopyranosyl(1→6)] β-D-glucopy-ranoside

These triterpenoid saponins have been isolated from *Gypsophila capillaris* (Caryophyllaceae); antiviral activity against Herpes simplex (Elgamal et al., 1995).

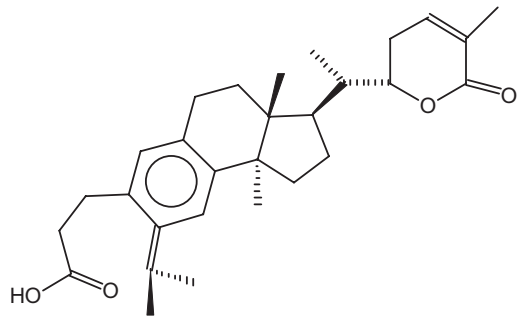
303



Isofouqueierol

Isofouqueierol was isolated from *Fouquiera splendens* Engelm (Fouquieraceae); active against Herpes virus (Gyorgy & Koch, 1969).

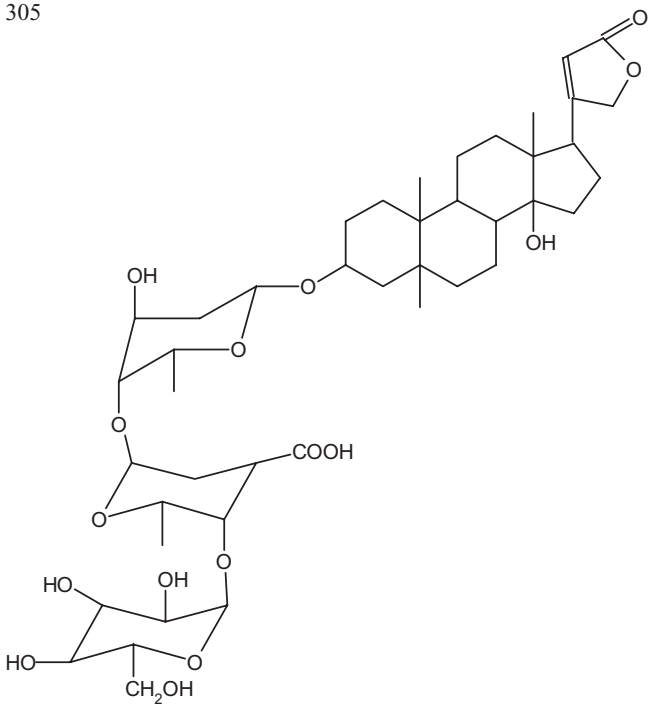
304



Lancilactones C

The triterpene lactone, lancilactones C, inhibited HIV replication with an EC_{50} value of 1.4 µg/ml and a therapeutic index of greater than 71.4. This compound was isolated from the roots of *Kadsura lancilimba* How (Schizandraceae) (Chen et al., 1999).

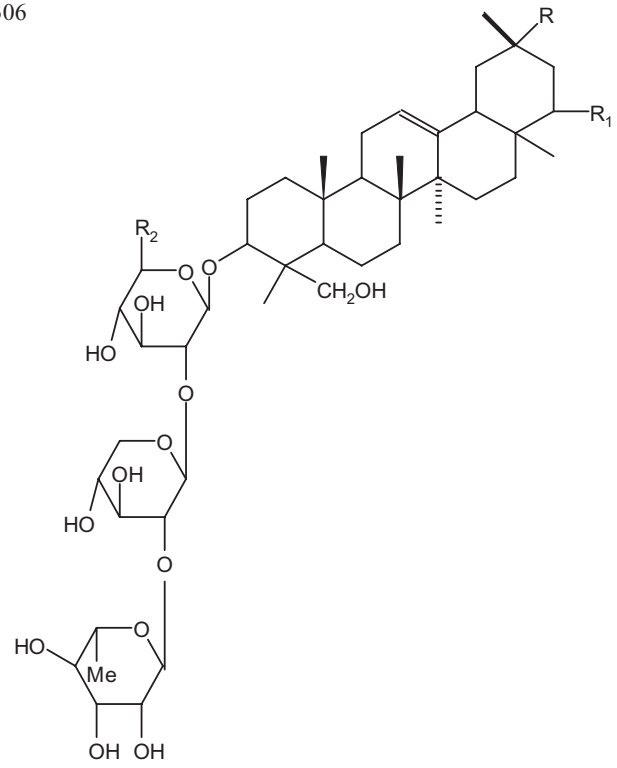
305



Lanatoside D

Lanatoside D was isolated from *Digitalis lanata* Ehrh. (Scrophulariaceae); active against influenza, Herpes and vaccinia viruses (Koch & Sandor, 1969).

