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MARINE NATURAL PRODUCTS, XIV.[1] SECODOLASTANE DITERPENOIDS OF *DICTYOTA INDICA* FROM THE ARABIAN SEA

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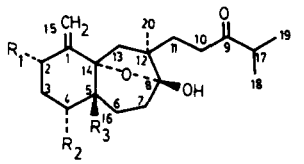
ABSTRACT.—From the brown alga *Dictyota indica* two new secodolastane diterpenoids, named indicol [**1**], and indicarol acetate [**2**], have been isolated together with the previously isolated isolinearol [**3**] and linearol [**4**]. The structures and relative configurations of compounds **1** and **2** were determined on the basis of spectroscopic studies.

Brown algae of the genus *Dictyota* have been the subject of numerous chemical studies (1–4). They have afforded diterpenes having a variety of skeletons together with some diterpenes possessing antifungal (5), antibiotic (6), and antitumor activities (7). Most of the diterpenes isolated from this genus belong to the prenylated guaiane, xeniane, dolabellane, and dolastane series together with a few novel diterpenes having new carbon skeletons (8,9). Among all species of *Dictyota*, the cosmopolitan *Dictyota dichotoma* has been the most extensively studied alga; there has been only one report on *Dictyota indica* Kützing (Dictyotaceae) regarding the isolation of two biologically active diterpenes belonging to the hydroazulene class of diterpene (10). This prompted us to carry out chemical investigations on *D. indica* from the Arabian Sea. In the present communication we describe two new diterpenes named as indicol [**1**] and indicarol acetate [**2**] together with isolinearol [**3**] and linearol [**4**] which were previously isolated from *Dictyota cervicornis* (11) and *Dictyota linearis* (12), respectively. All these diterpenes belong to the secodolastane class of diterpene. The determination of the structures and relative configuration of new compounds are discussed below.



1 R_1=R_2=H, R_3=Me
2 R_1=H, R_2=OH, R_3=CH_2OAc
3 R_1=H, R_2=OH, R_3=Me
4 R_1=OH, R_2=H, R_3=Me
5 R_1=H, R_2=OH, R_3=CH_2OH

Indicol [**1**] was obtained as a colorless viscous oil, $[\alpha]_D$ −44.0° (c = 0.426, $CHCl_3$), after repeated cc on Si gel. The ir spectrum indicated the presence of hydroxyl (3460 cm^{-1}) and carbonyl (1710 cm^{-1}) groups. The ^{1}H-nmr spectrum exhibited four methyl signals at δ 0.99 (3H, s), 1.10 and 1.09 (3H each, d, J = 6.9 Hz), and 0.70 (3H, s). Olefinic proton resonances appeared at δ 4.66 (1H, br s) and 4.84 (1H, br s), and there was no absorption in the CHOH region of the ^{1}H-nmr spectrum, indicating the presence of a tertiary hydroxyl group in the compound. The mass spectrum contained a molecular ion peak at m/z 320 corresponding to the molecular formula $C_{20}H_{32}O_3$. The ^{13}C-nmr spectrum using the DEPT technique exhibited signals for twenty carbon atoms corresponding to four Me, nine CH_2, one CH, and six >C< groups. It further showed the presence of an exomethylene group at 108.37 (=CH_2) and 148.70 (>C=), a hemiketal group at 104.84, a secondary carbon-bearing oxygen at 84.10, and a carbonyl group at 214.98 ppm (see Table 1). These data strongly supported the presence of the rare secodolastane class of diterpenoids. The mass spectrum

[1]For Part XIII, see *Phytochemistry*, **27**, 3879 (1988).

TABLE 1. ^{13}C-nmr Data for Compounds **1** and **2**.[a]

Carbon	Compound	
	1	**2**
C-1	148.70	145.97
C-2	34.42	31.00
C-3	32.66	31.33
C-4	23.31	73.78
C-5	37.07	42.47
C-6	32.63	29.59
C-7	29.95	28.27
C-8	104.84	105.77
C-9	214.98	214.60
C-10	28.70	26.91
C-11	36.26	35.75
C-12	44.18	43.30
C-13	40.73	40.74
C-14	84.10	84.28
C-15	108.37	110.41
C-16	21.53	67.44
C-17	41.04	40.89
C-18	18.35[b]	18.21[b]
C-19	18.38[b]	18.21[b]
C-20	22.95	22.29
OCOMe		170.95
$OCOCH_3$		20.63

[a]Data obtained in $CDCl_3$ at 75.43 MHz.
[b]Assignments may be reversed.

of compound **1** further supported the above hypothesis; it exhibited fragments at *m/z* 302 $[M-H_2O]^+$, 277 [M − isopropyl]$^+$, 259 $[M-H_2O-$isopropyl$]^+$, and 221 [M − side chain]$^+$ similar to isolinearol. The comparison of chemical shifts in the ^{13}C-nmr spectrum of **1** with those of isolinearol (11) indicated that both compounds are similar, except that the upfield shift of C-4 in **1** indicated the absence of the hydroxyl group found in isolinearol. The signals in the ^{1}H and ^{13}C spectra were correlated through a hetero COSY experiment. The spectral data outlined above led us to conclude the structure of indicol as **1**.

