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TRITERPENOID SAPONINS

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Key Word Index—Triterpenoid saponins; isolation; structure elucidation; natural distribution; biological activity.

Abstract—Triterpenoid saponins isolated from various sources are reviewed. The recent techniques used in their isolation and structure elucidation are discussed. A compilation of the triterpenoid saponins isolated and characterized during the period 1979–1986 along with their occurrence is included. The biological activities of the triterpenoid saponins are also covered.

INTRODUCTION

Triterpenoid saponins are naturally occurring sugar conjugates of triterpenes possessing the property of forming stable froth when shaken with water. The glycone part of these compounds are generally oligosaccharides, linear or branched, attached to a hydroxyl or a carboxyl group or both. The sites of attachment may be one (monodesmosides), two (bisdesmosides) or three (tridesmosides).

Excellent comprehensive reviews on the triterpenoid saponins by Rastogi and his co-workers [1, 2] covered the literature up to 1978. An excellent review on the chemistry and biological significance of saponins in foods and feeding stuffs has recently been published [3]. A comprehensive review on steroid saponins has also been published [4]. Ginseng saponins have been reviewed briefly by Pleinard [5]. Another review [6] briefly deals with the advances in structure elucidation of triterpenoid saponins. The bisdesmosidic triterpene saponins have been reviewed by Adler and Hiller [7] and new findings on triterpene saponins have also been reviewed [8]. This review is concerned with the recent developments in isolation and structure elucidation of triterpenoid saponins. A compilation of these saponins isolated during the period 1979–1986 is included. The biological activities of these glycosides isolated during the same period are also covered.

ISOLATION

The classical methods of isolation of triterpenoid saponins are available [1–4]. However, these methods are found to be inadequate for the separation of complex saponin mixtures into individual components. The advent of recent chromatographic techniques have provided valuable means for isolation of pure saponins or their derivatives.

High performance liquid chromatography (HPLC)

The use of HPLC in the separation of various complex mixtures including saponins is now widespread. Although, the determination of optimum parameters for the separation of individual components of a mixture is generally time-consuming, the process becomes indispensable in many cases for efficient and successful separation of pure saponins.

Two new dammarane saponins, notoginsenoside R_1 and notoginsenoside R_2 were isolated by preparative reversed phase HPLC on a ODS silica gel column using methanol–water (11:9) as the mobile phase [9]. The crude saponin mixture, however, was partially purified by dialysis through cellulose film prior to the application of the HPLC technique.

The isolation of Gymnocladus saponin D from the fruits of *Gymnocladus chinensis* was achieved by column chromatography on silica gel with chloroform–methanol–water (13:7:2 lower layer), gel filteration on a Sephadex LH-20 column in methanol and preparative HPLC on a μ-Bondapak C_{18} column (mobile phase MeOH–H_2O, 7:3) [10]. Kitagawa *et al.* [11] used the semipreparative μ-Bondapak C_{18} column and mobile phase methyl cyanide–methanol–water (1:1:1) for the successful separation of desulfated triterpenoid oligoglycosides from cuvierian tubules of *Actinopyga agassizi*. A reversed phase S-10-ODS column was used with solvent system methanol–water (7:3) for the separation of a number of saiko-saponins like triterpenoid glycosides, corchorusins from *Corchorus acutangulus* L. [12, 13]. Ireland and Dziedzic determined the saponins from defatted soyabean after extraction by ethyl acetate and methanol, passage through a Sep-pak C_{18} cartridge, and elution with methanol and water by HPLC on a column fitted with spherisorb 5 μm silica with chloroform containing 1% acetic acid or methanol–water–acetic acid (95:4:1) as solvent [14].

Droplet counter-current chromatography (DCCC)

The technique of DCCC [15] has found application in isolation and purification of saponins. Hostettmann *et al.* [16–18] reviewed the isolation of natural products by DCCC. Four new triterpenoid glycosides were successfully isolated from the methanol extract of *Tetrapanax papyriferum* by DCCC using solvent system, chloroform–methanol–water (7:13:8), the upper layer as the mobile phase and the lower layer as the stationary phase.

The fractions that flowed from the DCCC apparatus were monitored by TLC [19]. The crude saponin isolated from the leaves of *Bupleurum rotundifolium* was first fractioned by DCCC using a chloroform–methanol–water (7:13:8) solvent system (upper layer as the mobile phase, lower layer as the stationary phase) and then purified by silica gel chromatography to give pure rotundiosides D and G [20]. Silica gel column chromatography followed by DCCC was used to isolate the triterpenoid saponins present in the berries of *Lonicera nigra* [21]. The saikosaponins of *Bupleuri radix* have been isolated by DCCC using a solvent system, chloroform–benzene–ethyl-acetate–water [22].

Centrifugal liquid chromatography (CLC)

The technique of CLC [23] has potential for the separation of closely related saponins. Kitagawa *et al.* [24, 25] carried out the separation of a number of triterpenoid saponins (azukisaponins) from the seeds of *Vigna angularis* by a combination of ordinary column chromatography, CLC and some other means. For CLC, they used Hitachi centrifugal liquid chromatograph model CLC-5 with KT-Gel 2061 (Fuji-Gel) as the adsorbent.

Rotation locular counter-current chromatography (RLCC)

This recently described technique [26] may find application in the isolation of saponins. Three bisdesmosidic saponins were isolated from the methanol extract of *Phytolacca dodecandra* berries by combination of RLCC and reversed phase column chromatography [27].

Flash chromatography

Flash chromatography [28] is basically an air-pressure driven hybrid of medium pressure and short column chromatography which is optimized for particularly rapid separations. This technique has apparent great potential for the large scale isolation of plant saponins. Price *et al.* [29] have successfully applied this method for the isolation of saponins and their acetyl derivatives from *Pisum sativum*. Molluscicidal saponins from *Talinum tenussmicum* [30] have been isolated by this technique using commercially available prepacked columns containing reversed phase silica support. The isolation of alfalfa saponins from alfalfa roots has been achieved by a combination of normal phase flash chromatography and preparative TLC [31].

It may be concluded that several of these techniques are necessary for the separation of individual constituents of a complex saponin mixture. Nevertheless, the integration of silica gel column chromatography, semipreparative HPLC and repeated preparative TLC may yield expected separation in most of the cases.

STRUCTURE ELUCIDATION

The conventional method of structure elucidation of triterpenoid saponins starts with acid hydrolysis yielding the aglycone and the sugar moieties which are separately investigated. In recent spectroscopic methods, the saponin itself is examined for determination of its complete structure. However, partial hydrolysis and methylation studies are sometimes found to be necessary for the establishment of complex structures. Acid hydrolysis of saponins often leads to artifacts and as such newer techniques of hydrolysis have been developed for the generation of genuine aglycones.

Various techniques have been reported for specific cleavage of glucuronide linkages, Lead acetate and alkali [32], anodic oxidation [33] or acetic anhydride and pyridine [34] have been used for the purpose. The method of photochemical degradation developed by Kitagawa *et al.* [35] has been used for selective cleavage of the glucuronide linkage [24, 36–38]. Ogihara and Nose [39] have reported a simple method for the cleavage of the glycosidic bond of saponins containing acid-labile aglycones by the use of alcoholic alkali metal solution having a trace of water. This method afforded all the three partially hydrolysed prosapogenins and the genuine sapogenin, saikogenin E of saikosaponin c in satisfactory yield. The methods of periodate oxidation [40, 41] and the heterogeneous acid catalysis [42] are sometimes used for the mild hydrolysis of saponins.

Enzymic hydrolysis has been frequently employed for specific cleavage of sugar linkages in saponins. The use of hesperdinase for the hydrolysis of azukisaponins [24, 25] and astragalosides [41, 43] has been described. Application of almond emulsin [44], naringinase [45, 46] and cellulase [47, 48] for specific hydrolysis of sugar linkages has also been reported.

The structure of the sugar moieties of the saponins is determined by identification of the monosaccharides liberated as a result of the above techniques by GLC and sometimes by GC/MS analysis of the alditol acetate derivatives. The points of attachment of different sugar units are revealed by permethylation of the saponins followed by hydrolysis or methanolysis and identification of the partially methylated alditol acetate derivatives by GLC. The mode of sugar linkage may be determined enzymically or by the application of Klyne's rule [49]. ^{1}H and ^{13}C NMR spectroscopy have proved to be very useful in the determination of the anomeric mode of the sugar linkages [4].

^{13}C NMR *spectroscopy*

^{13}C NMR spectrsocopy is now widely used for the structure determination of triterpenoid saponins. Assignments of the signals of various carbons of the saponins are generally made by comparison with the ^{13}C NMR data of the aglycone and methyl sugars using known chemical shift rules and glycosylation shifts [50, 51]. However, in complex cases, utilisation of certain other techniques is necessary for complete signal assignments. Some recent assignment techniques including 2D-spectroscopy and selective single frequency proton decoupling have been reviewed for the structure elucidation of steroid saponins [52]. These techniques are equally applicable to triterpenoid saponins.

The partially relaxed Fourier transform (PRFT) [53, 54] and acylation shift methods have been applied for the signal assignments of ^{13}C NMR spectra of echinocystic acid-3-*O*-glycoside, 28-*O*-glycoside and desmonoterpenyl-3,28-*O*-bisglycoside [47]. The spin-lattice relaxation time (T_1) [55, 56] has also been used to determine sugar sequences of the echinocystic acid bis-glycosides [47]. For a carbon atom, the product of T_1 and N, the number of directly bonded hydrogen atoms is a function of the flexibility of the molecule at that carbon atom. The

values of NT_1 are shortest for aglycone and inner sugar carbon atoms and longest for those of the terminal sugar. This technique has been used by Ishii *et al.* [57] and Wagner *et al.* [58] for the determination of sugar sequences in saponins.

2D NMR *spectroscopy*

2D FT NMR techniques have greatly enhanced the power of NMR to unravel complex chemical structures including saponins. Homonuclear 2D *J*-resolved experiments can be helpful in elucidation complex overlapping coupling patterns. Homonuclear chemical shift correlation experiments may be used to determine the homonuclear coupling networks. Heteronuclear chemical shift correlation experiments can be used to relate the proton spectrum to the carbon spectrum. Carbon–carbon connecitivity experiments reflect carbon homonuclear coupling. Application of 2D NMR in carbohydrate structural analysis has been reviewed [59]. The structures of tetrasaccharide units of the antifungal saponins, camellidin-I and camellidin-II isolated from *Camellia japonica* was determined by two dimensional ^{1}H NMR techniques [60]. Two dimensional ^{1}H correlation (COSY) [61] and two dimensional nuclear Overhauser effect (NOESY) [62] spectroscopy can be used with advantage for complete elucidation of the structure of oligosaccharide moiety of the saponins. All the available chemical methods, ^{1}H and ^{13}C NMR spectroscopy were found to be inadequate for unambiguous determination of the structures of two triterpenoid tetrasaccharides from *Androsace saxifragifolia* [63]. The problem was successfully overcome by the use of two-dimensional COSY-45 and two-dimensional NOESY experiments. The complete structures of the tetrasaccharide moiety could be elucidated including conformations of the monosaccharide units.

Mass spectroscopy

Mass spectrometry has had limited application in the M_r determination and structural analysis of saponins, because the most common means of sample ionization, e.g. electron impact (EI) as well as chemical ionization (CI) requires volatalization of the sample. One of the most successful methods of ionization which has found application in the structure determination of saponins is the field desorption (FD) technique [64, 65]. FDMS of triterpenoid saponins yield valuable structural information [43, 66–68]. The FDMS show the presence of supramolecular ion species corresponding to $[M+Na]^+$ and $[M+K]^+$ and their abundance depends on the concentration of these cations during isolation. However, these ions and their fragments not only give information regarding the M_r, but also information with regard to the sequence of the sugar units in the molecule. The quality of the FD-MS can be improved by the variation of emitter ionization efficiency, sample temperature and the use of a sensitive collection system.

Fast atom bombardment mass spectrometry (FABMS) which has recently emerged as a powerful tool in M_r determination and structural investigation of polar molecules [69–71] was applied to some naturally occurring oligoglycosides of known structures viz. dioscin and gracillin [72], tribulosin [73], khasianine, solasonine and solamargin [74] to study the fragmentation pattern of such molecules [75]. From a comparison of FD- and FABMS of saponins, Schulten *et al.* [76] concluded that the combination of FDMS and FABMS is a powerful analytical combination for investigations on saponins and related species. The positive and negative FABMS of triterpene saponins and their FAB-MIKE (mass analysed ion kinetic energy) and FAB-CAD (collision activated dissociation) spectra have been described in detail [77]. It was demonstrated that the negative ion FAB using polyethylene glycol 200 as matrics gave more information than the positive ion spectrum, but the two may be judged as complimentary. The FABMS has been demonstrated to be an aid to the glycoside sequence determination in the structure elucidation of a novel hexasaccharides, muskarosides [78]. The structures of two glycosides isolated from *Polygala chamaebuxus* were also established by this technique [79].

Other techniques which have potential for the analysis of complex plant saponins include secondary ion mass spectrometry (SIMS) [80, 81], desorption chemical ionization mass spectrometry [82], laser desorption mass spectrometry [83], diethanolamine-assisted SIMS [84] and Curie point pyrolysis mass spectrometry [85].

X-ray crystallography

Although X-ray crystallography studies have been applied for the determination of the strucutre and stereochemistry of complex triterpenoids [86], the application of this technique to the structure determination of triterpenoid saponins is rare; presumably because it is difficult to obtain single crystal for most of the saponins. Recently, the molecular geometry of asiaticoside, a trisaccharide triterpene isolated from *Centella asiatica* has been determined by a single crystal X-ray analysis [87].

REPORTS OF NEW TRITERPENOID SAPONINS

The new saponins isolated during the period 1979–1986 are listed in Table 1.

