GLYCOSIDES OF ARALIACEAE

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Among medicinal plants, a special place is occupied by representatives of the unique family Araliaceae, which are distributed predominantly in the tropical regions and number about 60 genera, including 800 species. Only in maritime regions do the Araliaceae appear in the temperate zone, especially or the territory of the Soviet Far East, where two species of plants of this family, grouped into six genera, grow. In a number of species, the first place is taken by the genus Aralia, which is represented by small trees – Manchurian aralia (A. manshurica Rupr. et Maxim.) and Japanese aralia [A. elata (Miq.) Seem.], and by herbaceous plants – continental aralia (A. continentalis Kitagawa), udo (A. cordata Thunb.), and Schmidt's aralia (A. schmidtii Pojark). Other genera of the Araliaceae of the Soviet Far East include only one species each. To these belong the herbaceous plant ginseng (Panax ginseng C. A. Meyer), Kalopanax septemlobum (Thunb.) Koidz – a tree about 20 m high – and the bushes Echinopanax elatum Nakai, Acanthopanax sessiliflorum (Rupr. et Maxim.) Seem. and Eleutherococcus senticosus Rupr. et Maxim. The majority of the plants mentioned are widely distributed in the maritime regions of the Far East. In addition, eleutherococcus is found in the woods of southern Sakhalin and kalopanax in southern Sakhalin and the islands of Kunashir and Iturup. Some species of Aralia are known only in southern Sakhalin and some islands of the Kurile archipelago. Only one genus is characteristic for Europe – English ivy (Hedera helix L.) – which, however, in the systematic aspect is not a typical representative of the family Araliaceae.

Among the plants mentioned, a special position is occupied by ginseng – a unique relict plant. Thanks to their high biological activity, ginseng extracts have been used in folk medicine for about 5000 years. Ginseng extract is a medicinal agent with a new type of action, increasing the organism's capacity for resistance or enhancing its capacity for work [1]. A biological evaluation of various fractions from ginseng root has shown that the maximum physiological activity is possessed by the glycosides [2], and it can therefore be stated that it is just these that form the active principles of this plant [2, 3]. However, the reserves of ginseng are very limited and attempts to find plants with a similar biological action to that of ginseng among the other Araliaceae are fully justified. In this respect, particular attention has been devoted to eleutherococcus. As a result of the pharmacological investigations performed, it has been concluded that eleutherococcus may act as the best and most promising substitute for ginseng [4]. It has been established that the biological activity of eleutherococcus preparations is due to the glycosides that they contain. Thus, according to I. V. Dardymov [4] the stimulant activity of the so-called "liquid" extract (the combined extractive substances) is 5600 SAU_{33}* per 100 g of roots and 7150 SAU_{33} per gram of purified glycoside fraction from this plant. Since, according to V. F. Lapchik's estimate [5], the total concentration of glycosides in fractions of the liquid extract of eleutherococcus varies between 0.7 and 0.9%, it can be calculated that the stimulating activity of the combined glycosides from 100 g of roots must average 5800 SAU_{33}; this is very close to the stimulating activity given above for the whole of the extractive substances. Nevertheless, a further chemical investigation has shown that eleutherococcus roots contain only phenolic glycosides [6] sharply differing in structure and properties from the triterpene glycosides of ginseng [3]. Consequently, it is still premature to regard eleutherococcus as a substitute for ginseng. The most promising method of increasing the availability of ginseng preparations may be the complete or partial synthesis of the glycosides that they contain and of their biologically active analogs, all the more since at the present time this task has, in principle, been solved [7].

*Stimulating activity units [4].

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Although interest is presented by the influence of eleutherococcus extracts on free-radical processes in radiation damage [8], nevertheless if the pharmacological literature on eleutherococcus is analyzed [4], the impression is created that an extract of this plant affects the majority of processes occurring in the organism (protein-anabolyzing action, action on the carbohydrate metabolism, adaptogenic action, regulation of nervous activity, etc.) and can be used to treat extremely diverse diseases (diabetes, cancer, radiation disease, neurasthenia, atherosclerosis, etc.). Such a variety of biological actions is unwarranted and is probably explained by the weakness of the pharmacological methods used for their determination.

