Tetrahedron Letters No.9, pp. 849-852, 1967. Pergamon Press Ltd. Printed in Great Britain.

PHYTOCHEMICAL STUDIES. VI[1].
THE STRUCTURES OF TAIWANINS C AND E

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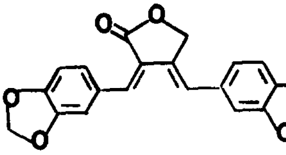
(Received 2 December 1966; in revised form 4 January 1967)

Four major heartwood components were originally obtained from the tree *Taiwania cryptomerioides* Hayata (Family Taxodiaceae, tribe Athrotaxeae, genus *Taiwania*, monotypic).[2] Taiwanins B and D were identified as savinin and hinokiol,[3] while Taiwanin A was reported to be α,β-dipiperonylidenebutyrolactone (I).[4] Evidence is presented here that permits Taiwanin C, m.p. 276°, to be characterized as 1-(3',4'-methylenedioxyphenyl)-3-hydroxymethyl-6,7-methylenedioxy-2-naphthoic acid lactone (IIa).

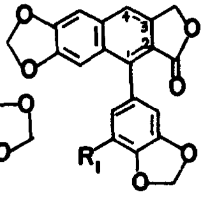
The formula $C_{20}H_{12}O_6$ followed from a double-focus mass spectrum measurement (parent ion, M^+ 348.06403); the next most prominent fragmentation was due to cleavage of the lactone ring (M-58). The infrared spectrum in potassium bromide contained bands associated with an aromatic-δ-lactone (1763 and 1740 $cm.^{-1}$), a methylenedioxy ether (935 $cm.^{-1}$) and a 1,2,4-trisubstituted benzene derivative (797 $cm.^{-1}$). The ultraviolet spectrum in methanol indicated the presence of an extended naphthalenic chromophore (217, 223, 251 sh., 257, 294, 305 and 350 mμ with ε 20,000, 19,500, 40,500, 43,750, 9750, 9250 and 5000). The nuclear magnetic resonance spectrum, recorded at 100 MHz. in deuterochloroform with tetramethylsilane as an internal standard, exhibited signals equivalent to six aromatic protons [7.71, 7.21, 7.14, 7.00 and 6.87(2) p.p.m.], four methylenedioxy protons [6.09 p.p.m.], and two methylene protons [5.38 p.p.m.]. The lack of any lower field singlet [*i.e.*, > 7.8 p.p.m.] reinforced the placement of the lactone carbonyl group at C-2, as the observation of such a shifted proton would have been diagnostic for a reversed isomer (IIIa).[5] The upfield shift of the aromatic ABX pattern seen for the three phenyl protons [7.00 and 6.87 p.p.m.] was attributed to shielding caused by the proximity of a neighboring aromatic ring, as well as adjacent ketonic and methylenedioxy oxygens. These postulated anisotropic effects were supported by a steric model (Dreiding) that dictated a perpendicular orientation for the two separate ring systems.

Additionally, a fifth, and previously unnamed minor constituent of the acidic mother residues, m.p. 263-267°, is designated now as Taiwanin E or 1-hydroxy-3-hydroxymethyl-4-(3',4'-methylenedioxyphenyl)-6,7-methylenedioxy-2-naphthoic acid lactone (IV). The compound analyzed for $C_{20}H_{12}O_7$ and gave a mass spectral pattern rich in metastable ions (parent ion, M^+ 364.05851). Hydroxyl (3420 cm.$^{-1}$), aromatic-δ-lactone (1745 cm.$^{-1}$), phenolic (1216 cm.$^{-1}$), methylenedioxy ether (932 cm.$^{-1}$) and substituted benzene (789 cm.$^{-1}$) correlations were seen in the infrared, while the ultraviolet revealed a series of bathochromic peaks (230, 263 sh., 269, 290 sh., 308-313 plateau, 322 and 357 mμ with ε 15,400, 21,300, 21,450, 6320, 5340, 5390 and 2850). The various displacements must be a consequence of both a hydrogen-bonded carbonyl and increased conjugation, as the lower intensities are associated with a change from an isolated ring system to a coplanar structure. The nuclear magnetic resonance spectrum of IV in perdeuterodimethyl sulfoxide containing some water at 100 MHz. integrated for five aromatic protons [7.60, 7.02, 6.84, 6.81, and 6.71 p.p.m.], four methylenedioxy protons [6.17 and 6.11 p.p.m.], and two methylene protons [5.34 p.p.m.]. The characteristic ABX pattern [7.02, 6.81 and 6.71 p.p.m.] indicated an unchanged substitution pattern in the lower phenyl ring and thereby eliminated consideration of associated substances (IIb and IIIb). Addition of deuterium oxide did not cause any new shifts; therefore, it is inferred that the phenolic proton may be buried beneath the water impurity signal.