306



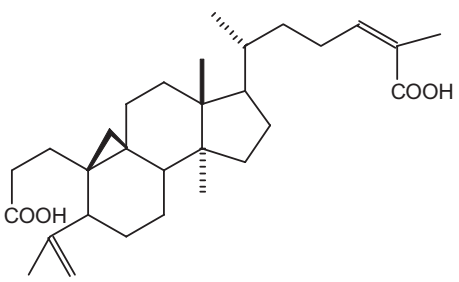
R = Me, R^1 = C = O, R_2 = COOMe
Methyl ester of wistariasaponin D

307 R = COOMe, R^1 = OAc, R^2 = COOMe
Methyl ester of wistariasaponin G

308 R = Me, R^1 = C = O, R_2 = COOMe
Methyl ester of dehydrosoyasaponin

Two triterpenoids saponins, wistaria saponins D and G, and the dehydrosoyasaponin, were isolated from the knots of *Wistaria brachybotrys* Sieb (Leguminosae). The inhibitory effects of these saponins on the activation of Epstein-Barr early antigen that was induced by tumor promoter (Konoshima & Kozuka, 1989).

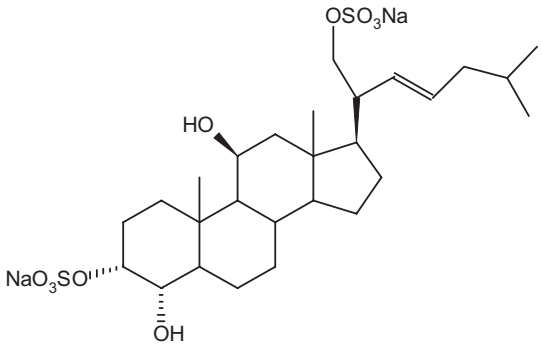
309



Nigranoic acid

Nigranoic acid showed activity in several anti-HIV reverse transcriptase and polymerase assays, was isolated from *Schisandra sphaerandra* Stapf. (Schisandraceae) (Sun et al., 1996).

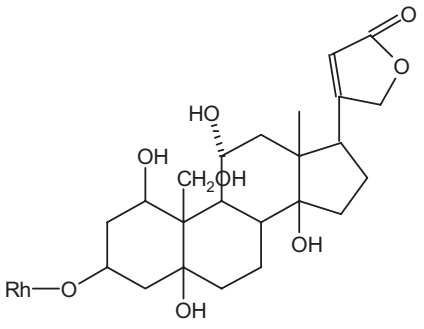
310



(22E)-5β-24-Norcholest-22-ene-3α,4α,11β,21-tetrol,3,2,1-disulfate

This compound was active against respiratory syncytial and polio viruses, was isolated from *Ophioplocus januarii* Luetken (Ophiuroidea) (Roccatagliata et al., 1996).

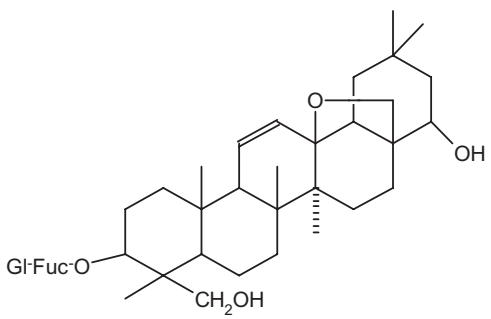
311



Ouabain

This triterpene was isolated from *Acokanthera ouabaio* Cathel. (Apocynaceae); active against Newcastle disease virus (Becher, 1976).