In spite of the large number of investigations devoted to the pharmacology of eleutherococcus [4], the question of the medicinal value of this plant still remains disputed.

There is information in the literature on the biological activity of other plants of the family Araliacease, as well; in particular, acanthopanax [9], aralia [10], and ivy [11]. But, as in the case of eleutherococcus, none of these plants contains glycosides similar in structure to those of ginseng.

The systematic chemical investigation of the glycosides of Manchurian aralia [12], ginseng [13, 14], kalopanax [15], eleutherococcus [16], and acanthopanax [17] was begun in the sixties; only in the case of the glycosides of ivy had some information been obtained previously [18, 19]. In a structural study of the glycosides of the Araliaceae it was found that the majority of them belong to two classes of natural compounds – triterpene glycosides and phenolic glycosides, and these will be discussed below.

Of other glycosides, we must mention the presence of daucosterol in ginseng [3, 20], eleutherococcus [6], and acanthopanax [21]. Another feature of eleutherococcus is the presence in its roots of small amounts of ethyl α-D-galactopyranoside [6], isolated previously from lupin seeds [22].

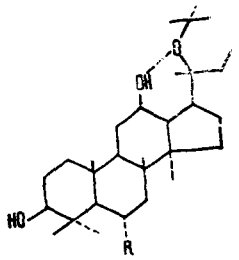
TRITERPENE GLYCOSIDES OF ARALIACEAE

All the triterpene glycosides isolated up to the present time from plants of the family Araliaceae can be subdivided into two groups: glycosides of tetracyclic triterpenes of the dammarane series and glycosides of pentacyclic triterpenes. The first group includes only the glycosides of ginseng – panaxosides. They have not been found in any other plants of this family. The second group is composed of glycosides of oleanolic acid and of hederagenin; they are absent from ginseng but are present in other species of plants of the family Araliaceae.

Panaxosides

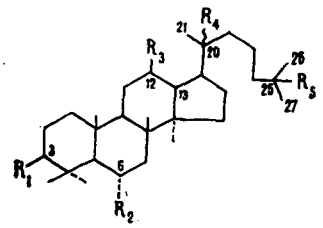
In 1962, G. B. Elyakov et al. [3, 13, 23] isolated from ginseng roots seven individual triterpene glycosides, called in order of increasing polarity panaxosides A–G. An analytical investigation of the glycoside fraction showed that the glycosides composing it form two groups: a less polar group comprising panaxosides A, B, and C (A series) [13, 23, 24] and a more polar group comprising panaxosides D, E, F, and G (F series) [25]. The partial separation of the glycoside fraction into these groups was first achieved by gel filtration on Sephadex [26]. Preparative partition and adsorption chromatography on alumina or silica gel enabled the individual glycosides of ginseng to be isolated and characterized [23, 25]. A feature of the panaxosides is the high lability of the glycone: under any conditions of hydrolysis a complex mixture of transformation products of the genin is formed. The main products of acid hydrolysis – panaxadiol [14] and panaxatriol [27] – are artefacts, and the native genins have not hitherto been obtained by direct methods. In order to deduce the structure of the native aglycones, the majority of the substances obtained on acid hydrolysis of the glycosides have been isolated [3, 14, 24, 28-32]. The determination of the structures of these compounds by the methods of nuclear magnetic resonance spectroscopy and mass spectrometry have shown their interrelationship and possible routes of their formation [3, 24-39]. The acid hydrolysis of the panaxosides of the A series under severe conditions [3, 24, 40] forms an equilibrium mixture of six triterpenoids of the dammarane series (A_1–A_6) with a predominance of the least polar compound A_6, the structure of which was established and which was given the name of panaxatriol (I) [27] (see structure on the following page.)

