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PETROSTYRENE, A CINNAMYLPHENOL FROM *MACHAERIUM ACUTIFOLIUM**

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Key Word Index—*Machaerium acutifolium*; Leguminosae–Lotoideae; cinnamylphenol; petrostyrene.

Abstract—The trunkwood of *Machaerium acutifolium* contains, in addition to pinosylvin monomethyl ether and (+)-medicarpin, a cinnamylphenol, petrostyrene [*E*-1-(5-hydroxy-2,3,4-trimethoxybenzyl)-2-(2-hydroxyphenyl)-ethylene], whose characterisation relied on spectra and synthesis of the dimethyl and diethyl ethers.

INTRODUCTION

The sapwood of *Machaerium acutifolium* Vog. (designated in a preliminary communication *M.* species URB/18 [2]), yielded pinosylvin monomethyl ether [3], (+)-medicarpin [(+)-demethylhomopterocarpin] [4] and a novel compound which, on account of the collection site of the tree, the vicinity of Petropolis, RJ, Brasil, and the structural analogy with violastyrene (**1a**) and isoviolastyrene (**1b**) [1], was called petrostyrene.

RESULTS AND DISCUSSION

The molecular formula of petrostyrene, $C_{18}H_{20}O_5$, was determined by HRMS. Analysis of the PMR spectrum allowed expansion to $C_6H.C_6H_4CH_A{=}CH_B{-}CH_{2X}(OH)_2(OMe)_3$. The chemical shifts and coupling constants of the ABX_2 system are characteristic of the *E*-propene unit of cinnamylphenol structures [5], amenable to catalytic hydrogenation to a $(CH_2)_3$-unit. The 5 aromatic protons of petrostyrene, as well as of its dimethyl and diethyl ethers, are represented by a singlet and an ABCD multiplet which both are shifted to lower field upon passing to petrostyrene diacetate. The association of one OH each with the disubstituted and the pentasubstituted rings was confirmed by the MS of petrostyrene which shows a fragment ion, *m/e* 107, corresponding to the formation of the hydroxytropylium cation $C_7H_7O^+$.

These data, in combination with biosynthetic considerations based on skeletal relations and oxygenation patterns of neoflavonoid constituents of *Dalbergia* and *Machaerium* species [6, 7], such as e.g. **2a** [8] and **2b** [9], suggested structure **1c** for petrostyrene dimethyl ether and, in analogy to violastyrene (**1a**) and isoviolastyrene (**1b**) respectively, either **1d** or **1a** for petrostyrene itself. Verification of the proposed oxygenation pattern required the synthesis of **1c**. This was achieved by $LiAlH_4/AlCl_3$ reduction of the chalcone **3a**, prepared by the condensation of *o*-methoxybenzaldehyde with 2,3,4,5-tetramethoxyacetophenone. It had previously been shown that reduction of similar chalcones by this method proceeds without rearrangement of the double bond [1]. Of the two structural hypotheses for petrostyrene, **1e** was shown to be the correct alternative by synthesis of **1f** and **1g**, respectively distinct from and identical with petrostyrene diethyl ether. The chalcones **3b** and **3c**, required for these syntheses, were prepared by condensation of *o*-ethoxybenzaldehyde with either 4-ethoxy-2,3,-5-trimethoxyacetophenone or 5-ethoxy-2,3,4-trimethoxy-acetophenone.

EXPERIMENTAL

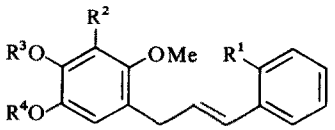
Unless otherwise stated spectra were measured in EtOH (UV), $CHCl_3$ (IR) and $CDCl_3$ (60 MHz PMR). All evapns of volatile material were performed under diminished pressure.

Isolation of the constituents. A specimen of *M. acutifolium* was collected in the humid Atlantic forest region called 'Reserva dos Príncipes' located along the old road which links Rio de Janeiro to Petrópolis, RJ, Brasil, and identified by Dr Carlos T. Rizzini. The C_6H_6 extract (73 g) of ground softwood (10 kg) was chromatographed on Si gel (1.2 kg), eluting successively in 2 l. fractions with C_6H_6 (fractions 1–10), C_6H_6–$CHCl_3$ (1:1) (fractions 10–21), $CHCl_3$ (fractions 22–32) and MeOH (fractions 33–37). Fractions 1–21 (58.0 g) contained fatty material. Fractions 22–26 (4.3 g) were separated by TLC and yielded pinosylvin monomethyl ether (20 mg), (+)-medicarpin (25 mg) and **1e** (220 mg). Fractions 27–37 (10.2 g) contained resinous material.