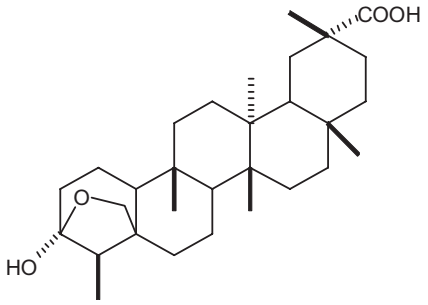
312



Saikosaponin-A

Saikosaponin-A is an inhibitor of influenza virus; isolated from *Bupleurum falcatum* L. (Umbilliferae) (Hiller, 1987).

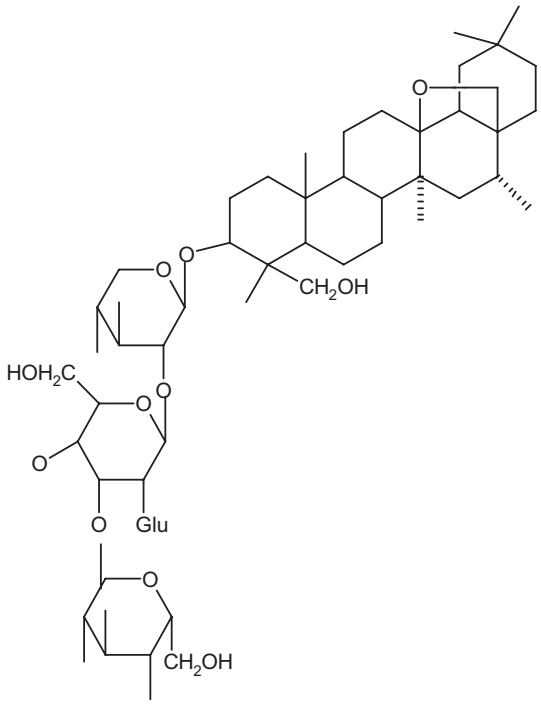
313



Salaspermic acid

Salaspermic acid is an inhibitor of HIV reverse transcriptase and HIV replication in H9 lymphocyte cells; isolated from the roots of *Triterygium wilfordii* Hook (Clastraceae) (Hiller, 1987).

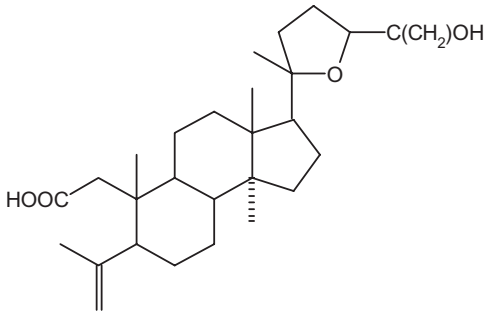
314



Saponin 2

Occurs in the leaves of *Anagallis arvensis* L. (Primulaceae); active against Herpes virus and poliovirus (Koch & Sandor, 1969).

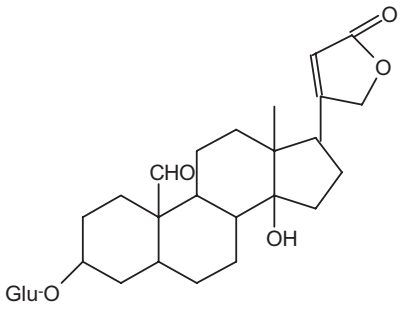
315



Shoeric acid

Shoeric acid, shows remarkable inhibitory effects against Herpes virus; isolated from *Strophanthus kombe* Oliv (Apocynaceae) (Kaij-a-Kamb et al., 1992).

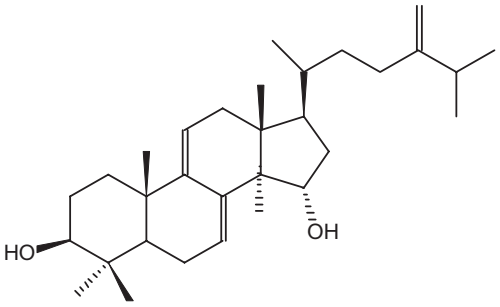
316



Strophanthin G

Occurs in *Strophanthus kombe* Oliv. (Apocynaceae); active against influenza, Herpes and vaccinia viruses (Kaij-a-Kamb et al., 1992).