Under conditions of severe acid hydrolysis, the panaxosides of the F series [29, 36-38] form an equilibrium mixture of five triterpenes of the dammarane series (F_1–F_5) differing from compounds A_1–A_6. The predominant component is the most polar one, F_5 – panaxadiol (II) – the structure of which has been established by Japanese workers [33].



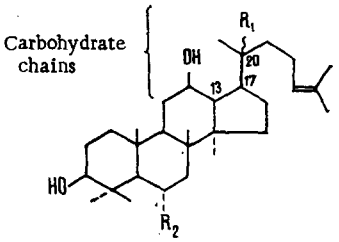
(I): R=OH; panaxatriol,
(II): R=H; panaxadiol.

The further elucidation of the structure of representatives of the individual groups of substances (A_1-A_6) and (F_1-F_6) has shown [34-37] that they are all derivatives of dihydroprotopanaxadiol (III).



III $R_1=R_3=R_4=OH$; $R_2=R_5=H$; dihydroprotopanaxadiol
A_1 (IV) $R_1=R_2=R_3=R_4=R_5=OH$
F_1 (V) $R_1=R_3=R_4=R_5=OH$; $R_2=H$
A_2 (VI) $R_1=R_2=R_3=R_4=OH$; $R_5=OCH_3$
F_2 (VII) $R_1=R_3=R_4=OH$; $R_2=H$; $R_5=OCH_3$
A_5 (VIII) $R_1=R_2=R_3=OH$; $R_4=R_5=OCH_3$
F_4 (IX) $R_1=R_3=OH$; $R_2=H$; $R_4=R_5=OCH_3$.

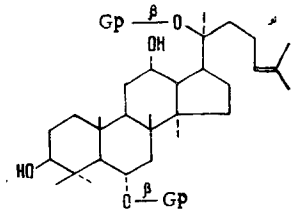
On the basis of the structures of these compounds, it could be concluded that none of them can be the native aglycone, since compounds (IV-IX), like the main products of acid hydrolysis (I) and (II), contain no multiple bonds. Furthermore, they have tertiary oxygen functions, which are absent from the panaxosides. And, finally, the panaxosides of the A and the F series each contain one hydrogenatable double bond in the side chain and, consequently, cannot have as the native aglycones any of compounds (I, II, and IV-IX). On the basis of a study of the products of hydrogenation and hydroxylation of the panaxosides [38], structures (Xa) and (Xb) were proposed for the native genins. These proposals have been confirmed subsequently [39, 41].



(Xa) $R_1=R_2=OH$ or $R_1=H$; $\Delta 13(17)$; $R_2=OH$; panaxosides of the A series;
(Xb) $R_1=OH$; $R_2=H$ or $R_1=R_2=H$; $\Delta 13(17)$; panaxosides of the F series.

The structures of the carbohydrate moieties of the panaxosides have been established by the usual methods of carbohydrate chemistry [42]: complete and partial acid hydrolysis and the method of methylation and periodate oxidation.

Glycosides analogous to the panaxosides have been isolated from ginseng by Shibata et al. [43] and have been called ginsenosides. Japanese workers [45] have also established the complete chemical structure of one of the series of triterpene glycosides of ginseng – panaxoside A [44] [= ginsenoside Rg_1 (XI)].



(XI) Panaxoside A (ginsenoside R_{g1}).

Glucose and rhamnose were detected in a hydrolyzate of panaxoside B [24]. Because of its low concentration in the roots of ginseng, panaxoside B was not studied in detail.

Subsequently [46], another panaxoside, B', was isolated and the following provisional formula has been established for it:

Gp-(1 → 2)-Gp-1, Gp-1 > aglycone

(XII) panaxoside B'

Gp = a D-glucopyranose residue.

