Irradiation of Tetrabromocyclopentadienone Dimer (1) (See Table II). A solution of 1 g of 1 in 450 mL of solvent was swept thoroughly with nitrogen, irradiated for 18 h, and monitored by IR and/or UV spectroscopy until the starting material was practically gone. The solvent was evaporated and the residue chromatographed on silica gel. The hexabromoindenone (2), mp 198 °C dec[2] was eluted with petroleum ether while the cage (3 partly hydrated) emerged with $CHCl_3$/EtOAc (1:1). The data for the new compounds are given below.

Octabromopentacyclo[5.3.0.0^{2,5}.0^{3,9}.0^{4,8}]deca-6,10-dione (3): purified by sublimation; IR (KBr) ν_{max} 1800 (CO) cm^{-1}; mass spectrum, m/e 712 (M^+ - Br), 684 (-CO), 604 (-Br).

Dihydrate of 3 (8): isolated from wet acetone and recrystallized from chloroform; IR (KBr) ν_{max} 3640-2800 (OH) cm^{-1}; mass spectrum identical with that of 3; ^{13}C NMR, see Table I.

Anal. Calcd for $C_{10}H_4O_4Br_8$: C, 14.51; H, 0.49; Br, 77.26. Found: C, 14.33; H. 0.85; Br, 76.96.

Tetramethyl Diketal of 3 (9). This was obtained by treating 8, suspended in ether, with an ethereal solution of diazomethane. The mixture was stirred overnight and, after evaporation of the solvent in the hood, the residue was chromatographed on neutral alumina. The diketal (9) was eluted with CCl_4 and isolated in 1% yield: IR (KBr) ν_{max} 2980, 2940, 2840 (CH) cm^{-1}; mass spectrum, m/e 803 (M^+ - Br); ^1H NMR ($CDCl_3$, Me_4Si) δ 3.62 (6 H, s), 3.78 (6 H, s).

Acknowledgment. One of us (C.D.) acknowledges a Bat-Sheva de Rotschild teachers research grant for a sabbatical stay at Tel-Aviv University. Mrs. Sarah Weinman and Mrs. Yardena Aboudi provided skillful technical assistance.

Registry No. 1, 31838-43-4; 2, 31838-44-5; 3, 76215-24-2; 8, 76215-25-3; 9, 76215-26-4; 10, 76252-05-6.

(8) B. Fuchs and G. Scharf, *Isr. J. Chem.*, 16, 335 (1977), and a discussion therein on this subject.

Notes

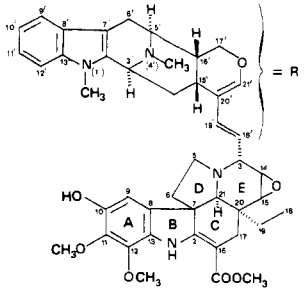
Structure Analysis by Carbon-13 Nuclear Magnetic Resonance Spectroscopy of Pandicine, a Novel Bisindole Alkaloid from *Pandacastrum saccharatum* Pichon[1]

Christiane Kan-Fan, Georges Massiot,*[2] Bhupesh C. Das,* and Pierre Potier

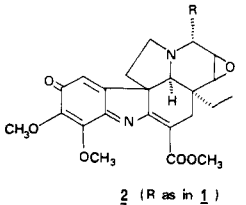
Institut de Chimie des Substances Naturelles, CNRS, 91190 Gif-sur-Yvette, France

Received August 28, 1980

From the leaves of *Pandacastrum saccharatum* Pichon (*Apocynaceae*) we have isolated a novel bisindole alkaloid, pandicine (1), possessing a hitherto unknown highly oxygenated tabersonine skeleton linked at its C(3) position to the C(18′) of a macroline[3] moiety. We report the structure 1 of pandicine, established mainly from an analysis of its ^1H and ^{13}C NMR spectra along with the consideration of its mass spectral fragmentation pattern. Although the chemistry of pandicine was little explored due to paucity of material, its facile oxidation to the iminoquinone 2 was singularly helpful for the structural elucidation.



