CHEMISTRY LETTERS, pp. 1399-1402, 1983. © The Chemical Society of Japan 1983

STRUCTURE AND CONFORMATION OF FURANOCYCLONONENE DITERPENOIDS FROM THE SEAWEED DICTYOTA DICHOTOMA

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The structure of new diterpenoids dictyofuran T and dictyofuran C, isolated from the brown seaweed Dictyota dichotoma, has been determined on the basis of spectral and chemical means.

In a previous paper we reported on structure and conformation of new diterpenes containing the 1,4-cyclononadiene skeleton, isolated from the brown alga Dictyota dichotoma.[1] We wish to report herein the isolation and structure of two further new nine-membered diterpenes, dictyofuran T (1) and dictyofuran C (2) from the same seaweed. The alga (16 kg) was collected in July 1979 at Oshoro bay, Hokkaido and immediately extracted with MeOH at room temperature. Crude extracts were purified by silica gel chromatography using increasing concentration of ether in hexane as eluent. Individual components were then obtained by rechromatography on silica gel impregnated with 20% $AgNO_3$.

Dictyofuran T (1) (0.003% from the alga) showed $[\alpha]_D^{25}$+101° (c 0.77, cyclohexane); IR 1070, 875, 795 cm^{-1} and moelcular formula $C_{20}H_{30}O$ (m/z M^+ found 286.2311, calcd 286.2300). The ^{13}C-NMR spectrum[2] indicated the presence of a furan moiety (132.4 s, 136.4 s, 138.4 d, 139.7 d), a trisubstituted double bond (125.0 d, 125.5 s), the 1,5-dimethyl-4-hexenyl side chain (17.7 q, 18.2 q, 25.7 t, 24.9 q, 37.2 t, 39.1 d, 125.0 d, 130.9 s), a CH group (40.4 d), four CH_2 groups (25.1 t, 30.7 t, 34.2 t, 40.2 t) and a methyl group (15.7 q). Therefore 1 must possess a bicyclic skeleton composed of a furan ring and a cycloalkene ring. In the ^{1}H-NMR spectrum of 1, a methyl signal appeared as a broad singlet at δ 0.99 (weakly coupled, olefinic methyl), and signals due to protons on the furan were observed as two broad 1H singlets at δ 6.92 and 6.96. Peaks ascribed to the olefinic proton on the cycloalkene ring appeared as a double doublet (J=11, 4 Hz) at 5.31 and those due to the eight carbon side chain were seen as singlets at δ 1.53, 1.62 (olefinic methyls), a triplet (J=5 Hz) at 5.04 (trisubstituted olefinic proton) and a doublet (J=6 Hz) at δ 0.88 (secondary methyl). Since the cycloalkene ring bears a methyl, two carbon atoms of the furan and a C_8 side chain, the ring is nine-membered. The J values (11, 4 Hz) of the olefinic proton on the cyclononene ring indicated that the ring is rigid and accordingly the double bond

has trans configuration. Appearance of the olefinic methyl signal at an unusually high field (δ 0.99) must be due to the magnetic anisotropy effect of the furan ring. These findings, coupled with biogenetic considerations, suggested formula 1 for this compound.