The structure of panaxoside C can be represented by two variants [46, 47]:

D-Gp-(1 → 2)-D-Gp-1, L-Rhap-1 > aglycone L-Rhap-(1 → 2)-D-Gp-1, D-Gp-1 > aglycone

(XIII) panaxoside C

Recently [48], panaxoside C has also been isolated from the herbage and pulp of the fruit of ginseng grown near Moscow.

Panaxosides D, E, and F have much in common in the structure of the carbohydrate chains [3, 49-51]. The structure of panaxoside D is represented by formula (XIV):

D-Gp-(1 → 3) D-Gp-(1 → 3)-D-Gp-1, D-Gp-(1 → 6)-D-Gp-1 > aglycone

(XIV) panaxoside D

and panaxoside E by formula (XV):

D-Gp-(1 → 3)-D-Gp-(1 → 3)-D-Gp-1, L-Ara*f*-(1 → 6)-D-Gp-1 > aglycone

(XV) panaxoside E

L-Ara*f* = L-arabofuranose residue.

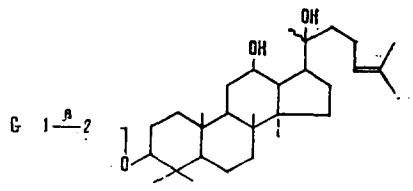
while for panaxoside F (XVI) the following two structures are equally probable:

D-Gp-(1 → 3)-D-Gp-(1 → 3)-D-Gp-1, D-Gp-(1 → 2)-D-Gp-(1 → 6)-D-Gp-1 > aglycone

D-Gp-(1 → 2)-D-Gp-(1 → 3)-D-Gp-(1 → 3)-D-Gp-1, D-Gp-(1 → 6)-D-Gp-1 > aglycone

(XVI) panaxoside F

Shibata et al. [45, 52] have given a structure for the prosapogenin of glycosides R_{b-d}, which should correspond to panaxosides D, E, and F. However, they do not show the identity of the former and the latter.



(XVIa) Prosapogenin of ginsenoside R_6.

The question of the position of attachment of each carbohydrate chain in panaxosides C – F has not been definitely answered. There is no doubt that one of the carbohydrate chains is attached to the hydroxyl at C_3 of the aglycone and the most probable position of attachment of the other chain is the hydroxyl at C_{20}. This chain stabilizes the aglycone and only when it is eliminated are the equilibrium transformations and conversions of the aglycone observed [38, 45]. Panaxosides C – G belong to the class of triterpene oligosides [53] and serve as the first examples of oligosides of neutral tetracyclic triterpenoids with two linear sugar chains [3]. This circumstance explains their high stability to hydrolysis, since the formation of a secondary structure is possible with the aid of hydrogen bonds between the monosaccharide residues of each carbohydrate chain. The existence of such a secondary structure affects the chemical and biochemical behavior of the molecule (difficulty of acid hydrolysis and of exhaustive methylation, increased resistance to enzymatic cleavage, etc.).

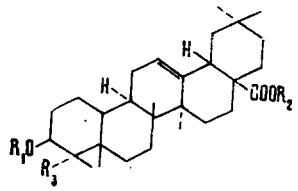
According to preliminary results, panaxosides may be present in another species of ginseng – American ginseng (P. quinquefolium) [84]. No panaxosides have been found in other species, which shows the special position of P. ginseng and, possibly, P. quinquefolium in the family Araliaceae.

Glycosides of Oleanolic Acid

Triterpene glycosides the genin of which is oleanolic acid (oleanolosides) have been found in various species of aralia [12, 55-61], in two species of ginseng – P. japonicus and P. repens [16] –, ivy [63], and eleutherococcus [6, 64, 65].

A study of a methanolic extract of the roots of Manchurian aralia showed that it contained three triterpene glycosides, which were called aralosides A, B, and C [12, 55]. The same glycosides are present in other species of aralia [58-61]. The aralosides are present in all the organs of the plant, but the greatest amount is found in the bark of the roots.

