Di-O-methyl-3,3′-di-O-benzylellagic acid separated in colorless needles, m.p. 239–241°.

Anal. Calcd. for $C_{30}H_{22}O_8$: C, 70.5; H, 4.35; 2 MeO–, 12.2. Found: C, 71.8; H, 4.45; MeO–, 10.0.

The crude di-O-methyl-di-O-benzylellagic acid (0.7 g.) was suspended in acetic anhydride (20.0 ml.). Concentrated sulfuric acid (1.0 ml.) was added and the solution was heated on a steam-bath for 2 hours. It was allowed to stand at room temperature for 24 hours, diluted with water and filtered. The solid thus obtained was washed with acetone and recrystallized from dioxane–methanol. 4,4′-Di-O-methylellagic acid diacetate thus was obtained in colorless needles, m.p. 324° (0.4 g.).

Anal. Calcd. for $C_{20}H_{14}O_{10}$: C, 57.95; H, 3.41; 2 MeO–, 15.0; 2 CH_3CO–, 20.8. Found: C, 58.1; H, 3.42; MeO–, 14.7; CH_3CO–, 21.6.

The diacetate was hydrolyzed by heating it with dioxane (10.0 ml.), methanol (10 ml.) and 10% aqueous sodium hydroxide (5.0 ml.) for 10 minutes. After dilution with water and acidification the solid product was collected and recrystallized from a large volume of N,N-dimethylformamide. 4,4′-Di-O-methylellagic acid was thereby obtained in colorless needles, m.p. >360° (lit.[4] m.p. > 320°).

Anal. Calcd. for $C_{16}H_{10}O_8$: C, 58.2; H, 3.27; 2 MeO–, 18.8. Found: C, 58.0; H, 3.22; MeO–, 18.2.

Acknowledgment.—The author is indebted to L. M. White for performing the elementary analyses.

PASADENA, CALIF.

[CONTRIBUTED FROM THE FRUIT AND VEGETABLE CHEMISTRY LABORATORY, A LABORATORY OF THE WESTERN UTILIZATION RESEARCH AND DEVELOPMENT DIVISION, AGRICULTURAL RESEARCH SERVICE, U. S. DEPARTMENT OF AGRICULTURE]

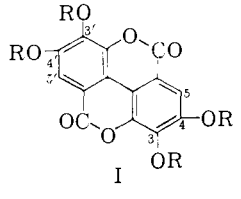
Plant Polyphenols. VII. The Structure of Ellagorubin[1]

BY LEONARD JURD

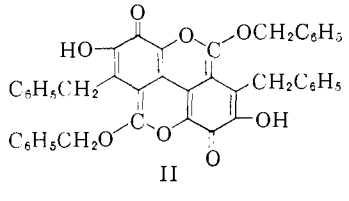
RECEIVED JANUARY 20, 1959

Hydrolysis of di-O-methylellagorubin gives a di-O-methyl-5,5′-di-C-benzylellagic acid (A). Hydrolysis of di-O-benzylellagorubin forms the corresponding di-O-benzyl-5,5′-di-C-benzylellagic acid. Methylation and subsequent debenzylation of this gives a di-O-methyl-5,5′-di-C-benzylellagic acid (B). Comparison of the ultraviolet spectra of these ethers, (A) and (B), with the spectra of synthetic 3,3′-di-O-methylellagic acid (IV) and 4,4′-di-O-methylellagic acid (V) establishes the constitution of (A) as 3,3′-di-O-methyl-5,5′-di-C-benzylellagic acid (X) and of (B) as 4,4′-di-O-methyl-5,5′-di-C-benzylellagic acid (XI). From these data it follows that ellagorubin has the structure XII and not II as previously reported.

The widespread distribution of ellagic acid derivatives in the plant kingdom[2–4] has resulted in a considerable current interest in the chemistry of this acid.[5–7] The extensive investigations of Schmidt and his co-workers at Heidelberg are particularly significant.[8] Ellagic acid is a polyphenolic dilactone (I, R = H) which reacts normally with benzyl chloride in acetophenone to give the colorless tetra-O-benzyl derivative (I, R = $C_6H_5CH_2$–).[9] In aqueous alkali, however, Schmidt, Voigt and Bernauer[10] found that ellagic acid and benzyl chloride react to form a deep red pigment, ellagorubin, for which they proposed the quinoidal structure II.

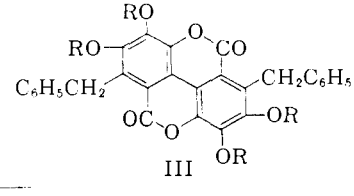


I



II

Because of the novel nature of this benzylation product, Schmidt's work has been extended in this Laboratory. It already has been reported[11] that, although the benzylation of ellagic acid gives ellagorubin under the conditions described by Schmidt, the presence of small amounts of pyridine inhibits the formation of ellagorubin and produces the colorless compound, 5,5′-di-C-benzyl-tetra-O-benzylellagic acid (III, R = $C_6H_5CH_2$–), together with a small quantity of a yellow pigment which is partially quinoidal and partially aromatic. In the process of identifying the ellagorubin formed in these reactions its dimethyl ether was hydrolyzed to the di-O-methyl-5,5′-di-C-benzylellagic acid described by Schmidt and his co-workers as the 4,4′-di-O-methyl derivative XI. The ultraviolet spectra of this dimethylellagic acid derivative in various media, however, could not be satisfactorily accounted for on the basis of the orientation of methoxyl and hydroxyl groups suggested by these authors. The reactions of ellagorubin have therefore been re-examined. In this paper chemical evidence and ultraviolet spectral data are presented which establish structure XII for ellagorubin. In the following paper[12] structure XII, but not structure II, is shown to be compatible with infrared and nuclear magnetic resonance spectral data.