1 3β-OH, 28-COOH, oleanolic acid
2 3β, 23-OH, 28-COOH, hederagenin
3 3β, 16α-OH, 28-COOH, echinocystic acid
4 3β, 16β-OH, 28-COOH, cochalic acid
5 3β, 16α, 23, 28-OH
6 3β, 16α-OH, 23-CHO, 28-COOH, quilaic acid
7 3, 21-Oxo, 11α-OMe, 28-COOH
8 3α-OH, 11α-OMe, 21-Oxo, 28-COOH
9 3α, 11α-OH, 21-Oxo, 28-COOH
10 3, 21-Oxo, 11α-OH, 28-COOH, propapyriogenin A_2
11 3β, 21β, 22β, 24-OH, soyasapogenol A
12 3β, 21β, 23-OH, 28-COOH, 21β-hydroxy, hederagenin

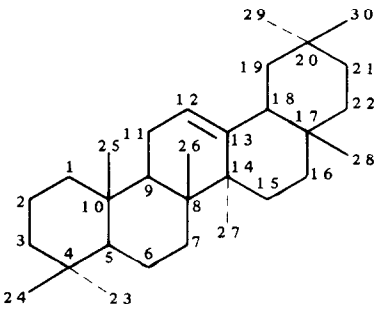


Table 1. Reports of new triterpenoid saponins

Saponin	Source	Structure	Reference
Acanthophylloside D	*Acanthophyllus gypsophiloides*	Quilaic acid (**6**) gal-^{4}ara-^{4}glc (3β-OH) gal^{2} xyl-^{3}xyl-^{3}xyl-^{4}rham-^{4}fuc (28-COOH) ^{2}chi	[88]
Acetyl Shengmanol xyloxide	*Cimicifuga japonica*	Aglycone (**84**) xyl (3β-OH)	[89]
Anchusoside-4	*Anchusa officinalis*	Aglycone (**36**) glc (21-OH)	[90]
Anchusoside-5	*Anchusa officinalis*	21β-hydroxy hederagenin (**12**) glc-^{2}glc (21β-OH)	[91]
Androseptoside A	*Androsace septentrionalis*	Oleanolic acid (**1**) glc (3β-OH)	[92]
Androseptoside B	*Androsace septentrionalis*	Erythrodiol (**39**) glc (3β-OH)	[92]
Androseptoside C	*Androsace septentrionalis*	Cochalic acid (**4**) ara-^{4}glc (3β-OH)	[92]
Androseptoside C_1	*Androsace septentrionalis*	Oleanolic acid (**1**) ara-^{2}ara-^{4}glc (3β-OH)	[93]
Androseptoside D	*Androsace septentrionalis*	Longispinogenin (**15**) ara-^{4}glc (3β-OH)	[92]
Androseptoside D_1	*Androsace septentrionalis*	Primulagenin A (**14**) ara-^{2}ara-^{4}glc (3β-OH)	[93]
Androseptoside F	*Androsace septentrionalis*	Primulagenin A (**14**) rham-^{2}ara-^{2}ara-^{4}glc (3β-OH)	[94]
Aquilegifolin	*Thalictrum aquilegifolium*	aglycone (**50**) rham-^{2}glc (28-COOH)	[95]
Arjunglycoside III	*Terminalia arjuna*	aglycone (**24**) glc (28-COOH)	[96]
Arjunoside I	*Terminalia arjuna*	Arjunic acid (**37**) gal (3β-OH)	[97]
Arjunoside II	*Terminalia arjuna*	Arjunic acid (**37**) rham-^{2}glc (3β-OH)	[98]
Askendoside A	*Astragalus taschkendicus*	aglycone (**89**) ara-^{2}(3'-OAc)xyl (3β-OH)	[98]
Askendoside B	*Astragalus taschkendicus*	Cycloastragenol (**88**) ara-^{2}(3'-OAc)xyl (3β-OH) xyl (6β-OH)	[99]
Askendoside C	*Astragalus taschkendicus*	aglycone (**89**) ara-^{2}xyl (3β-OH)	[100]
Askendoside D	*Astragalus taschkendicus*	Cycloastragenol (**88**) ara-^{2}xyl (3β-OH) xyl (6α-OH)	[101]
Astichiposide C	*Stichopous chloronotus*	aglycone (**112**) (3'-OMe)glc-^{3}glc $^{4}_{2}$xyl (3β-OH) (3'-OMe)glc-^{3}xyl-^{4}Quin	[102]
Acetyl astragaloside	*Astragali radix*, *Astragalus membranaceus*	Cycloastragenol (**88**) (2',3',4'-triOAc)xyl (3β-OH)	[103,104]
Astragaloside I	*Astragali radix*, *Astragalus membranaceus*	Cycloastragenol (**88**) (2',3'-diOAc)xyl (3β-OH)	[103,104]
Astragaloside II	*Astragali radix*, *Astragalus membranaceus*	Cycloastragenol (**88**) (2'-OAc)xyl (3β-OH)	[103,104]
Isoastragaloside II	*Astragali radix*, *Astragalus membranaceus*	Cycloastragenol (**88**) (3'-OAc)xyl (3β-OH) glc (6α-OH)	[103,104]
Isoastragaloside I	*Astragali radix*, *Astragalus membranaceus*	Cycloastragenol (**88**) (2',4'-diOAc)xyl (3β-OH)	[103,104]
Astragaloside III	*Astragali radix*, *Astragalus membranaceus*	Cycloastragenol (**88**) glc-^{2}xyl (3β-OH)	[43]
Astragaloside IV	*Astragali radix*, *Astragalus membranaceus*	Cycloastragenol (**88**) *xyl* (3β-OH); glc (6α-OH)	[103,104]

Table 1. *Continued*

Saponin	Source	Structure	Reference
Astragaloside V	*Astragali radix*, *Astragalus membranaceus*	Cycloastragenol (**88**) glc-^{2}xyl (3β-OH) glc (25-OH)	[43]
Astragaloside VI	*Astragali radix*, *Astragalus membranaceus*	Cycloastragenol (**88**) glc-^{2}xyl (3β-OH) glc (6α-OH)	[43]
Astragaloside VII	*Astragali radix*, *Astragalus membranaceus*	Cycloastragenol (**88**) xyl (3β-OH) glc (6α-OH) glc (25-OH)	[37]
Astragaloside VIII	*Astragali radix*, *Astragalus membranaceus*	Soyasapogel B (**16**) rham-^{2}xyl-^{2}glu (3β-OH)	[37]
Astragalus saponin AS I	*Astragali radix*, *Astragalus membranaceus*	Cycloastragenol (**88**) xyl (3β-OH) glc (6α-OH)	[105]
Astragalus saponin AS II	*Astragali radix*, *Astragalus membranaceus*	Cycloastragenol (**88**) Xyl (3β-OH)	[105]
Azukisaponin I	*Vigna angularis*	Sophoradiol (**17**) glc-^{2}glu (3β-OH)	[25]
Azukisaponin II	*Vigna angularis*	Soyasapogenol B (**16**) glc-^{2}glu (3β-OH)	[25]
Azukisaponin III	*Vigna angularis*	Azukisapogenol (**18**) glc-^{2}glu (3β-OH)	[25]
Azukisaponin IV	*Vigna angularis*	Gypsogenic acid (**13**) glc (3β-OH) glc-^{6}glc (28-COOH)	[25]
Azukisaponin V	*Vigna angularis*	Soyasapogenol B (**16**) rham-^{2}glc-^{2}glu (3β-OH)	[23]
Azukisaponin VI	*Vigna angularis*	Azukisapogenol (**18**) glc-^{2}glc (3β-OH) glc-^{6}glc (29-OH)	[23]
Beesioside III	*Beesia cathaefolia* *Souliea vaginata*	Cyclolanostane tetraol (**91**) xyl (3β-OH)	[106]
Bryonoside	*Bryonia dioica*	Aglycone (**121**) rham-^{2}glc (3β-OH) glc (25-OH)	[68]
Bryoside	*Bryonia dioica*	Aglycone (**121**) rham-^{2}glc (3β-OH) glc (25-OH)	[68]
Camellidin I	*Camellia japonica*	Aglycone (**43**) glc-^{2}gal-$^{4}_{2}$glu (3β-OH) gal	[60]
Camellidin II	*Camellia japonica*	Aglycone (**59**) glc-^{2}gal gal-$^{4}_{2}$glu (3β-OH)	
Capsin	*Corchorus capsularis*	Capsugenin (**100**) glc (3β-OH)	[107]
Caulloside B	*Caullophyllum robustum*	Hederagenin (**2**) rham-^{2}ara (3β-OH)	[108]
Caulloside C	*Caullophyllum robustum*	Hederagenin (**2**) ara-^{3}rham-^{2}ara (3β-OH)	[108]
Chikusaikoside I	*Bupleurum longeradiatum*	Saikogenin F (**73**) xyl-^{2}glc-^{3}fuc (3β-OH)	[109]
Chikusaikoside II	*Bupleurum longeradiatum*	Saikogenin E (**74**) glc rham-$^{6}_{4}$glc (3β-OH)	[109]
Chiisanoside I	*Acanthopanax chiisanensis*	Chiisanogenin (**142**) rham-^{4}glc-^{6}glc (28-COOH)	[110]
Chikusetsusaponin II	*Panacis japonici*	Oleanolic acid (**1**) glc-^{6}glu (3β-OH)	[111]

Table 1. *Continued*

Saponin	Source	Structure	Reference
Chikusetsusaponin	*Panacis japonici*	20(*S*) Protopanaxatriol (**98**) rham-^{2}glc (6α-OH) glc (20β-OH)	[111]
Chikusetsusaponin LT_5	*Panacis japonicus*	Aglycone (**94**) glc (3β-OH) glc-^{6}glc (20β-OH)	[112]
Chikusetsusaponin LT_8	*Panacis japonicus*	Aglycone (**94**) glc (3β-OH) glc (20β-OH)	[112]
Chikusetsusaponin LN_4	*Panacis japonicus*	Aglycone (**94**) xyl-^{6}glc (3β-OH) ara-^{6}glc (20β-OH)	[112]
Chrysantellin A	*Chrysanthellum procumbens*	Echinocystic acid (**3**) rham-^{3}xyl-^{4}rham-^{2}xyl (28-COOH) glc (3β-OH)	[113]
Chrysantellin B	*Chrysanthellum procumbens*	Caullophyllogenin (**27**) rham-^{3}xyl-^{4}rham-^{2}xyl (28-COOH) glc (3β-OH)	[114]
Cimicifugoside	*Cimicifuga* species	Aglycone (**86**) ara (3β-OH)	[115]
Colubrinoside	*Colubrina asiatica*	Jujubogenin (**97**) xyl-^{3}(4′-OAc)glc-^{3}(2′-OAc)ara(3β-OH)	[116]
Colubrin	*Colubrina asiatica*	Jujubogenin (**97**) xyl-^{2}glc-^{3}(2′-OAc)ara(3β-OH)	[116]
Compound G-2	Alfalfa	Aglycone (**53**) glc (3β-OH)	[117]
Copteroside B	*Climacoptera transoxana*	Hederagenin (**2**)	[118]
Copteroside C	*Climacoptera transoxana*	Hederagenin (**2**) xyl-^{2}glu (3β-OH)	[118]
Copteroside D	*Climacoptera transoxana*	Hederagenin (**2**) xyl-^{2}glu (3β-OH) glc (28-COOH)	[119]
Copteroside E	*Climacoptera transoxana*	Oleanolic acid (**1**) xyl—4 xyl—2 glu (3β-OH) glc (28-COOH)	[120]
Copteroside F	*Climcoptera transoxana*	Hederagenin (**2**) xyl—4 xyl—2 glu (3β-OH) glc (28-COOH)	[120]
Copteroside G	*Climcoptera transoxana*	Gypsogenic acid (**13**) glu (3β-OH) glc (28-COOH)	[121]
Copteroside H	*Climcoptera transoxana*	Gypsogenic acid (**13**) glc-^{2}glu (3β-OH) glc (28-COOH)	[121]
Corchorusin A	*Corchorus acutangulus*	Longispinogenin (**15**) gal (3β-OH)	[12]
Corchorusin B	*Corchorus acutangulus*	Saikogenin F (**73**) gal (3β-OH)	[12]
Corchorusin C	*Corchorus acutangulus*	23-hydroxy longispinogenin (**20**) gal (3β-OH)	[12]
Corchorusin D	*Corchorus acutangulus*	Saikogenin E (**74**) glc-^{2}gal (3β-OH)	[12]
Corchorusin C_1	*Corchorus acutangulus*	Saikogenin C (**75**) gal (3β-OH)	[13]
Corchorusin D_1	*Corchorus acutangulus*	Saikogenin B (**76**) glc-^{2}gal (3β-OH)	[13]
Corchorusin D_2	*Corchorus acutangulus*	Longispinogenin (**15**) glc-^{2}gal (3β-OH)	[13]
Corchorusin D_3	*Corchorus acutangulus*	Saikogenin C (**75**) glc-^{2}gal (3β-OH)	[13]