The mixture of aralosides was separated into its individual components by partition chromatography on columns of alumina with gradient elution [56]. Acid hydrolysis of the aralosides formed as the genin only oleanolic acid. From the results of elementary and chromatographic analysis it was concluded that araloside A is a trioside and aralosides B and C are tetraosides of oleanolic acid. Araloside A (XVII) contains one residue each of D-glucose, L-arabinose, and D-glucuronic acid, while araloside B (XVIII) contains the same monosaccharides in a ratio of 1:2:1. The carbohydrate moiety of araloside C (XIX) consists of residues of D-glucose, D-galactose, D-xylose, and D-glucuronic acid (1:1:1:1). The configurations of the glycosidic bonds were determined with the aid of Klyne's rule [66].



(XVII) R_1=α–*L*–Ara f 1–4β–*D*–G A 1→; R_2=β–*D*–G →; R_3=H araloside A

(XVIII) R_1=α–*L*–Ara f 1→3
α–*L*–Ara f 1→4 β–*D*–G A 1→; R_2=β–*D*–G →; R_3=H araloside B

(XIX) R_1=β–*D*–Gal p 1→3
β–*D*–Xyl p 1→4 β–*D*–G A 1→; R_2=β–*D*–G →; R_3=H araloside C

(XX) R_1=α–*L*–Rha p 1–4α–*L*–Ara p 1→; R_2=R_3=H mubenin B= eleutheroside E

(XXI) R_1=α–*L*–Rha p 1→2α–*L*–Ara p 1→; R_2=R_3=H eleutheroside K

(XXII) R_1=α–*L*–Rha p 1→4α–*L*–Ara p 1→; eleutheroside L
R_2=α–*L*–Rhα p 1→4β–*D*–G p1→6β–*D*–G p 1→; R_3=H

(XXIII) R_1=α–*L*–Rha p 1→2α–*L*–Ara p 1→; hederasaponin B= eleutheroside M
R_2=α–*L*–Rha p 1→4β–*D*–G p 1→6β–*D*–G p 1→; R_3=H

(XXIV) R_1=G 1→4 Ara 1→; R_2=H; R_3=CH_2OH hederacoside A kalopanax saponin A

(XXV) R_1=α–*L*–Rha p 1→2α–*L*–Ara p 1→; R_2=H; R_3=CH_2OH kalopanax saponin A

A

(XXVI) R_1=α–*L*–Rha p 1→2α–*L*–Ara p 1→; kalopanax saponin B= hederasaponin

R_2=α–*L*–Rha p 1→4β–*D*–G p 1–6β–*D*–G p 1→; R_3=CH_2OH

Thus, the aralosides belong to the class of triterpene oligosides, which are widely distributed in nature [53]. Characteristic for their structure is the presence of two carbohydrate chains, one of which is

attached by anO-acyl glycosidic bond, and of branching in the carbohydrate moiety of aralosides B and C. A feature of this group of oleanolosides is that they all contain D-glucuronic acid. Similar oleanolosides containing D-glucose, L-arabinose, and D-glucuronic acid in the carbohydrate chain have been isolated from the roots of P. repens and P. japonicus; the structures of these glycosides have not been described [62].

The oleanolic acid glycosides isolated from the leaves of eleutherococcus and ivy differ from the aralosides by the absence of D-glucuronic acid from their carbohydrate chain.

Four glycosides, called eleutherosides J–M have been found in the leaves of eleutherococcus [6, 64], while the leaves of ivy contain only one oleanolic acid glycoside – hederasaponin B [63]. A recent investigation [65] has shown that eleutheroside J is identical with mubenin B (XX) isolated from the seeds of the South Japanese plant Stauntonia hexaphylla and studied previously by Japanese workers [67]. In addition, it has been found that eleutheroside M and hederasaponin B (XXIII) have the same structure. Eleutherosides J (XX) and K (XXI) are biosides and contain one L-rhamnose residue and one L-arabinose residue in their carbohydrate chains; hederasaponin B (XXIII) and eleutheroside L (XXII) are pentaosides; their molecules contain D-glucose, L-rhamnose, and L-arabinose residues in a ratio of 2 : 2 : 1. The complete structures of eleutherosides J–L [65] and of hederasaponin B [63] are represented by formulas (XX-XXIII).