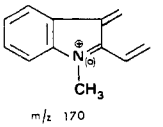
1



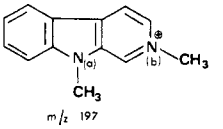
2 (R as in 1)

Pandicine was obtained as a brown amorphous solid which resisted all attempts toward crystallization. Determination of its specific rotation was precluded due to the immediate development of a dark color (coloration may be due to traces of 2 and possibly other oxidation products) whenever pandicine was dissolved in an organic solvent. The mass spectrum of pandicine (1) showed the molecular ion peak at m/z 746.3698, corresponding to the formula $C_{44}H_{50}N_4O_7$ (calcd 746.3679). The UV spectrum of 1 showed maxima (EtOH) at 231, 234, 297, 307, and 342 nm with a shoulder at 250 nm. In acid medium the maxima were observed at 228, 265, 297, 304, and 342 nm while in alkaline medium there was a markedly visible bathochromic shift above 350 nm with broadening of absorption but no appreciable change below 300 nm. Compound 2, which was obtained in quantitative yield by swirling a chloroform solution of 1 with activated MnO_2, showed a very different UV spectrum, having maxima at 233, 260, and 396 nm with a shoulder at 288 nm. The IR spectrum of 1 showed complex C=O and C=C absorptions at 1680, 1640, and 1610 cm^{-1} and a broad NH/OH band at 3400 cm^{-1}. The latter disappeared in the IR spectrum of 2 while strong bands were observed at 1690, 1640, and 1580 cm^{-1}.

The mass spectrum of pandicine (1) displayed fragmentation peaks at m/z 170 and 197 (base peak) typical



m/z 170



m/z 197

of the $N_{(a)}$–CH_3 and $N_{(b)}$–CH_3 macroline skeleton.[3] Complementary peaks at m/z 290 and 456 (M - 290) may be attributed to well-known retro-Diels–Alder opening of ring C followed by cleavage of the C(5)–C(6) bond.[4]

The complete structural elucidation of pandicine (1) followed from an analysis of its ^{13}C NMR spectrum. Resonances due to the 44 carbons appeared as distinct

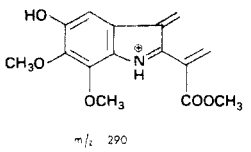
(1) Part 21 in the series "Plantes Malgaches". For Part 20, see N. Langlois, L. Diatta, and R. Z. Andriamialisoa, *Phytochemistry*, 18, 467 (1979).

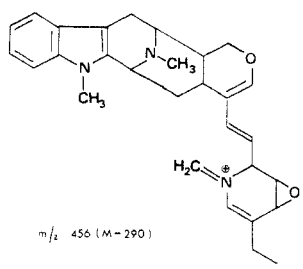
(2) Present address: Faculté de Pharmacie, 51 rue Cognac-Jay, 51096 Reims Cedex, France.

(3) M. Hesse, H. Hürzeler, C. W. Gemenden, B. S. Joshi, W. I. Taylor, and H. Schmid, *Helv. Chim. Acta*, 48, 689 (1965).

(4) H. Budzikiewicz, C. Djerassi, and D. H. Williams in "Structure Elucidation of Natural Products by Mass Spectrometry", Vol. I, Holden-Day, Inc., San Francisco, CA, 1964.

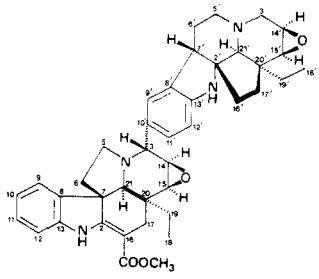
0022-3263/81/1946-1481$01.25/0



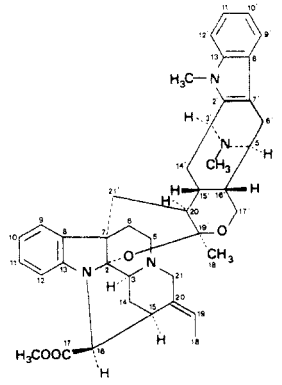


signals and their proton-resonance-decoupled chemical shift values (Table I) as well as the single-frequency off-resonance decoupled multiplicities are in full agreement with the proposed structure 1.

Previous chemical-shift information on the two bisindole alkaloids criophylline (3)[5] and villalstonine (4)[6] largely