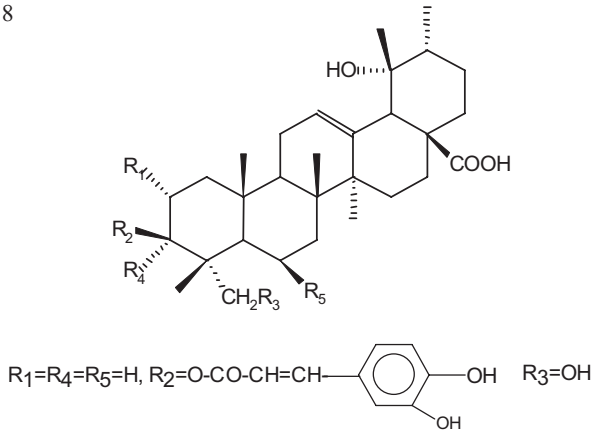
317



Suberosol

A C_{31}, lanostane-type triterpene, assigned the trivial name suberosol has been isolated from *Polyalthia suberosa* Roxburgh Thwaites (Annonaceae); anti-HIV replication activity in H9 lymphocyte cells with an EC_{50} of 3 µg/ml (Li et al., 1993).

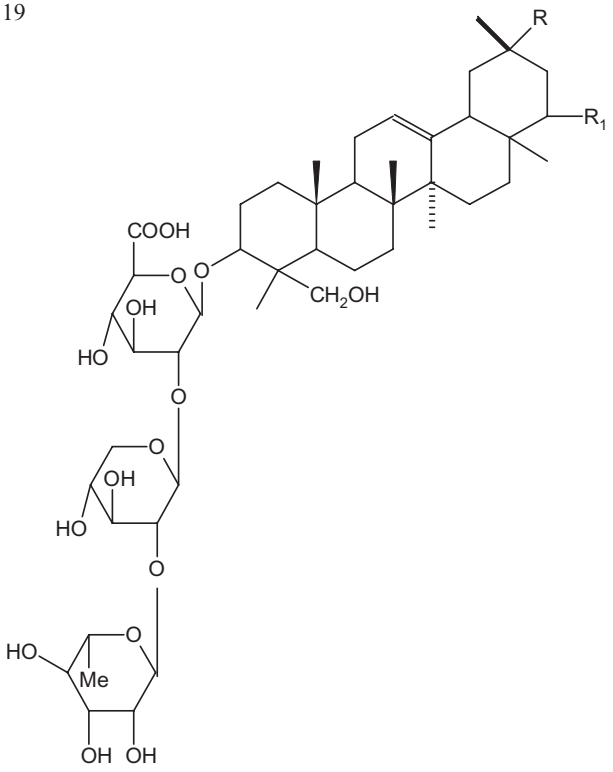
318



3-*O*-*trans*-Caffeoyltormentic acid

The chloroform extract of *Eriobotrya japonica* Lindl. (Rosaceae) contains some triterpene esters; only the 3-*O*-*trans*-caffeoyltormentic acid reduced rhinovirus infection. The compound was ineffective towards human immunodeficiency virus type (HIV-1) and Sindbis virus replication (Tommasi et al., 1992).

319



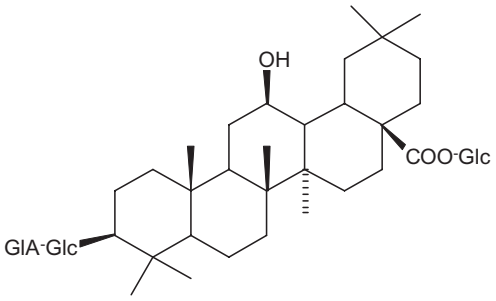
R_1 = O, R_2 = CH_2OH
Wistariasaponins A

320 $R_1 = OH$, $R_2 = CH_2OH$
Wistariasaponins B

321 $R_1 = OH$, $R_2 = CH_3$
Wistariasaponins C

Obtained from *Wistaria brachybotrys* Sieb (Leguminosae); active against Epstein-Barr virus activation induced by a tumor promoter (Konoshima et al., 1989).