In conformity with this formulation, oxidation of the trans double bond with 0.9 eq m-CPBA in CH_2Cl_2 at 0 °C gave monoepoxydictyofuran T (3) [$C_{20}H_{30}O_2$; m/z M^+ found 302.2236, calcd 302.2247; IR 1070 cm^{-1}; ^{1}H-NMR δ 0.64 (3H, s), 0.92 (3H, d, J=5 Hz), 1.58 (3H, s), 1.68 (3H, s), 2.84(1H, dt, J=11, 5 Hz), 3.00 (1H, dd, J=12, 3 Hz), 5.05 (1H, t, J=5 Hz), 7.18 (1H, brs), 7.22 (1H, brs),for ^{13}C-NMR see Table 1] in which the methyl on the oxirane ring was unusually shielded (δ 0.64). Moreover the above described coupling constants of the epoxide suggested a 6a-like conformation. Inspection of molecular models of 1 shows that it has eight main conformations, 6a, 6b, 6c, 6d, 6e, 6f, 6g, and 6h, [Fig. 1, anti or syn shows the spatial relationship of methyl and the furan ring, + or - denotes the dihedral angle of 3-4-5-6 (see Fig. 2) and ax or eq designates stereochemistry of isopropyl group]. In order to obtain strain energies of these conformations, empirical force field calculations using the program MMI[3] was carried out on model compounds containing a cyclopentadiene ring instead of the furan ring. The result is shown in Fig. 1.[4] Stability of the inferred conformation 1* of dictyofuran T from NMR was thus ascertained by molecular mechanics calculations. Dictyofuran C (2); $[\alpha]_D^{25}$+59.1° (c 1.22, cyclohexane); IR 1060, 840, 790 cm^{-1}; molecular formula $C_{20}H_{30}O$ (m/z M^+ foud 286.2309, calcd 286.2300); ^{1}H-NMR δ 0.96 (3H, d, J=6 Hz), 1.54 (3H, s), 1.65 (6H, brs), 2.64 (1H, m), 5.00 (1H, t, J=5.5 Hz), 5.35 (1H, t, J=6 Hz), 7.12 (2H, s); ^{13}C-NMR Table 1. These data implied that 2 has a similar structure to 1. The obvious differences between the NMR spectra of 1 and 2 were the absence of the high field olefinic methyl singlet and the double doublet due to the olefinic proton and the presence of a methyl singlet at an usual position δ 1.67 and a triplet (J=5.5 Hz) rather than a double doublet at 5.50. The triplet with J=5.5 Hz suggested that 2 was conformationally mobile and therefore, the cis isomer. One of the possible conformers is shown by 2*. For the purpose of confirming the suggested structural formulae 1 and 2, dictyolactone (4), a major diterpene of this alga,[5] was treated with I_2 in refluxing toluene for 2 h to give an isomeric lactone 5 [m/z M^+ 302, $C_{20}H_{30}O_2$; IR 1750, 1665 cm^{-1}; ^{1}H-NMR δ 0.94 (3H, d, J=6 Hz), 1.52 (3H, s), 1.64 (3H, s), 1.65 (3H, s), 4.62 (2H, brs), 5.00 (1H, t, J=6 Hz), 5.11 (1H, t, J=5 Hz); ^{13}C-NMR Table 1]. The lactone 5 was reduced with 1 eq DIBAL in THF at -20 °C to afford a furan[6] which was identical with dictyofuran C in all respects (IR, ^{1}H-NMR, MS,and optical rotation). Irradiation of dictyofuran T by means of a 300 W high pressure mercury lamp in ether afforded an isomeric mixture which was separated by chromatography on silica gel coated with $AgNO_3$. The separated two isomer were identical with dictyofuran T and dictyofuran C.

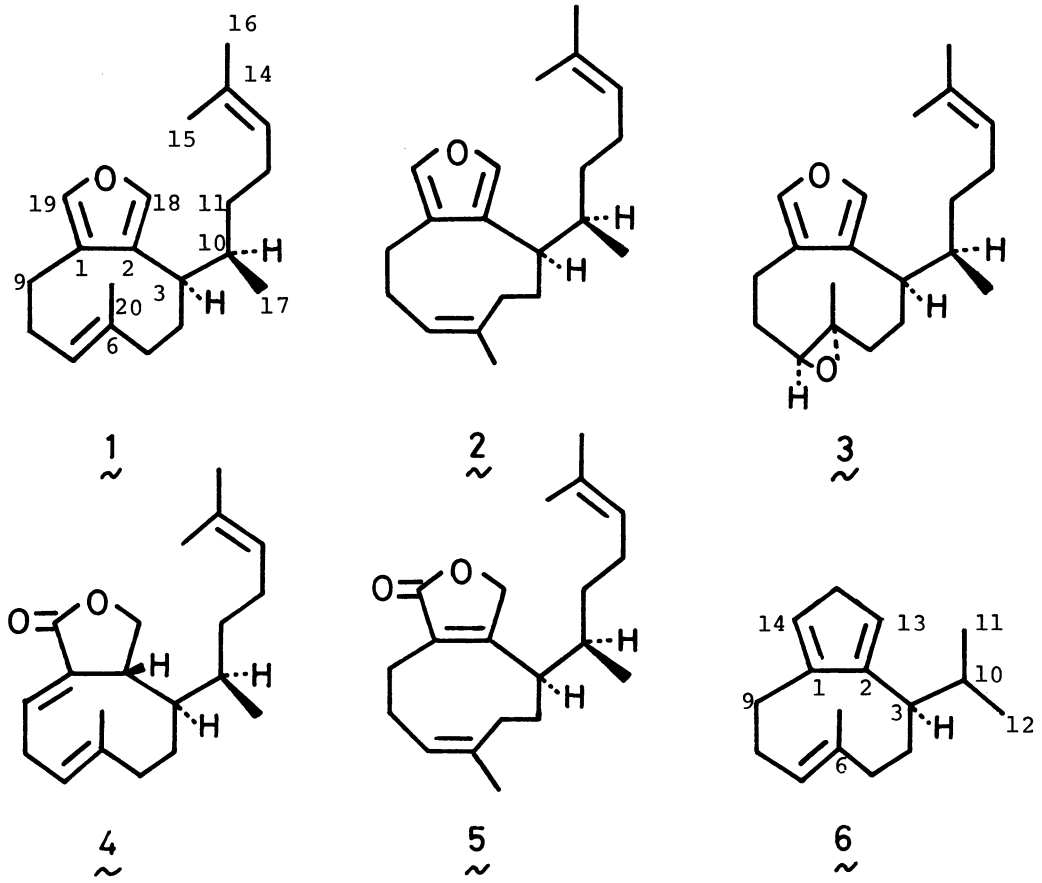
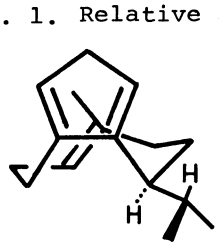
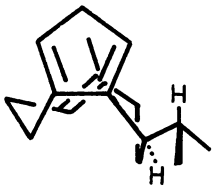


Fig. 1. Relative strain energy (kcal/mol, 25 °C).