Table 1. *Continued*

Saponin	Source	Structure	Reference
Cucurbitacin I glucoside	*Bryonia alba*	Aglycone (**127**) glc (2χ-OH)	[122]
Cucurbitacin II glucoside	*Bryonia alba*	Aglycone (**127**) glc (25-OH)	[122]
22-Deoxo cucurbitoside A	*Bryonia alba*	Aglycone (**124**) rham-^{4}glc (2β-OH)	[123]
22-Deoxo cucurbitoside B	*Bryonia alba* *Ecbalium elaterium*	Aglycone (**125**) rham-^{2}glc (2β-OH)	[123]
22-Deoxo cucurbitacin D	*Bryonia alba*	Aglycone (**120**) rham-^{4}glc (2β-OH)	[123]
Cucurbitacin IIa glycoside	*Hymsleya amabilis*	Cucurbitacin II (**130**) glc (2β-OH)	[124]
Cucurbitacin IIb glycoside	*Hymseleya amabilis*	Aglycone (**126**) glc (2β-OH)	[125]
Cyclamiretin glucoside I	*Cyclamen neapolitanum*	Cyclamiretin A (**70**) glc (3β-OH)	[126]
Cyclofoetoside A	*Thalictrum foetidum*	Aglycone (**86**) ara (3β-OH) rham-^{6}glc (16β-OH)	[127]
Cyclogaleginoside A	*Astragalus galegiformis*	Cycloastragenol (**88**) (2′-OAc)xyl (3β-OH)	[128]
Cyclogaleginoside B	*Astragalus galegiformis*	Cycloastragenol (**88**) xyl (3β-OH)	[128]
Cyclosiversioside A	*Astragalus siverianas*	Cycloastragenol (**88**) (2′,3′-di-OAc)xyl (3β-OH) xyl (6α-OH)	[129]
Cyclosiversioside B	*Astragalus basineri*	Cycloastragenol (**88**) (2′,3′ di-OAc)glc (3β-OH) glc (6α-OH)	[130]
Cyclosiversioside C	*Astragalus siverianas*	Cycloastragenol (**88**) (2′-OAc)xyl (3β-OH) xyl (6α-OH)	[129]
Cyclosiversioside D	*Astragalus basineri*	Cycloastragenol (**88**) (2′-OAc)glc (3β-OH) glc (6α-OH)	[130]
Cyclosiversioside E	*Astragalus siverianas*	Cycloastragenol (**88**) glc (3β-OH) glc (6α-OH)	[131]
Cyclosiversioside F	*Astragalus siverianas*	Cycloastragenol (**88**) xyl (3β-OH) glc (6α-OH)	[132]
Cyclosiversioside G	*Astragalus siverianas*	Cycloastragenol (**88**) rham-^{2}xyl (3β-OH) xyl (6α-OH)	[133]
Cyclosiversioside H	*Astragalus siverianas*	Cycloastragenol (**88**) rham-^{2}xyl (3β-OH) glc (6α-OH)	[134]
Cymbidoside	*Cimbidium giganteum*	Cymbidosone (**141**) glc (29-OH)	[135]
Desacyl jegosaponin	*Styrax japonica*	Aglycone (**28**) rham-^{2}gal $\diagdown^{3}$ glc $\diagup_{2}$ glu (3β-OH)	[136]
Desacyl boninsaponin A	*Schima mertensiana*	Aglycone (**29**) rham-^{2}gal $\diagdown^{3}$ glc $\diagup_{2}$ glu (3β-OH)	[136]
Desmonoterpenyl glucoside	*Gleditsia japonica*	Echinocystic acid (**3**) xyl-^{2}ara-^{6}glc (3β-OH rham $\diagdown^{6}$ xyl-^{3}xyl-^{4}-rham $\diagup_{2}$glc (28-COOH)	[137]
Dianoside C	*Dianthus superbus* var *longicalycinus*	Aglycone (**30**) glc (3β-OH) glc (28-COOH)	[138]

Table 1. *Continued*

Saponin	Source	Structure	Reference
Doliroside	*Dolichos falcata*	Medicagenic acid 23-mono-methylate (**21**) glc (3β-OH)	[139]
Echinoside A	*Actiropyga echinites*	Aglycone (**119**) (3′-OMe)glc-^{3}glc-^{4}quin-^{2}(4′-SO_3Na)ara (3β-OH)	[140]
Echinoside B	*Actiropyga echinites*	Aglycone (**119**) quin-^{2}(4′-SO_3Na)ara (3β-OH)	[140]
Esculetin	*Patrinia scabiosaefolia*	Hederagenin (**2**) rham-^{2}ara (3β-OH)	[141]
Fatsiaside A_1	*Fatsia japonica*	Oleanolic acid (**1**) ara (3β-OH)	[142]
Fatsiaside B_1	*Fatsia japonica*	Hederagenin (**2**) ara (3β-OH)	[142]
Fatsiaside C_1	*Fatsia japonica*	Oleanolic acid (**1**) glc (3β-OH)	[142]
Fatsiaside D_1	*Fatsia japonica*	Hederagenin (**2**) glc-^{2}ara (3β-OH)	[142]
Fatsiaside D	*Fatsia japonica*	Hederagenin (**2**) ara (3β-OH) rham-^{4}glc-^{4}glc (28-COOH)	[143]
Fatsiaside E	*Fatsia japonica*	Oleanolic acid (**1**) glc-^{2}ara (3β-OH) rham-^{4}glc-^{4} glc (28-COOH)	[143]
Fatsiaside F	*Fatsia japonica*	Hederagenin (**2**) glc-^{2}ara (3β-OH) rham-^{4}glc-^{4}glc (28-COOH)	[143]
Geniculatin	*Euphorbia geniculata*	Oleanolic acid (**1**) rham-^{4}xyl-^{4}glu (3β-OH)	[144]
Giganteaside D	*Cephalaria gigantea*	Oleanolic acid (**1**) rham-^{2}xyl (3β-OH)	[145]
Giganteaside E_1	*Cephalaria gigantea*	Hederagenin (**2**) rham-^{2}xyl-^{2}ara (3β-OH)	[146]
Giganteaside G	*Cephalaria gigantea*	Oleanolic acid (**1**) rham-^{2}xyl (3β-OH) glc (28-COOH)	[145]
Giganteaside H_1	*Cephalaria gigantea*	Hederagenin (**2**) rham-^{2}xyl-^{2}ara (3β-OH) glc (28-COOH)	[146]
Ginsensoside Ra_3	White & red *ginseng*	20(*S*)-Protopanaxadiol (**99**) glc-^{2}glc (3β-OH) xyl-^{3}glc-^{6}glc (20-OH)	[147]
Ginsenoside Re	*Panax pseudoginseng* subsp. *himalicus*	20(*S*)-Protopanaxatriol (**98**) rham-^{2} glc (6α-OH) glc (20β-OH)	[148]
Ginsenoside Rd	*Panax pseudoginseng* subsp. *himalicus*	20(*S*)-Protopanaxatriol (**98**) glc-^{2}glc (3β-OH) glc (20β-OH)	[148]
Ginsenoside Rb_3	*Panax pseudoginseng* subsp. *himalicus*	20(*S*)-Protopanaxatriol (**98**) glc-^{2}glc (3β-OH) xyl-^{6}glc (20β-OH)	[148]
Ginsenoside Rh_1	*Panax ginseng*	20(*S*)-Protopanaxatriol (**98**) glc (6α-OH)	[149]
Ginsenoside M_{7cd}	*Panax ginseng*	Dammarene pentaol (**96**) glc (20β-OH)	[149]
Ginsenoside Rg_2	Red *ginseng*	20(*S*)-Protopanaxatriol (**98**) rham-^{2}glc (6α-OH)	[150]
Ginsenoside Rs_1	Red *ginseng*	Protopanaxadiol (**99**) glc-^{2}glc (3β-OH) ara-^{6}glc (20-OH)	[151]
Ginsenoside prosapogenin II	*Panax ginseng*	20(*S*)-Protopanaxadiol (**99**) glc (3β-OH) glc (20β-OH)	[152]

Table 1. *Continued*

Saponin	Source	Structure	Reference
Ginsenoside prosapogenin III	*Panax ginseng*	20(*S*)-Protopanaxadiol (**99**) glc (3β-OH) xyl-^{4}ara-^{6}glc (20β-OH)	[152]
Ginsenoside prosapogenin IV	*Panax ginseng*	20(*S*)-Protopanaxadiol (**99**) xyl-^{4}ara-^{6}glc (20β-OH)	[152]
Ginsenoside prosapogenin V	*Panax ginseng*	20(*S*)-Protopanaxadiol (**99**) glc (3β-OH) ara-^{6}glc (20β-OH)	[152]
Ginsenoside prosapogenin VI	*Panax ginseng*	20(*S*)-Protopanaxadiol (**99**) ara-^{6}glc (20β-OH)	[152]
Gleditsia saponin B	*Gleditsia japonica*	Echinocystic acid (**3**) xyl-^{2}ara-^{6}glc (3β-OH) 2′(V), 3′(V) dimono-terp. rham ^{6}glc (28-COOH) xyl-^{3}xyl-^{4}rham^{2}	[47]
Gleditsia saponin C	*Gleditsia japonica*	Echinocystic acid (**3**) xyl-^{2}ara-^{6}glc (3β-OH) 2′(IV), 3′(V) dimono-terp rham ^{6}glc (28-COOH) xyl-^{3}xyl-^{4}rham^{2}	[47]
Glycoside I	*Ichnucarpus frutescens*	α-Amyrin (**63**) rham-^{4}glc (3β-OH)	[153]
Glycoside S_1	*Bupleurum chinese*	Oleanolic acid (**1**) ara-^{3}glu(3β-OH) glc (28-COOH)	[154]
Glycoside S_3 (16-epichikusaikoside I)	*Bupleurum kunmingense*	epi-Saikogenin F (**72**) xyl-^{2}glc-^{3}fuc (3β-OH)	[155]
Gymnocladus saponin A	*Gymnocladus chinensis*	2β,23-dihydroxy accacic acid lactone (**19**) glc-^{6}glc (3β-OH)	[10]
Gymnocladus saponin B	*Gymnocladus chinensis*	2β,23-dihydroxy accacic acid lactone (**19**) glc-^{2}glc (3β-OH)	[10]
Gymnocladus saponin C	*Gymnocladus chinensis*	2β,23-dihydroxy accacic acid lactone (**19**) xyl-^{2}ara-^{6}glc (3β-OH)	[10]
Gymnocladus saponin D	*Gymnocladus chinensis*	2β,23-dihydroxy accacic acid lactone (**19**) rham (3β-OH)	[10]
Gynosaponin TN_1	*Gynostema pentaphyllum*	Aglycone (**92**) glc (20-OH)	[156]
Gynosaponin TN_2	*Gynostema pentaphyllum*	Aglycone (**92**) rham-^{6}glc (20-OH)	[156]
Gypenoside XXV	*Gynostema pentaphyllum*	Aglycone (**109**) glc-^{2}ara (3β-OH) glc (21-OH)	[157]
Gypenoside XXVI	*Gynostema pentaphyllum*	Aglycone (**109**) glc-^{2}ara (3β-OH) glc (20-OH)	[157]
Gypenoside XXXIV	*Gynostema pentaphyllum*	Aglycone (**109**) sophorose (3β-OH) rutinose (20-OH)	[157]
Gypenoside XXXV	*Gynostema pentaphyllum*	Aglycone (**109**) sophonose (3β-OH) primerose (20-OH)	[157]
Gypenoside XXIX	*Gynostema pentaphyllum*	Aglycone (**93**) glc-^{2}ara (3β-OH)	[157]
Gypenoside XLVII	*Gynostema pentaphyllum*	Aglycone (**108**) sophorose (3β-OH) Rutinose (20-OH)	[158]
Gypenoside XLVIII	*Gynostema pentaphyllum*	Aglycone (**109**) rham-^{2}glc-^{3}ara (3β-OH) glc (21-OH)	[158]

Table 1. *Continued*

Saponin	Source	Structure	Reference
Gypenoside XLIX	*Gynostema pentaphyllum*	Aglycone (**109**) rham-^{2}xyl-^{3}ara (3β-OH) glc (21-OH)	[158]
Gypenoside L	*Gynostema pentaphyllum*	Aglycone (**92**) sophorose (3β-OH)	[158]
Gypenoside LI	*Gynostema pentaphyllum*	Aglycone (**92**) sophorose (3β-OH)	[158]
Hainanenside	*Ilex hainanensis*	Aglycone (**34**) glc (28-COOH)	[159]
Hebevinoside I	*Hebeloma vinosophyllum*	Aglycone (122) xyl (β-OH) (6′-OAc)glc (16β-OH)	[160]
Hebevinoside II	*Hebeloma vinosophyllum*	Aglycone (**123**) (4′-OAc)xyl (3β-OH) (6′-OAc)glc (16β-OH)	[160]
Hebevinoside III	*Hebeloma vinosophyllum*	Aglycone (**123**) xyl (3β-OH) 6′-OAc)glc (16β-OH)	[160]
Hebevinoside IV	*Hebeloma vinosophyllum*	Aglycone (**122**) (4′-OAc)xyl (3β-OH) (6′-OAc)glc (16β-OH)	[160]
Hishousi saponin A	*Sapindus delavayi*	Oleanolic acid (**1**) ara-^{3}rham-^{2}ara (3β-OH)	[161]
Hovenoside G	*Hovenia dulcis*	Jujubogenin (**97**) xyl-^{2}glc(-^{3}) xyl-^{2}ara (3β-OH)	[162]
Hovenoside D	*Hovenia dulcis*	Jujubogenin (**97**) glc(-^{6}) xyl-^{2}glc(-^{3}) xyl-^{2}ara (3β-OH)	[162]
Hovenoside I	*Hovenia dulcis*	Jujubogenin (**97**) glc(-^{3}) xyl-^{2}ara (3β-OH)	[162]
Holothurion A	*Holothurin mexicana*	Aglycone (**111**) xyl-^{4}quin(-^{4}) (3′-OMe)glc-^{3}glc-^{2}xyl (3β-OH)	[163]
Holothurin A	*Holothurin leucospilota*	Holothurigenol (**116**) (3′-OMe)glc-^{3}glc-^{4}qui-^{2}(4′SO_3Na)xyl (3β-OH)	[164]
Holothurin A_1	*Carribani seacucumber*	Aglycone (**114**) (3′-OMe)glc-^{3}glc-^{4}quin-^{2}(4′-SO_3Na)xyl (3β-OH)	[165]
Holothurin A_2	*Holthuria floridana*	Aglycone (**115**) (3′-OMe)glc-^{3}-glc-^{4}quin-^{2}(4′SO_3Na)xyl (3β-OH)	[166]
Holothurin B	*Holothurin bohadschia*	Holothurigenol (**116**) (3′-OMe)glc-^{3}glc-^{4}quin-^{2}(4′-SO_4Na)xyl (3β-OH)	[167, 168]
Holothurin B_1	*Holothuria floridana*	Aglycone (**115**) quin-^{2}(4′-SO_4Na)xyl (3β-OH)	[169]
Holotoxin A_1	*Stichophus japonica*	Aglycone (**113**) (3′-OMe)glc-^{3}xyl-^{4}qui(-^{2}) (3′-OMe)glc-^{3}glc-^{4}xyl (3β-OH)	[170]
Huzangoside A	*Anemone rivularis*	Oleanolic acid (**1**) xyl-^{2}rham-^{3}rib (3β-OH)	[171]
Hopane glycoside I	*Diplazium subsinuatum*	Aglycone (**144**) glc (24-OH)	[172]
Hopane glycoside II	*Diplazium subsinuatum*	Aglycone (**144**) ara-^{2}glc (24-OH)	[172]
Hopane glycoside III	*Diplazium subsinuation*	Aglycone (**144**) ara (*f*)-^{2}glc-^{6}glc (24-OH)	[172]

