HYDROLYZABLE TANNIN SUBSTANCES

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Tannin substances of plant origin which decompose under the conditions of acid or enzymatic hydrolysis to their simplest component parts are called hydrolyzable [1-4]. Hydrolyzable tannin substances, as a rule, consist of carbohydrates esterified with aromatic acids and are divided into two groups: gallotannins, giving on hydrolysis a sugar (or related compound) and gallic acid, and ellagitannins which, on decomposing under the action of acids or enzymes, form a sugar and ellagic acid or a compound related to it. The most important gallotannins are Chinese (a growth on the leaves of *Rhus semialata*, Turkish (a growth on the flowers of *Quercus infectoria*), sumach (*Rhus coriara, R. typhyna*), Smoke tree (*Cotinus coggygria*), tara (pods of *Caesalpinia spinosa*), witch hazel (*Hamamelis virginica*), and maple (*Acer ginnala*).

The main sources of ellagitannins are valonia (the cups of the acorns of *Quercus aegilops*), myrobalans (the fruit of *Terminalia chebula*), divi-divi (pods of *Caesalpinia coriaria*), algarobilla (the pods of *Caesalpinia brevifolia*), pomegranate (the rind of the fruit, the stems, and roots of *Punica granatum*), chestnut (the bark and wood of *Castanea vesca, C. sativa, C. dentata*), oak (the bark and wood of various species of *Quercus*), gall nuts (a growth on the carpophores of the oak *Q. pedunculata* caused by a gall wasp), and the epigeal parts of the upland, meadow, and straight geraniums (*Geranium collinum, G. pratense,* and *G. rectum*)

Methods of Determining the Structure of Hydrolyzable Tannin Substances

Qualitative Reactions. Hydrolyzable tannin substances give a blue coloration with a 1% aqueous solution of ammonium ferric alum and a 0.5% solution of ferric chloride. Ferric chloride with potassium ferrocyanide, the Gibbs reagent, the base mixture, and others, are also recommended for their detection, [5, 6]. In order to reveal bound ellagic (hexahydroxydiphenic) acid, a few crystals of sodium nitrite and then 3-5 drops of 0.1 N sulfuric or hydrochloric acid are added to an ethanolic solution of the substance: a pink or camine-red coloration is formed. Chromatograms are run first with 2% acetic acid and then with 4% aqueous solution of sodium nitrite [7, 8].

An investigation of the intensity of the qualitative reaction for hydrocarbons performed by Schmidt [9] for galloylglucoses with different positions of the ester bonds has shown that when the first and second hydroxyls are esterified the sugar is not revealed by aniline phthalate. Schmidt considers that when the second hydroxyl is esterified with a large substituent, especially a galloyl group, the reaction with aniline phthalate is negative because of the steric hindrance, since 2-O-methylglucose forms an intense coloration with the reagent mentioned.

Hydrolysis. A. Acid hydrolysis makes it possible to establish the structure of the cleavage products.

B. Aqueous hydrolysis at various temperatures permits the isolation of the intermediate cleavage products of substances and it also enables the group of hydrolyzable tannin substances in which the carbohydrate is bound with an aromatic acid by a carbon–carbon bond that was discovered by Mayer to be distinguished. This bond is cleaved on hydrolysis by

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dilute mineral acids in the boiling-water bath.

C. A comparative determination of the rate of acid hydrolysis performed by Schmidt et al., [8] for hexahydroxydiphenoylglucoses with different positions of the ester bonds has shown that when the dicarboxylic acid esterifies the fourth and sixth hydroxyls the substance is hydrolyzed considerably faster than when the third and sixth hydroxyls of the sugar are substituted.

D. The methanolysis reaction developed by Haworth et al., [10] is of great value in determining the structure of gallotannins, especially Chinese, Turkish, sumach, and tara gallotannins, since it enables the structure of the galloylglucose and galloylquinic nucleus to be established. The method is based on the fact that in 90% methanol at pH 5-6 the cleavage of depside bonds takes place but the ester groups of the sugar and of the aliphatic acid with the gallic acid are not affected. The authors have put forward a suggested reaction mechanism.

Investigation of the Exhaustively Methylated Product. Methylation of the phenolic hydroxyls is performed by repeated treatment with an ethereal solution of diazomethane. Substitution of the hydroxyls of the sugar by methoxy groups is achieved by the action of methyl iodide in the presence of silver oxide.

Alkaline cleavage of the completely methylated product enables the positions of the ester bonds and the structure of the acids splitting off to be found and, in particular, in what form ellagic acid is bound to the sugar: as such or in the form of the doubly opened lactone — optically active hexahydrodiphenic acid. In the first case, the trimethyl ether of ellagic acid is formed and in the second case optically active hexamethoxydiphenic acid.

The determination of the positions of esterification of the carbohydrate with aromatic acids consists in the following steps:

establishment of the structure of the sugar formed on the cleavage of the exhaustively methylated substances; and

determination of the number of glycol units with the aid of periodate oxidation, which enables the presence and number of nuclear substituents in the molecule to be established [11, 12].

NMR Spectroscopy. Recording the NMR spectra of the hydrolyzable tannin substances, and also of their acetyl and methyl derivatives with determination of the correlation constants and chemical shifts in association with chemical methods of investigation of the compounds makes it possible to determine the structure of the tannin substances and also to perform a conformational analysis of substituted glucopyranoses.

Schmidt and Jochims [13], considering ellagitannins isolated previously and studied by chemical methods, were able not only to confirm and, in a number of cases, to refine the established structures but also to suggest the conformations of these compounds. According to the results of the investigations, the 1C conformation characteristic for free and galloylated glucopyranoses is retained if the dicarboxylic acid binds the second and third, or the fourth and sixth, hydroxyls of the glucopyranose.

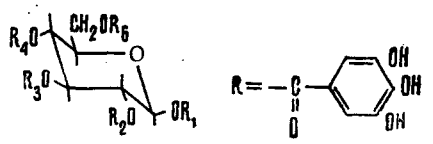
Gallotannins

The carbohydrate nucleus of gallotannins consists of glucose and, in one case, of hamamelose. In addition, this group includes substances in which the gallic acid esterifies an alcohol (the tannin substance of maple) and an aliphatic acid (the tannin substance of tara). The most important representative of this group of tannin substances is the tannin from Chinese nut galls.