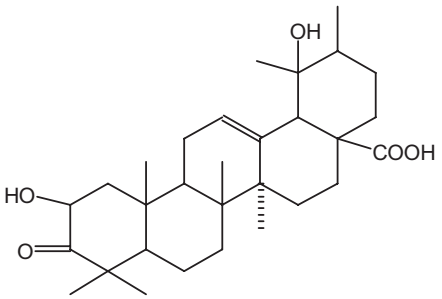
322



Zingibroside R_1

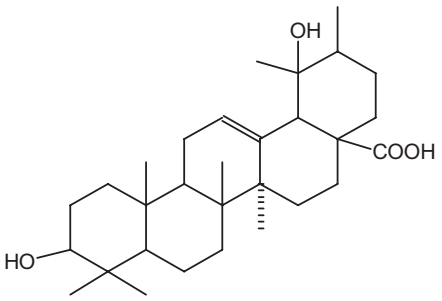
Isolated from rhizomes of *Panax zingiberensis* Wu et Feng; has an anti-HIV activity (Hasegawa et al., 1994).

323



2α-19α-Dihydroxy-3-oxo-12-ursen-28-oic-acid

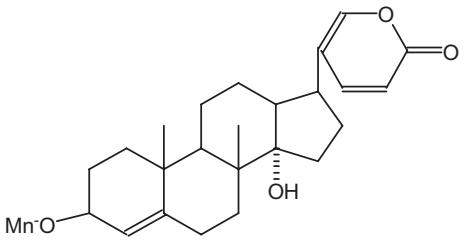
324



Mastinic acid

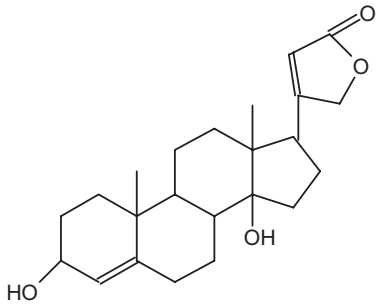
Found in *Geum japonicum* (Rosaceae); showed potent inhibitory activity against HIV-1 protease (Hiller, 1987).

325



Proscillaridin A

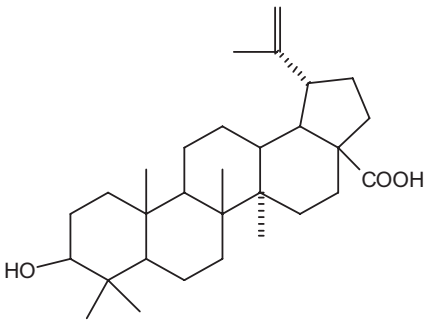
326



Scillarenin

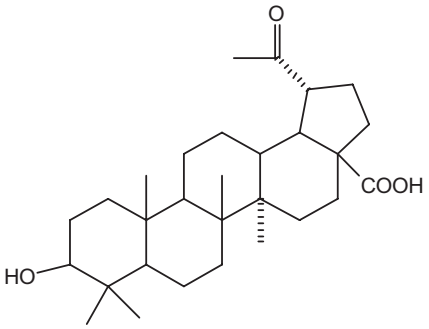
Proscillaridin A and scillarenin were isolated from *Urginea scilla* Steinh (Liliaceae). Proscillaridin A is active against influenza, Herpes and vaccinia virus (Koch & Sandor, 1969). Scillarenin inhibited picornaviruses, especially rhinoviruses.

327



Betulinic acid

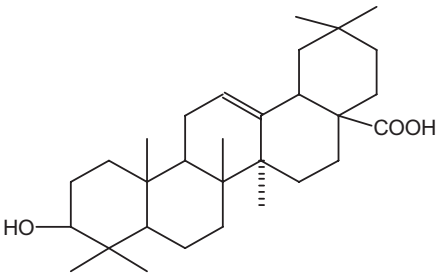
328



Platanic acid

Betulinic acid and platanic acid isolated from the leaves of *Syzigium claviflorum* (Roxb.) Wall (Myraceae); inhibitors of HIV replication in H9 lymphocyte cells (Fujioka et al., 1994).