III

(1) Financial support for this work was provided by the Diamond Walnut Growers, Inc.

(2) A. G. Perkin and M. Nierenstein, *J. Chem. Soc. (Trans.)*, **87**, 1412 (1905).

(3) E. C. Bate-Smith, *Chemistry & Industry*, R 32 (1956).

(4) O. T. Schmidt and W. Mayer, *Angew. Chem.*, **68**, 103 (1956).

(5) D. E. Hathway, *Nature*, **177**, 747 (1956).

(6) D. E. Hathway, *Biochem. J.*, **67**, 445 (1957).

(7) D. E. Hathway, *J. Chem. Soc.*, 519 (1957).

(8) O. T. Schmidt, E. Komarek and H. Rentél, *Ann.*, **602**, 50 (1957), and previous papers in this series.

(9) O. T. Schmidt, H. Voigt, W. Puff and R. Köster, *ibid.*, **586**, 165 (1954).

(10) O. T. Schmidt, H. Voigt and K. Bernauer, *Chem. Ber.*, **88**, 91 (1955).

(11) Part II, L. Jurd, THIS JOURNAL, **79**, 6043 (1957).

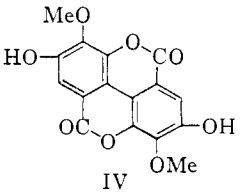
(12) Part VIII, F. Stitt, E. Cong, K. J. Palmer and J. N. Shoolery, *ibid.*, **81**, 4615 (1959).

Ellagorubin, $C_{42}H_{30}O_8$, forms a dimethyl ether and a diacetate and therefore contains two free hydroxyl groups. It differs from ellagic acid, $C_{14}H_6O_8$, in that four hydrogen atoms of the latter have been replaced by benzyl groups. Two of these benzyl groups are extremely labile. Thus catalytic hydrogenation or acid hydrolysis of ellagorubin and ellagorubin dimethyl ether results in the loss of two benzyl groups and the formation of 5,5′-di-C-benzylellagic acid (III, R = H) and its di-O-methyl derivative, respectively. It is clear, therefore, that the conversion of the almost colorless ellagic acid into the red ellagorubin does not involve an oxidation process but is due to the stabilization of a potentially tautomeric form of ellagic acid by replacement of the active hydrogen atoms by benzyl groups. The production of 5,5′-di-C-benzylellagic acid proves that at least two of these are C-benzyl groups. The ease of hydrogenation and hydrolysis of the two remaining benzyl groups (with subsequent rearrangement to the phenolic lactone form I of ellagic acid) led Schmidt, *et al.*, to assume that these benzyl groups were attached to oxygen. If this assumption is valid then the only formula possible for ellagorubin is that which they proposed, *viz.*, II. It follows that the di-O-methyl-5,5′-di-C-benzylellagic acid obtained from ellagorubin dimethyl ether must then be 4,4′-di-O-methyl-5,5′-di-C-benzylellagic acid (XI). This structure, however, was not verified in any other way.

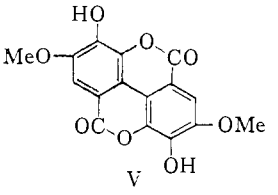
To establish the constitution of ellagorubin it is clearly necessary to confirm the structure of the above di-O-methyl-5,5′-di-C-benzylellagic acid. Ellagorubin dimethyl ether was therefore hydrolyzed by Schmidt's process[10] to give this di-O-methylellagic acid derivative (A), m.p. 317–315°. On acetylation, A formed a diacetate, m.p. 294–295°, which also was obtained directly from ellagorubin dimethyl ether by reaction with acetic anhydride and sulfuric acid. Benzylation of A gave a di-O-benzyl-di-O-methyl-5,5′-di-C-benzylellagic acid, m.p. 240°.

Attempts to benzylate ellagorubin in acetone solution with benzyl chloride and potassium carbonate were unsuccessful. However it was later found that in the presence of *large* quantities of potassium iodide ellagorubin reacted smoothly to give ellagorubin dibenzyl ether, m.p. 217°. Mild acid hydrolysis of the ellagorubin dibenzyl ether converted it into a di-O-benzyl-5,5′-di-C-benzylellagic acid, m.p. 315–320°. This formed a diacetate, m.p. 292°, which also was obtained directly from ellagorubin dibenzyl ether on brief treatment with acetic anhydride and sulfuric acid. Methylation of the di-O-benzylellagic acid then gave a di-O-benzyl-di-O-methyl-5,5′-di-C-benzylellagic acid, m.p. 212°, which was debenzylated to yield a di-O-methyl-5,5′-di-C-benzylellagic acid (B), m.p. 360° (diacetate, m.p. 325°). Thus the orientation of methoxy and hydroxy groups in B is the reverse of that in A. The orientations of these groups in A and B were then determined by direct comparison of their spectra with those of synthetic[13] 3,3′-di-O-methylellagic acid (IV) and 4,4′-di-O-methylellagic acid (V).

(13) Part VI, L. Jurd, THIS JOURNAL, **81**, 4606 (1959).