Table 1. *Continued*

Saponin	Source	Structure	Reference
Ilexolide A	*Ilex pubescens*	Ilexolic acid (**65**) xyl(*f*)(3β-OH)	[173, 174]
Ilexside I	*Ilex cornuta*	Aglycone (**62**) glc-^{2}ara (3β-OH)	[175]
Ilexside II	*Ilex cornuta*	Aglycone (**62**) glc-^{2}ara (3β-OH) glc (28-COOH)	[175]
Innundoside A	*Lycopodium inundatum*	Serratenediol (**134**) ara (3β-OH)	[176, 177]
Innundoside B	*Lycopodium inundatum*	Serratenediol acetate (**142**) ara (3β-OH)	[176, 177]
Innundoside D_1	*Lycopodium inundatum*	Serratenediol (**134**) (4′-*p*-coumaroyl)ara (3β-OH)	[176] [176]
Innundoside D_2	*Lycopodium inundatum*	Serratenediol acetate (**135**) 4′-*p*-coumaroyl)ara (3β-OH)	[176]
Innundoside E	*Lycopodium inundatum*	21-*epi*-serratenediol (**136**) ara (3β-OH)	[176, 177]
Innundoside F	*Lycopodium inundatum*	21-*epi*-serratenediol (**136**) 4′-*p*-coumaroyl)ara (3β-OH)	[176]
Jujuboside A	*Zizyphus jujuba*	Jujubogenin (**97**) glc—^{6} xyl—^{2}glc—^{3} rham—^{2}ara (3β-OH)	[178]
Jujuboside B	*Zizyphus jujuba*	Jujubogenin (**97**) xyl-^{2}glc—^{3} rham—^{2}ara (3β-OH)	[178]
Kizuta saponin K_4	*Hedera rhombea*	Aglycone (**102**) glc (26-OH)	[179]
Kizuta saponin K_5	*Hedera rhombea*	Aglycone (**103**) glc (26-OH)	[179]
Kizuta saponin K_7	*Hedera rhombea*	Aglycone (**104**) glc (26-OH)	[179]
Kizuta saponin K_{7C}	*Hedera rhombea*	Aglycone (**105**) glc (3β-OH) glc (26-OH)	[179]
Kizuta saponin K_8	*Hedera rhombea*	Hederagenin (**2**) ara (3β-OH) rham-^{4}(6′OAc-glc)-^{6}glc (28-COOH)	[180]
Kizuta saponin K_{11}	*Hedera rhombea*	Hederagenin (**2**) glc-^{6}glc (3β-OH)	[180]
Kizuta saponin K_{7A}	*Hedera rhombea*	Aglycone (**106**) glc (26-OH)	[181]
Kizuta saponin K_{7B}	*Hedera rhombea*	Aglycone (**107**) glc (26-OH)	[181]
Kizuta saponin K_9	*Hedera rhombea*	Aglycone (**104**) glc (3β-OH) glc (26-OH)	[181]
Kizuta saponin K_{13}	*Hedera rhombea*	Aglycone (**104**) sophorose (3β-OH) glc (26-OH)	[181]
Lasioside A	*Lansium domesticum*	Lansiogenin (**137**) *N*-Ac-glucosamine (3β-OH)	[182]
Lasioside B	*Lansium domesticum*	Lansiogenin (**137**) glc (3β-OH)	[182]
Lansioside C	*Lansium domesticum*	Lansiogenin (**137**) xyl (3β-OH)	[182]
Ligustrin A	*Lingustrum obtusifolium*	Aglycone (**44**) (3′,4′-di-palmitoyl)ara (28-COOH)	[183]
Majideagenin	*Majidea fosteri*	Aglycone (**33**) (3′,4′-diangeloyl)ara (21β-OH)	[184]
Medicoside C	*Medicago sativa*	Hederagenin (**2**) ara-^{2}glc-^{2}ara (3β-OH)	[185]

Table 1. *Continued*

Saponin	Source	Structure	References
Momordicoside A	*Momordica charantia*	Cucurbita-5-ene pentol (**119**) glc-^{6}glc (3β-OH)	[186]
Memordicoside B	*Momordica charantia*	Cucurbita-5-enr pentol (**119**) glc $\diagdown^{6}$ xyl $\diagup_{4}$ glc (3β-OH)	[186]
Momordicoside C	*Momordica charantia*	Cucurbita-5-ene tetraol (**128**) glc-^{6}glc (3β-OH)	[187]
Momordicoside D	*Momordica charantia*	Aglycone (**129**) glc-^{6}glc (3β-OH)	[187]
Momordicoside E	*Momordica charantia*	Aglycone (**118**) glc-^{6}glc (3β-OH)	[187]
Momordicoside F_1	*Momordica charantia*	Aglycone (**117**) glc (3β-OH)	[188]
Momordicoside F_2	*Momordica charantia*	Aglycone (**133**) allo(p) (3β-OH)	[188]
Momordicoside G	*Momordica charantia*	Aglycone (**117**) allo(p) (3β-OH)	[188]
Momordicoside I	*Momordica charantia*	Aglycone (**133**) glc (3β-OH)	[188]
Momordicoside K	*Momordica charantia*	Aglycone (**131**) glc (7β-OH)	[188]
Momordicoside L	*Momordica charantia*	Aglycone (**132**) glc (7β-OH)	[188, 189]
Momordin I	*Momordica cochinchinensis*	Oleanolic acid (**1**) ara-^{3}glu (3β-OH)	[66]
Momordin II	*Momordica cochinchinensis*	Oleanolic acid (**1**) ara-^{3}glu (3β-OH) glc (28-COOH)	[66]
Momordin III	*Momordica cochinchinensis*	Aglycone (**51**) ara-^{3}glu (3β-OH)	[66]
Mukurozi saponin E_1	*Sapindus mukurossi*	Hederagenin (**2**) (4-OAc)xyl-^{3}rham-^{2}ara(p) (3β-OH)	[190]
Mukurozi saponin G	*Sapindus mukurossi*	Hederagenin (**2**) (3′,4′-di-OAc)ara-^{3}rham-^{2}ara(p) (3β-OH)	[190]
Mukurozi saponin X	*Sapindus mukurossi*	Hederagenin (**2**) rham-^{2}ara(p) (3β-OH) glc-^{2}glc (28-COOH)	[190]
Mukurozi saponin Y_1	*Sapindus mukurossi*	Hederagenin (**2**) xyl-^{3}rham-^{2}ara (3β-OH) glc-^{2}glc (28-COOH)	[190]
Mukurozi saponin Y_2	*Sapindus mukurossi*	Hederagenin (**2**) ara(*p*)-^{3}rham-^{2}ara(p) (3β-OH) glc-^{2}glc (28-COOH)	[190]
Muscaroside A	*Muscari comosum*	Eucosterol (**147**) rham-^{2}glc-ara (3β-OH)	[78]
Muscaroside B	*Muscari comosum*	Eucosterol (**147**) ara(*f*)-^{2}ara $\diagdown^{3}$ rham $\diagup_{2}$ glc-^{2}ara-^{6}glc (3β-OH)	[78]
Muscaroside C	*Muscari comosum*	Aglycone (**149**) api(*f*)-^{2}glc-^{2}ara^{6}glc (3β-OH)	[191]
Monodesmosidic saponin I	*Lonicera nigra*	Hederagenin (**2**) glc (3β-OH)	[192]
Monodesmosidic saponin II	*Lonicera nigra*	Oleanolic acid (**1**) glc (3β-OH)	[192]
Monodesmosidic saponin III	*Lonicera nigra*	Hederagenin (**2**) glc (3β-OH) gent (28-COOH)	[192]
Monodesmosidic saponin IV	*Lonicera nigra*	Oleanolic acid (**1**) glc (3β-OH) gent. (28-COOH)	[192]
Narcisflorine	*Anemone narcissiflora*	Oleanolic acid (**1**) ara(*f*)-^{4}glu (3β-OH)	[193]

Table 1. *Continued*

Saponin	Source	Structure	Reference
Narcisfloridine	*Anemone narcissiflora*	Oleanolic acid (**1**) ara(*f*)-^{2}rham-^{4}glu (3β-OH)	[193]
Narcisflorinine	*Anemone narcissiflora*	Oleanolic acid (**1**) ara(*f*)-^{2}rham-^{4}glc (3β-OH)	[193]
Notoginsenoside R_1	*Panax notoginseng*	20(*S*)-Protopanaxatriol (**98**) xyl-^{2}glc (6α-OH) glc (20β-OH)	[9]
Notoginsenoside R_2	*Panax notoginseng*	20(*S*)-Protopanaxatriol (**98**) xyl-^{2}glc (6α-OH)	[9]
Notoginsenoside R_3	*Panax notoginseng*	20(*S*)-Protopanaxatriol (**98**) glc (6 α-OH) glc-^{6}glc (20β-OH)	[194]
Notoginsenoside R_4	*Panax notoginseng*	20(*S*)-Protopanaxadiol (**99**) glc-^{2}glc (3β-OH) xyl-^{6}glc-^{6}glc (20β-OH)	[194]
Notoginsenoside R_6	*Panax notoginseng*	20(*S*)-Protopanaxatriol (**98**) glc (6α-OH) glc-^{6}glc (20β-OH)	[194]
Obtusilobicinin	*Anemone obtusiloba*	Oleanolic acid (**1**) ara(*f*)-^{2}rham $\diagdown^{4}$ ara (*f*) $\diagup_{2}$glc (3β-OH)	[195]
Obtusilobin	*Anemone obtusiloba*	Oleanolic acid (**1**) ara(*f*)-^{2}rham (3β-OH)	[196]
Obtusilobinin	*Anemone obtusiloba*	Oleanolic acid (**1**) rham $\diagdown^{4}$ ara (*f*) $\diagup_{2}$glc (3β-OH)	[196]
Onjisaponin A	*Polygala tenufolia*	Presenegenin (**40**) glc (3β-OH) glc-^{4}xyl-^{4}rham-^{2}(4′-MC*)qui (28-COOH) glc-^{4}xyl-^{4}rham-^{2}(4′-MC*)qui (28-COOH) api^{3} rham^{3} (*MC = Methoxy cinnamoyl)	[197]
Onjisaponin B	*Polygala tenufolia*	Presenegenin (**40**) glc-^{4}xyl-^{4}rham-^{2}(4′-MC*) qui (28-COOH) rham^{3}	[197]
Onjisaponin C	*Polygala tenufolia*	Presenegenin (**40**) glc-^{4}xyl-^{4}rham-^{2}(4′-TC*)qui (28-COOH) (*TC = Trimethoxy cinnamoyl)	[197]
Olaxoside	*Olax andronensis* *Olax glabriflora* *Olax psittacorum*	Oleanolic acid (**1**) rham-^{4}glu (3β-OH) glc (28-COOH)	[198]
Papyrioside L-IIa	*Tetrapanax papyriferum* *Bupleurum rotundifolium*	Aglycone (**7**) rham-^{4}xyl-^{5}xyl (28-COOH)	[199]
Papyrioside L-IIb	*Tetrapanax papyriferum*	Aglycone (**8**) rham-^{4}glc-^{6}glc (28-COOH)	
Papyrioside L-IIc	*Tetrapanax papyriferum* *Bupleurum rotundifolium*	Propapyriogenin A_2 (**14**) rham-^{4}glc-^{5}glc (28-COOH)	[200]
Papyrioside L-IId	*Tetrapanax papyriferum*	Aglycone (**9**) rham-^{4}glc-^{6}glc-^{6}glc (28-COOH)	[200]
Papyrioside L-IIe	*Tetrapanax papyriferum*	Aglycone E (**10**) rham-^{4}glc-^{6}glc-^{6}glc (28-COOH)	[200]
Pavophylline	*Pavonia zeylanica*	Betulinic acid (**66**) ara(*f*)-^{2}rham-^{4}glc (3β-OH)	[201]
Periandrin I	*Periandra dulcis*	Aglycone (**78**) glu-^{2}glu (3β-OH)	[202]
Periandrin II	*Periandra dulcis*	Aglycone (**25**) glu-^{2}glu (3β-OH)	[203]
Periandrin IV	*Periandra dulcis*	Aglycone (**26**) glu-^{2} glu (3β-OH)	[203]
Phytolaccoside A	*Phytolacca americana*	Aglycone (**23**) glc-^{4}xyl (3β-OH)	[204]