Eleutherosides J and K, and also L and M, differ from one another in the carbohydrate chain attached to the C_3 hydroxyl of oleanolic acid. It is possible that eleutherosides J and K are biogenetic precursors of eleutherosides L and M, and, most probably, a preformed carbohydrate chain added to the carboxy group of the genin. Similar considerations have recently been put forward by a number of workers [54, 68]. Hederasaponin B and eleutherosides L and M are typical representatives of the triterpene oligosides and have all the structural features characterist for this class.

Hederagenin Glycosides

As long ago as 1912, Van der Haar [18] isolated α-hederin from ivy leaves and showed that it was a bioside of hederagenin containing one rhamnose residue and one arabinose residue in the carbohydrate chain.

In 1955, Scheidegger and Cherbuliez [19], on studying the stems and leaves of the plant found no α-hederin; they isolated hederacoside A and established its structure (XXIV), showing that it is a bioside of hederagenin containing glucose and arabinose residues.

In 1964, of the three triterpene glycosides present in the roots of Kalopanax septemlobum, two were isolated in the individual state and were named kalopanax saponins A and B [69]. They proved to be bioside and a pentaoside of hederagenin, respectively.

In 1965, Tschesche et al. [63] found in a methanolic extract of ivy, in addition to α-hederin, two other triterpene glycosides: hederasaponins B and C. The structure of hederasaponin B (XXIII) is given above; hederasaponin C is a hederagenin pentaoside. A direct comparison of α-hederin with kalopanax saponin A and of hederasaponin C with kalopanax saponin B showed that these glycosides are completely identical [63].

The structures of kalopanax saponins A and B [70, 71], α-hederin, and hederasaponin C [63] were determined almost simultaneously. The complete structures of these compounds correspond to formulas (XXV) and (XXVI).

A simple comparison has shown that the carbohydrate chains of eleutheroside K and of α-hederin (kalopanax saponin A) are identical, while kalopanax saponin B (hederasaponin C) has a carbohydrate chain of the same structure as hederasaponin B (eleutheroside M) (compare formula XXI with XXV and XXIII with XXVI).

It is possible that kalopanax saponin A (α-hederin) is a biogenetic precursor of kalopanax saponin B (hederasaponin C). It may be assumed that in the case of hederasaponin B a similar precursor is present in ivy, in the same way as is found in eleutherococcus.

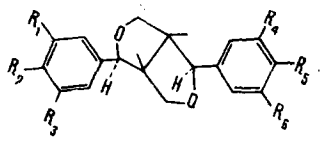
Thus, the triterpene glycosides of kalopanax, ivy, and eleutherococcus have much in common in their structure, which shows the biogenetic affinity of these plants.

PHENOLIC GLYCOSIDES

A preliminary investigation of methanolic extracts of the roots of eleutherococcus, acanthopanax, and echinopanax has shown that they contain phenolic glycosides and glycosidic fractions of similar com-

position [3, 5], 6, 21]. It is important to note the complete absence of triterpene glycosides from the roots of these plants [3]. At the present time, the glycosides of the roots of acanthopanax (17, 21, 72, 73) and of eleutherococcus [5, 6, 16, 74-78] have been studied in detail.