IV



V

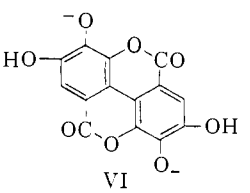
Ultraviolet Spectra in Ethanol.—In ethanol the ultraviolet spectra of these ellagic acid derivatives showed characteristic differences. The spectrum

	λ_{max}, mμ				λ_{max}, mμ		
Ellagic acid	255	352[a]	366	5,5′-Di-C-benzylellagic acid	256	363	378
IV	248	359[a]	372	A	249	371	387
V	253	346[a]	361	B	252	345	359

[a] Inflection.

of IV relative to ellagic acid is closely similar to that of A relative to 5,5′-di-C-benzylellagic acid; *i.e.*, the conversion of ellagic acid into 3,3′-di-O-methylellagic acid (IV) and of 5,5′-di-C-benzylellagic acid into A results in a considerable hypsochromic shift (7 mμ) of the low wave length band and a considerable bathochromic shift (6–9 mμ) of the long wave length band in each case. On the other hand, the conversion of ellagic acid into 4,4′-di-O-methylellagic acid (V) and of 5,5′-di-C-benzylellagic acid into B results in a hypsochromic shift (3–4 mμ) of the low wave length band and a hypsochromic shift (5–19 mμ) of the long wave length band.

Spectra in Sodium Acetate.—In previous studies on flavonoid compounds[14] it has been shown that sodium acetate selectively ionizes the more acidic phenolic groups of polyphenols, *e.g.*, those which are conjugated with a carbonyl group. Unconjugated hydroxyls are not normally sufficiently acidic to be ionized by sodium acetate. The 3,3′-hydroxyls of ellagic acid and 5,5′-di-C-benzylellagic acid are conjugated with the carbonyl groups of the lactone rings. Addition of sodium acetate to alcoholic solutions of those acids selectively ionizes the 3,3′-hydroxyls (VI), therefore, and results in a significant alteration in the spectra of the acids (Fig. 1), the low wave length band being characteristically divided into two bands at 256 and 278 mμ. It would be anticipated that the spectrum



VI

of 3,3′-di-*O*-methylellagic acid (IV) would not be appreciably affected by sodium acetate while the 4,4′-di-O-methylellagic acid would be ionized and show the same division of the low wave length band as ellagic acid. This was found to be the case. The spectra of 3,3′-di-O-methylellagic acid (IV) and of A were not appreciably affected on the addition of sodium acetate[15] (Fig. 2) while those of 4,

(14) L. Jurd and R. M. Horowitz, *J. Org. Chem.*, **22**, 1618 (1957).

(15) Although sodium acetate does not essentially alter the ultraviolet spectra of IV and A, the solutions of these compounds in alcoholic

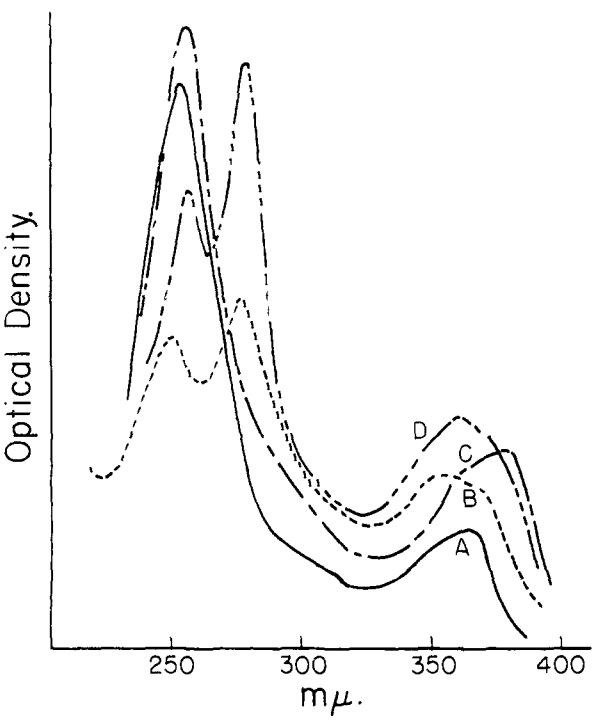


Fig. 1.—Ultraviolet absorption spectra in ethanol of: (A) ———, ellagic acid; (B) – – – –, ellagic acid + sodium acetate; (C) — – —, 5,5′-di-C-benzylellagic acid; (D) — · · —, 5,5′-di-C-benzylellagic acid + sodium acetate.

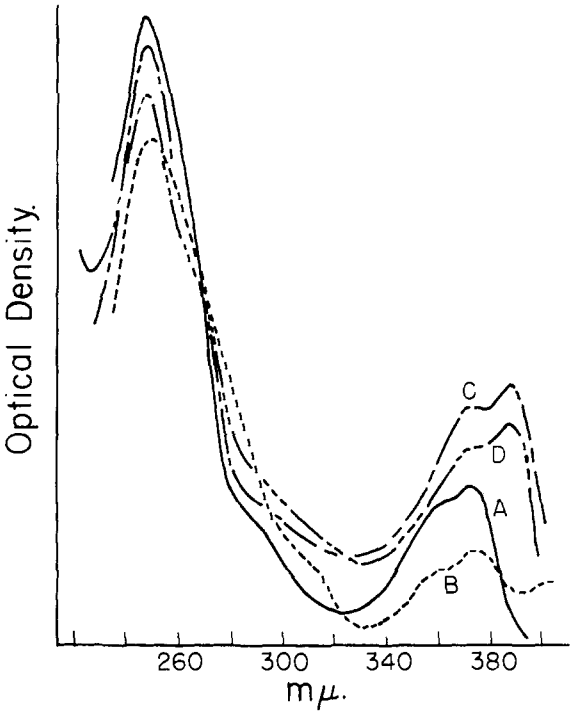
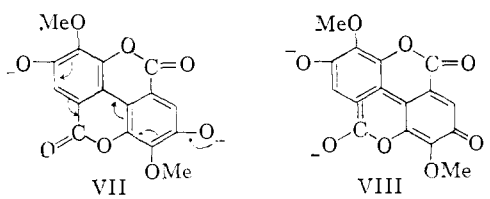