Table 1. *Continued*

Saponin	Source	Structure	References
Phytolaccoside D	*Phytolacca americana*	Aglycone (**22**) xyl (3β-OH)	[204]
Phytolaccoside E	*Phytolacca americana*	Aglycone (**23**) glc-^{4}xyl (3β-OH)	[204]
Picfeltarraenin IA	*Picria feltarrae*	Picfeltarraegenin I (**140**) rham-^{2}xyl (3β-OH)	[205]
Picfeltarraenin IB	*Picria feltarrae*	Picfeltarraegenin I (**140**) rham-^{2} glc (3β-OH)	[205]
Prosaikosaponin A	*Bupleurum falctum*	Saikogenin A (**79**) fuc (3β-OH)	[206]
Prosaikosaponin H	*Bupleurum falctum*	Saikogenin H (**80**) fuc (3β-OH)	[206]
Prosaikosaponin D	*Bupleurum falctum*	Saikogenin D (**81**) fuc (3β-OH)	[206]
Prosapogenin CP_2	*Clematis chinensis*	Oleanolic acid (**1**) rham-^{2}ara (3β-OH)	[207]
Prosapogenin CP_6	*Clematis chinensis*	Hederagenin (**2**) xyl-^{3}rham-^{2}ara (3β-OH)	[207]
Prosapogenin CP_1	*Clematis chinensis*	Hederagenin (**2**) ara (3β-OH)	[208]
Prosapogenin CP_3	*Clematis chinensis*	Oleanolic acid (**1**) xyl-^{3}rham-^{2}ara (3β-OH)	[208]
Prosapogenin CP_4	*Clematis chinensis*	Oleanolic acid (**1**) rib-^{3}rham-^{2}ara (3β-OH)	
Prosapogenin CP_5	*Clematis chinensis*	Hederagenin (**2**) xyl-^{3}rham-^{2}ara (3β-OH)	[208]
Prosapogenin CP_0	*Clematis chinensis*	Hederagenin (**2**) ara (23-OH)	[209]
Prosapogenin CP_{2a}	*Clematis chinensis*	Hederagenin (**2**) glc (23-OH)	[209]
Prosapogenin CP_{3a}	*Clematis chinensis*	Hederagenin (**2**) rham-^{2}ara (3β-OH)	[209]
Prosapogenin CP_7	*Clematis chinensis*	Oleanolic acid (**1**) glc-^{4}rib-^{3}rham-^{2}ara (3β-OH)	[207]
Prosapogenin CP_8	*Clematis chinensis*	Hederagenin (**2**) glc-^{4}rib-^{3}rham-^{2}ara (3β-OH)	[207]
PS-4	*Primula elatior*	Protoprimulagenin A (**71**) rham-^{2}gal, glc $\rangle$ ^{3} $_2$ glu (3β-OH)	[210]
Pseudoginsenoside F_8	*Panax* species	Aglycone (**95**) glc-^{2}(6′-OAc)glc (3β-OH) xyl-^{6}glc (20β-OH)	[148]
Pseudoginsenoside F_{11}	*Panax* species	Aglycone (**95**) rham-^{2}glc (6α-OH)	[148, 211]
Pseudoginsenoside RC_1	*Panax* species	20(*S*)-Protopanaxadiol (**99**) (6′-OAc)glc-^{2}glc (3β-OH) glc (20β-OH)	[211]
Psoluthurin A	*Psolus fabricii*	Aglycone (113) (6′-SO_3Na), (3′-OMe) glc-^{4} quin-^{3} (6′-SO_3Na) quin ^{2}xyl (3β-OH)	[212]
Quadranguloside	*Passiflora guadrangularis*	Aglycone (**83**) glc-^{6}glc (3β-OH) glc-^{6}glc (26-OH)	[213]
Querilicoside A	*Anchusa officinalis*	Aglycone (**60**) glc (28-COOH)	[214]
Quinquenoside R_1	*Panax quinquefolium*	20(*S*)-Protopanaxadiol (**99**) (6′-OAc)glc-^{2}glc (3β-OH) glc-^{6}glc (20β-OH)	[215]
Raddeanin D	*Anemone raddeana*	Oleanolic acid (**1**) rham-^{2}glc-^{2}ara (3β-OH) rham-^{4}glc (28-COOH)	[216]

Table 1. *Continued*

Saponin	Source	Structure	Reference
Raddeanin E	*Anemone raddeana*	Oleanolic acid (**1**) glc-^{2}rham-^{4}ara (3β-OH)	[217]
Raddeanin F	*Anemone raddeana*	Oleanolic acid (**1**) glc-^{2}ara (3β-OH) rham-^{4}glc (28-COOH)	[217]
Rivularinin	*Anemone rivularis*	Oleanolic acid (**1**) xyl (*f*)-^{2}rham-^{3}glc-^{4}glu (3β-OH)	[218]
Rosamultin	*Rosa multiflora*	Aglycone (**64**) glc (28-COOH)	[219]
Rotundioside A	*Bupleurum rotundifolium*	Aglycone (**38**) glc-^{6}glc-^{2}glc-^{6}glc (28-COOH)	[220]
Rotundioside B	*Bupleurum rotundifolium*	Aglycone (**52**) glc-^{6}glc-^{2}glc-^{6}glc (28-COOH)	[220]
Rotundioside C	*Bupleurum rotundifolium*	Aglycone (**52**) glc-^{6}glc-^{2}glc-^{2}glc (28-COOH)	[220]
Rotundioside E	*Bupleurum rotundifolium*	Saikogenin C (**82**) rham-^{2}glc-^{2}fuc (3β-OH)	[199, 221]
Rotundioside F	*Bupleurum rotundifolium*	Rotundiogenin A (**68**) rham-^{2}glc-^{2}fuc (3β-OH)	[199, 221]
Rotundioside D	*Bupleurum rotundifolium*	Primulagenin A (**14**) rham-^{2}glc-^{2}glc (3β-OH)	[20]
Rotundioside G	*Bupleurum rotundifolium*	Rotundiogenin A (**68**) xyl-^{2}glc-^{2}fuc (3β-OH)	[20]
Saikosaponin g	*Bupleurum falctum*	Saikogenin H (**80**) glc-^{3}fuc (3β-OH)	[206]
Saikosaponin i	*Bupleurum falctum*	Saikogenin B (**76**) glc-^{6}glc (3β-OH) rham^{4}	[206]
Saikosaponin b_4	*Bupleurum falctum*	Aglycone (**5**) glc-^{6}fuc (3β-OH)	[222]
Sakurasosaponin	*Primula sieboldi*	Protoprimulgenin A (**71**) rham-^{2}rham-^{2}gal—^{3} glc—^{2}glu (3β-OH)	[136]
Salsoloside C	*Salsola micranthera*	Oleanolic acid (**1**) xyl-^{4}glc (3β-OH) glc (28-COOH)	[223]
Salsoloside D	*Salsola micranthera*	Hederagenin (**2**) xyl-^{4}glc (3β-OH) glc (28-COOH)	[223]
Salsoloside E	*Salsola micranthera*	Oleanolic acid (**1**) xyl—^{4} glc—^{2}glu (3β-OH) glc (28-COOH)	[224]
Santholin	*Trichosanthes palmata*	Aglycone (**147**) glc-^{6}glc (3β-OH)	[225]
Sanchinoside B	*Panax notoginseng*	Dammarene tetraol (**101**) glc (6α-OH)	[226]
Sanchinoside B_1	*Panax notoginseng*	Protopanaxatriol (**98**) glc-xyl (6α-OH) glc (20β-OH)	[226]
Sanchinoside C_1	*Panax notoginseng*	Protopanaxatriol (**98**) glc (6α-OH) glc (20β-OH)	[226]
Sanchinoside E_1	*Panax notoginseng*	Protopanaxatriol (**98**) glc-^{2}glc (3β-OH) glc-^{6}glc (20β-OH)	[226]
Saponin B	*Polygala japonica*	Aglycone **48**) glc-^{2}glc-^{2}glc (28-COOH)	[227]
Saponin E	*Hovenia dulcis*	Hovenolactone (**138**) rham-^{2}glc (3β-OH)	[228]
Saponin H	*Hovenia dulcis*	Hovenolactone (**138**) glc (3β-OH)	[228]

Table 1. *Continued*

Saponin	Source	Structure	Reference
Saponin D	*Hovenia dulcis*	Jujubogenin (**97**) rham-^{2}glc (3β-OH) rham (20β-OH)	[228]
Saponin G	*Hovenia dulcis*	Jujubogenin (**97**) glc (3β-OH) rham (20β-OH)	[228]
Saponin C_2	*Hovenia dullcis*	Jujubogenin (**97**) rham, glc $\rightarrow^{2,3}$ ara (3β-OH)	[228]
Saponin I	*Fatsia japonica*	Cochalic acid (**4**) ara (3β-OH)	[229]
Saponin II	*Fatsia japonica*	Echinocystic acid (**3**) ara (3β-OH)	[229]
Saponin III	*Fatsia japonica*	Oleanolic acid (**1**) ara (3β-OH)	[229]
Saponin IV	*Wisterca simensis*	α-Amyrin (**63**) rham-^{6}xyl(f) (3β-OH)	[230]
Saponin V	*Anchusa officinalis*	Oleanolic acid (**1**) glc (3β-OH) glc (28-COOH)	[231]
Saponin VI	*Anchusa officinalis*	Oleanolic acid (**1**) glc, glc $\rightarrow^{2,3}$ glc (3β-OH)	[231]
Saponin VII	*Anchusa officinalis*	Oleanolic acid (**1**) glc-^{3}glc (3β-OH) glc (28-COOH)	[231]
Saponin VIII	*Anemone raddeana*	Oleanolic acid (**1**) rham-^{4}ara (3β-OH)	[232]
Saponin IX	*Platycodon grandiflorum*	Aglycone (**30**) glc (3β-OH) api(f)-^{3}xyl-^{4}(2'OAc)rham-^{2}ara (28-COOH)	[233]
Saponin X	*Pittosporum undulatum*	Aglycone (**32**) gal, glc $\rightarrow^{2,3}$ glu (3β-OH)	[234]
Saponin XI	*Pittosporum undulatum*	Aglycone (**32**) xyl (f) $\rightarrow^{4}$, ara $\rightarrow^{3}$ xyl (3β-OH) glc $\rightarrow^{2}$	[234]
Saponin XII	*Zizyphus joazeiro*	Jujubogenin (**97**) glc, ara(f) $\rightarrow^{2,3}$ ara (3β-OH)	[235]
Saponin XIII	*Tetrapanax papyriferum*	Oleanolic acid (**1**) ara (f), gal $\rightarrow^{2,4}$ glu (3β-OH)	[236]
Saponin XIV	*Tetrapanax papyriferum*	Oleanolic acid (**1**) gal-^{2}glu (3β-OH)	[236]
Saponin XV	*Gleditsia japonica*	Oleanolic acid (**1**) xyl-^{2}ara-^{6}glc (3β-OH)	[237]
Saponin XVI	*Acanthus illicifolius*	Lupeol (**67**) xyl (f)-^{4}gly (3β-OH)	[238]
Saponin XVII	*Glinus lotoides*	Oleanolic acid (**1**) glc-^{4}ara (3β-OH) glc (28-COOH)	[239]
Saponin XVIII	*Anchusa officinalis*	Oleanolic acid (**1**) glc-^{2}glc (3β-OH)	[240]
Saponin XIX	*Anchusa officinalis*	Oleanolic acid (**1**) glc-^{2}glc (3β-OH) glc (28-COOH)	[240]
Saponin XX	*Anchusa officinalis*	Oleanolic acid (**1**) glc (3β-OH) glc (28-COOH)	[240]

Table 1. *Continued*

Saponin	Source	Structure	Reference
Saponin XXI	*Anchusa officinalis*	Oleinolic acid (**1**) glc-^{3}glc (3β-OH)	[240]
Saponin XXII	*Zizyphus vulgaris*	Jujubogenin (**101**) glc $\diagdown^{3}_{2}$ ara (3β-OH) fuc $\diagup$	[241]
Saponin XXIII	*Quercusilex*	Asiatic acid (**61**) glc (28-COOH)	[242]
Saponin XXIV	*Panax japonicum*	Oleanolic acid (**1**) glc (28-COOH)	[243]
Saponin XXV	*Anemone raddeana*	Oleanolic acid (**1**) rham-^{4}ara (3β-OH)	[244]
Saponin XXVI	*Anemone raddeana*	Oleanolic acid (**1**) rham-^{2}glu-^{2}ara (3β-OH) rham-^{2}glc (28-COOH)	[244]
Saponin XXVII	*Anemone raddeana*	Oleanolic acid (**1**) rham-^{4}ara (3β-OH) rham-^{4}glc (28-COOH)	[244]
Saponin XXIX	*Anemone raddeana*	Oleanolic acid (**1**) rham-^{2}glc-^{2}ara (3β-OH)	[244]
Saponin XXX	*Ilex cornuta*	Pomolic acid (**62**) (2′-OAc)ara (3β-OH) glc (28-COOH)	[245]
Saponin XXXI	*Ilex cornuta*	29-Hydroxy oleanolic acid (**49**) ara (3β-OH) glc (28-COOH)	[245]
Saponin XXXII	*Xeromphis spinosa*	Oleanolic acid (**1**) xyl (3β-OH)	[246]
Saponin XXXIII	*Combretum molle*	Aglycone (**87**) ara (3β-OH)	[247]
Saponin XXXIV	*Fatsia japonica*	Echinocystic acid (**3**) ara (3β-OH) rham-^{4}glc-^{4}glc (28-COOH)	[248]
Saponin XXXV	*Fatsia japonica*	Hederagenin (**2**) ara (3β-OH) rham-^{4}glc-^{4}glc (28-COOH)	[248]
Saponin XXXVI	*Fatsia japonica*	Oleanolic acid (**1**) glc-^{2}ara (3β-OH) rham-^{4}glc-^{4}glc (28-COOH)	[248]
Saponin XXXVII	*Fatsia japonica*	Hederagenin (**2**) glc-^{2}ara (3β-OH) rham-^{4}glc-^{4}glc (28-COOH)	[248]
Saponin XXXVIII	*Platycodon grandiflorum*	Aglycone (**46**) glc (3β-OH)	[249]
Saponin XXXIX	*Platycodon grandiflorum*	Aglycone (**55**) glc (3β-OH)	[249]
Saponin XXXX	*Platycodon grandiflorum*	Aglycone (**56**) glc (3β-OH)	[249]
Saponin XXXXI	*Platycodon grandiflorum*	Aglycone (**46**) laminarbiosyl (3β-OH)	[249]
Saponin XXXXII	*Platycodon grandiflorum*	Aglycone (**47**) laminarbiosyl (3β-OH)	[249]
Saponin XXXXIII	*Platycodon grandiflorum*	Aglycone (**47**) gentibioside (3β-OH)	[249]
Saponin XXXXIV	*Platycodon grandiflorum*	Aglycone (**57**) glc (3β-OH)	[249]
Saponin XXXXV	*Phytolacca dodecandra*	Aglycone (**54**) glc-^{4}glc (3β-OH) glc (28-COOH)	[27]
Saponin XXXXVI	*Phytolacca dodecandra*	Oleanolic acid (**1**) glc $\diagdown^{4}_{2}$ glc (3β-OH) glc $\diagup$ glc (28-COOH)	[27]