3



4

facilitated the analysis of the ^{13}C NMR spectrum of pandicine. Criophylline is constituted of a 3-substituted 14,15β-epoxy tabersonine moiety while villalstonine contains a macroline unit in the molecule. Comparison of the ^{13}C NMR spectrum of pandicine with that of criophylline[5] clearly revealed all the nonaromatic ^{13}C shifts of the substituted tabersonine moiety. Thus, the chemical shift values of C(2), C(5), C(6), C(7), C(14), C(15), C(16), C(17), C(18), C(19), C(20), C(21), and the $COOCH_3$ carbons of pandicine are essentially the same as those found for the corresponding carbons of criophylline. The only carbon which appears to be affected is C(3) and its upfield shift (δ 55.1) in comparison to the corresponding carbon (δ 58.1) of criophylline may be attributed to a different olefinic substituent at this center. The excellent correlation of all the carbons of the ring E of pandicine (1) with those of criophylline ascertains the depicted configuration of the 14,15-epoxide ring and the 3α-substitution. The chemical shift assignment of the aromatic carbons of the substituted tabersonine portion of pandicine (1) was based on the chemical shift additivity rules.[7] The location of the hydroxyl at C(10) and the methoxyls at C(11) and C(12) also finds support from the following arguments. If the only methine carbon of the aromatic ring were situated between two ortho substituents (hydroxy or methoxy), it would be subject to strong shielding and would consequently resonate more upfield than at 104 ppm attributed to C(9). Furthermore, the unusual methyl carbon chemical shifts observed at 60.5 and 61.0 ppm are only consistent with the highly hindered OCH_3 groups forced out of the plane of the aromatic ring due to their occurrence in an ortho arrangement.

Table I. ^{13}C NMR Chemical Shifts[a] of Pandicine (1)

C(2)	164.8	C(2′)	133.3[c]
C(3)	55.1[b]	C(3′)	54.9[b]
C(5)	48.4	C(5′)	53.6[b]
C(6)	42.2	C(6′)	22.7
C(7)	54.0	C(7′)	106.5
C(8)	134.0[c]	C(8′)	126.6
C(9)	104.2	C(9′)	118.2[e]
C(10)	138.7[d]	C(10′)	120.8
C(11)	137.0[d]	C(11′)	118.0[e]
C(12)	143.8	C(12′)	108.7
C(13)	126.6	C(13′)	136.8[d]
C(14)	56.4	C(14′)	32.7
C(15)	54.4[b]	C(15′)	39.1[f]
C(16)	90.4	C(16′)	41.9[f]
C(17)	24.3	C(17′)	67.0
C(18)	7.3	C(18′)	115.5
C(19)	27.3	C(19′)	131.4
C(20)	36.0	C(20′)	115.9
C(21)	62.5	C(21′)	145.7
OCH_3 (ester)	50.9	$N_{(1')}CH_3$	29.0
OCH_3 (aromatic)	60.5, 61.0	$N_{(4')}CH_3$	23.0
C=O (ester)	168.8		

[a] The spectrum was recorded in $CDCl_3$ solution at 22.63 MHz on a Bruker HX 90E Fourier transform spectrometer, using Me_4Si as internal standard. Chemical shifts (parts per million) are with respect to Me_4Si. [b-f] These assignments may be interchanged.

Examples of similar results in the literature[8] have long been noted by one of us (G.M.) and also recently reported by Wenkert et al.[9] Thus, it has been observed that anisoles having at least two large ortho substituents have their methyl carbon signals shifted well above 58 ppm. The origin of this phenomenon is not clear at the moment but it may be due to the aromatic ring, to the heteroatom lone-pair anisotropies, or to a combination of both. Finally, this arrangement of the oxygenated substituents accounts very well for the facile transformation of 1 into 2 and also for the ^1H NMR shift of H(9) from 6.34 ppm in 1 to 5.63 ppm in 2 (Table II).

As regards the carbons belonging to the macroline portion of pandicine, all the carbons except C(18′), C(19′), C(20′), and C(21′) could be identified in a straightforward manner through comparison of its ^{13}C NMR spectrum with that of villalstonine.[6] However, appreciable deviation was observed for the resonance of $N_{(4')}$–CH_3 (−4.0 ppm), but identical change in the shift value was also noted for the similarly situated $N_{(4')}$–CH_3 carbon of the recently reported bisindole alkaloid macrocarpamine.[10] In contrast to their resonance positions in villalstonine, the δ values of C(18′), C(19′), C(20′), and C(21′) of pandicine (1) are now displaced to 115.5, 131.4, 115.9, and 145.7 ppm, respectively, reflecting the structural alteration in the molecule of pandicine (1). The protons attached to these carbons showed signals at 5.05 (dd, J = 16, 8 Hz), 5.85 (d, J = 16 Hz), and 6.41 (s) ppm. These data are compatible with an exocyclic trans-disubstituted C(18′)–(C19′) double bond forming a diene system with the cyclic olefinic bond be-