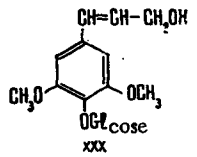
In an investigation of the chemical composition of the extractive substances from the roots of acanthopanax, it was established that the glycosidic fraction consists mainly in lignane glycosides the genins of which belong to lignanes of the diphenyl-3,7-dioxobicyclo[3.3.0]octane series. Similar glycosides have been found in the roots of eleutherococcus [74]. Chromatographic analysis of the glycoside fraction of acanthopanax has shown that it contains four glycosides, which have been called acanthosides A–D [17]. The individual acanthosides were obtained by partition chromatography on alumina in the butan-1-ol–ethanol–water system and by adsorption chromatography on silica gel with gradient elution by chloroform–methanol mixtures. In this way it was established that the main component of the mixture of glycosides is acanthoside D. Acanthosides A and B are monoglucosides and acanthosides C and D are diglucosides of lignanes. A chromatographic investigation of the extractive substances of eleutherococcus showed that the glycosidic fraction of the roots and stems of this plant contained, in addition to daucosterol (eleutheroside A) and ethyl α-D-galactopyranoside (eleutheroside C), which have been discussed above, a group of phenolic glycosides which have been called eleutherosides B, B_1, and D–G [5, 6, 16]. The main components of this mixture – eleutherosides B, B_1, and E – were obtained in the individual state by adsorption chromatography on silica gel. It is interesting to note that eleutherosides B and B_1 accumulate mainly in the bark of the roots and the stems, while eleutheroside E is found in the core of these organs [5,78]. The amounts of the other eleutherosides are very small and vary widely, so that some of these compounds are completely absent from individual batches of raw material. The amount of the eleutheroside fraction in the stems is 1.5 times greater, on an average, than in the roots and rhizomes [5, 77]. The results of a comparison of eleutheroside E and acanthoside D has shown that they are completely identical [74]. Both compounds are diglucosides and have the same lignane-type genin, which is also that of acanthoside B. A comparison with synthetic (±)-syringaresinol and natural (+)-syringaresinol (lirioresinol C) [79] showed that the genin of acanthosides B and D and of eleutheroside E is (–)-syringaresinol [21, 74]. The complete structures of these glycosides are shown by formulas (XXVII) and (XXVIII).



(XXVII) $R_1=R_2=R_4=R_6=OCH_3$; $R_3=\beta$–*D*– Gp → O; $R_5=OH$ – acanthoside B
(XXVIII) $R_1=R_3=R_4=R_6=OCH_3$; $R_2=R_5=\beta$–*D*–Gp → O– acanthoside D, eleutheroside E
(XXIX) $R_1=R_3=H$; $R_2=R_4=OH$; $R_5=R_6=OCH_3$

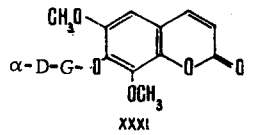
Neither (–)-syringaresinol itself nor its glycosides had been isolated previously; however, it has been shown [79] that the tulip tree Liriodendron tulipifera L. contains liriodendrin, which is a diglucoside of (+)-syringaresinol. The properties of acanthosides A and C are similar to those of acanthosides B and D. The results of a study of the IR and NMR spectra of their genin permitted it to be ascribed the structure of the lignane (XXIX). Acanthoside A is its monoglucoside at one of the phenolic hydroxyls and acanthoside C is a diglucoside of this lignane. Lignane glycosides are important components of the glycosidic fraction of this group of plants.

The roots of Eleutherococcus senticosus contain two other glycosides besides eleutheroside E: eleutherosides B and B_1. Their structures have also been established [6, 75, 76]. They proved to be identical with previously known compounds. Eleutheroside B is syringin, i.e., the 4-β-glucoside of sinapyl alcohol (XXX). Considerable amounts of syringin are present in common lilac Syringa vulgaris L. [80].



XXX

Eleutheroside B_1 is calycanthoside, i.e., isofraxidin 7-α-glucoside (XXXI) [75]. This glycoside has been isolated from the branches of Calycanthus occidentalis Hook [81].



XXXI

We may note that no unusual compounds characteristic only of eleutherococcus have so far been found in appreciable amounts in any of the organs of this plant.