Table 1. *Continued*

Saponin	Source	Structure	Reference
Saponin XXXXVII	*Phytolacca dodecandra*	Hederagenin (**2**) glc $\rightarrow^{4}_{2}$ glc (3β-OH) glc (28-COOH)	[27]
Saponin XXXXVIII	*Ginseng* roots	Protopanaxadiol (**99**) (6′-Malonate)glc-glc (3β-OH)	[250]
	Ginseng roots	Protopanaxadiol (**99**) (6′-Malonate)glc-glc (3β-OH) ara-^{6}glc (20β-OH)	[250]
Saponin XXXXIX	*Ginseng* roots	Protopanaxadiol (**99**) (6′-Malonate)glc-^{2}glc (3β-OH) glc-^{6}glc (20β-OH)	[250]
	Ginseng roots	Protopanaxadiol (**99**) (6′-Malonate)glc-^{2}glc (3β-OH) glc (20β-OH)	[250]
Saponin L	*Ginseng* roots	Protopanaxadiol (**99**) (6′-Malonate)glc-^{2}glc (3β-OH)) ara(f)-^{6}glc (20β-OH)	[251]
Saponin LI	*Ginseng* roots	Protopanaxadiol (**99**) (6′-Malonate)glc-^{2}glc (3β-OH) glc (20β-OH)	[251]
Saponin LIV	*Fatsia japonica*	Hederagenin (**2**) glc-^{2}ara (3β-OH)	[252]
Saponin LV	*Fatsia japonica*	Oleanolic acid (**1**) glc-^{2}ara (3β-OH)	[252]
Saponin LVI	*Hedera helix*	Hederagenin (**2**) glc (3β-OH)	[253]
Saponin LVII	*Hedera helix*	Hederagenin (**2**) rham-^{2}ara (3β-OH)	[253]
Saponin LVIII	*Hedera helix*	*Hederagenin* (**2**) ara (3β-OH)	[253]
Saponin LIX	*Hedera helix*	Hederagenin (**2**) glc-^{2}glc (3β-OH)	[253]
Saponin LX	*Tetrapanax papyriferum*	Oleanolic acid (**1**) ara(f)-^{4}glc (3β-OH)	[254]
Saponin LXI	*Ficaria ranunculoides*	Hederagenin (**2**) ara (3β-OH) glc-^{6}rham-^{4}glc (28-COOH)	[255]
Saponin LXII	*Zexmania buphthalmiflora*	Oleanolic acid (**1**) rham-^{3}glc (3β-OH)	[256]
Saponin LXIII	*Zexmania buphthalmiflora*	Oleanolic acid (**1**) rham-^{3}glu (3β-OH) glc (28-COOH)	[256]
Saponin LXIV	*Patrinia scabiosaefolia*	Oleanolic acid (**1**) rham-^{2}ara (3β-OH)	[257]
Saponin LXV	*Patrinia scabiosaefolia*	Hederagenin (**2**) rham-^{2}ara (3β-OH)	[257]
Saponin LXVI	*Eryngium bromeliifolium*	Betulinic acid (**66**) glc-^{6}glc (3β-OH)	[258]
Saponin LXIX	*Bryonia alba*	Aglycone (**143**) glc (2β-OH)	[259]
Saponin LXX	*Bryonia alba*	Aglycone (**143**) glc (2β-OH) glc (25-OH)	[259]
Saponin LXXI	*Verbascum nigrum*	Aglycone (**77**) glc-^{4}gal $\rightarrow^{4}_{2}$ fuc (3β-OH)	[260]
Saponin LXXII	*Dillenia pentagyna*	Betulinic acid (**66**) rham (3β-OH)	[261]
Saponin LXXIV	*Pithecellobium cubense* *Pithecellobium arboreum*	Oleanolic acid (**1**) 2′-acetylamino-2-deoxy glc (3β-OH)	[262]

Table 1. *Continued*

Saponin	Source	Structure	Reference
Saponin LXXV	*Tetrapanax papyriferum*	Oleanolic acid (1) ara(*f*)—(4,2)—(6′-OMe)glu (3β-OH) gal—(4,2)—(6′-OMe)glu (3β-OH) glc (28-COOH)	[19]
Saponin CP_{2b}	*Cleamatis chinensis*	Oleanolic acid (1) xyl-^{2}ara (3β-OH)	[263]
Saponin CP_{3b}	*Clematis chinensis*	Hederagenin (2) rham-^{2}ara (3β-OH)	[263]
Saponin CP_{9}	*Clematis chinensis*	Oleanolic acid (1) glc-^{4}glc-^{4}rib-^{3}rham-^{2}ara (3β-OH)	[263]
Saponin CP_{10}	*Clematis chinensis*	Hederagenin (2) glc-^{4}glc-^{4}rib-^{3}rham-^{2}ara (3β-OH)	[263]
Saponin CP_{7a}	*Clematis chinensis*	Oleanolic acid (1) glc-^{4}xyl-^{3}rham-^{2}ara (3β-OH)	[48]
Saponin CP_{8a}	*Clematis chinensis*	Hederagenin (2) glc-^{4}xyl-^{3}rham-^{3}ara (3β-OH)	[48]
Saponin CP_{9a}	*Clematis chinensis*	Oleanolic acid (1) glc-^{4}glc-^{4}xyl-^{3}rham-^{2}ara (3β-OH)	[48]
Saponin CP_{10a}	*Clematis chinensis*	Hederagenin (2) glc-^{4}glc-^{3}xyl-^{3}rham-^{2}ara (3β-OH)	[48]
Saponin P_{js-2}	*Panax japonicus*	Oleanolic acid (1) xyl-^{2}glu (3β-OH) glc (28-COOH)	[264]
Saponin P_{js-4}	*Panax japonicus*	Oleanolic acid (1) ara (3β-OH) glc (28-COOH)	[264]
Saxifragifolin A	*Androsace saxifragifolia*	Androsacenol (**69**) xyl-^{2}glc—(4,2)—ara (3β-OH) glc	[63]
Saxifragifolin B	*Androsace saxifragifolia*	Cyclamiretin A (**70**) xyl-glc—(4,2)—ara (3β-OH) glc	[63]
Saxifragifolin C	*Androsace saxifragifolia*	Androsacenol (**69**) xyl-^{2}glc—(4,2)—ara (3β-OH) glc-^{4}glc	[67]
Saxifragifolin D	*Androsace saxifragifolia*	Cyclamiretin A (**70**) xyl-^{2} glc—(4,2)—ara (3β-OH) glc-^{4}glc	[67]
Scopoletin	*Patrinia scabiosaefolia*	Oleanolic acid (1) rham-^{2}ara (3β-OH)	[141]
Secodammarane triterpene saponin I	*Alnus serrulatoides*	*Alnustic acid* (**144**) ara(*f*) (12β-OH)	[265]
Secodammarane triterpene saponin II	*Alnus serrulatoides*	Alnustic acid (**144**) (2′-OAc)ara(*f*) (12β-OH)	[265]
Secodammarane triterpene saponin III	*Alnul serrulatoides*	Alnustic acid (**144**) xyl (12β-OH)	[265]
Secodammarane triterpene saponin IV	*Alnus serrulatoides*	Alnustic acid (**144**) glc (12β-OH)	[265]
Silphioside B	*Silphium perfoliatum*	Oleanolic acid (1) glc (3β-OH) glc (28-COOH)	[266]
Silphioside C	*Silphium perfoliatum*	Oleanolic acid (1) glc-^{2}(6-OAc)glc (3β-OH) glc (28-COOH)	[267]
Silphioside E	*Silphium perfoliatum*	Oleanolic acid (1) glc-^{2}glc (3β-OH) glc (28-COOH)	[268]
Soyasaponin A_1	*Glycine max*	Soyasapogenol A (**11**) glc-^{2}gal-^{2}glu (3β-OH) glc-^{3}ara (22-OH)	[44]

Table 1. *Continued*

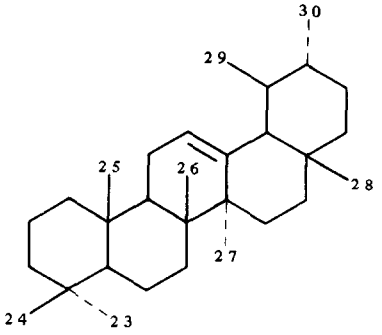
Saponin	Source	Structure	Reference
Soyasaponin A_2	*Glycine max*	Soyasapogenol A (**11**) gal-^{2}glu (3β-OH) glc-^{3}ara (22β-OH)	[44]
Soyasaponin I	*Rothia trifolata*	Soyasapogenol B (**16**) rham-^{2}gal-^{2}glc (3β-OH)	[269]
Sophoraflavoside I	*Sophora radix* *Sophora flavescens*	Soyasapogenol B (**16**) rham-^{2}gal-^{2}glu (3β-OH) glc-^{2}ara (22β-OH)	[38]
Spergulacin I	*Mollugo spergula*	Spergulagenin (**139**) rham-^{3}xyl (3β-OH)	[270]
Spergulacin A	*Mollugo spergula*	Spergulagenin (**139**) rham-^{2}xyl (3β-OH)	[271]
Stichoposide C	*Stichopous chloronotus*	Aglycone (**110**) (3′-OMe)glc-^{3}glc (4, 2) xyl (3β-OH) (3′-OMe)glc-^{3}xyl-^{4}quin	[101]
Stichoposide D	*Stichoposide variegatus*	Aglycone (**110**) (3′-OMe)glc-^{3}glc (4, 2) xyl (3β-OH) (3′-OMe)glc-^{3}xyl-^{3}glc	[272]
Suavissimoside R′	*Rubus suavissimus*	Aglycone (**59**) glc (28-COOH)	[273]
Swericinctoside	*Swertia cincta*	Aglycone (**35**) glc-^{6}glc-^{2}glc (28-COOH)	[274]
Thalicoside A	*Thalictrum minus*	Thalicogenin (**90**) gal (3β-OH) glc (28-OH)	[275]
Thalicoside B	*Thalictrum minus*	Oleanolic acid (**1**) rham-^{2}glc-^{3}ara (3β-OH) glc (28-COOH)	[276]
Trichonin	*Trichosanthes palmata*	Aglycone (**146**) glc-^{6}glc (3β-OH)	[277]
Triterpene oligosaccharide	*Actinopyga agassizi*	Aglycone (**126**) (3′-OMe)glc-^{3}glc-^{4}fuc-^{2}(4′-SO_3Na)xyl (3β-OH)	[11]
Triterpene glycoside	*Lansium domesticum*	Lansiogenin (**137**) glc (3β-OH)	[278]
Tubeimoside I	*Bolbostemma peniculatum*	Aglycone (**42**) ara-^{2}glc(3β-OH) (28-COOH)-ara (4) 3-hydroxy-3-methylglutarate (2, 4) rham^3-xyl	[279]
Uralsaponin A	*Glyceyrrihiza uralensis*	Aglycon (**41**) glu-^{2}glu (3β-OH)	[280]
Uralsaponin B	*Glyceyrrihiza uralensis*	Aglycone (**41**) glu-^{3}glu (3β-OH)	[280]
Verbascosaponin	*Verbascum phlomoides*	Aglycone (**77**) rham-^{4}glc (4, 2) fuc (3β-OH) glc	[281]
Weddlin	*Wedelia scaberrima*	Oleanolic acid (**1**) galu(3β-OH) glc (28-COOH)	[282]
Yiamoloside B	*Phytolacca octandra*	Aglycone (**45**) glc-^{4}glc (3β-OH)	[283]
Saponin LXXVI	*Tetrapanax papyriferum*	Oleanolic acid (**1**) ara(*f*)-(6′OMe)glu (3β-OH) rham-^{4}glc-6glc (28-COOH)	[19]
Saponin LXXVII	*Tetrapanax papyriferum*	Oleanolic acid (**1**) gal-^{2}(6′OMe)glu (3β-OH) glc (28-COOH)	[19]
Saponin LXXVIII	*Tetrapanax papyriferum*	Oleanolic acid (**1**) gal-^{2}fuc (3β-OH)	[19]

Table 1. *Continued*

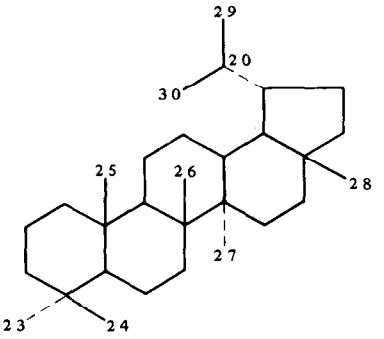
Saponin	Source	Structure	Reference
Saponin LXXIX	*Tetrapanax papyriferum*	Oleanolic acid (**1**) ara(*f*) gal $\rightarrow^{4}_{2}$ (6'-OMe)glu (3β-OH) glc (28-COOH)	[19]

Abbreviations: glc, β-D-glucopyranosyl; rha, α-L-rhamnopyranosyl; gal, β-D-galactopyranosyl; xyl, β-D-xylopyranosyl; ara(*f*), α-L-arabinofuranosyl; quin, β-D-quinovopyranosyl; api(*f*), β-D-apiofuranosyl; gent, gentibiosyl, chi, chinovopyranosyl; fuc, α-D-fucopyranosyl, glu, β-D-glucoronic acid pyranosyl; galu, β-D-galacturonic acid pyranosyl; rib, β-D-ribopyranosyl; xyl(*f*), β-D-xylofuranosyl; allo(*p*), β-D-allopyranosyl; ara(*p*), β-arabinopyranosyl; apio (*f*), β-D-apiofuranosyl.