Chinese Gallotannin. From the products of methylation and subsequent acid hydrolysis have been isolated 3,4-dimethylgallic and 3,4,5-trimethylgallic acids, which shows the presence in the product under investigation of depside-bound gallic acid. According to Haworth et al., [14-16], the elementary analysis and molecular weight of the chromatographically pure tannin substance corresponds to an octa- or nonagalloylglucose. From the products of methanolysis it was possible to isolate pentagalloyl- and 2,3,4,6-tetragalloyl-β-glucose in a ratio of 10:1, methylgallic acid, and methyl metadigallate.

Thus, Chinese tannin consists of pentagalloyl-β-glucose (1, R = galloyl) to which three of four galloyl residues, possibly interconnected, are attached by depside bonds.

The positions of the depside bonds were not determined [17].

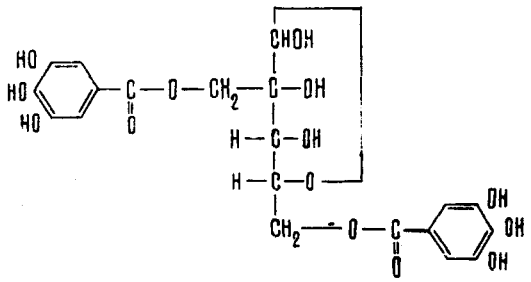


(1)

Sumach Gallotannin. On the basis of an elementary analysis of the chromatographically pure tannin substance of sumach and a study of the products of methanolysis, its identity with Chinese gallotannin has been shown.

Turkish tannin is more heterogeneous in its composition. By chromatography on cellulose it has been separated into three fractions differing in their specific rotations and glucose contents (14.4-18.6%). Methanolysis of the completely methylated fractions showed that they differed by the number of depside-bound gallic acid residues. According to Haworth et al., [15, 18], the complete methylation and hydrolysis of Turkish gallotannin led to the formation of a mixture of 2-O- and 4-O-methylglucoses and 3,4,5-trimethyl- and 3,4-dimethylgallic acids. Methanolysis of Turkish tannin formed a mixture of tetragalloyl- and trigalloylglucoses, the former being characterized by the presence of a substituent on the first carbon atom of the glucose; in both cases, complete methylation and hydrolysis gave a mixture of 2-O- and 4-O-methylglucoses. Thus, Turkish tannin consists of a mixture of 1,3,4,6- (1, R_2 = H, R_1 = R_3 = R_4 = R_6 = galloyl), 1,2,3,6- (1, R_4 = H, R_1 = R_2 = R_3 = R_6 = galloyl), 3, 4,6- (R_1 = R_2 = H, R_3 = R_4 = R_6 = galloyl), and 2,3,6- (R_1 = R_4 = H, R_2 = R_3 = R_6 = galloyl) -galloylglucoses to which two or three galloyl groups are attached by depside bonds. The positions of the depside bonds have not been established, but judging from the finding of methyl metadigallate in the intermediate methanolysis products the presence of chains of three or more galloyl residues is possible.

Hamamelitannin. In 1898, Grüttner isolated from *Hamamelis virginica* a well-crystallizing tannin substance consisting of a digalloylglucose in which the two galloyl residues were bound separately to two primary hydroxyl groups of the sugar. Schmidt [19] showed that the carbohydrate nucleus was α-hydroxymethyl-d-ribose and proposed for hamamelitannin structure (2), which was confirmed by Mayer [20].



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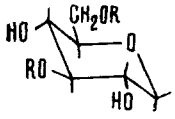
The Tannin Substances of Maple (3). In 1922, Perkin isolated from the leaves of Korean maple a tannin substance consisting of 3,6-digalloyl-1,5-anhydro-d-sorbitol. The structure of this substance was established by Kutani [21].

The tannin substance of tara, which was isolated in 1961 by Horler and Nursten [22], is the first tannin in which quinic acid is esterified. The chromatography of an extract of tara on cellulose permitted the isolation of tri-, tetra-, and pentagalloylquinic acids. Their methanolysis in all cases gave trigalloylquinic acid, so that the fractions differ by the number of depside-bound galloyl residues. Complete methylation and hydrolysis gave 1-methylquinic acid and a mixture of 3,4,5-trimethyl- and 3,4-dimethylgallic acids. Methyl metadigallate was found in the products of methanolysis [15, 23]. The structure of the nucleus of the tannin substance as 3,4,5-trigalloylquinic acid (4) [24] has been confirmed by synthesis. The positions of the depside bonds have not been established.



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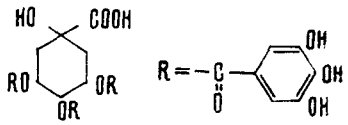

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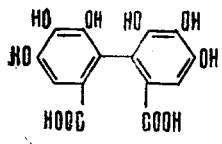
Ellagitannins. The Acids Formed in the Cleavage of the Ellagitannins

Hexahydroxydiphenic acid (5) is exceptionally important in the chemistry of the ellagitannins. When isolated by hydrolysis, it is immediately converted into ellagic acid by the closure of the lactone rings. According to Schmidt's scheme for the biosynthesis of the ellagitannins [19, 25], the hexahydroxydiphenoyl residue most probably arises in the oxidative linkage of galloyl groups in a galloylated sugar. This enables its optical activity to be explained. In divi-divi, the midrobalans, and geranium, hexahydroxydiphenic acid is present in the dextrorotatory form, and in oak, chestnut, valonia, algarobilla, gall nuts, guava, and eucalyptus, it is present in the levorotatory form.

Optically active hexamethoxydiphenic acid has a half-period of racemization of 14 h 35 min in boiling alkali and 2 h 38 min in glacial acetic acid [26].

