C4—C5	1.350 (4)	C20—C21	1.381 (7)
C4—C8	1.492 (4)	C21—C22	1.384 (5)
C5—C6	1.495 (5)		
N1—S1—C1	97.4 (2)	O4—C8—C4	111.1 (3)
O1—S1—C1	105.0 (2)	O3—C8—C4	126.1 (3)
O1—S1—N1	112.6 (2)	O3—C8—O4	122.9 (3)
C8—O4—C9	115.0 (2)	O4—C9—C10	108.5 (3)
S1—N1—C16	119.5 (3)	C9—C10—C15	121.0 (3)
C3—N2—C4	132.2 (3)	C9—C10—C11	120.3 (3)
C1—N2—C4	133.6 (3)	C11—C10—C15	118.7 (3)
C1—N2—C3	94.2 (3)	C10—C11—C12	121.2 (3)
S1—C1—N2	111.1 (2)	C11—C12—C13	120.2 (4)
N2—C1—C2	87.9 (2)	C12—C13—C14	119.9 (4)
S1—C1—C2	117.4 (2)	C13—C14—C15	120.4 (4)
C1—C2—C3	85.2 (2)	C10—C15—C14	119.6 (4)
N2—C3—C2	92.6 (3)	N1—C16—C17	113.8 (3)
O2—C3—C2	135.9 (3)	C16—C17—C22	118.4 (3)
O2—C3—N2	131.5 (3)	C16—C17—C18	122.9 (3)
N2—C4—C8	116.2 (3)	C18—C17—C22	118.6 (3)
N2—C4—C5	119.0 (3)	C17—C18—C19	120.4 (3)
C5—C4—C8	124.8 (3)	C18—C19—C20	120.4 (4)
C4—C5—C7	124.0 (3)	C19—C20—C21	119.6 (4)
C4—C5—C6	121.6 (3)	C20—C21—C22	120.3 (4)
C6—C5—C7	114.5 (3)	C17—C22—C21	120.6 (4)

Table 3. *Hydrogen-bonding geometry* (Å, °)

D	H	*A*	*D*—H	*D*···*A*	*D*—H···*A*
N1	H1N1	O2^{i}	0.959 (2)	2.957 (4)	163.3 (3)

Symmetry code: (i) $x-1, y, z$.

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Lists of structure factors, anisotropic thermal parameters, H-atom coordinates and complete geometry have been deposited with the British Library Document Supply Centre as Supplementary Publication No. SUP 71201 (21 pp.). Copies may be obtained through The Technical Editor, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England. [CIF reference: KA1032]

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Structure of an Antimalarial Alkaloid, Jatrorrhizine

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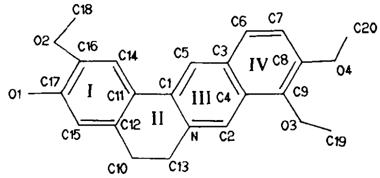
Abstract

Jatrorrhizine is a naturally occurring antimalarial alkaloid. The structure of jatrorrhizine, determined from its chloride (5,6-dihydro-3-hydroxy-2,9,10-trimethoxydibenzo[*a*,*g*]quinolizinium chloride dihydrate), consists of four fused rings. The conformation of ring I (benzo) is a boat and ring II (dihydropyrido moiety) is deviated from its twist-boat conformation. The planar rings III (pyrido moiety) and IV (benzo) are very similar to the quinoline part of several quinine derivatives. Hydrogen-bonded water molecules stabilize the crystal.

Comment

The title compound, jatrorrhizine (1) was isolated as its chloride from the bark of *Enantia chlorantha*. The protoberberine alkaloid, jatrorrhizine was tested for antimalarial activity *in vitro* against *Plasmodium falciparum* and *in vivo* against *Plasmodium berghei*, and exhibited a potency comparable to that of quinine *in vitro* but not *in vivo*.



(I)

The antimalarial compound jatrorrhizine contains a moiety closely resembling the quinoline moiety of several quinine derivatives (Dupont, Konour, Lewinski & Oleksyn, 1985). The bond lengths and bond angles of rings III and IV are very close to those found in the quinoline part of cinchona alkaloids. However, the main differences are as follows: the methoxy group normally attached to the

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C(7) position is shifted to C(8); N and C(2) are interchanged in the structure with respect to cinchona. Unlike other antimalarial compounds, there is an additional methoxy group at C(9) in jatrorrhizine. Both rings III and IV are planar and almost coplanar. The additional methoxy group O(3)—C(19) is not coplanar with rings III and IV. The methoxy group O(4)—C(20) shows a tendency to be coplanar with rings III and IV, probably as a consequence of some degree of conjugation between O(4) and ring IV. This results in an enlargement of C(7)—C(8)—O(4) [124.5 (9)°], a narrowing of C(9)—C(8)—O(4) [116.3 (8)°] and a shortening of C(8)—O(4) [1.352 (5)°], which is very similar to an antimalarial compound (Purzycka, Lipinska, Piotrowska & Oleksyn, 1985). The torsion angles around the bond O(4)—C(8) show that the bonds C(20)—O(4) and C(7)—C(8) are in mutual *cis* positions.