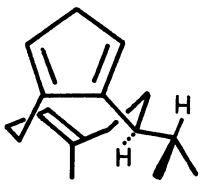
syn+eq 0.00

6a



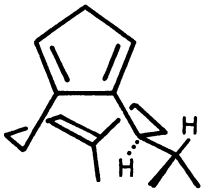
syn-eq ----

6b



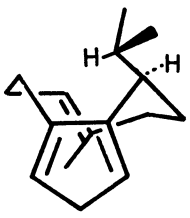
anti+eq 3.77

6c



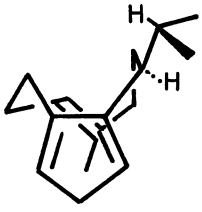
anti-eq 4.30

6d



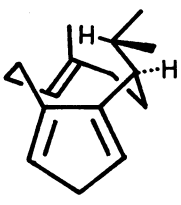
syn-ax 4.69

6e



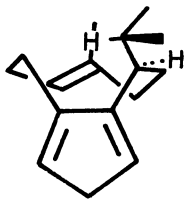
syn+ax 8.68

6f



anti-ax 8.66

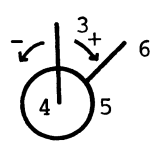
6g



anti+ax 12.46

6h

Fig. 2.



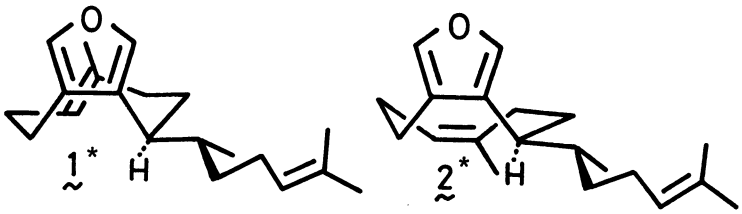


Table 1. ^{13}C-NMR data[a] of 1, 2, 3, and 5

Carbon	Compounds 1	2	3	5
1	132.4,s[b]	131.0,s[b]	132.5,s[b]	137.8,s
2	136.4,s[b]	136.2,s[b]	132.8,s[b]	163.3,s
3	40.4,d[c]	37.8,d[c]	39.4,d[c]	40.2,d[b]
4	30.7,t	29.2,t	33.9,t	26.8,t
5	40.2,t	33.3,t	35.1,t	29.4,t
6	125.5,s	128.9,s	68.2,s	128.9,s
7	125.0,d	126.1,d	65.1,d	124.9,d[c]
8	34.2,t	24.0,t	26.2,t	24.9,t
9	25.1,t	21.4,t	34.4,t	28.8,t
10	39.1,d[c]	35.2,d[c]	38.5,d[c]	31.4,d[b]
11	37.2,t	37.4,t	37.5,t	36.0,t
12	25.9,t	25.7,t	25.4,t	25.8,t
13	125.0,d	124.8,d	124.8,d	124.8,d[c]
14	130.9,s	129.5,s	130.9,s	131.0,s
15	17.7,q	17.6,q	17.7,q	17.7,q
16	25.7,q	25.5,q	25.7,q	25.7,q
17	18.2,q	18.0,q	18.5,q	17.5,q
18	138.4,d[d]	138.3,d[d]	138.9,d[d]	71.7,t
19	139.7,d[d]	138.5,d[d]	139.9,d[d]	173.4,s
20	15.7,q	22.4,q	15.7,q	22.3,q

[a] Values are relative to TMS in $CDCl_3$.

[b, c, d] Signals within a column may be reversed.

References

1) N. Enoki, R. Ishida,and T. Matsumoto, Chem. Lett., 1982, 1749.

2) The ^{1}H-NMR and ^{13}C-NMR spectra were obtained at 200 and 25 MHz respectively in $CDCl_3$.

3) QCPE 318. N. L. Allinger, J. T. Sprague, J. Liljefors, J. Am. Chem. Soc., 96, 5100 (1974); D. H. Wertz, N. L. Allinger, Tetrahedron, 30, 1579 (1974).

4) Since the reliable force field parameters for furan ring were not available, present calculation was carried out by replacing the furan by a cyclopentadiene. Conformer 6b changes into 6a during calculation since energy well of 6b may be shallow.

5) J. Finer, J. Clardy, W. Fenical, L. Minale, R. Riccio, J. Battaile, M. Kirkup, and R. E. Moore, J. Org. Chem., 44, 2044 (1979).

6) H. Minato and T. Nagasaki, J. Chem. Soc., C, 1966, 377.

(Received July 6, 1983)