Apart from hexahydroxydiphenic acid, on hydrolysis ellagic acid gives, in addition to brevifolin and brevifolincarboxylic acid, two acids from the cleavage of the ellagitannins similar to it in structure — isohexahydroxydiphenic acid (6) [27] and dehydrohexahydroxydiphenic acid (7) [28]. In contrast to hexahydroxydiphenic acid, they do not give a positive qualitative reaction for ellagic acid but form phenazine derivatives with o-phenylenediamine. The latter reaction showed the presence of orthoquinoid groupings in the molecules of these acids. Characteristic for the dehydrohexadroxydiphenoyl residue is the formation of chloroellagic acid on hydrolysis with concentrated hydrochloric acid.



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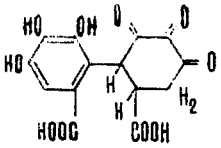

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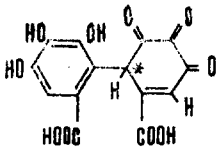

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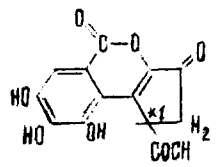
Brevifolincarboxylic acid (8) was first isolated from algarobilla by Schmidt et al., [29], and they also established its structure which was later confirmed by synthesis [33]. After being formed on hydrolysis, it gradually undergoes decarboxylation and is converted into brevifolin (9). Racemic brevifolincarboxylic acid obtained from algarobilla has been resolved into its optical antipodes with the aid of quinidine (asymmetric C_1 atom).

Chebulic acid, according to Schmidt's scheme for the biosynthesis of the ellagitannins [31] is closely related biogenetically to brevifolincarboxylic acid. Chebulic acid (10) was isolated in a study of the structure of chebulinic and chebulagic acids. A structure for it was proposed by Schmidt [32, 33], and independently, by Haworth [34-36], on the basis of a number of chemical transformations. The hydrolysis of an extract of algarobilla gave (—)-chebulic acid, and its optical antipode has been isolated from the myrobalans [37].



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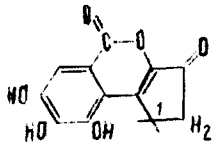

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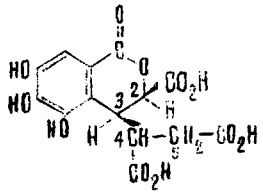
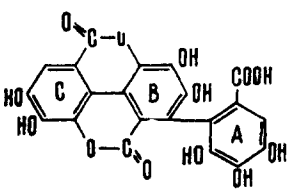


(10)

Flavogallolic acid, the dilactone of valoneic acid, and dehydrodigallic acid are closely related biogentically to hexahydrodiphenic acid and also to one another.

Flavogallolic acid (11), previously synthesized [38], was obtained by Mayer in the acid hydrolysis of the tannin substances of the wood of the sweet chestnut and of the oak [39, 40], and also of valonia [41]. The dilactone of valoneic acid (12) isolated from valonia by Schmidt [42] possesses a related structure. After the methylation and alkaline cleavage of an extract from valonia, an optically active (—)-octa-O-methyl derivative is formed [43]. This shows that the dilactone of valoneic acid is present in it in the bound form, like hexahydroxydiphenic acid. No tannin containing valoneic acid in its structure has yet been isolated. The structure of the dilactone of valoneic acid has been confirmed by the synthesis of its octa-O-methyl derivative [44].

Dehydrodigallic acid (13), $C_{14}H_{10}O_{10}$, was isolated by Mayer [45] from young chestnut leaves, and although it is not related to hexahydrodiphenic acid it is closely connected biogenetically with the dilactone of valoneic acid. Tannin substances including dehydrogallic acid in their structure have not yet been described either. Dehydrogallic acid is stable to the action of dilute acids and alkalis, but on being heated with concentrated alkali it is cleaved, giving approximately 50% of gallic acid. On rapid heating with concentrated sulfuric acid for 5 min, xanthone is formed; its structure has been confirmed by synthesis [46].



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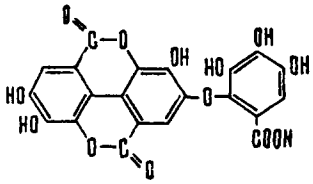

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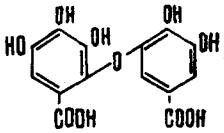
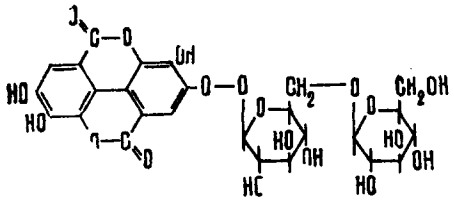


(13)

Some Representatives of the Ellagitannins

Amritoside — the 4'-β-gentiobioside of ellagic acid — was isolated by Seshadri [47] from the bark of the stems of *Psidium guava*. The substance was identified from the basis of a study of the products of the cleavage of the methylated derivative, periodate oxidation, and also the acid and enzymatic hydrolysis of the product under investigation and its UV and IR spectroscopy (14).



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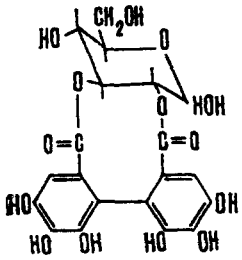
(—)-2,3-Hexahydroxydiphenoylglucose (15) — a hydrolyzable tannin substance — was first isolated by Schmidt et al., [9] in the partial hydrolysis of pedunculagin and was later isolated by M. K. Seikel [6] from eucalyptus wood. The substance was identified from the results of a study of the products of acid and aqueous hydrolysis, the negative qualitative reaction with aniline phthalate, and a determination of the structure of the sugar formed on the hydrolysis of the exhaustively methylated product as methyl 4,6-dimethyl-β-glucoside, which was also confirmed by the IR and NMR spectroscopy of the compound under investigation.

(—)-4,6-Hexahydroxydiphenoylglucose (16) was first isolated by Schmidt et al. [8] in the hydrolysis of the phenazine derivative of brevilagin-2, and then by M. K. Seikel from eucalyptus wood [6]. The substance is revealed by aniline phthalate: the hydrolysis of the exhaustively methylated product yielded 2,3-dimethylglucose and (—)-hexamethoxydiphenic acid. According to NMR spectroscopy, the substance consists of a mixture of α and β anomers.