329



Oleanolic acid

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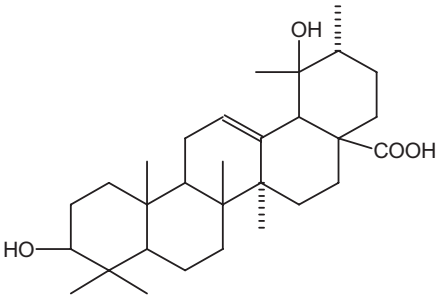
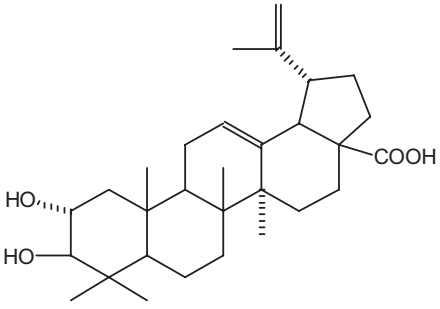


Pomolic acid

331



Alphitolic acid

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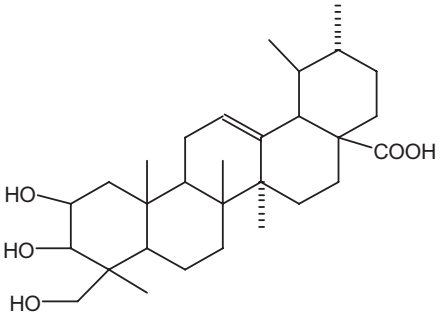

Asiantic acid

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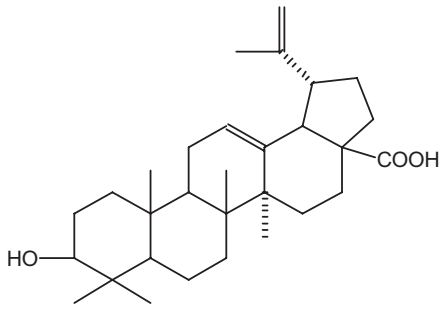
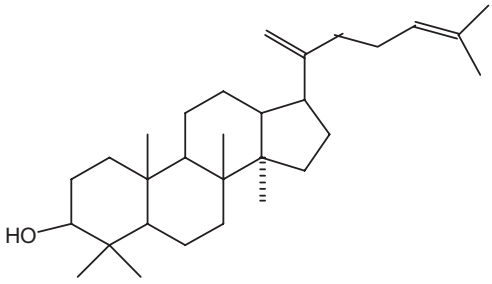


Betulinic acid

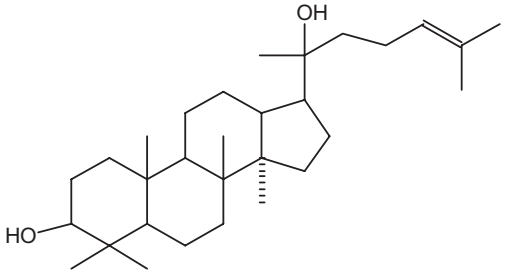
The HIV inhibitory effects of oleanolic acid (*Prosopis glandulosa*, Torr, Leguminosae), pomolic acid, alphitolic acid (*Rosa woodsii* Lindl. Rosaceae), arjunolic acid, asiantic acid, betulinic acid (*Syzygium claviflorum* Wall, Myrtaceae) isolated from various plant sources were examined. All compounds inhibited HIV-1 replication in acutely infected H9 cells (Kashiwada et al., 1998).