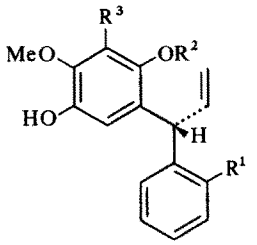
Identifications. Pinosylvin monomethyl ether [3] and (+)-medicarpin [4] were identified by direct comparison with authentic samples.

Petrostyrene (**1e**). Oil. [Found: M 316.1328. $C_{18}H_{20}O_5$ requires: M 316.1311]. λ_{max} (nm): 254, 286, 306 (6400, 3100, 2200). ν_{max} (cm^{-1}): 3500, 3250, 1600. PMR (τ): 2.6–3.4 (*m*, 4 ArH), 3.42 (*s*, H-6 of benzyl), 3.04 (*d*, A part), 3.76 (*dt*, B part), 6.52 (*d*, X, part of ABX, *system*, J_{AB} = 16 Hz, J_{AX} = *ca* 0 Hz, J_{BX} = 6 Hz), 4.4 (*br. s*, 2 OH), 6.07 (*s*, 2 OMe). *Dimethyl ether* (**1c**) (**1e**, MeI, K_2CO_3, Me_2CO), oil, bp 180° (bath temp., 0.1 mm). [Found: C, 69.83; H, 7.24. $C_{20}H_{24}O_5$ requires: C, 69.75; H, 7.02%]. λ_{max} (nm): 261, 280, 304 (ε 5800, 5200, 2500). ν_{max} (cm^{-1}): 1600. *Diethyl ether* (**1g**) (**1e**, EtI, K_2CO_3, Me_2CO), oil, bp 180° (bath temp., 0.1 mm). [Found: C, 71.23; H, 7.55. $C_{22}H_{28}O_5$ requires: C, 70.94; H, 7.58%]. λ_{max} (nm): 258, 280, 304 (ε 9700, 4050, 2100). ν_{max} (cm^{-1}): 1600. PMR (τ): 2.5–3.4 (*m*, 4 ArH), 2.5–4.0 (*m*, AB

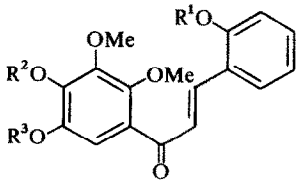
* Part 5 in the series 'The Neoflavonoid Group of Natural Products'. For Part 4 see ref. [1].



1a $R^1 = R^2 = R^3 = H$, $R^4 = Me$
1b $R^1 = R^2 = R^4 = H$, $R^3 = Me$
1c $R^1 = R^2 = OMe$, $R^3 = R^4 = Me$
1d $R^1 = OH$, $R^2 = OMe$, $R^3 = H$, $R^4 = Me$
1e $R^1 = OH$, $R^2 = OMe$, $R^3 = Me$, $R^4 = H$
1f $R^1 = OEt$, $R^2 = OMe$, $R^3 = Et$, $R^4 = Me$
1g $R^1 = OEt$, $R^2 = OMe$, $R^3 = Me$, $R^4 = Et$



2a $R^1 = R^2 = H$, $R^3 = OMe$
2b $R^1 = OH$, $R^2 = Me$, $R^3 = H$



3a $R^1 = R^2 = R^3 = Me$
3b $R^1 = R^2 = Et$, $R^3 = Me$
3c $R^1 = R^3 = Et$, $R^2 = Me$