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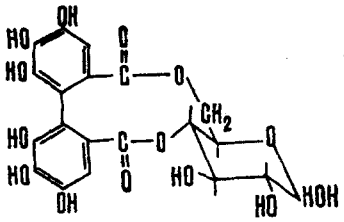

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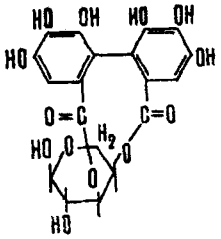

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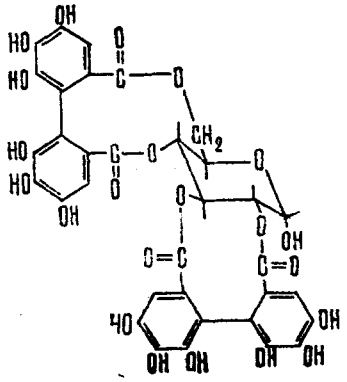
(−)-3,4-Hexahydroxydiphenoylarabinose, isolated by Vasishta [48] from guava fruit, is the first and so far the only ellagitannin containing arabinose. The hydrolysis of the compound methylated with diazomethane formed (−)-hexamethoxydiphenoic acid. On the basis of the positive reaction to aniline phthalate and the presence of one glycol unit in the substance, it has been concluded that the hexahydroxydiphenic acid is bound to carbon atoms 3 and 4 of the arabinose molecules [17].

Pedunculagin (−)-2,3,4,6-dihexahydroxydiphenoylglucose (18), was isolated by Schmidt [9] from gall nuts and then by M. K. Seikel [6] from eucalyptus wood. Acid hydrolysis led to the formation of glucose and ellagic acid in a ratio of 1:2. The alkaline hydrolysis of the methylated substance required four equivalents of alkali. It yielded (−)-hexamethoxydiphenic acid and a mixture of α- and β-methylglucoses. An investigation of the NMR spectrum of the tridecaacetyl derivative enabled the α configuration and the 1C conformation of pedunculagin to be established.



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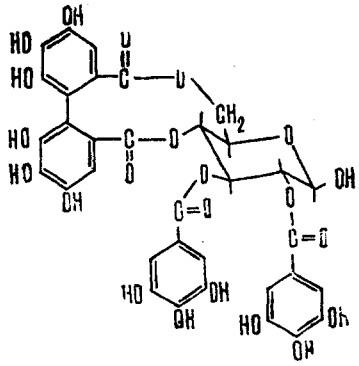

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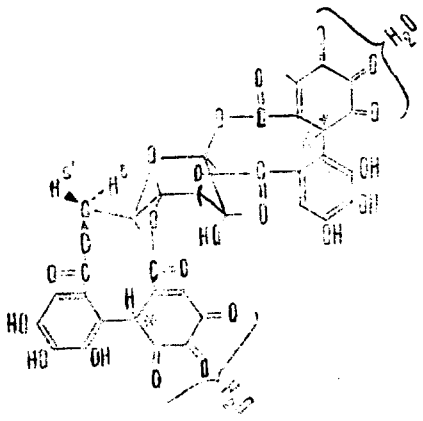
Collinin (19), 2,3-digalloyl-4,6-(+)-hexahydroxydiphenoylglucose, was isolated by T. K. Chumbalov and T. N. Bikbulatova [49] from the leaves of upland geranium. The substance does not give a positive qualitative reaction with aniline phthalate. On hydrolysis with water, ellagic acid is first split off with the formation of 2,3-digalloylglucose. The alkaline cleavage of the exhaustively methylated product requires four equivalents of alkali and leads to the formation of (+)-hexamethoxydiphenic acid and methyl glucoside. Periodate oxidation showed the presence of two glycol units in it. A comparison of the rate of acid hydrolysis with the results of 3,6- and 4,6-hexahydroxydiphenoylglucoses confirmed the the hexahydroxydiphenic acid was bound to the 4th and 6th carbon atoms of the glucose. On the basis of the presence in the IR spectrum of an absorption maximum at 890 cm^{-1}, the β configuration of the glucose nucleus was proposed, and the 1C conformation was ascribed to it in agreement with the results of the NMR investigations of Jochims and Schmidt.

Brevilagin-1 (20), 1,3,4,6-bis (dehydrohexahydroxydiphenoyl)-glucose, was isolated by Schmidt from algarobilla [28]. Hydrolysis of the exhaustively-methylated product formed 2-O-methylglucose. The substance did not give a positive qualitative reaction for ellagic acid, but this was formed, together with brevifolincarboxylic acid, on acid hydrolysis. Cleavage of the substance with concentrated hydrochloric acid formed chloroellagic acid. Brevilagin-1 reacts with two molecules of o-phenylenediamine. Consequently, the substance is a derivative of glucose and two molecules of dehydrohexahydroxydiphenic acid which, according to NMR, is

present in the hydrated form. The β configuration and the 2B conformation of the glucopyranose were determined by NMR. A change in the NMR spectra in solutions in dimethyl sulfoxide and acetone is connected with the presence in the cyclohexanetrione ring of an asymmetric carbon and racemization. Since there are two such rings in brevilagin-1, there should be an equilibrium mixture of four diastereoisomers; however, Jochims and Schmidt [13] have observed only a temporary change in the NMR spectra. It was not possible accurately to determine which carbonyl groups were hydrated.

Brevilagin-2 (21), gives a positive qualitative reaction for bound ellagic acid, and on hydrolysis with concentrated hydrochloric acid it forms a mixture of ellagic and chloroellagic acids. The substance reacts with one molecule of o-phenylenediamine with the formation of a phenazine derivative the hydrolysis of which permitted the isolation of 4,6-hexahydroxydiphenoylglucose. The hydrolysis of the exhaustively methylated product formed (—)-hexamethoxydiphenic acid and 2-O-methylglucose. Thus, brevilagin-2 is 1,3-dehydrohexahydroxydiphenoyl-4,6-(—)-hexahydroxydiphenoyl glucose [8].