(5) A. Cavé, J. Bruneton, A. Ahond, A.-M. Bui, H.-P. Husson, C. Kan, G. Lukacs, and P. Potier, *Tetrahedron Lett.*, 5081 (1973).
(6) B. C. Das, J.-P. Cosson, G. Lukacs, and P. Potier, *Tetrahedron Lett.*, 4299 (1974).
(7) J. B. Stothers, "Carbon-13 NMR Spectroscopy", Academic Press, New York, 1972.
(8) P. Yates, F. N. Mac Lachlan, I. D. Rae, M. Rosenberger, A. G. Szabo, C. R. Willis, M. P. Cava, M. Behforouz, M. V. Lakshikantham, and W. Zeiger, *J. Am. Chem. Soc.*, **95**, 7842 (1973); R. H. Levin, J.-Y. Lallemand, and J. D. Roberts, *J. Org. Chem.*, **38**, 1983 (1973); N. Aprin, J. Favre-Bonvin, and S. Thivend, *Tetrahedron Lett.*, 819 (1977); A. Arnone, L. Camarda, L. Merlini, and G. Nasini, *J. Chem. Soc., Perkin Trans. 1*, 2118 (1977); A. D. Harmon, J. M. Edwards, and R. J. Highet, *Tetrahedron Lett.*, 4471 (1977); M. Dobler and W. Keller-Schierlein, *Helv. Chim. Acta*, **60**, 178 (1977).
(9) A. F. Erasmusson, R. J. Ferrier, N. C. Franca, H. E. Gottlieb, and E. Wenkert, *J. Chem. Soc., Perkin Trans. 1*, 492 (1977).
(10) F. Mayerl and M. Hesse, *Helv. Chim. Acta*, **61**, 337 (1978).

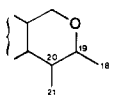
Table II. ^{1}H NMR Data of 1-4[a]

	1	2	3		1	2	4
H-3′	4.02	4.05 br t (2)	3.95 br t	H-3	3.93	3.93 dd	3.60 (d)-2.92 (d)
H-5′	3.10 d	3.19 d (7)	2.92 d	H-5α	2.86 dd	2.84 dd (10, 6.5)	3.02 m
H-6′α	3.30 dd	3.38 dd (17.5, 7)	3.26 dd	H-5β	2.79 ddd	2.54 ddd (10, 11, 5)	2.70 m
H-6′β	2.56 d	2.68 d (17.5)	2.47 d	H-6α	2.00 dt	2.00 dt (11, 11, 6.5)	2.10 dt
H-9′	7.40 br d	7.48 br d (7)	-	H-6β	1.65	1.62 dd (11, 5)	1.72 dd
H-10′	6.95 br t	7.02 br t (7)	-	H-9	6.34 s	5.63 s	-
H-11′	7.06 br t	7.13 br t (7)	-	H-14	3.09 br d	3.15 dd (3, 1)	3.28 br d
H-12′	7.32 br d	7.24 br d (7)		H-15	3.02 d	3.07 d (3)	3.06 d
H-13′	1.67		2.40 m	H-17α	2.58 br d	2.91 br d (16.5)	2.70 d
H-14′	2.15	2.10-2.20 m	1.46 br d	H-17β	2.40 d	2.73 d (16.5)	2.52 d
H-15′	2.20		2.22 m	H-18	0.69 m	0.81 m	0.72 t
H-16′	2.11		2.06 m	H-19	0.82 m		0.98 m
H-17′α	4.40 t	4.50 t (11)	4.12 t	H-21	2.50 s	2.30 br s	2.42 s
H-17′β	4.00 dd	4.10 dd (11, 3.5)	3.92 dd	OCH_3	3.71 s	3.93 s	-
H-18′	5.05 dd	5.06 dd (16, 8)	-		3.87 s	4.08 s	-
H-19′	5.85 d	6.02 d (16)	-		3.89 s	4.27 s	-
H-21′	6.41 s	6.56 s	-				
N(1′)CH_3	3.62 s	3.65 s	3.64 s				
N(4′)CH_3	2.39 s	2.39 s	2.30 s				

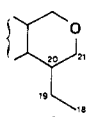
[a] $CDCl_3$, Me_4Si = 0 ppm, s = singlet, d = doublet, t = triplet, m = multiplet. Numbers in parentheses are the coupling constants J (hertz). For clarity the J values for 1, 3, and 4 are omitted, but they are roughly equal to the corresponding values observed for 2.

tween C(20′) and C(21′), the latter carbon being linked to an oxygen as evident from its chemical shift: C(21′) at 145.7 ppm and H(21′) at 6.41 ppm.