part), 6.46 (m, X_2 part of ABX_2 system), 3.47 (*s*, H-6 of benzyl), 5.96 and 8.58 (resp. *q* and *t*, $J = 7$ Hz, OEt), 6.07 (*s*, OMe), 6.12 (*s*, 2 OMe). *Diacetate* (**1e**, Ac_2O, C_5H_5N, room temp., 16 hr), oil. [Found: M 400. $C_{22}H_{24}O_5$ requires: M 400]. ν_{max} (cm^{-1}): 1750, 1600. PMR (τ): 2.4–3.4 (*m*, 4 ArH), 3.37 (*s*, H-6 of benzyl), 3.60–3.75 (*m*, AB part), 6.52 (*m*, X_2 part of ABX_2 system), 6.08 (*s*, OMe), 6.15 (*s*, 2 OMe), 7.73 (*s*, OAc), 7.75 (*s*, OAc). *Dihydropetrostyrene* (**1e**, EtOH, 10% Pd/C, H_2, 16 hr), oil. [Found: 318.1461. $C_{18}H_{22}O_5$ requires: 318.1467]. ν_{max} (cm^{-1}): 1590.

Synthesis of petrostyrene dimethyl ether (**1c**). *Preparation of 2,2',3',4',5'-pentamethoxychalcone* (**3a**). 2,5-Dihydroxy-3,4-dimethoxyacetophenone [10] (7.5 g), MeI (10 ml), K_2CO_3 (10 g), Me_2CO (50 ml), reflux, 48 hr, gave 2,3,4,5-tetramethoxyacetophenone [11] (7.0 g), oil, bp 140° (0.1 mm) [Found: C, 59.98; H, 6.67. $C_{12}H_{16}O_5$ requires: C, 59.99; H, 6.71%]. This cmpd (1.6 g), salicylaldehyde methyl ether (0.9 g), EtOH (5 ml) and KOH (5 g) in H_2O (10 ml) were stirred (room temp., 4 hr). Evap of the H_2O gave a residue which was purified by chromatography (Si gel, $CHCl_3$) to **3a** (2.0 g), yellow oil, bp 180° (bath temp., 0.1 mm). [Found: C, 66.74; H, 5.92. $C_{20}H_{22}O_6$ requires C, 67.02; H, 6.19%]. ν_{max}(cm^{-1}): 1650. PMR (τ): 1.98 and 2.42 (2 *d*, $J = 16$ Hz, H-α,β), 2.3–3.3 (*m*, H-3,4,5,6), 2.97 (*s*, H-6'), 6.08 (*s*, 2 OMe), 6.15 (*s*, OMe), 6.17 (*s*, 2 OMe). *Preparation of* E-1-(2,3,4,5-*tetramethoxybenzyl*)-2-(2-*methoxyphenyl*)*ethylene* (**1c**). $LiAlH_4$ (1 g) in Et_2O (10 ml) was added to **3a** (0.9 g) and the mixture heated under reflux (15 min), then $AlCl_3$ (5 g) in Et_2O (20 ml) was added and the heating continued (15 min). Excess reagent was decomposed with H_2O. The mixture was acidified and extracted with Et_2O. The Et_2O soln was evapd. The residue was purified by TLC (Si gel, $CHCl_3$) to an oil, bp 180° (bath temp., 0.1 mm). [Found: C, 69.83; H, 7.24. $C_{20}H_{24}O_5$ requires: C, 69.75; H, 7.02%], identical with the dimethyl ether of natural petrostyrene.