Algarobin (22), isolated by Schmidt [50] from algarobilla, is glucose esterified with (—)-brevifolincarboxylic acid. The substance gives a positive qualitative reaction with aniline phthalate. A comparison of the rates of acid hydrolysis with various hydroxydiphenoylglucoses as markers indicated the esterification of the hydroxyls at carbon atoms 4 and 6 of the glucose. The positions of these bonds and the α configuration and 1C conformation of the glucopyranose were shown on the basis of the NMR spectra, but it was not possible to determine precisely the presence of the pentanedione ring on carbon atom 4 and the galloyl residue on carbon atom 6 of the glucose.



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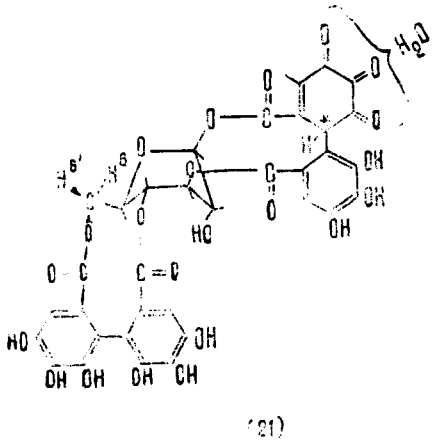
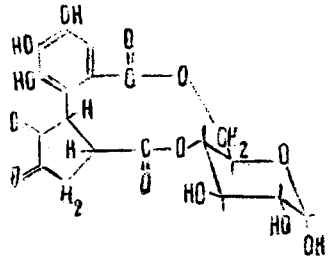


(21)

The ellagitannis of the myrobalans — corilagins, chebulic and chebulinic acids, and terchebin — form a biogenetically related group.

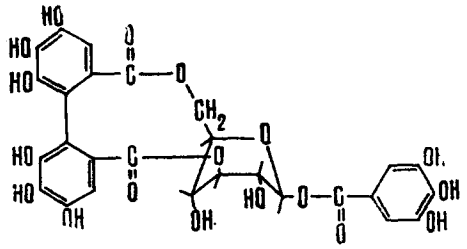


(22)

Corilagin, a crystalline tannin substance, was first isolated from divi-divi [51], then from myrobalans [52], and later from the fruit of ambla (emblic leaf-flower) (*Phyllanthus emblica*) and jambolan (black plum) (*Syzygium cumini; Eugenia jambolana*) [53, 54]. The acid

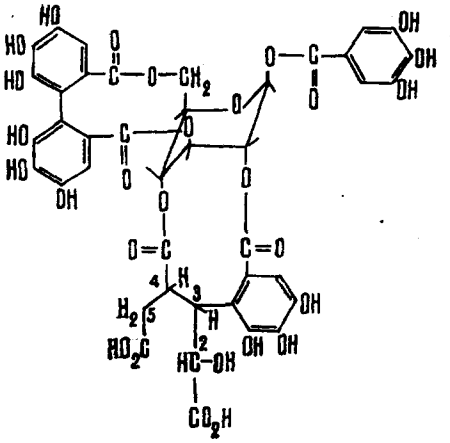
hydrolysis of corilagin led to the formation of equimolecular amounts of glucose and gallic and ellagic acids, the gallic acid being split off first with the formation of a compound giving, unlike corilagin, a positive qualitative reaction with aniline phthalate. Methylation with diazomethane formed nonamethylcorilagin, and exhaustive methylation and hydrolysis yielded 3,4,5-trimethyl gallic acid, (+)-hexamethoxydiphenic acid, and a mixture of methyl 2,4-di-O-methyl-α- and -β-glucosides. On the basis of a study of its chemical properties, corilagin was identified as 3,6-(+)-hexahydroxydiphenoyl-1-β-galloyl-d-glucose [55, 56]. A consideration of the NMR spectra confirmed this identification and showed the 1B⇄3B conformation of the glucopyranose (23) [13].

From the skin of the Persian walnut, Jurd [57] has isolated a substance giving, on acid hydrolysis, equimolecular amounts of glucose and gallic and ellagic acids which is possibly isomeric with corrilagin —guglanin. The structure of this substance has not been established.



(23)

Chebulagic acid was first obtained from myrobalans [7, 58], and then from divi-divi [7, 59, 60]. On complete acid hydrolysis it formed equimolecular amounts of glucose and gallic, ellagic, and chebulic acids. Hydrolysis with water at 85°C gave 3,6-(+)-hexahydroxydiphenoylglucose [55], at 60°C it gave corilagin and chebulic acid [61], and at 55°C for 3 days it gave neochebulagic acid [62]. Exhaustive methylation of the latter and hydrolysis led to the formation of 2-O-methylglucose. An investigation of the NMR spectrum enabled the structure proposed previously for chebulagic acid to be refined. In neochebulagic acid, chebulic acid is bound in the form of the lactone and the glucopyranose has the 1B⇄3B (1C) conformation, and the aliphatic moiety of chebulic acid is attached to carbon atom 4 (25). Chebulagic acid (24) is characterized by the 1C conformation of its glucopyranose and by the fact that the chebulic acid is bound to the sugar in the open form, its galloyl moiety being attached to carbon atoms 2 of the glucose.