Fig. 2.—Ultraviolet absorption spectra in ethanol of: (A) ———, 3,3′-di-O-methylellagic acid (IV); (B) – – – –, IV + sodium acetate; (C) — – —, product A; (D) — · · —, product A + sodium acetate.

4′-di-O-methylellagic acid (V) and B showed the characteristic division into two peaks at approximately 255 and 280 mμ (Fig. 3).

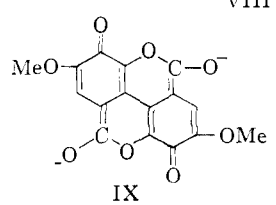
Spectra in 0.02 *M* Sodium Ethylate.—Sodium ethylate normally ionizes all free phenolic groups. Since the 3,3′-hydroxyl groups of 4,4′-di-O-methylellagic acid (V) and of B are ionized by sodium acetate it was expected and found (Fig. 3) that these compounds have identical spectra in either sodium acetate or sodium ethylate solutions. Unlike sodium acetate, however, sodium ethylate ionizes the 4,4′-hydroxyls of 3,3′-di-O-methylellagic acid (IV) and of A; IV and A produce intensely yellow solutions in sodium ethylate with strong absorption bands at 438 and 460 mμ, respectively; *i.e.*, the long wave length bands of IV and A show bathochromic shifts of 66 and 73 mμ, respectively (Fig. 4).

It is noteworthy that the solutions of V and B in sodium ethylate are almost colorless whereas those of IV and A are yellow. The intense color of A in sodium ethylate provides further strong evidence of the existence of 4,4′-hydroxyl groups since ionization of these hydroxyl groups (VII) would give rise to two (identical) extended quinoidal resonance forms as VIII, whereas ionization of B produces only one completely quinoidal resonance form (IX) and in this form the chromophores are separate.



VII

VIII



IX

Spectra of Acetates.—Acetylation of the ellagic acid derivatives significantly alters their spectra.

	λ_{max}, mμ				λ_{max}, mμ		
IV	248	359	372	V	253	346	361
Diacetate of IV	245	333	347	Diacetate of V	239	354	368
A	249	371	387	B	252	345	359
Diacetate of A	247	345	362	Diacetate of B	238	356	371

Acetylation of 3,3′-di-O-methylellagic acid (IV) and of A has an identical effect on their spectra; it causes hypsochromic shifts of 2 (3), 26, 25 mμ of their respective bands. The spectra of 4,4′-di-O-methylellagic acid (V) and of B are also affected similarly on acetylation; it produces a hypsochromic shift (14 mμ) of the low wave length band, a bathochromic shift (12, 11 mμ) of the intermediate band and a bathochromic shift (7, 12 mμ) of the long wave length band.

It is apparent from these spectral data that the orientation of methoxyl and hydroxyl groups in A and B is identical with that in IV and V, respectively; A, therefore, has the structure X and B the structure XI. The quinoidal oxygen atoms

sodium acetate become slightly yellow and develop a low intensity absorption band above 400 mμ. This is due to some ionization of the 4,4′ hydroxyls.

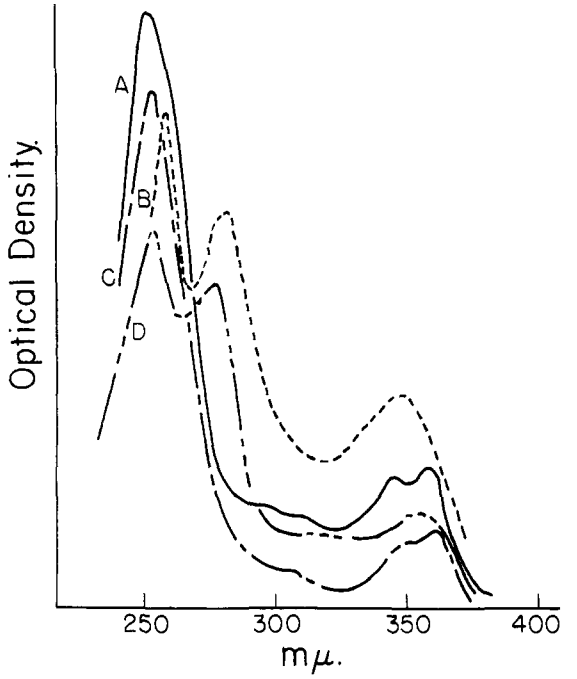
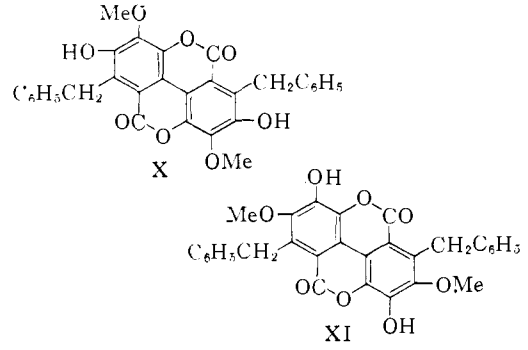
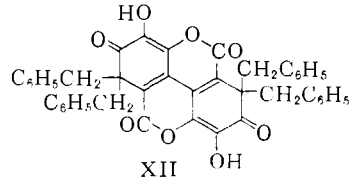