Synthesis of E-1-(4-*ethoxy*-2,3,5-*trimethoxybenzyl*)-2-(2-*ethoxyphenyl*)-*ethylene* (**1f**). (*a*) *Preparation of 2,4'-diethoxy-2'3',5'-trimethoxychalcone* (**3b**). Pyrogallol-2-methyl ether [12] (9.8 g) in BF_3–HOAc (40 ml) was heated (100°, 30 min). The mixture was then poured into H_2O and the pptd 2,4-dihydroxy-3-methoxyacetophenone (10.0 g) collected as needles, mp 76° (lit. [13] mp 76°) This compd (8.7 g), EtI (7.5 g), K_2CO_3 (10 g), Me_2CO (200 ml) heated under reflux (16 hr), gave 4-ethoxy-2-hydroxy-3-methoxyacetophenone (6.4 g), cubes, mp 76–77° (EtOH). [Found: C, 62.64; H, 6.66. $C_{11}H_{14}O_4$ requires: C, 62.84; H, 6.71%]. ν_{max} (cm^{-1}): 1630. PMR (τ): −2.54 (*s*, OH-2), 2.56 (*d*, $J = 8$ Hz, H-6), 3.55 (*d*, $J = 8$ Hz, H-5), 5.87 and 8.53 (resp. *q* and *t*, $J = 7$ Hz, OEt), 6.14 (*s*, OMe), 7.45 (*s*, Ac). This compd (6.1 g) in 10% aq. NaOH (60 ml) was oxidized [14] by slow addition (stirring, 20°, 3–4 hr) of a satd soln of $K_2S_2O_8$ (8.5 g) in H_2O. After standing *ca* 18 hr, HCl was added to a Congo red end point, filtered and extracted with Et_2O. The aq. layer was treated with excess HCl, heated on the water bath (0.5 hr), cooled and extracted with Et_2O. The Et_2O solns were dried and evapd. The residue and MeI (5 ml) etc. as above gave 4-ethoxy-2,3,5-trimethoxyacetophenone (2.8 g), oil, bp 180° (bath temp., 0.1 mm). [Found: C, 61.67; H, 7.26. $C_{13}H_{18}O_5$ requires: C, 61.40; H, 7.14%]. ν_{max} (cm^{-1}): 1660. PMR (τ): 2.92 (*s*, H-6), 5.82 and 8.60 (resp. *q* and *t*, $J = 7$ Hz, OEt), 6.08 (*s*, 2 OMe), 6.16 (*s*, OMe), 7.36 (*s*, Ac). This compd (1.24 g), salicylaldehyde ethyl ether (0.75 g), EtOH (5 ml) and KOH (5 g) in H_2O (10 ml), as described above, gave **3b** (1.58 g), yellow oil, bp 180° (bath temp., 0.1 mm). [Found: C, 68.69; H, 7.10. $C_{22}H_{26}O_6$ requires: C, 68.38; H, 6.78%]. ν_{max} (cm^{-1}): 1650. PMR (τ): 1.93 and 2.37 (2 *d*, $J = 16$ Hz, H-α,β), 2.3–3.3 (*m*, H-3,4,5,6), 2.97 (*s*, H-6'), 5.81, 8.55 and 8.58 (resp. *q*, *t* and *t*, $J = 7$ Hz, 2 OEt), 6.03 (*s*, OMe), 6.14 (*s*, 2 OMe). (*b*) *Preparation of the isomer of petrostyrene diethyl ether* **1f**. **3b** (0.61 g), $LiAlH_4$ (1 g) in Et_2O (10 ml) and $AlCl_3$ (5 g) in Et_2O (20 ml), as described above, gave **1f**, oil, bp 180° (bath temp., 0.1 mm). [Found: C, 71.15, H, 7.62. $C_{22}H_{28}O_5$ requires: C, 70.94; H, 7.58%]. ν_{max} (cm^{-1}): 1600. PMR (τ) 2.5–3.5 (*m*, 4 ArH), 2.5–4.0 (*m*, AB part), 6.46 (*m*, X_2 part of ABX_2 system), 3.50 (*s*, H-6 of benzyl), 5.98, 6.00, 8.59 and 8.61 (resp. *q*, *q*, *t* and *t*, $J = 7$ Hz, 2 OEt), 6.07 (*s*, OMe), 6.18 (*s*, OMe), 6.23 (*s*, OMe).

Synthesis of petrostyrene diethyl ether (**1g**). (*a*) *Preparation of 2,5'-diethoxy-2',3',4'-trimethoxychalcone* (**3c**). 2,5-Dihydroxy-3,4-dimethoxyacetophenone (6.0 g) and EtI (5.5 g) etc., as described above, gave 5-ethoxy-2-hydroxy-3,4-dimethoxyacetophenone (3.9 g), oil, bp 120° (bath temp., 0.1 mm) [Found: C, 59.74; H, 6.76. $C_{12}H_{16}O_5$ requires: C, 59.99, H, 7.61%]. ν_{max} (cm^{-1}): 630. PMR (τ): −2.33 (*s*, OH-2), 3.07 (*s*, H-6), 5.98 and 8.58 (resp. *q* and *t*, $J = 7$ Hz, OEt), 5.99 (*s*, OMe), 6.09 (*s*, OMe), 7.44 (*s*, Ac). This compound (2.7 g) and MeI (5 ml) etc., as described above, gave 5-ethoxy-2,3,4-trimethoxyacetophenone (2.8 g) oil, bp 140° (bath temp., 0.1 mm). [Found: C, 61.43; H, 7.36. $C_{13}H_{18}O_5$ re-