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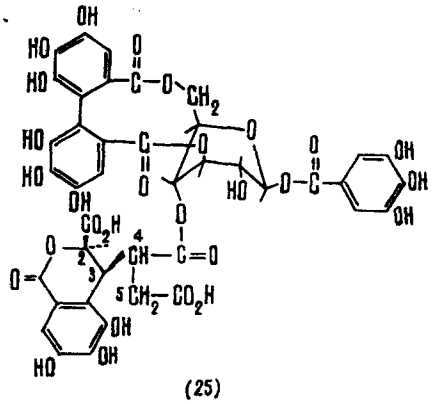
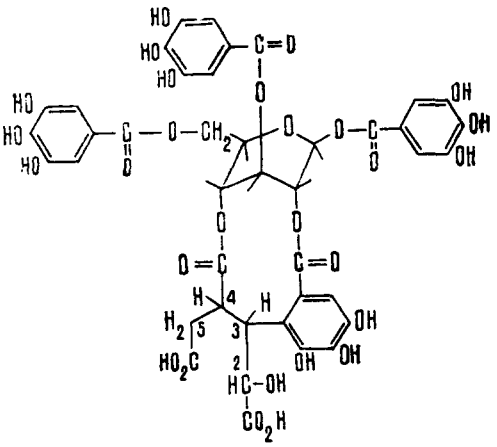


(25)

Chebulinic acid (26) was first isolated by Fridolin from myrobalans [19, 63] and then by Sastry from divi-divi [60]. On acid hydrolysis it forms one molecule of chebulic acid and three molecules of gallic acid. Hydrolysis by water in the boiling water bath gave 3,6-digalloylglucose [64], and at 60°C for 2-3 days 1,3,6-trigalloylglucose [65]. The hydrolysis

of chebulinic acid at 60°C for 2-3 days in the acetone–water system formed the crystalline dicarboxylic acid neochebulinic acid giving 2-O-methylglucose on complete methylation and hydrolysis [66]. On the basis of the NMR spectra, Haslam [67] and then Schmidt [13] established that chebulic acid is present in chebulinic acid in the open form, and with carbon atom 2 of the glucose is bound the galloyl moiety of chebulic acid; conformationally, the glucopyranose is between the 1B and 3B forms, the 3B predominating.

In neochebulinic acid (27), the glucopyranose has returned to the 1C conformation. Chebulic acid is present in the lactone form with the cis arrangement of H_2 and H_3.



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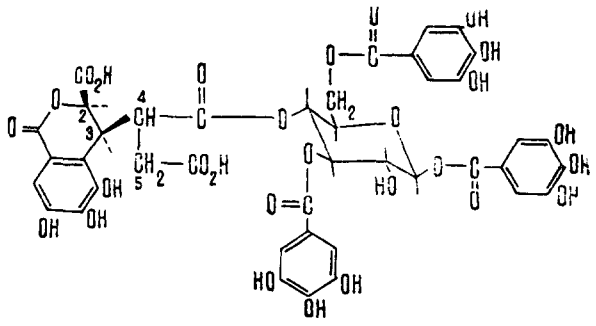


(27)

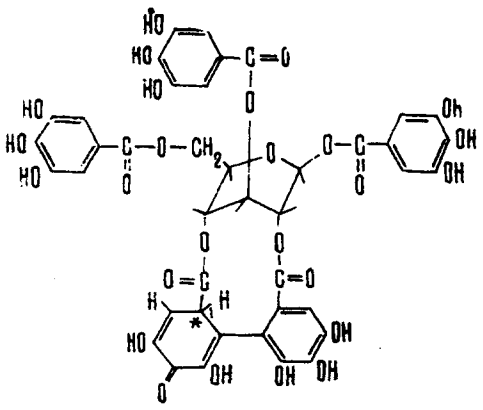
Terchebin (28), isolated by Schmidt from myrobalans [27] and then by Sastry from ambla fruit [53], is characterized by reactions showing the presence in it of an isohexahydroxydiphenoyl residue. Hydrolysis of the derivative formed with o-phenylenediamine yielded 1,3,6-trigalloylglucose. Consequently, terchebin is 1,3,6-trigalloyl-2,4-isohexahydroxydiphenoylglucose. As a study of NMR spectra has shown, the isohexahydroxydiphenic acid is bound in terchebin not in the cyclohexane trione form but as the isomeric cyclohexadienone form with an asymmetric C_1 atom. In solution it forms an equilibrium mixture of diastereoisomers. The glucopyranose has the β-configuration and the 3B conformation. (See scheme on following page).

A special group of ellagitannins is formed by the tannin substances isolated by Mayer from the wood of the sweet chestnut and the oak [39] and also from valonia [41] — castalin (29), vescalin (30), castalagin (31), and vescalagin — which are characterized by the presence of a carbon–carbon bond between the carbohydrate and the aromatic acid through a hydrolytically-opened pyranose ring.

When their aqueous solutions are heated, castalagin is converted into vescalagin, and castalin into vascalin. The mild acid hydrolysis of castalagin and vescalagin led to the splitting off of ellagic acid and the formation of castalin and vescalin, respectively, but in the first case, in addition to castalin, vescalagin was found after some time. Hydrolysis with mineral acids under more severe conditions led to the formation from castalin and vescalin of glucose and flavogallic acid [40, 68]. Castalin and vescalin each contained three