The conformation of ring I is a boat, as derived from ring-puckering parameters [$\varphi = -57.65$, $\theta = 96.72°$, $Q = 0.007$, $q_2 = 0.0077$, $q_3 = -0.0009$ Å (Cremer & Pople, 1975)]. But ring II deviates from its twist-boat conformation because of its position between two rings – a planar ring III and a ring I with boat conformation.

The water molecules are involved in three hydrogen bonds, twice as a donor with Cl [Cl···O(5) 3.17 (3), Cl···O(6) 3.08 (3) Å] and once as an acceptor [O(1)···O(6) 2.56 (1) Å]. There are no hyrogen bonds between the alkaloid molecules. The presence of the water molecules appears to stabilize the crystal.

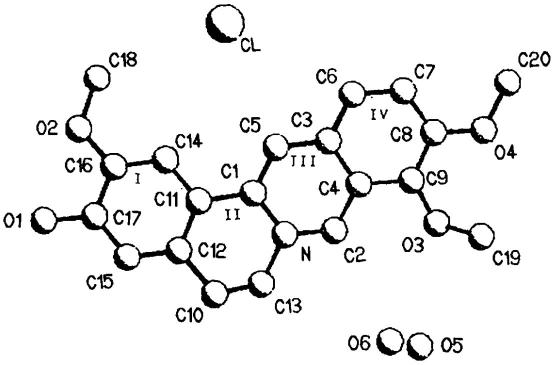

Fig. 1. A view of the jatrorrhizine molecule.

Experimental

Crystal data

$C_{20}H_{20}NO_4^+.Cl^-.2H_2O$
$M_r = 409.87$
Monoclinic
$P2_1/n$
$a = 7.736$ (8) Å
$b = 12.591$ (4) Å
$c = 20.196$ (7) Å
$\beta = 95.08$ (6)°

Mo $K\alpha$ radiation
$\lambda = 0.7135$ Å
Cell parameters from 14 reflections
$\theta = 10$–$18°$
$\mu = 0.228$ mm^{-1}
$T = 293$ K
Needles

$V = 1960$ (2) Å^3
$Z = 4$
$D_x = 1.39$ Mg m^{-3}
$D_m = 1.38$ Mg m^{-3}
Density measured by flotation in $C_6H_6/CHBr_3$

0.20 × 0.20 × 0.15 mm
Red
Crystal source: bark of *Enantia chlorantha*; alcohol solution

Data collection

Enraf-Nonius CAD-4 diffractometer
$\omega/2\theta$ scans
Absorption correction: none
3704 measured reflections
3163 independent reflections
2660 observed reflections [$I \geq 2.5\sigma(I)$]

$R_{\rm int} = 0.0572$
$\theta_{\rm max} = 24°$
$h = -9 \rightarrow 9$
$k = 0 \rightarrow 14$
$l = 0 \rightarrow 23$
2 standard reflections
frequency: 120 min
intensity variation: <2%

Refinement

Refinement on F
Final $R = 0.057$
$wR = 0.065$
$S = 1.2$
2660 reflections
328 parameters
Only coordinates of H atoms refined

$w = 1/[\sigma^2(F)+0.001174F^2]$
$(\Delta/\sigma)_{\rm max} = 0.389$
$\Delta\rho_{\rm max} = 0.27$ e Å^{-3}
$\Delta\rho_{\rm min} = -0.41$ e Å^{-3}
Atomic scattering factors from *International Tables for X-ray Crystallography* (1974, Vol. IV)

Table 1. *Fractional atomic coordinates and equivalent isotropic thermal parameters* (Å^2)

$$U_{\rm eq} = \tfrac{1}{3}\textstyle\sum_i\sum_j U_{ij}a_i^*a_j^*\mathbf{a}_i.\mathbf{a}_j.$$