Indicarol acetate **2** was obtained as a colorless viscous oil $[\alpha]_D$ −36.9° (c = 0.676), after repeated cc on Si gel. Its ir spectrum indicated the presence of hydroxy (3460 cm^{-1}), ester carbonyl (1730 cm^{-1}), and ketone (1710 cm^{-1}) groups and a disubstituted double bond (3055, 1650, 890 cm^{-1}). The eims of the diterpene afforded the molecular ion peak at *m/z* 394 corresponding to the molecular formula $C_{22}H_{34}O_6$ and revealing six degrees of unsaturation in the molecule. The molecular ion peak was confirmed by fdms.

The ^{1}H-nmr spectrum of indicarol acetate **2** showed the characteristic features of secodolastane derivatives. A comparison of chemical shifts with previously reported compounds showed that indicarol acetate **2** has a structure that is very similar to isolinearol (11) but with several additional structural features. The ^{1}H-nmr spectrum showed the characteristic exocyclic methylene proton resonances as broad singlets at δ 4.94 and 4.8. The presence of an acetate group was suggested by its characteristic methyl singlet at δ 2.0. The ^{1}H-nmr spectrum further showed the presence of two secondary methyl groups at δ 1.07 and 1.08 (each d, J = 6.9 Hz) and a tertiary methyl group at δ 0.97 (s, Me). The tertiary methyl at the 16 position was replaced by a CH_2OAc group that appeared as a double doublet at δ 3.60 (1H, d, J = 11.7 Hz) and 3.78 (1H, d, J = 11.7 H). The upfield shift of these signals to δ 3.15 and 3.36 after alkaline hydrolysis provided further confirmation of the acetate group at this position. It further showed the presence of another C*H*OH signal at δ 3.96 (t, J = 3.5 Hz) suggesting the equatorial (β) orientation of the carbinol hydrogen and the axial (α) orientation of the hydroxyl group. All the coupling interactions were illustrated by correlated spectroscopy COSY-45°.

The ^{13}C-nmr spectrum ($CDCl_3$, 75 MHz) showed the presence of 22 carbon atoms in the molecule. The multiplicity assignments were made using a DEPT pulse sequence. The assignments were made by comparing these data with published ^{13}C-nmr data of secodolastane derivatives (11) and confirmed by ^{1}H-^{13}C heteronuclear chemical shift correlated spectroscopy (hetero COSY) (Table 1).

Compounds [3] and [4] were isolated as colorless needles by repeated cc on Si gel. Comparison of ^{1}H- and ^{13}C-nmr data with the reported data suggested the structures of **3** and **4** as isolinearol and linearol, respectively.

EXPERIMENTAL

EXPERIMENTAL INSTRUMENTS.—Ir were measured on JASCO IRA-I spectrometer. Optical rotations were recorded on a Schmidt and Haensch Polartronic-D electronic polarimeter. Mass spectra were recorded on MAT-312 spectrometers. ^{1}H- and ^{13}C-nmr spectra were recorded in $CDCl_3$ with TMS as internal reference on a Bruker AM-400 at 400 and 75.43 MHz, respectively. The purity of the sample was checked on tlc (Si gel S.I.F. 254).

EXTRACTION AND ISOLATION OF COMPOUNDS.—The brown alga *D. indica* was collected from Bulegi near the Karachi coast and was identified by Prof. Mustafa Shameel, Department of Botany, University of Karachi, where a voucher specimen no. KUH 3753 has been deposited in the Herbarium of the botany department. The dried alga (1.0 kg) was extracted with Me_2CO. The Me_2CO-soluble extract, after evaporation of solvent under reduced pressure, was applied to a Si gel column. The column was eluted with a solvent gradient system of hexane, hexane/Et_2O, Et_2O, $CHCl_3$, $CHCl_3$/MeOH, and finally with MeOH. A number of fractions (100 ml each) were collected. Fractions 14–18 eluted with 15% Et_2O in hexane were combined on the basis of similar tlc. These combined fractions were subjected to repeated cc on Si gel columns, affording compound **1** (15 mg) which was finally purified through tlc developed in hexane/Et_2O (1:1). Fractions 34–38 eluted with 50% Et_2O in hexane were combined on the basis of tlc. Repeated cc of these combined fractions yielded compound **2** (30 mg), which was further purified by tlc developed in $CHCl_3$-MeOH (9.75:0.25). Compounds **3** and **4** were obtained as colorless needles by repeated chromatography of the combined fractions 31–33. Compound **3** (35 mg) was eluted with 40% Et_2O while compound **4** (21 mg) was eluted with 45% Et_2O in hexane.