TABLE 1. Constants and Qualitative Reactions of the Ellagitannins

Substance	Empirical formula	mp, °C	Specific rotation	Qualitative reaction			Literature
				$FeCl_3$	aniline phthalate	$CH_3COOH + NaNO_2$	
Amritoside	$C_{26}H_{28}O_{18}$	360 (decomp.)	−41,4 (pyridine)	Blue-green	−	+	47
2,3-(−)-Hexahydroxydiphenoylglucose	$C_{20}H_{18}O_{14} \cdot 2H_2O$	—	+55,6 (methanol)	Blue	−	+	6,9
4,6-(−)-Hexahydroxydiphenoylarabinose	$C_{20}H_{18}O_{14} \cdot H_2O$	—	+45,1 — +58,5 (ethanol)	"	+	+	6, 8, 13
3,4-(−)-Hexahydroxydiphenoylglucose		230—235(decomp.)	—	"	+	+	48
Pedunculagin	$C_{34}H_{24}O_{22}$	—	+106 (methanol)	"	−	+	6, 9, 13
Collinin	$C_{34}H_{26}O_{22} \cdot 6H_2O$	230(decomp.)	−164,5 (methanol)	"	−	+	49
Brevilagin-1	$C_{34}H_{24}O_{24} \cdot 5H_2O$	—	−159,5 (methanol)	Blue-green	−	−	13, 28
Brevilagin-2	$C_{34}H_{24}O_{23} \cdot 6H_2O$	—	+81 (ethanol)	Blue	−	+	8, 13
Algarobin	$C_{19}H_{18}O_{13} \cdot 3,5H_2O$	—	−21 — −42,8(ethanol)	"	+	−	13, 50
Corilagin	$C_{27}H_{22}O_{18}$	204—205	−228 water −246(ethanol)	"	−	+	7, 13, 51—56
Juglanin	$C_{27}H_{22}O_{18}$	235—237	+52,0 (water)	"		+	57
Chebulagic acid	$C_{41}H_{32}O_{28}$	—	−57,2 (ethanol)	"	−	+	7, 13, 55, 58—62
Chebulinic acid	$C_{41}H_{34}O_{28}$	—		"	−	−	13, 19, 60, 63—67
Terchebin	$C_{41}H_{30}O_{25} \cdot 10H_2O$	200(decomp.)	−39,4 (ethanol)	"	−	−	13, 27, 53
Castalin	$C_{27}H_{20}O_{18}$	—	+19,3 (water)	"	−	−	39, 40
Vescalin	$C_{27}H_{20}O_{18}$	—	−13,0 (water)	"	−	−	39, 68
Castalagin	$C_{47}H_{26}O_{26}$	220(decomp.)	−147,5 (water)	"	−	+	39, 41, 69
Vescalagin	$C_{47}H_{26}O_{26}$	200(decomp.)	−109,6 (water)	"	−	+	39, 41, 70



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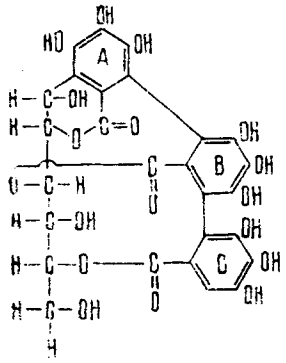

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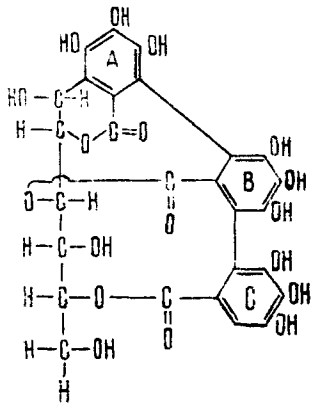

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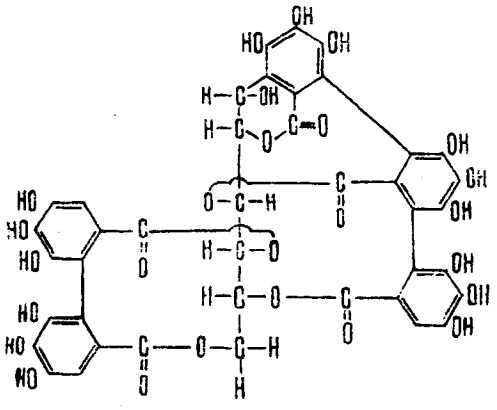

(31)

aliphatic and nine phenolic hydroxy groups. An investigation of the IR, NMR, and mass spectra of castalin and vescalin, and also their nonamethyl, triacetylnonamethyl, and dodecaacetyl derivatives and a determination of the chemical shifts and coupling constants have enabled the structures of these compounds to be established. The presence of only one aromatic proton in the NMR spectrum shows the presence of a carbon–carbon bond between the flavogallic acid and the glucose, which explains the reduced tendency to hydrolysis. Castalin and vescalin are isomeric compounds and differ by the fact that the hydroxy group on carbon atom 1 of the glucose in the castalin molecule is turned to the right and in vescalin to the left.

Castalagin is isomeric with vescalagin [69, 70]. The structures of these compounds has been shown by comparing the IR, mass, and NMR spectra of castalagin and vescalagin and their corresponding pentadecamethyl, pentadecamethylmonoacetyl, and hexadecaacetyl derivatives, and

also by the cleavage of their pentadecamethyl derivatives to dimethyl esters of (–)-hexamethoxydiphenic acid and the corresponding methyl ethers of nonamethylneocastalin and vescalin. In castalagin, the hydroxy group from carbon atom 1 of the glucose is directed to the right, and vescalagin to the left.