Fig. 3.—Ultraviolet absorption spectra in ethanol of: (A), ———, product B; (B) — — —, product B + sodium acetate; (C) — - —, 4,4′-di-O-methylellagic acid (V); (D) — · · —, V + sodium acetate.

in ellagorubin, consequently, are located in the 4,4′-positions and not in the 3,3′-positions as proposed by Schmidt. Ellagorubin must, therefore have the structure XII.





It is of interest to note that Curtin, Crawford and Wilhelm[16] recently found that the benzylation of the sodium salt of 2,6-dimethylphenol (XIII) gives both XIV and XV. The hexadienone system in XIV is identical with that in ellagorubin (XII). Furthermore, the ether XV corresponds to the colorless product, 5,5′-di-C-benzyltetra-O-benzyl-

(16) D. Y. Curtin, R. J. Crawford and M. Wilhelm, THIS JOURNAL, **80**, 1391 (1958).

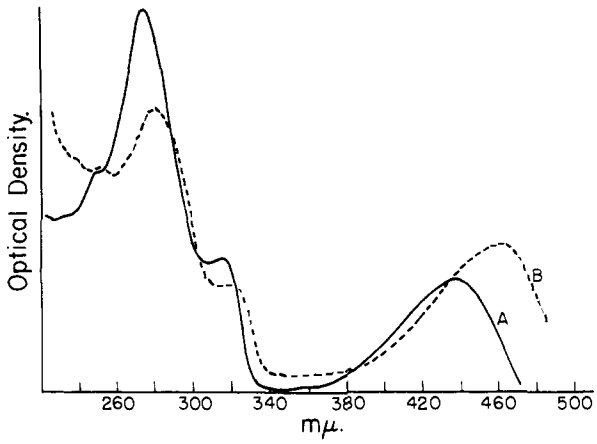
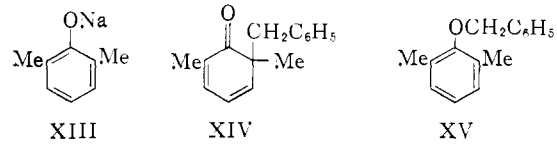
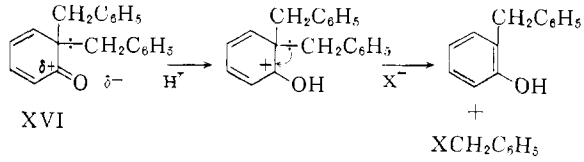


Fig. 4.—Ultraviolet absorption spectra in 0.002 *M* sodium ethylate of: (A) ———, 3,3′-di-O-methylellagic acid; (B) — — —, product A.

ellagic acid (III, R = $C_6H_5CH_2$–), formed together with the ellagorubin in the benzylation of ellagic acid.



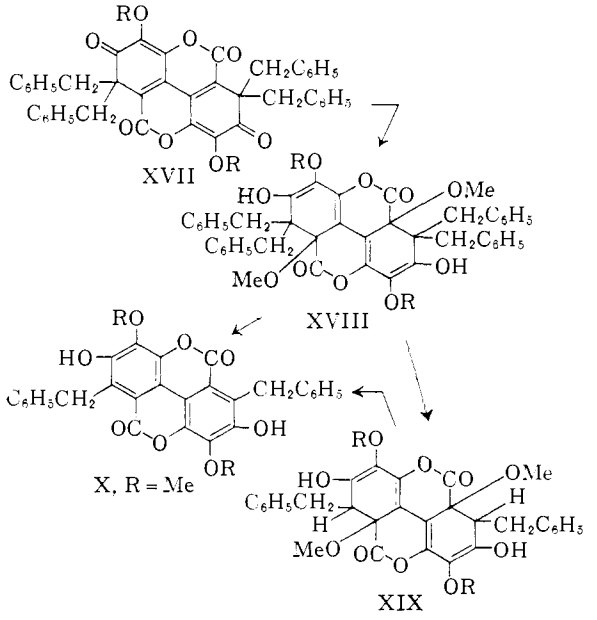
It already has been pointed out that Schmidt and his co-workers assumed that the labile benzyl groups in ellagorubin were O-benzyl groups since the facile cleavage of such linkages is well known. The structure XII now assigned to ellagorubin indicates that a C-benzyl linkage in the grouping XVI must be cleaved as readily as an O-benzyl linkage. This may be accounted for by the mechanism



Cleavage of such C-benzyl linkages does not seem to have been described previously. It is hoped, therefore, to prepare and study the reactions of a number of model C-dibenzyl compounds at a future date.