quires: C, 61.40; H, 7.14%]. ν_{max} (cm^{-1}): 1660. PMR (τ): 2.92 (*s*, H-6), 5.91 and 8.56 (resp. *q* and *t*, $J = 7$ Hz, OEt), 6.02 (*s*, OMe), 6.08 (*s*, 2 OMe), 7.36 (*s*, Ac). This compd (1.34 g), salicylaldehyde ethyl ether (0.8 g), EtOH (5 ml) and KOH (5 g) in H_2O (10 ml), as described above, gave **3c** (1.9 g), yellow oil, bp 180° (bath temp., 0.1 mm). [Found: C, 68.19; H, 6.91. $C_{22}H_{26}O_6$ requires: C, 68.38; H, 6.78%]. ν_{max} (cm^{-1}): 1650. PMR (τ): 1.93 and 2.37 (2*d*, $J = 16$ Hz, H-α,β), 2.3–3.3 (*m*, H-3,4,5,6), 2.97 (*s*, H-6'). 5.88, 8.52 and 8.54 (resp. 2 *q*, *t*, *t*, $J = 7$ Hz, 2 OEt), 6.02 (*s*, 3 OMe).

(b) *Preparation of* E-1-(5-*ethoxy*-2,3,4-*trimethoxybenzyl*)-2-(2-*ethoxyphenyl*)-*ethylene* (**1g**). **3c** (0.96 g), $LiAlH_4$ (1 g) in Et_2O (10 ml) and $AlCl_3$ (5 g) in Et_2O (20 ml), as described above, gave **1g** (145 mg), oil, bp 180° (bath temp., 0.1 mm). [Found: C, 71.23; H, 7.55. $C_{22}H_{28}O_5$ requires: C, 70.94; H, 7.58%], identical with the diethyl ether of natural petrostyrene.

REFERENCES

1. Gregson, M., Ollis, W. D., Sutherland, I. O., Gottlieb, O. R. and Magalhães, M. T. (1978) *Phytochemistry* **17**, 1375.
2. Gregson, M., Kurosawa, K., Ollis, W. D., Redman, B. T., Roberts, R. J., Sutherland, I. O., Oliveira, A. B. de, Eyton, W. B., Gottlieb, O. R. and Dietrichs, H. H. (1968) *Chem. Commun.* 1390.
3. Erdtman, H. (1939) *Naturwissenschaften* **27**, 130; *Ann. Chem.* **539**, 116.
4. Matos, F. J. de A., Gottlieb, O. R. and Andrade, C. H. S. (1975) *Phytochemistry* **14**, 825.
5. Barnes, M. F., Ollis, W. D., Sutherland, I. O., Gottlieb, O. R. and Magalhães, M. T. (1965) *Tetrahedron* **21**, 2707.
6. Ollis, W. D. and Gottlieb, O. R. (1968) *Chem. Commun.* 1396.
7. Oliveira, A. B. de, Gottlieb, O. R., Ollis, W. D. and Rizzini, C. T. (1971) *Phytochemistry* **10**, 1863.
8. Eyton, W. B., Ollis, W. D., Fineberg, M., Gottlieb, O. R., Guimarães, I. S. de S. and Magalhães, M. T. (1965) *Tetrahedron* **21**, 2697.
9. Balakrishna, S., Raw, M. M. and Seshadri, T. R. (1962) *Tetrahedron* **18**, 1503.
10. Baker, W. (1941) *J. Chem. Soc.* 662.
11. Bargellini, G. and Oliverio, A. (1942) *Chem. Ber.* **75B**, 2083.
12. Bredereck, H., Henning, I. and Rau, W. (1953) *Chem. Ber.* **86**, 1085.
13. Khanna, R. N. and Seshadri, T. R. (1963) *Indian J. Chem.* **1**, 385.
14. Baker, W. and Brown, N. C. (1948) *J. Chem. Soc.* 2303.