The molecules of eleutherosides B, B_1, and E, and also those of acanthosides A–D, are based on a phenylpropane grouping and, consequently, the biosynthesis of these compounds must be connected with the biosynthesis of phenolic compounds in general of the C_6–C_3 fragment in particular. Starting from modern ideas on the routes of biosynthesis of phenylpropanes in plants and from the structure of the above-mentioned glycosides it may be assumed with a high degree of probability that these glycosides are formed in the plant from low-molecular-weight nonaromatic compounds via shikimic acid [5]. The possibility of the dimerization of sinapyl alcohol with the formation of syringaresinol has been shown by Freudenberg [82]. Since in syringin the C_3 fragment of the molecule of sinapyl alcohol remains unchanged, the possibility of the dimerization of eleutheroside B in the plant with the formation of eleutheroside E appears fully probable [5]. There is no doubt that eleutheroside B_1 is also a product of the biosynthetic transformation of syringin – in particular, of sinapyl alcohol [6].

SOME CHEMICOTAXONOMIC LAWS IN THE FAMILY ARALIACEAE

Information on the chemical composition of plants of the family Araliaceae has permitted some conclusions which are useful for the systematics of these plants [3]. The majority of the plants of this family that have been studied contain triterpene glycosides which can play the part of taxonomically valuable substances. It is therefore desirable to compare the systematic position of the Araliaceae of the Far East with the presence of triterpene glycosides in them and with the structure of these compounds. Nearly every species has numerous synonyms: earlier, on the basis of a number of botanical, geographical, and other characteristics authors distinguished individual species, which were then combined into a single species. This led to confusion in the systematics of the species found in the Soviet Far East, as well. The species composition of plants of the genus Aralia proved to be particularly numerous. At the present time it has been reduced to four species. Chemical data confirm their taxonomic propinquity. They all contain aralosides – glycosides of oleanolic acid the carbohydrate chain of which contains a glucuronic acid residue. The separation of this genus into species has been done on the basis of their geographical distribution. Very close to this genus are two species of ginseng: P. repens and P. japonicus, in the roots of which there are glycosides similar to the aralosides. Another group of Araliaceae consists of kalopanax and ivy, which contain hederagenin glycosides. Another group is represented by eleutherococcus, acanthopanax, and echinopanax, in the roots of which triterpene glycosides are completely absent and lignane glycosides are present.

From the composition of the glycoside fraction of the leaves, eleutherococcus is close to ivy and aralia. The presence of oleanolic acid glycosides in these plants may show their phylogenetic kinship. Unfortunately, the leaves of acanthopanax and echinopanax have not been studied, but it is not excluded that they also contain triterpene glycosides, and it may be assumed that these are glycosides of oleanolic acid.

In the genus Panax, ginseng, P. ginseng, has been studied in greatest detail. As mentioned above, this plant contains a special type of neutral glycosides of tetracyclic triterpenoids. Closest to this species is American ginseng P. quinquefolium. It is not a matter of doubt that these species of the genus are the most woody of the whole family. This genus is distinguished from all the others by the fact that almost all its representatives are herbaceous plants. P. ginseng, a species with a rudimentary embryo, differs considerably in its biology from the other species. It is apparently closest to those ancient ancesters from which the Araliaceae were formed. This is also confirmed by the chemical structure of the glycosides isolated from ginseng. If one considers generally accepted theories of biogenesis, the stage of a tetracyclic triterpene ion is intermediate in the synthesis of all the pentacyclic triterpenoids, and they are, as it were, the highest phase of cyclization and are present in botanically younger species.

Thus, the determination of the chemical nature of the glycosides of the Araliaceae family has permitted the drawing of a number of important conclusions concerning the biological activity of extracts of various species in direct connection with the composition of their glycoside fractions and an approach to an elucidation of the mechanism of the action of the individual glycosides on the organism as a function of their structure [83].

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