In the course of this investigation an interesting reaction involving the addition of methanol to the conjugated system of ellagorubin was found. Ellagorubin dimethyl ether (XVII, R = Me) warmed for a short time with a solution of sodium methoxide in methanol adds the elements of two molecules of methanol to form an almost colorless, crystalline addition product (XVIII, R = Me), $C_{46}H_{42}O_{10}$, m.p. 159°. Ellagorubin dibenzyl ether (XVII, R = $C_6H_5CH_2$–) similarly forms an addition product, $C_{58}H_{50}O_{10}$, m.p. 179–180° (XVIII, R = $C_6H_5CH_2$–). These products are not esters formed by the opening of the lactone rings since they can be recovered unchanged after prolonged treatment with aqueous alkali. Catalytic hydro-

genation of the ellagorubin dimethyl ether addition product (XVIII, R = Me) results in the loss of two benzyl groups with the formation of a colorless compound (XIX, R = Me), m.p. 216–217°, $C_{32}H_{30}O_{10}$. Treated briefly with aqueous alkali or warm methanolic hydrochloric acid the hydrogenation product (XIX, R = Me) loses the elements of two molecules of methanol and forms 3,3′-di-O-methyl-5,5′-di-C-benzylellagic acid (X). The ellagorubin dimethyl ether addition product (XVIII, R = Me) also forms the ellagic acid (X) on treat-



ment with methanolic hydrochloric acid. The series of reactions may best be accounted for by 1,6-addition of methanol to the ellagorubin dialkyl ether

Experimental

Ellagorubin[10] crystallized from acetone–methanol in red prisms, m.p. 220° (lit. m.p. 220–224°).

Anal. Calcd. for $C_{42}H_{36}O_8$: C, 76.1; H, 4.56. Found: C, 76.2; H, 4.65.

Di-O-methyl-ellagorubin.—Ellagorubin was methylated with diazomethane as previously described[11] and with dimethyl sulfate. A mixture of ellagorubin (2.0 g.), dimethyl sulfate (8.0 ml.), anhydrous potassium carbonate (8.0 g.) and acetone (100 ml.) was heated under reflux for 5 hours. The solid was collected and extracted several times with warm chloroform. The chloroform extract was concentrated and cooled. Di-O-methylellagorubin thereby separated in orange-red rhombs, m.p. 241° (1.6 g.).

Acid Hydrolysis of Di-O-methylellagorubin.—A solution of di-O-methylellagorubin (2.0 g.) in dioxane (200 ml.) and concentrated hydrochloric acid (20.0 ml.) was refluxed for 3.5 hours. The yellow solution then was evaporated *in vacuo* and the crystalline residue was recrystallized from tetrahydrofuran–methanol. 3,3′-Di-O-methyl-5,5′-di-C-benzylellagic acid thereby separated in lemon-yellow needles, m.p. 317–318° (lit.[10] m.p. 312°), which did not give a color with alcoholic ferric chloride.

Acetylation of the above product (40 mg.) was effected by heating it with pyridine (1.0 ml.) and acetic anhydride (0.5 ml.) for 10 minutes. Water was added and the solid was collected. Recrystallized from dioxane–methanol 3,3′-di-O-dimethyl-5,5′-di-C-benzylellagic acid diacetate separated in colorless felted needles, m.p. 294–295°.

Anal. Calcd. for $C_{34}H_{26}O_{10}$: C, 68.7; H, 4.41; 2 CH_3CO–, 14.4. Found: C, 68.4; H, 4.61; CH_3CO–, 14.2.

A mixture of the 3,3′-di-O-methyl-5,5′-di-C-benzylellagic acid (0.25 g.), potassium iodide (2.0 g.), potassium carbonate (5.0 g.), benzyl chloride (2.0 ml.) and acetone (80 ml.) was refluxed for 17 hours. The solid (A) was collected. The acetone filtrate was evaporated to an oil which was suspended in hexane thereby giving a solid. This was combined with the solid (A) and suspended in water (100 ml.). The undissolved solid was collected and recrystallized from benzene–hexane. 3,3′-Di-O-methyl-4,4′-di-O-benzyl-5,5′-di-C-benzylellagic acid was thus obtained in colorless needles, m.p. 240°.

Anal. Calcd. for $C_{44}H_{34}O_8$: C, 76.5; H, 4.96; 2 MeO–, 8.99. Found: C, 76.7; H, 5.03; MeO–, 8.81.

Action of Acetic Anhydride and Sulfuric Acid on Di-O-methylellagorubin.—A mixture of di-O-methylellagorubin (0.05 g.), acetic anhydride (2.0 ml.) and concentrated sulfuric acid (2 drops) was heated on a steam-bath for 10 minutes. Water was added and the solid product was collected. Recrystallized from dioxane–methanol, 3,3′-di-O-methyl-5,5′-di-C-benzylellagic acid diacetate, m.p. and mixed m.p. with above diacetate 294–295°, was thus obtained.

Anal. Calcd for $C_{34}H_{26}O_{10}$: C, 68.7; H, 4.41; 2 MeO–, 10.4; 2 CH_3CO–, 14.5. Found: C, 68.3; H, 4.75; MeO–, 10.1; CH_3CO–, 13.4.

Di-O-benzylellagorubin.—A mixture of finely powdered ellagorubin (2.0 g.), anhydrous potassium carbonate (10 g.), potassium iodide (10 g.), benzyl chloride (10.0 ml.) and dry acetone (120 ml.) was heated under reflux for 30 hours. The undissolved solids were collected and suspended in water (300 ml.) thereby giving an orange-red crystalline solid (A). The acetone filtrate was evaporated to an oil. Hexane (50 ml.) was added and the solution was cooled. A small quantity of orange-red crystalline solid was thereby obtained. It was combined with A and recrystallized from chloroform–hexane. Di-O-benzylellagorubin separated in orange-red prisms, m.p. 217°, which did not dissolve in aqueous sodium hydroxide (2.1 g.).