	x	y	z	$U_{\rm eq}$
Cl	0.1178 (1)	0.8319	−0.0393	0.0568 (3)
C(1)	0.1828 (3)	0.5230 (2)	0.0781 (1)	0.0348 (8)
C(2)	0.2350 (4)	0.3566 (2)	0.0278 (1)	0.0376 (8)
C(3)	0.2852 (3)	0.5173 (2)	−0.0327 (1)	0.0357 (8)
C(4)	0.2856 (3)	0.4044 (2)	−0.0299 (1)	0.0358 (8)
C(5)	0.2343 (4)	0.5730 (2)	0.0225 (1)	0.0373 (9)
C(6)	0.3354 (4)	0.5666 (2)	−0.0905 (1)	0.0419 (9)
C(7)	0.3736 (4)	0.5067 (3)	−0.1432 (2)	0.045 (1)
C(8)	0.3688 (4)	0.3954 (2)	−0.1424 (1)	0.042 (1)
C(9)	0.3303 (4)	0.3434 (2)	−0.0845 (1)	0.039 (1)
C(10)	0.1695 (5)	0.4097 (2)	0.2000 (2)	0.047 (1)
C(11)	0.1272 (3)	0.5786 (2)	0.1367 (1)	0.0349 (9)
C(12)	0.1189 (4)	0.5249 (2)	0.1965 (1)	0.0397 (9)
C(13)	0.1189 (4)	0.3553 (2)	0.1356 (1)	0.045 (1)
C(14)	0.0861 (4)	0.6875 (2)	0.1329 (1)	0.0381 (9)
C(15)	0.0700 (4)	0.5795 (3)	0.2515 (2)	0.044 (1)
C(16)	0.0393 (4)	0.7413 (2)	0.1879 (1)	0.0381 (9)
C(17)	0.0312 (4)	0.6863 (2)	0.2485 (1)	0.0399 (9)
C(18)	0.0261 (6)	0.9066 (3)	0.1321 (2)	0.058 (1)
C(19)	0.4516 (7)	0.1699 (4)	−0.0988 (3)	0.074 (2)
C(20)	0.4206 (6)	0.3805 (4)	−0.2569 (2)	0.063 (1)
N	0.1863 (3)	0.4126 (2)	0.0784 (1)	0.0356 (7)
O(1)	−0.0171 (3)	0.7435 (2)	0.3005 (1)	0.0528 (8)
O(2)	−0.0045 (3)	0.8459 (2)	0.1896 (1)	0.0487 (7)
O(3)	0.3186 (3)	0.2368 (2)	−0.0780 (1)	0.0541 (7)
O(4)	0.3951 (3)	0.3329 (2)	−0.1950 (1)	0.0586 (9)
O(5)	0.2410 (4)	0.0488 (2)	0.0308 (2)	0.072 (1)
O(6)	0.5256 (5)	0.1339 (4)	0.0933 (2)	0.105 (2)

Table 2. *Geometric parameters* (Å, °)

C(1)—C(5)	1.377 (5)	C(10)—C(12)	1.502 (6)
C(1)—C(11)	1.472 (5)	C(10)—C(13)	1.491 (6)
C(1)—N	1.390 (6)	C(11)—C(12)	1.391 (5)