Indicol [**1**].—Compound **1** was isolated as a colorless viscous oil $[\alpha]_D$ −44.0 (c = 0.426, $CHCl_3$); ir ν max 3460, 3020, 1710, 1625, 1460, 1420, 1410, 1370, 1310, 1145, 1105, 1010, 970, 900, 855 cm^{-1}; ms *m/z* (rel. int. %) $[M]^+$ 320 (5), 302 (6), 292 (8), 277 (10), 259 (8), 247 (10), 235 (14), 229 (24), 221 (34), 217 (4), 203 (5), 195 (12), 180 (10), 173 (15), 161 (100), 150 (20), 147 (20), 137 (25), 133 (15), 125 (74), 121 (34), 110 (30), 107 (40), 105 (30), 96 (34), 94 (32), 91 (24), 82 (40), 80 (25), 71 (80), 69 (54), 67 (40), 53 (22); ^{1}H-nmr ($CDCl_3$, 400 MHz) δ ppm 4.84 (1H, br s, H-15), 4.66 (1H, br s, H-15), 2.60 (1H, m, H-17), 1.10 and 1.09 (3H each, d, J = 6.9 Hz, H-18 and H-19), 0.99 (3H, br s, H-20), 0.70 (3H, br s, H-16); ^{13}C-nmr ($CDCl_3$, 75.43 MHz) see Table 1.

Indicarol acetate [**2**].—$[\alpha]_D$ −36.9 (c = 0.676, $CHCl_3$); ir ($CHCl_3$) ν max 3460 cm^{-1} (hydroxyl), 1730 cm^{-1} (ester carbonyl), 1710 cm^{-1} (ketone), 3055, 1650, 890 cm^{-1} (exocyclic disubstituted double bond); fdms $[M]^+$ 394.00 ($C_{22}H_{34}O_6$); ms *m/z* (rel. int. %) $[M]^+$ 394 (81), 334 (5), 316 (20), 273 (15), 245 (18), 230 (35), 217 (100), 199 (20), 157 (50), 145 (25), 125 (65), 119 (30), 105 (35), 71 (100); ^{1}H-nmr ($CDCl_3$, 400 MHz) δ ppm 4.94 (1H, br s, H-15), 4.80 (1H, br s, H-15), 4.56 (1H, d, J = 11.4 Hz, 4-OH), 3.96 (1H, distorted triplet, J = 3.5 Hz, H-4), 3.78 (1H, d, J = 11.7 Hz, H-16), 3.60 (1H, d, J = 11.7 Hz, H-16), 2.58 (1H, m, H-17), 2.00 (3H, s, 16-OAc), 1.08 and 1.07 (3H each, d, J = 6.9 Hz, H-18 and H-19), 0.97 (3H, s, H-20); ^{13}C-nmr ($CDCl_3$, 75.43 MHz) see Table 1.

BASE-CATALYZED HYDROLYSIS OF INDICAROL ACETATE [**2**].—Compound **2** (15 mg) was hydrolyzed with 5% KOH in MeOH at 60° for 1 h. The reaction mixture was acidified with 5% HCl and worked up in the usual manner. The parent alcohol **5** was isolated in a pure state (11 mg): $[\alpha]_D$ −46.42° (c = 0.28, $CHCl_3$); ir ($CHCl_3$) ν max 3400 cm^{-1} (hydroxyl), 1710 (ketone), 3055, 1650, 890 cm^{-1} (exocyclic disubstituted double bond); ms *m/z* (rel. int. %) $[M]^+$ 334 (2), 316 (2), 273 (5), 245 (8), 230 (10), 217 (30), 199 (10), 157 (32), 145 (28), 125 (35), 119 (25), 105 (35), 71 (98); ^{1}H-nmr ($CDCl_3$, 400 MHz, δ ppm) 4.93 (1H, br s, H-15), 4.79 (1H, br s, H-15), 4.51 (1H, d, J = 11.4 Hz, 4-OH), 4.00 (1H, distorted triplet, H-4), 3.36 (1H, d, J = 11.7 Hz, H-16), 3.18 (1H, d, J = 11.7 Hz, H-16), 2.58 (1H, m, H-17), 1.09 (3H, d, J = 6.9 Hz, H-18), 1.08 (3H, d, J = 6.9 Hz, H-19), 0.98 (3H, s, H-20).

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