Anal. Calcd. for $C_{56}H_{42}O_8$: C, 79.8; H, 5.03. Found: C, 79.5; H, 5.10.

Acid Hydrolysis of Di-O-benzylellagorubin.—A suspension of di-O-benzylellagorubin (2.0 g.) in glacial acetic acid (50 ml.) was heated to boiling. Concentrated sulfuric acid (0.5 ml.) was added and the mixture was refluxed for 2 minutes. Water (200 ml.) was added and the crystalline precipitate (1.5 g.) was collected, washed with acetone and methanol and recrystallized from aqueous pyridine and from tetrahydrofuran–methanol. 3,3′-Di-O-benzyl-5,5′-di-C-benzylellagic acid was thereby obtained as colorless needles, m.p. 315–320° (with darkening at 275°). It did not give a color with alcoholic ferric chloride but dissolved in aqueous alkali to give an intensely yellow solution.

Anal. Calcd. for $C_{42}H_{30}O_8$: C, 76.1; H, 4.56. Found: C, 75.8; H, 4.73.

A mixture of the above product (1.4 g.), dimethyl sulfate (6.0 ml.), potassium carbonate (4.0 g.) and acetone (250 ml.) was refluxed for 18 hours. The filtered acetone solution was evaporated and diluted with dilute aqueous sodium hydroxide. The colorless precipitate was collected, dried and recrystallized from benzene–hexane. 4,4′-Di-O-methyl-3,3′-di-O-benzyl-5,5′-di-C-benzylellagic acid separated in clusters of colorless needles, m.p. 212° (1.1 g.).

Anal. Calcd. for $C_{44}H_{34}O_8$: C, 76.5; H, 4.96; 2 MeO–, 8.99. Found: C, 76.3; H, 4.97; MeO–, 8.54.

Action of Acetic Anhydride and Sulfuric Acid on Di-O-benzylellagorubin.—Di-O-benzylellagorubin (1.0 g.) was dissolved in boiling acetic anhydride (50 ml.). Concentrated sulfuric acid (1.0 ml.) was added and the solution was immediately cooled under cold water. The red color of the solution was discharged and a colorless crystalline solid began to precipitate. After 5 minutes, excess of water was added. The solid (0.95 g.) was collected and recrystallized from tetrahydrofuran–methanol. 3,3′-Di-O-benzyl-5,5′-di-C-benzylellagic acid diacetate was thus obtained in colorless needles, m.p. 292°.

Anal. Calcd. for $C_{38}H_{34}O_{10}$: C, 74.0; H, 4.59. Found: C, 74.1; H, 4.68.

Alkaline hydrolysis of the above diacetate (0.7 g.) gave 3,3′-di-O-benzyl-5,5′-di-C-benzylellagic acid, m.p. 315–320° (0.4 g.). Methylation of this gave the above 4,4′-di-O-methyl-3,3′-di-O-benzyl-5,5′-di-C-benzylellagic acid, m.p. 212°.

Anal. Calcd. for $C_{44}H_{34}O_8$: C, 76.5; H, 4.36. Found: C, 76.4; H, 5.00.

4,4'-Di-O-methyl-5,5'-di-C-benzylellagic Acid.—A solution of 4,4'-di-O-methyl-3,3'-di-O-benzyl-5,5'-di-C-benzylellagic acid (0.5 g.) in ethyl acetate (200 ml.) was hydrogenated at room temperature and pressure in the presence of a palladium–charcoal catalyst. The filtered ethyl acetate solution was evaporated and the crystalline residue was recrystallized from tetrahydrofuran–methanol. 4,4'-Di-O-methyl-5,5'-di-C-benzylellagic acid was obtained as colorless needles, m.p. 360°.

Anal. Calcd. for $C_{30}H_{22}O_8$: C, 70.6; H, 4.35; 2 MeO–, 12.2. Found: C, 70.6; H, 4.32; MeO–, 11.8.

The diacetate of this product was prepared by heating it with acetic anhydride and sodium acetate for 30 minutes. After adding water the acetate was collected and recrystallized from dioxane–methanol. It separated in colorless felted needles, m.p. 325°.

Anal. Calcd. for $C_{34}H_{26}O_{10}$: C, 68.7; H, 4.41. Found: C, 68.7; H, 4.49.

Action of Sodium Methoxide on Di-O-methylellagorubin.—Di-O-methylellagorubin (1.6 g.) was refluxed with a solution of sodium (2.0 g.) in anhydrous methanol (100 ml.) for 15 minutes. The dimethyl ether gradually passed into solution and yellow sodium salt began to crystallize out. The mixture was cooled, acidified with hydrochloric acid and diluted with water. The solid product was collected and recrystallized successively from methanol and benzene–hexane (1.4 g.). It separated in almost colorless needles, m.p. 159°, which did not give a color with methanolic ferric chloride but dissolved in aqueous sodium bicarbonate to give an intensely yellow solution. Heated with aqueous sodium hydroxide for 1 hour it was recovered unchanged on acidification.

Anal. Calcd. for: $C_{46}H_{42}O_{10}$: C, 73.2; H, 5.61; 4 MeO–, 16.4. Found: C, 73.2; H, 5.76; MeO–, 16.3.