334



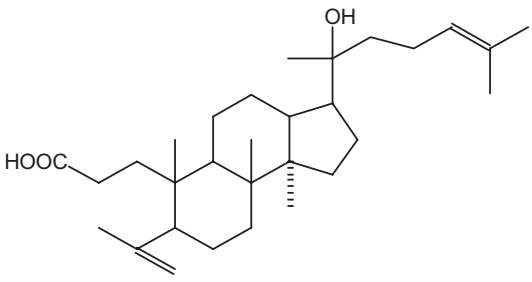
Dammaradienol

335



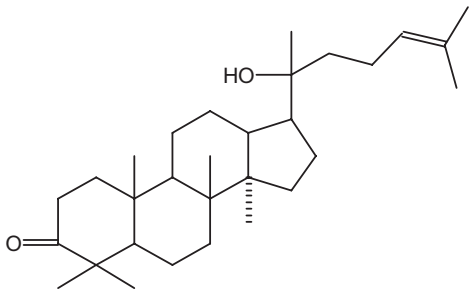
Dammaradienol II

336



Dammarenolic acid

337



Hydroxydammarenone I

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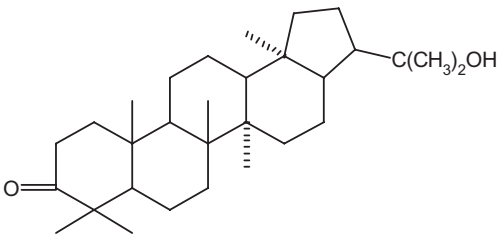
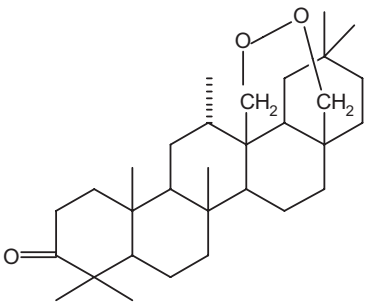


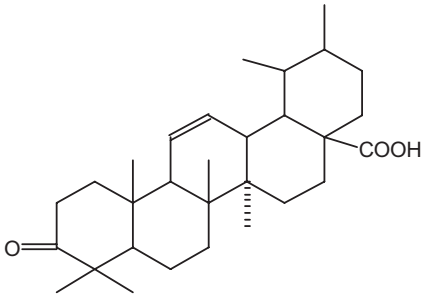
Hydroxyhopanone

339



Hydroxyoleanolic acid

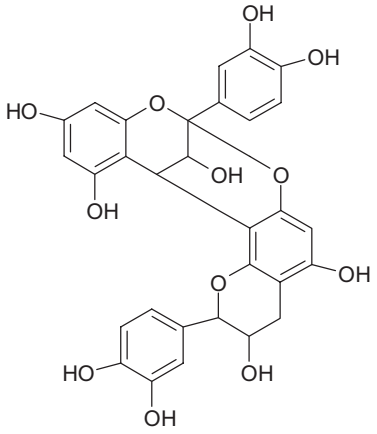
340



Ursonic acid

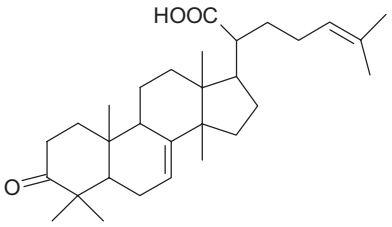
Seven triterpenes were isolated from *Balanocarpus heimii* King (Dipterocarpaceae); possess antiviral activity against Herpes virus (Swallow et al., 1975).

341



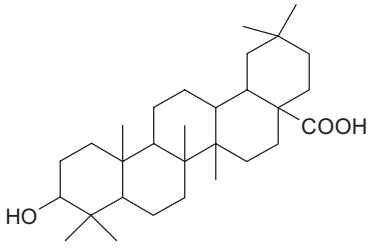
Epigallocatechin-(4β→8,2β→*O*-7)-epicatechin

342



3-Oxotirucalla-7–24-dien-21oic acid

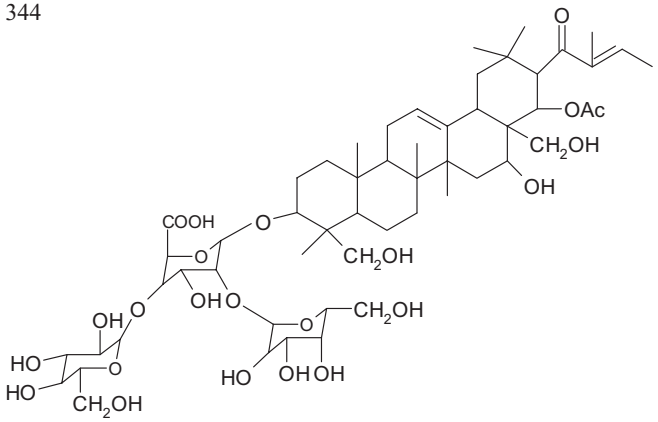
343



Oleanolic acid

From a methanolic extract of the wood of *Xanthoceras sorbifolia* Bunge (Sapindaceae), these constituents were isolated; inhibitory substances against human inmunodeficiency virus (HIV-1) protease (Ma et al., 2000).

344



Escin

Found in the seeds of *Aesculus chinensis* Bge. (Hippocastanaceae); moderate anti-HIV protease activity (Yang et al., 1999; Xiu-Wuei et al., 1999).

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