C(2)—C(4)	1.398 (5)	C(11)—C(14)	1.408 (6)
C(2)—N	1.323 (5)	C(12)—C(15)	1.387 (6)
C(3)—C(4)	1.423 (6)	C(13)—N	1.494 (5)
C(3)—C(5)	1.403 (5)	C(14)—C(16)	1.377 (5)
C(3)—C(6)	1.407 (5)	C(15)—C(17)	1.378 (6)
C(4)—C(9)	1.412 (5)	C(16)—C(17)	1.412 (5)
C(6)—C(7)	1.358 (6)	C(16)—O(2)	1.361 (5)
C(7)—C(8)	1.402 (6)	C(17)—O(1)	1.353 (5)
C(8)—C(9)	1.395 (5)	C(18)—O(2)	1.427 (6)
C(8)—O(4)	1.352 (5)	C(19)—O(3)	1.420 (1)
C(9)—O(3)	1.352 (5)	C(20)—O(4)	1.416 (6)
C(2)—C(4)—C(9)	121.5 (8)	C(1)—N—C(2)	122.4 (9)
C(1)—C(5)—C(3)	122.8 (8)	C(16)—O(2)—C(18)	116.0 (9)
C(3)—C(6)—C(7)	120.8 (8)	C(9)—O(3)—C(19)	120.2 (9)
C(6)—C(7)—C(8)	123.0 (1)	C(8)—O(4)—C(20)	119.3 (8)
C(7)—C(8)—O(4)	124.5 (9)	C(1)—C(11)—C(14)	120.0 (9)
C(7)—C(8)—C(9)	119.1 (8)	C(8)—C(9)—O(3)	125.0 (1)
C(9)—C(8)—O(4)	116.3 (8)	C(4)—C(9)—O(3)	117.0 (1)
C(4)—C(9)—C(8)	118.9 (7)	C(12)—C(10)—C(13)	110.8 (8)
C(10)—C(12)—C(15)	121.9 (8)	C(10)—C(12)—C(11)	118.6 (8)
C(10)—C(13)—N	111.7 (8)	C(12)—C(11)—C(14)	119.5 (9)
C(11)—C(14)—C(16)	120.6 (9)	C(11)—C(12)—C(15)	119.4 (8)
C(12)—C(15)—C(17)	122.0 (1)	C(1)—C(11)—C(12)	120.4 (8)
C(14)—C(16)—O(2)	126.0 (1)	C(11)—C(1)—N	118.6 (9)
C(14)—C(16)—C(17)	119.5 (8)	C(5)—C(1)—N	117.0 (9)
C(17)—C(16)—O(2)	115.5 (8)	C(5)—C(1)—C(11)	124.4 (7)
C(15)—C(17)—C(16)	119.4 (9)	C(4)—C(2)—N	122.3 (8)
C(16)—C(17)—O(1)	116.6 (8)	C(6)—C(3)—C(4)	118.3 (8)
C(15)—C(17)—O(1)	124.0 (9)	C(5)—C(3)—C(6)	123.8 (7)
C(2)—N—C(13)	118.8 (8)	C(5)—C(3)—C(4)	117.9 (8)
C(1)—N—C(13)	118.6 (8)	C(2)—C(4)—C(3)	117.6 (9)
C(3)—C(4)—C(9)—C(8)	−177.9	C(4)—C(9)—C(8)—C(7)	175.7
C(1)—C(5)—C(3)—C(4)	−178.9	C(9)—C(8)—C(7)—C(6)	−177.3
C(1)—N—C(2)—C(4)	−179.6	C(7)—C(6)—C(3)—C(4)	176.4
C(3)—C(4)—C(2)—N	179.3	N—C(1)—C(11)—C(12)	164.6
C(3)—C(5)—C(1)—N	178.7	N—C(13)—C(10)—C(12)	137.1
C(2)—C(4)—C(3)—C(5)	180.0	C(11)—C(1)—N—C(13)	174.8
C(2)—N—C(1)—C(5)	−179.4	C(11)—C(12)—C(10)—C(13)	−141.1
C(6)—C(3)—C(4)—C(9)	−178.2	C(8)—C(7)—C(6)—C(3)	−178.6
C(1)—N—C(13)—C(10)	−141.1	C(1)—C(11)—C(12)—C(10)	179.3
C(11)—C(12)—C(15)—C(17)	−179.2	C(11)—C(14)—C(16)—C(17)	−179.4
C(12)—C(15)—C(17)—C(16)	179.1	C(12)—C(11)—C(14)—C(16)	179.4
C(14)—C(16)—C(17)—C(15)	−179.8	C(14)—C(11)—C(12)—C(15)	179.9

The structure was solved by direct and Fourier methods: *SHELXS*86 (Sheldrick, 1986) used with 304 *E*'s > 1.2. Most of the C atoms were located from the best *E* map. A subsequent difference Fourier map based on these atoms revealed the rest of the non-H atoms in the asymmetric unit. The structure was refined by full-matrix least squares using *SHELX*76 (Sheldrick, 1976).

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Lists of structure factors, anisotropic thermal parameters, H-atom coordinates and complete geometry have been deposited with the British Library Document Supply Centre as Supplementary Publication No. SUP 71129 (24 pp.). Copies may be obtained through The Technical Editor, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England. [CIF reference: CD1033]

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5,10,15,20-Tetrakis(*p*-chlorophenyl)-porphyrin

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Abstract

The title molecule, 2,7,12,17-tetrakis(4-chlorophenyl)-21,22,23,24-tetraazapentacyclo[16.2.1.1^{3,6}.1^{8,11}.1^{13,16}]tetracosa-1,3(22),4,6,8,10,12,14,16(24),17,19-undecaene, is crystallographically centrosymmetric and the dihedral angle between the two pyrrole ring planes is 5.0 (4)°. The molecular structure is a consequence of steric hinderances between the α-H atoms of the pyrrole and the *ortho*-H atoms of the phenyl rings. The dihedral angles between the pyrrole and phenyl rings are 54.8 (4) and 111.1 (3)°, respectively. The sums of the angles around *meso*-C atoms are 360° and the average bond length between *meso* and adjacent macrocyclic ring C atoms is 1.398 (6) Å.

Comment

Porphyrins and their metal complexes are used as catalysts (Ostovic & Bruice, 1989), photosensitizers (Milgrom, 1984; Davila & Harriman, 1990) or useful synthetic precursors to mono-oxygenase and allosteric enzyme model systems (Tabushi & Kugimiya, 1986). The substituents in porphyrins, bonded to *meso*-C atoms, are effective in forming metal complexes (Ulman, Fisher & Ibers, 1982).

The X-ray crystallographic structure determinations of some synthetic free-base porphyrins have been reported, *e.g.* porphine (Chen & Tulinsky, 1972), tetraphenyl porphyrin (TPP) (Silvers & Tulinsky, 1967) and tetra-*n*-propylporphyrin