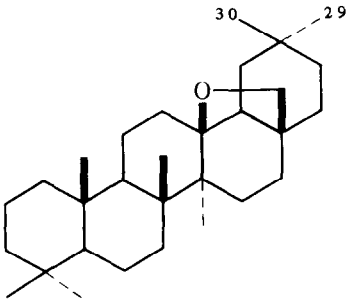
13 3β-OH, 23, 28-COOH
14 3β, 16α, 28-OH, primulagenin A
15 3β, 16β, 28-OH, longispinogenin
16 3β, 22β, 24-OH, soyasapogenol B
17 3β, 22β-OH, sophoradiol
18 3β, 24-OH, 29-COOH, azukisapogenol
19 2β, 3β, 16β, 23-OH, 28→21 lactone
20 3β, 16β, 23, 28-OH, 23-hydroxy, longispinogenin
21 2β, 3β-OH, 23-COOMe, 28-COOH, 23-monomethylmedicagenic acid
22 3β, 23-OH, 28-COOH, 30-COOMe
23 2ζ, 3β, 23-OH, 28-COOH, 30-COOMe
24 2α, 3β, 19 α-OH, 11-Oxo, 28-COOH
25 3β-OH, 25-CHO, 30-COOH
26 3β, 25-OH, 30-COOH
27 3β, 16α, 23-OH, 28-COOH, caullophyllogenin
28 3β, 16α, 21β, 22α, 28-OH
29 3β, 15α, 16α, 22α, 28-OH
30 2β, 3β, 16α, 23, 24-OH, 28-COOH
31 3β, 29-OH, 23, 28-COOH
32 3β, 15α, 16α, 28-OH, 22α-CoCHMeEt, COCH:CMe_2
33 3β, 16α, 21β, 22α-OH, 28-OAc
34 3β, 16α-OH, 23, 28-COOH
35 2α, 3β-OH, 28-COOH, maslinic acid
36 3β, 21β, 23-OH, 28-COOH
37 2α, 3β, 19α-OH, 28-COOH, arjunic acid
38 3β-OSO_3^-, 16α-OH, 28-COOH
39 3β, 28-OH, erythrodiol
40 2β, 3β, 27-OH, 23, 28-COOH
41 3β-OH, 11-oxo, 30-COOH
42 2β, 3β, 23, 28-OH, barringtogenol
43 3β-OH, 16-oxo, 18-OAc
44 3β-palmitoyl, 28-COOH
45 3β-OH, 28-COOH, 30-COOme
46 2β, 3β, 16α, 23-OH, 28-COOMe
47 2β, 3β, 16α, 23, 24-OH, 28-COOMe
48 2α, 3α, 24-OH, 28-COOH
49 3β, 29-OH
50 2α, 3β-OAc, 28-COOH, 30-OH
51 3β-OH, 11α: 12α-epoxy, 28: 13-olide
52 3β-OSO_3^-, 28-COOH
53 2β, 3β-OH, 23, 28-COOH, barringtogenic acid
54 2β, 3β, 23-OH, 28-COOH
55 2β, 3β, 16α, 23-OH, 24-COOH, 28-COOMe
56 2β-OMe, 3β, 16α, 23-OH, 28-COOMe
57 2β, 3β, 16α, 23-OH, 24-CHO, 28-COOMe
58 3β-OH, 16-oxo, 18-OH



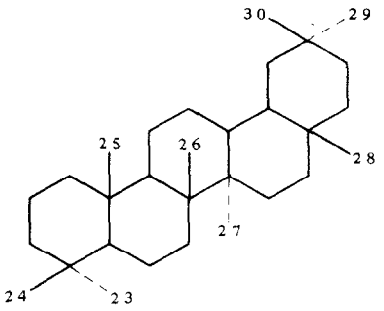
59 2α, 3β-OH, 23, 28-COOH
60 2α, 3β, 19α, 23-OH, 28-COOH
61 2α, 3β, 23-OH, 28-COOH, asiatic acid
62 3β, 19α-OH, 28-COOH, pomolic acid
63 3β-OH, α-amyrin
64 2α, 3β, 19α-OH, 28-COOH
65 3β-OH, 18-ene, 20-*epi*, 28-COOH, ilexolic acid



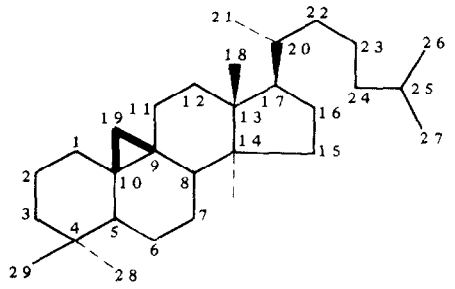
66 3β-OH, 20:29-ene, 28-COOH, betulinic acid
67 3β-OH, 20:29-ene, lupeol



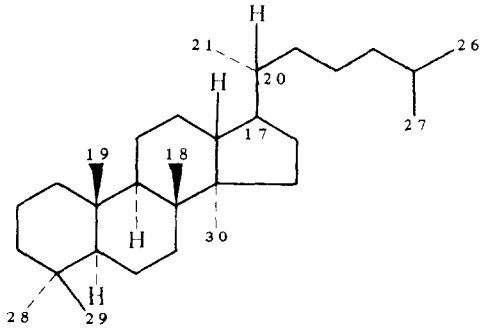
68 3β, 16α-OH, 11-ene, rotundiogenin A
69 3β, 16α-OH, 22β-OAc, 30-CHO, androsacenol
70 3β, 16α-OH, 30-CHO, cyclamiretin A
71 3β, 16α-OH, protoprimulagenin A
72 3β, 16α, 23-OH, 11-ene, *epi*-saikogenin F
73 3β, 16β, 23-OH, 11-ene, saikogenin F
74 3β, 16α-OH, 11-ene, saikogenin E



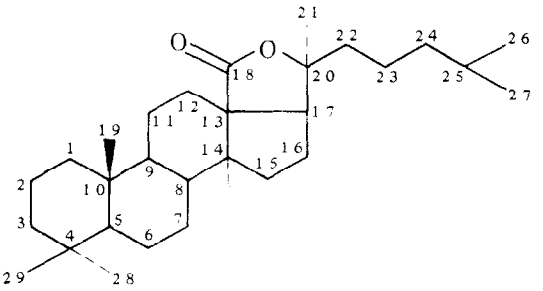
75 3β, 16β, 28-OH, 11:12, 13:18-ene, saikogenin C
76 3β, 16β, 28-OH, 9:11, 12:13-ene, saikogenin B
77 3β, 13,23,28-OH, 11:12-ene
78 3β-OH, 25-CHO, 18:19-ene, 30-COOH
79 3β, 16β, 23,28-OH, 11:12, 13:18-ene, saikogenin A
80 3β, 16β, 23,28-OH, 9:11, 12:13-ene, saikogenin H
81 3β, 16α, 23,28-OH, 11:12, 13:18-ene, saikogenin D
82 3β, 16α, 28-OH, 11:12, 13:18-ene, 16-*epi*-saikogenin C



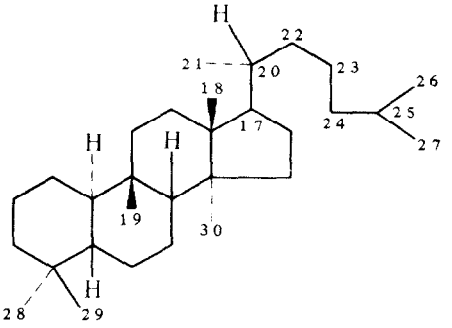
83 3β, 21, 26-OH, 24-ene
84 3β, 15-OH, 16-oxo, 23α-OAc, 24:25-epoxy
85 3β, 27-OH, 12-OAc, 16:23, 24:27, 24:25-epoxy, 7-ene
86 3β, 16β, 24,25-OH
87 1α, 3β-OH, 28-COOH, 24-ene
88 3β, 6α, 16β, 25-OH, 20S, 24R-epoxy, cycloastragenol
89 3β, 6α, 16β, 24(*R*) 25-OH
90 3β, 16β, 22,28-OH, 24-ene, thalicogenin
91 3β, 12β, 15α-OAc, 16β, 25-OH, 20:24-epoxy



92 2α, 3β, 12β, 20-OH, 24-ene
93 3β, 20(*S*)-OH, 19-oxo, 24-ene
94 3β, 20(*S*)-OH, 12-oxo, 24-ene
95 3β, 6α, 12β, 25-OH, 20:24-epoxy
96 3β, 6α, 12β, 20(*S*), 24-OH, 25-ene
97 3β, 20β-OH, 16α:30, 16β:23-epoxy, 24-ene, jujubogenin
98 3β, 6α, 12β, 20β-OH, 24-ene, 20(*S*)-protopanaxatriol
99 3β, 12β, 20β-OH, 24-ene, 20(*S*)-protopanaxadiol
100 3β, 12β, 25, 30-OH, 20:24-epoxy, capsugenin
101 3β, 6α, 12β, 25-OH, 20:22-ene,
102 3β-OAc, 6α, 20,26-OH, 24-ene
103 3-oxo, 6α, 20,26-OH, 24-ene
104 3β, 6α, 20,26-OH, 24-ene
105 3β, 20,26-OH, 24-ene
106 3-oxo, 6α, 20,21,26-OH, 24-ene
107 3β, 6α, 20,21,26-OH, 24-ene
108 2α, 3β, 12β, 20,26-OH, 24-ene
109 3β, 20,21-OH, 19-oxo, 24-ene

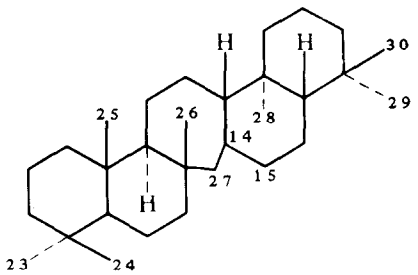


110 3β-OH, 7:8-ene, 23-OAc
111 3β, 25-OH, 16-oxo, 9:11-ene
112 3β, 23α-OAc, 7:8, 25:26-ene
113 3β-OH, 16-oxo, 9:11, 25:26-ene
114 3β, 12α, 17α, 22-OH, 9:11-ene
115 3β, 12α, 17α-OH, 9:11-ene
116 3β, 12α, 17α-OH, 22:25-epoxy, 9:11-ene, holothurigenin

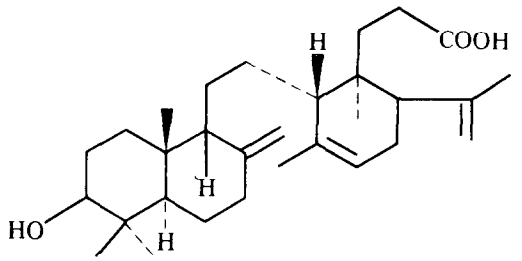


117 3β-OH, 5,19-epoxy, 6:7, 23:24-ene, 25-OMe
118 3β-OH, 5:6-ene, 22-al, 23,24,25,26,27-nor
119 3β, 22(*S*), 23(*R*), 24(*R*) 25-OH, 5:6-ene
120 2β, 20-OH, 3,11-oxo, 5:6, 24:25-ene, 16α:23α-epoxy
121 3β, 24,25-OH, 5:6-ene, 11-oxo
122 3β, 16β-OH, 7β-OMe, 5:6, 24:25-ene
123 3β, 7β, 16β-OH, 5:6, 24:25-ene
124 2β, 30-OH, 3,11-oxo, 16α:23α-epoxy, 5:6, 24:25-ene
125 2β, 20-OH, 3,11-oxo, 1:2, 5:6, 24:25-ene, 16α:23α-epoxy
126 2β, 3α, 16α, 20β, 25-OH, 5:6-ene, 11,22-oxo

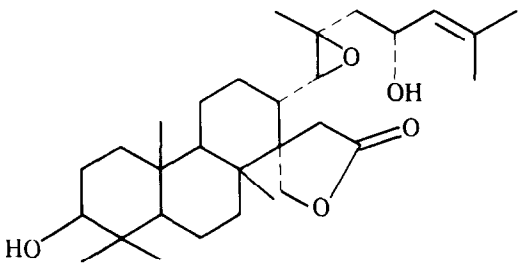
127 3,11,22-oxo, 2ζ, 16α, 20β, 25-OH
128 3β, 23,24,25-OH, 5:6-ene
129 3β, 22,23-OH, 5:6, 24:25-ene
130 2β, 3α, 20-OH, 5:6-ene, 11,22-oxo, 16α, 25-OAc
131 3β, 7β-OH, 5:6, 23:24-ene, 19-al, 25-OMe
132 3β, 7β, 25-OH, 5:6, 23:24-ene, 19-al
133 3β, 25-OH, 6:7, 23:24-ene, 5,19-epoxy



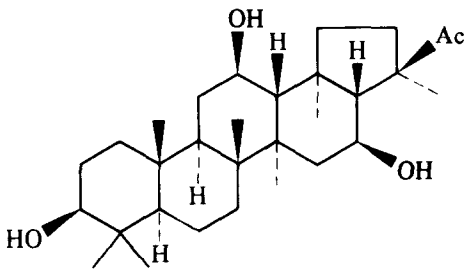
134 3β, 21α-OH, 14:15-ene, serratenediol
135 3β, OH, 21α-OAc, 14:15-ene, serratenediol acetate
136 3β, 21β-OH, 14:15-ene, 21-*epi* serratenediol