Acid Hydrolysis of the Methanol Addition Product.—The above product (0.2 g.) was heated with methanol (4.0 ml.) and concentrated hydrochloric acid (1.0 ml.) for 10 minutes. Water was added and the crystalline product was collected and recrystallized from tetrahydrofuran–methanol. 3,3'-Di-O-methyl-5,5'-di-C-benzylellagic acid, m.p. and mixed m.p. 317–318°, was thus obtained.

Anal. Calcd. for $C_{30}H_{22}O_8$: C, 70.6; H, 4.35; MeO–, 12.2. Found: C, 70.6; H, 4.49; MeO–, 11.9.

Catalytic Hydrogenation of the Methanol Addition Product.—A solution of the di-O-methylellagorubin–methanol addition product (0.26 g.) in methanol (15.0 ml.) was hydrogenated at room temperature and pressure in the presence of 30% palladium–charcoal catalyst until the hydrogen uptake was complete. The catalyst was filtered. Evaporation of the filtrate gave a crystallized residue which was recrystallized from ethyl acetate–hexane. The product separated in colorless blades, m.p. 216–217°.

Anal. Calcd. for $C_{32}H_{30}O_{10}$: C, 66.8; H, 5.27; 4 MeO–, 21.6. Found: C, 66.8; H, 5.26; MeO–, 21.5.

A solution of the above hydrogenation product (50 mg.) in methanol (10.0 ml.) and concentrated hydrochloric acid (2.0 ml.) was heated on a steam-bath for 15 minutes. Water was added. The solid product was collected and recrystallized from tetrahydrofuran–methanol. 3,3'-Di-O-methyl-5,5'-di-C-benzylellagic acid thereby separated in slightly yellow needles, m.p. 317–318°.

Anal. Calcd. for $C_{30}H_{22}O_8$: C, 70.6; H, 4.35; 2 MeO–, 12.2. Found: C, 70.6; H, 4.42; MeO–, 12.2.

A solution of the hydrogenation product (60 mg.) in a 1% methanolic potassium hydroxide solution (5.0 ml.) was allowed to stand at room temperature for 10 minutes. It was acidified (HCl) and diluted with water. The yellow needles were collected and recrystallized from tetrahydrofuran–methanol. 3,3'-Di-O-methyl-5,5'-di-C-benzylellagic acid, m.p. and mixed m.p. 317–318°, was thus obtained.

Action of Sodium Methoxide on Di-O-benzylellagorubin.—Di-O-benzylellagorubin (0.2 g.) was refluxed with a solution of sodium (0.4 g.) in methanol (10.0 ml.) for 20 minutes. The mixture was cooled, acidified, diluted with water and filtered. The solid was recrystallized from benzene–hexane and from methanol. The methanol addition product separated in colorless rectangular flakes, m.p. 179–180°. It was recovered unchanged on treatment with warm aqueous sodium hydroxide.

Anal. Calcd. for $C_{58}H_{50}O_{10}$: C, 76.8; H, 5.56. Found: C, 76.8; H, 5.60.

Acknowledgments.—The author is indebted to Dr. T. A. Geissman and Dr. R. M. Horowitz for many helpful discussions and to L. M. White for the elementary analyses.

PASADENA, CALIF.

[CONTRIBUTION FROM WESTERN REGIONAL RESEARCH LABORATORY, A LABORATORY OF THE WESTERN UTILIZATION RESEARCH AND DEVELOPMENT DIVISION, AGRICULTURAL RESEARCH SERVICE, U. S. DEPARTMENT OF AGRICULTURE]

Plant Polyphenols. VIII. The Structure of Ellagorubin. Part A. Infrared Spectra. Part B. High Resolution Nuclear Magnetic Resonance Spectra

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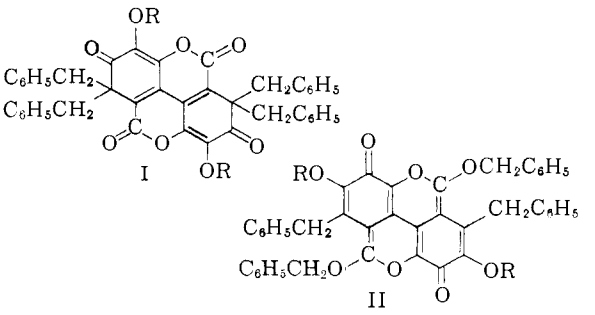
RECEIVED JANUARY 20, 1959

It is shown that both infrared and nuclear magnetic resonance spectra of ellagorubin are compatible with structure I (R = H) proposed by Jurd, but not with II (R = H) proposed by other investigators. The n.m.r. spectra for ellagorubin, two of its derivatives, and two derivatives of ellagic acid are analyzed. Infrared data in the carbonyl stretching region are discussed for these same compounds as well as for ellagic acid and nine other derivatives.

In the preceding paper of this series,[2] chemical evidence in conjunction with ultraviolet spectra indicate that ellagorubin has the structure I (R = H) rather than II (R = H) as proposed by Schmidt, Voigt and Bernauer.[3] Both infrared and nuclear magnetic resonance (n.m.r.) spectra are shown in this paper to be compatible with structure I (R = H) and incompatible with structure II (R = H) for ellagorubin.



(1) (a) Part A. (b) Part B. (c) Varian Associates, Palo Alto, Calif.

(2) Part VII, L. Jurd, THIS JOURNAL, **81**, 4610 (1959).

(3) O. T. Schmidt, H. Voigt and K. Bernauer, *Chem. Ber.*, **88**, 91 (1955).