LITERATURE CITED

1. T. White, The Chemistry and Technology of Bark [Russian translation], Moscow (1962), p. 78.
2. E. Haslam, Chemistry of Vegetable Tannins, Academic Press, London (1966).
3. E. Haslam and R. D. Haworth, Progr. Org. Chem., 6, 1 (1964).
4. K. N. S. Sastry and J. Nayudamma, J. Proc. Inst. Chem., XXXVIII, July, 181 (1966).
5. O. T. Schmidt and R. Lademann, Ann. Chem., 571, 47 (1951).
6. M. K. Seikel and W. E. Hillis, Phytochem., 9, 1115 (1970).
7. O. T. Schmidt, in: Biochemical Methods of Plant Analysis [in Russian], Moscow (1960), p. 549.
8. O. T. Schmidt, R. Schanz, R. Wurmb, and W. Groebke, Ann. Chem., 706, 154 (1967).
9. O. T. Schmidt, L. Würtel, and A. Harreus, Ann. Chem., 690, 150 (1965).
10. E. Haslam, R. D. Haworth, S. D. Mills, H. J. Rogers, R. Armitage, T. Searle, J. Chem. Soc., 1836 (1961).
11. N. K. Kochetkov, I. V. Torgov, and M. M. Botvinnik, The Chemistry of Natural Compounds [in Russian], Moscow (1961), pp. 52, 88.
12. L. M. Likhosherstov and L. É. Brossar, Khim. Prirodn. Soedin., 7 (1967).
13. J. C. Jochims, G. Taigel and O. T. Schmidt, Ann. Chem., 717, 169 (1961).
14. E. Haslam, R. D. Haworth, K. Jones, and H. J. Rogers, J. Chem. Soc., 1829 (1961).
15. R. Armitage, G. S. Bayliss, J. W. Gramshaw, E. Haslam, R. D. Haworth, K. Jones, H. J. Rogers, and T. Searle, J. Chem. Soc., 842 (1961).
16. J. W. Gramshaw, E. Haslam, R. D. Haworth, and T. Searle, J. Chem. Soc., 2944 (1962).
17. G. Britton, P. W. Crabtree, E. Haslam, and J. E. Stangroom, J. Chem. Soc., C 783 (1966).
18. R. Armitage, E. Haslam, R. D. Haworth, and T. Searle, J. Chem. Soc., 3808 (1962).
19. O. T. Schmidt, Angew. Chem., 4, 103 (1956).
20. W. Mayer, W. Kunst, and W. Loebich, Ann. Chem., 688, 232 (1965).
21. E. Haslam, Phytochem., 4, 495 (1965).
22. D. F. Horler and H. E. Nursten, J. Chem. Soc., 3786 (1962).
23. E. Haslam, R. D. Haworth, and P. C. Keen, J. Chem. Soc., 3814 (1962).
24. D. Burton and H. E. Nursten, in: The Chemistry of the Vegetable Tannins, Society of Leather Trades Chemists, Croydon, 60 (1956).
25. O. T. Schmidt, J. Schulz, and H. Fiesser, Ann. Chem., 706, 187 (1967).
26. O. T. Schmidt and K. Demmler, Ann. Chem., 576, 85 (1952).
27. O. T. Schmidt, J. Schulz, and R. Wurmb, Ann. Chem., 706, 169 (1967).
28. O. T. Schmidt, R. Schanz, R. Eckert and R. Wurmb., Ann. Chem., 706, 131 (1967).
29. O. T. Schmidt and K. Bernauer, Ann. Chem., 588, 211 (1954).
30. O. T. Schmidt and R. Eckert, Ann. Chem., 618, 71 (1958).
31. O. T. Schmidt, R. Wurmb and J. Schulz, Ann. Chem., 706, 180 (1967).
32. O. T. Schmidt and W. Mayer, Ann. Chem., 571, 1 (1951).
33. W. Mayer, Ann. Chem., 571, 15 (1951).
34. R. D. Haworth and L. B. de Silva, J. Chem. Soc., 3511 (1951).
35. R. D. Haworth and L. B. de Silva, J. Chem. Soc., 3611 (1954).
36. R. D. Haworth, H. Pinder and P. Jeffries, J. Chem. Soc., 3617 (1954).
37. O. T. Schmidt and H. Kottenhahn, Ann. Chem., 729, 209 (1969).
38. J. Grimshaw and R. D. Haworth, J. Chem. Soc., 4225 (1956).
39. W. Mayer, W. Gabler, A. Riester, and H. Korger, Ann. Chem., 707, 177 (1967).
40. W. Mayer, A. Linwiller, and J. C. Jochims, Ann. Chem., 707, 182 (1967).
41. W. Mayer, W. Bilzer, and K. Schauerte, Ann. Chem., 754, 149 (1971).
42. O. T. Schmidt and E. Komarek, Ann. Chem., 591, 156 (1955).
43. O. T. Schmidt and H. H. Grüenwald, Ann. Chem., 603, 183 (1957).
44. O. T. Schmidt, E. Komarek, and H. Rentel, Ann. Chem., 602, 50 (1956).
45. W. Mayer, Ann. Chem., 578, 34 (1952).
46. W. Mayer and R. Tiekentscher, Chem. Ber. 91, 1542 (1958).
47. T. K. Seshadry and K. Vasishta, Phytochem., 4, 317, (1965).
48. K. Vasishta, Current Sci., 33, 334 (1964).
49. T. K. Chumbalov and T. N. Bikbulatova, Khim. Prirodn. Soedin., 496 (1970).

50. O. T. Schmidt, R. Eckert, E. Günter, and H. Fiesser, Ann. Chem., 706, 294 (1967).
51. O. T. Schmidt and R. Lademann, Ann. Chem., 571, 232 (1951).
52. O. T. Schmidt and D. M. Schmidt, Ann. Chem., 578, 31 (1952).
53. Theresa Y. Margaret and K. N. S. Sastry, Leather Sci., 15, 337 (1968).
54. J. S. Bhatia, K. S. Bajaj, and G. S. Ghangas, Phytochem., 10, 219 (1971).
55. O. T. Schmidt, F. Blinn, and R. Lademann, Ann. Chem., 576, 75 (1952).
56. O. T. Schmidt, D. M. Schmidt, and J. Herok, Ann. Chem., 587, 67 (1954).
57. L. Jurd, J. Amer. Chem. Soc., 80, 2249 (1958).
58. O. T. Schmidt and W. Nieswandt, Ann. Chem., 568, 165 (1950).
59. O. T. Schmidt and R. Lademann, Ann. Chem., 569, 149 (1950).
60. K. N. S. Sastry, J. B. Rao, and Y. Nayudamma, Bull. Centr. Leather Res. Inst., 6, 267 (1960).
61. O. T. Schmidt and D. M. Schmidt, Ann. Chem., 578, 25 (1952).
62. O. T. Schmidt, R. D. Hensler, and P. Stephan, Ann. Chem., 609, 186 (1957).
63. O. T. Schmidt, in: The Chemistry of the Vegetable Tannins, Society of Leather Trades Chemists, Croydon, (1965), p. 67.
64. O. T. Schmidt, S. Berg, and H. H. Baer, Ann. Chem., 571, 19 (1951).
65. O. T. Schmidt and G. Klinger, Ann. Chem., 609, 192 (1957).
66. O. T. Schmidt, K. Demmler, H. Bifterman, and P. Stephan, Ann. Chem., 609, 192 (1957).
67. E. Haslam and M. Uddin, J. Chem. Soc., 2381 (1967).
68. W. Mayer, F. Kuhlman, and G. Schilling, Ann. Chem. Soc., 747, 51 (1971).
69. W. Mayer, H. Seitz, and J. C. Jochims, Ann. Chem., 721, 186 (1969).
70. W. Mayer, H. Seitz, J. C. Jochims, K. Schauerte, and G. Schilling, Ann. Chem., 751, 60 (1971).