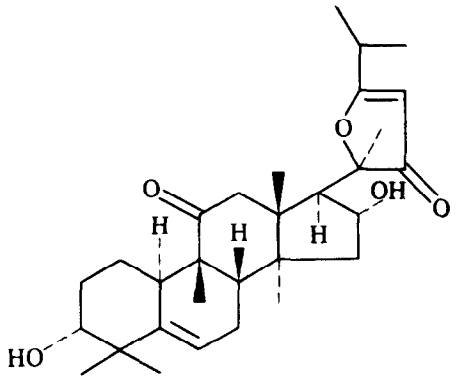
137 lansiogenin



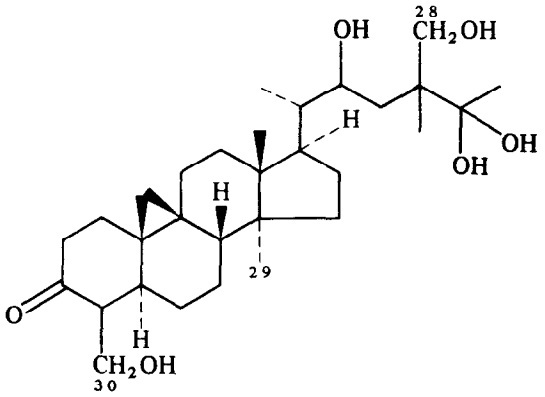
138 hovenolactone



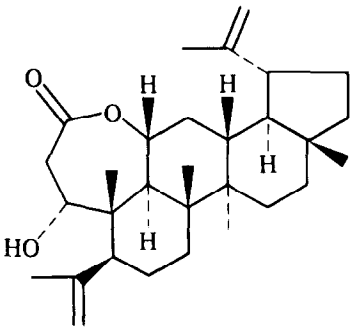
139 spergulagenin



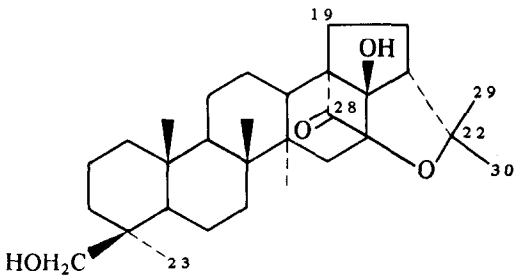
140 picfeltarraegenin



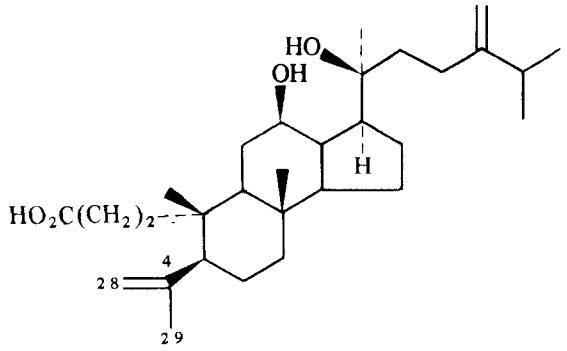
141 cymbiodosone



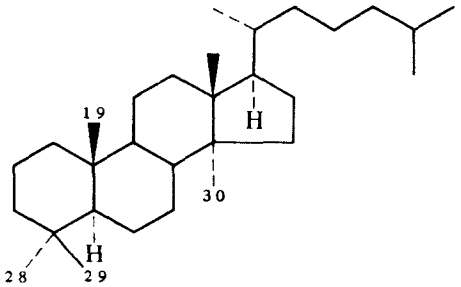
142 chaiisanogenin



143 hopan-22,28-olide



144 alnustic acid



145 3β, 22,25-OH, 24-oxo, 9:11-ene
146 3β, 22,24(*S*), 25-OH, 9:11-ene
147 3β, 29-OH, 15,24-oxo, 17:23-epoxy, 8:9-ene, 27-nor
148 3β, 28,29-OH, 17:23-epoxy, 24-oxo, 8:9-ene, 27-nor
149 3β, 30,31-OH, 8-ene, 27-nor, 23(*S*), 17:23-epoxy

BIOLOGICAL ACTIVITY

The wide occurrence in nature and varied biological activities of saponins have attracted the attention of mankind from the early stage of civilization. The use of saponins as natural detergents and fish poison were known to the primitive people. Earlier works on biological activities of saponins were mainly conducted on saponin-rich extracts or crude saponin mixtures containing not necessarily only saponins but also other constituents. Consequently, the results of such studies are non-specific and should be accepted with reservation. The advent of various efficient sophisticated techniques of isolation and structure elucidation and sporadic reports on interesting biological activities of crude saponins have prompted many workers to study the biological activities of pure saponin constituents or pure saponin mixtures and a considerable literature has already been accumulated. An excellent review on the occurrence and biological activities of triterpene glycosides in plants and animals has been published [284] and there are several reviews on the properties of saponins [285–290]. The effects of triterpenoid saponins derived from several plants on the secretion of ACTH and corticosterone have been discussed in detail by Hiai [291] and a review on the pharmacology of ginseng saponins, *Bupleurum falcatum* saponins and glycyrrihizin from *Glycyrrihiza glabra* has been published [292]. The antibiotic properties of triterpene glycosides of the Holothuroidea class of marine echinoderm animals have been reviewed by Somolilov and Girshovich [293]. The various biological activities of triterpene saponins reported during the period 1979 to 1986 are described here.

Action on metabolism

The hypocholesterolaemic effect of some saponins has prompted considerable clinical interest. Malinow *et al.* [294] and Oakenfull [295] have suggested that consumption of saponins may provide a useful means of controlling plasma cholesterol in man. Saponins (10 g/kg) in the high cholesterol diet of rats reversed the hypercholesteromia and increased both the rate of bile acid secretion and the fecal excretion of bile acids and neutral sterols [296]. In normal human blood serum, glutamate-pyruvate transaminase activity was highest in the presence of 1×10^{-7}% ginseng saponin [297]. Total triterpenoid glycosides of buttercup (*Caltha palustris*) root at 50 mg/kg orally, reduced serum cholesterol in cholesterol fed rats from 87 to 55.8 mg% and raised blood sugar from 126 to 137.8 mg% [298]. The i.p. administration of saponin from the roots of *Panax ginseng* increased adrenal cyclic-AMP in a dose-dependent manner and increased plasma 11-hydroxycorticosteroids in intact rats [299]. The isolated ginsenosides, protopanaxadiol or protopanaxatriol glycosides also increased plasma corticosterone [300]. Oral administration of several ginsenosides especially ginsenoside Rb_2, Saikosaponin A and extracts from Xiao-chai-Hu-Tang, *Bupleurum* and Gui-zhi-Fu-Ling-Wan counteracted hyperlipidemia in rats [301]. Administration of ammoniated glycyrrhizin for 14 days in diets of rats at 2% level caused a significant increase in Fe-excretion and a significant depletion in liver Mg stores [302]. The effect of ginseng saponins on alcohol oxidation was studied by Joo *et al.* [303]. The K_m's of horse hepatic alcohol dehydrogenase for ethanol and NAD^+ were lowest when the concentration of ginseng saponin was 1.33×10^{-4}%. Thus, the stimulatory effect of ginseng saponin might be brought about by a lowering of these K_m's. The inhibitory effect of 24 triterpenoids from *Cimici fuga* species on lymphocyte blastogenesis with phytohaemagglutinin (PHA) was studied and a structure–activity relation of potent suppressive activities provided. A hemiacetal group in the side chain an oxygenated group in the C-12 position, a cyclopropane ring on the B ring and a double bond at the C-7(8) position were responsible for the activity of cimicifugoside which was the strongest inhibitor of thymidine transport into PHA-stimulated lymphocytes [115]. Ginsenoside Rb_1 and Re was observed by Mita *et al.* [304] to increase the number of Ig-M-forming lymphocytes in a study of production of Ig-M in response to sheep erythrocytes in mice. Administration of sugar beet saponins orally to rats at 50 or 100 times above the basic dose of 0.22 mg/kg/day for 2–10 months resulted in the increased motor activity and blood serum α-lipoproteins and decreased blood serum pre-β-lipoproteins and erythrocyte osmotic resistance [305]. Saponins of ginseng given orally or i.p., stimulated phagocytosis in the reticuloendothellial system in normal and tumour-bearing mice and promoted antibody production [306]. The isolated saponin Rb_1 and Rc from ginseng have both been shown to stimulate the synthesis of serum proteins and cholesterol *in vivo* [307, 308]. The optimum doses of glycyrrhizic acid and DL-methionine for treatment of rat hepatic failure induced by tetrachloromethane or D-galactosamine were 100 mg/kg/day

whereas that of a glycyrrhizinic acid-DL-methionine mixture was 50 mg/kg/day for each compound [309]. The mixture had obviously greater therapeutic effects than components alone.

Antimicrobial activity

Triterpenoid saponins exhibit divergent antimicrobial activities. A glucoside of Δ^{12}-oleanene-23, 28-dioic acid isolated from alfalfa root demonstrated considerable activity against *Cryptococcus neoformans*. This glucoside also exhibited rapid killing of this fungus at a little higher concentration, suggesting that it might be a useful active agent in the treatment of cryoptococcosis [310]. Comparative studies with 0.1 and 0.001% saponin from Korean ginseng on the bacterial growth of *Escherichia coli* showed stimulated growth at lower concentration and the bacterial growth was considerably impaired at higher concentration (0.1%) [311]. A methanolic extract of *Anagallis arvensis* inhibits herpes and poliomyelitis virus development and this activity is attributed to saponins [312]. The saponins of alfalfa favoured *N*-immobilization and denitrification and inhibited proteolysis and ammonification in both peat inoculated and *Pseudomonas* inoculated media. Alfalfa root saponins and sapogenins reduced the fungal population, but did not affect the bacterial population of peat [313]. Triterpene saponins, camellidin I and II isolated from *Camellia* leaves have been reported to be microbicides. Camellidin I controlled spore germination of *Gloeosporium theaesinensis*, at 250 ppm and of *Piricularia oryzae* and *Cochliobolus miyabeanus*, at 10 ppm on nutrient agar plates [314]. Yiamoloside B, a new triterpenoid saponin isolated from *Phytolacca octandra* has been reported to be fungistatic [283].

Anti-inflammatory activity

The inflammation-inihibiting activity of triterpenoid saponins from *Solidago virgaurea*, *Polemonium coeruleum* and *Hydrocotyle vulgaris* is comparable to that observed with Na-escinate as determined by the rat paw edema test [315]. Saponins from Yunnan Bai Yao was effective against several experimental inflammations in rats. The s.c.LD_{50} of the saponins was 299 mg/kg. Histamine and total Prostaglandin concentrations of the tissue exudate were decreased and increases in capillary permeability induced by histamine and PGE_2, but not by 5-HT, were inhibited by the saponins. Ascorbic acid content in the adrenal glands was also decreased [316]. The anti-inflammatory activities of Mi-saponins mixture isolated from the seeds of *Modhuca longifolia* were compared with those of phenylbutazone and β-escin in mice. The anti-inflammatory actions of the Mi-saponin mixture were nearly equal to those of β-escin, but were weaker than those of phenyl butazone in general [317]. Triterpene saponin of *Anemone raddeana* at a dosage of 30μg/ml showed marked antitumour activity and suppressed the growth of ascitic hepatoma by 81% [244]. The anti-inflammatory activities of oleanane triterpenoid glycosides, papyrioside L-IIa, L-IIb, L-IIc and L-IId extracted from *Tetrapanax papyriferum* and their aglycones, Papyrigenin A and A_2 were investigated by using carrageenin-induced edema and the cotton pellet granulomatous in mice. Papyriogenin A and A_2 (30 mg/kg orally) manifested in these tests almost the same potency as prednisolone (25 mg/kg orally). The structure–activity relationship of these and related triterpenes were investigated taking into account particularly the variation in the oxygen function and molecular conformation. The anti-inflammatory activity of these triterpenes was higher when the molecules tended to take a planar conformation induced by the heteroannular diene group between the C and D rings [318]. The total saponins of *Panax notoginseng* were effective against several experimental inflammations in mice and rats; the anti-inflammatory effect of the saponins was stronger in normal rats than in adrenalectomized rats. The content of ascorbic acid in rat adrenals was decreased by saponins. Thus, in addition to the direct anti-inflammatory effect, the saponins may act indirectly via the pituitary adrenocortical system [319]. The effects of saikosaponin d (I) from *Bupleurum radix* on the antigranulomatus action of dexamethasone (II) was examined in rats using the cotton pellet method . Administration of I, II and I + II (each at 0.1 mg/kg/day) immediately after the insertion of cotton pellet, reduced the weight of cotton-induced granuloma by 10.42,11.46 and 37.50% respectively at four days [320].

Action on the cardio-vascular system

Saponins of *Panax quinquefolium* at a dose of 80 mg/kg i.v. inhibited the cardiac arrythmias induced by chloroform in mice, by barium chloride in rats and by ouabain in guniea pigs [321]. The effect of total ginseng saponins, ginsenoside Rb_1 and ginsenoside Re on the contractile force in isolated sponataneously beating normal rat heart was investigated. Total ginseng saponin slightly increased the contractile force. Ginsenoside Rb_1 markedly increased the contractile force dose dependently. The activity of Na^+, K^+-AT Pase was inihibited by ginsenoside Rb_1, Re and total saponin [322]. Ilexolide A extracted from the roots of *Ilex pubescens* exhibits cardiac activity [173, 174]. Vasodilation by ginseng saponins was observed in rabbits [323]. Total saponins of *Panax notoginseng* cause vasodillation by inhibiting Ca^{2+} influx which in turn affects the adrenergic receptors [324].

Haemolytic and cytotoxic activity

Comparative study of cytotoxic activity of triterpene glycosides of holothurian A and B from *Holothuria mexicana* and stichoposide A and C from *Cucumaria frandatrix* showed a higher toxicity than the glycosides of plant origin. Their cytotoxic activity depended on the number of monosaccharide units attached to the hydroxy group at C-3. Holothurin A, having four units are more toxic than Holothurin B, with only two sugar units. On the other hand, the increase in the length of saccharide chains to six (stichoposide C with A) had little effect on activity. The changes noted indicated the general tendency of these glycosides to have increased physiological activity in response to an increase in length of the chains to 4–6 monosaccharide residue [163]. Relationships between chemical structure, haemolytic action and surface activity of five oleanolic acid glucosides were studied. Monodesmosidic saponins are more haemolytic than bisdesmosidic saponins. The haemolytic activity of monodesmosides decreases with the length and hranching of the glycosidic chain. Surface activity is major in bisdesmosides and increases with length of the chain for monodesmosides. Increase of haemolytic action is accom-

panied by a decrease on surface activity [231]. Fukunda *et al.* [325] demonstrated that some saponins have the ability to cause agglutination of phospholipid vesicles *in vitro*.

Miscellaneous

Extensive studies have been made on the pharmacological activity of ginseng saponins [326–329]. Astragalus saponins produced a dose-dependent analgesic effect at 50 mg/kg. The analgesic effect was weaker and shorter than that of morphine at 20 mg/kg and inhibited contraction of the isolated guinea pig ileum *in vitro* [330]. Saponins of pericarps of *Sapindus mukurossi* cause remarkable enhancement of the absorption of Na-ampicillin from rat intestine and rectum [190]. Two oleanolic acid saponins isolated from *Momordica cochinchinensis* showed hypoglycemic activity in diabetic rats [331]. A triterpenoid saponin isolated from the bark of *Schima argentea* was found to be useful as an oral anthelmintic [332]. The use of plant saponins in a liposomal drug delivery system has recently been demonstrated [333].

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