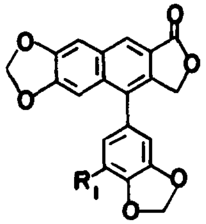
These structures for Taiwanin C and E are upheld by a set of physical constants and two spectral comparisons. Both compounds IIa and IIIa were prepared three decades ago and possessed respective m.ps. of 275° and 264°.[6] Although the former value is close to the sum recorded for Taiwanin C, the original specimens are no longer available for comparison purposes.[7] The related dehydro-dimethyl-α-retrodendrin (Va)[8] has parallel absorptions to IIa in the infrared (1767 and 1755 cm.$^{-1}$) and ultraviolet (213-223 plateau,



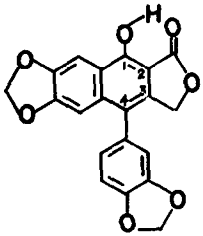
I



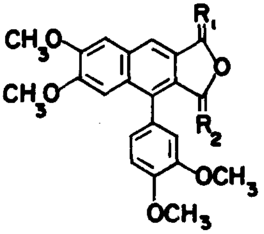
IIa, R_1=H
IIb, R_1=OH



IIIa, R_1=H
IIIb, R_1=OH

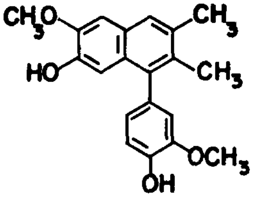


IV

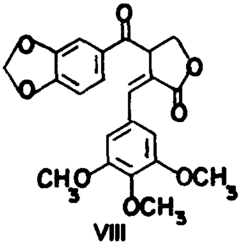


Va, R_1=H_2; R_2=O
Vb, R_1=O; R_2=H_2

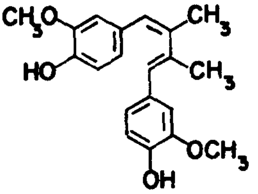
VI



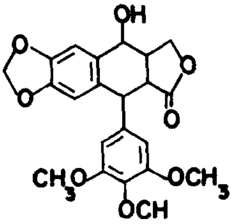
VII



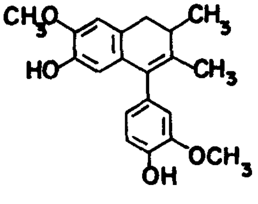
VIII



IX



X



XI

249 inf., 257, 286 sh., 313 and 346 mμ with ε 23,500, 33,350, 46,700, 7280, 8830 and 4910).[9] Dehydro-dimethyl-α-conidendrin (Vb), in contrast, is considerably different from IIa on the basis of similar data.[10] Most importantly, it was found that an acetone solution of the butyrolactone I, after standing in the light, deposited both crystalline IIa and IV. A comparable photolysis reaction was utilized recently to obtain various 1-arylnaphthalenes.[11] This cyclization involves an unexceptional geometrical isomerization around the least hindered double bond, followed by an oxidative coupling to form the new nucleus; however, a formal Diels-Alder mechanism is conceivable, also.[12] The solvent used here must play a major rôle in the secondary oxidation of C-1 in IV, which no doubt involves a hydroperoxide intermediate.[13]

Such a facile conversion raises the question of whether Taiwanins C and E actually exist in Nature or may be artifacts of the extraction procedure (prolonged boiling with acetone in subdued sunlight). It is interesting to note that the rare lignans dehydro-podophyllotoxin

(VI)[14] and dehydro-guariaretic acid (VII)[15] were isolated only in minute amounts after lengthy purification measures. Unnoticed precursors -- such as α-3,4,5-trimethoxybenzylidene-β-piperonyloylbutyrolactone (VIII) and 1,4-(di-4'-guaicyl)-2,3-dimethyl-1,3-butadiene (IX) -- could have undergone chemical transformation during the conventional workup process to yield the fully aromatized products VI and VII. Moreover, if an oxidative cyclization route is found *in vivo*, and an enzyme system exists for the reduction of the central ring, then a direct phytochemical relationship between VIII→VI→X (podophyllotoxin),[16] for IX→XI (guariaretic acid)[16] and analogous systems are interesting possibilities. These points are under current investigation.

REFERENCES

1. Paper V. G.A. Swoboda, K.-T. Wang, and B. Weinstein, J.Chem.Soc., C, in press (1967).
2. Y.-T. Lin, T.-B. Lo, and E.-H. Shih, J.Chinese Chem.Soc.(Taiwan), II, 2, 87 (1955).
3. Y.-T. Lin, Y.-S. Lin, and T.-B. Lo, ibid., 10, 163 (1963).
4. Y.-T. Lin, K.-T. Wang, and B. Weinstein, Chem.Commun., 592 (1965).
5. L.H. Klemm, K.W. Gopinath, D. Hsu Lee, F.W. Kelly, E. Trod, and T.M. McGuire, Tetrahedron, 22, 1797 (1966).
6. R.D. Haworth and W. Kelly, J.Chem.Soc., 745 (1936).
7. Dr. R.D. Haworth, University of Sheffield, personal communication (September 20, 1966).
8. M.E. Cisney, W.L. Shilling, W.M. Hearon, and D.W. Goheen, J.Am.Chem.Soc., 76, 5083 (1954).
9. We wish to thank Dr. L.H. Klemm, University of Oregon, for a sample of dehydro-dimethyl-α-retrodendrin.
10. We wish to thank Dr. W.L. Shilling, Crown Zellerbach Corporation, for a sample of dehydro-dimethyl-α-conidendrin.
11. D.C. Ayres, B.G. Carpenter, and R.C. Denney, J.Chem.Soc., 3578 (1965).
12. L.H. Klemm, D. Hsu Lee, K.W. Gopinath, and C.E. Klopfenstein, J.Org.Chem., 31, 2376 (1966).
13. G.O. Schenck, Angew.Chem., 69, 579 (1957).
14. H. Kofod and C. Jörgensen, Acta Chem.Scand., 8, 1296 (1954).
15. F.E. King and J.G. Wilson, J.Chem.Soc., 4011 (1964).
16. W.M. Hearon and W.S. MacGregor, Chem.Rev., 55, 957 (1955).