Of the two biogenetically possible arrangements, 5 and 6, of the C(18′) → C(21′) chain linkage of the macroline moiety, only the latter (6) can accommodate the above-mentioned facts.

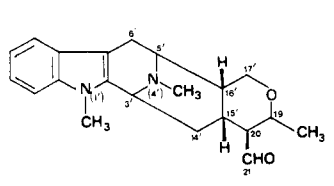


5

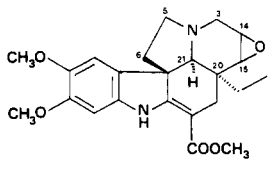


6

The same conclusions could be reached from a close examination of the 240-MHz ^{1}H NMR spectra[11] (Table II) of 1 and 2. Thus, irradiation of H(18′) at 5.06 ppm in the spectrum of 1 transformed the H(3) at 3.93 ppm into a doublet (J = 1 Hz), which is coupled in turn to the AB system formed by H(14) and H(15) [δ 3.15 (dd, J = 3, 1 Hz), 3.07 (d, J = 3 Hz)]. These results were obtained by direct irradiation, but H(3), which is hidden in the congested methoxyl proton region, could be recognized by using the difference spectroscopy technique.[12] This procedure allowed identification of all the 48 protons in 2 and it was interesting to note that in the nonaromatic region the spectrum was almost a superimposition of the spectra of the two monoindole alkaloids talcarpine[13] (7) and hazuntinine[14] (8), most of the protons having the same shapes and the same chemical shifts.



7



8

(11) We are grateful to Drs. S. K. Kan and P. Gonord for 240-MHz ^{1}H NMR spectra.

(12) G. Massiot, S. K. Kan, P. Gonord, and C. Duret, *J. Am. Chem. Soc.*, **97**, 3227 (1975).

(13) J. Naranjo, M. Pinar, M. Hesse, and H. Schmid, *Helv. Chim. Acta*, **55**, 752 (1972).

(14) E. Wenkert, D. W. Cochran, E. W. Hagaman, F. M. Schell, N. Neuss, A. S. Katner, P. Potier, C. Kan, M. Plat, M. Koch, H. Mehri, J. Poisson, N. Kunesch, and Y. Rolland, *J. Am. Chem. Soc.*, **95**, 4990 (1973).

The above results lead us to propose structure 1 for pandicine with the depicted stereochemistry. Although we have no proof for the relative stereochemistry of the two moieties present in pandicine (1), it seems reasonable to assume that they have the natural configurations of talcarpine (7) and hazuntinine (8).

The highly substituted aromatic ring of the tabersonine moiety and a modified macroline unit in the form of anhydromacrosalhine[10] are the novel features of the structure of pandicine (1).

Registry No. 1, 76282-39-8; 2, 76282-40-1; 3, 52659-53-7; 4, 2723-56-0.

Dienophilic Reactions of 3-[(Trimethylsilyl)oxy]-3-buten-2-one

Robert J. Ardecky, Francis A. J. Kerdesky, and Michael P. Cava*

Department of Chemistry, University of Pennsylvania, Philadelphia, Pennsylvania 19104

Received June 12, 1980

The monoenol derivatives of the inexpensive diketone biacetyl are α-oxygenated analogues of methyl vinyl ketone, and as such they should be synthetically useful dienophiles in [4 + 2] addition reactions. The first example of such a reaction was reported in 1966, using 3-acetoxy-3-buten-2-one.[1] Since the preparation of the latter from biacetyl afforded a low yield after a tedious purification,[1] we decided to examine the dienophilic properties of 3-[(trimethylsilyl)oxy]-3-buten-2-one (1, TBO), the readily prepared mono(trimethylsilyl) derivative of biacetyl.[2,3] The only Diels–Alder reactions of TBO hitherto reported are its thermal dimerization and its addition to the bis(trimethylsilyl) derivative of biacetyl.[3]

We have studied the reaction of a series of representative dienes with excess TBO. The initial adducts were not

(1) Wharton, P. S.; Aw, B. T. *J. Org. Chem.* **1966**, **31**, 3789.

(2) Barnier, J. P.; Garnier, B.; Girard, C.; Denis, J. M.; Salaun, J.; Conia, J. M. *Tetrahedron Lett.* **1973**, 1747.

(3) Murai, S.; Ryu, I.; Kadono, Y.; Katayama, H.; Kondo, K.; Sonoda, N. *Chem. Lett.* **1977**, 1219.

0022-3263/81/1946-1483$01.25/0