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AN ACYCLIC DITERPENE FROM THE BROWN ALGA *BIFURCARIA BIFURCATA*

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Key Word Index—*Bifurcaria bifurcata*; Cystoseiraceae; brown alga; 12-(*S*)-hydroxygeranylgeraniol; ^{1}H, ^{13}C, 2D-NMR spectroscopy.

Abstract—Structure elucidation and total assignment of the ^{13}C NMR spectrum of 12-(*S*)-hydroxygeranylgeraniol, a new acyclic diterpene from the grown alga *Bifurcaria bifurcata*, was accomplished through the use of ^{1}H NMR, ^{13}C NMR and 2D NMR spectroscopy including 2D long range ^{1}H–^{13}C chemical shift correlations.

INTRODUCTION

The diterpenoids of Cystoseiraceae are of great interest to organic chemists because of their biological activities and/or their novel skeletons [1–4]. Generally, the structures of new diterpenoids have been established by comparison with other related compounds and degradative techniques. We now report the isolation and structure determination, using 2D NMR spectroscopy, of a new acyclic diterpene from *Bifurcaria bifurcata* (Atlantic coast, Morocco).

RESULTS AND DISCUSSION

The new compound (**1**), $C_{20}H_{34}O_2$, was obtained as an oil, $[\alpha]_D = -12.47°$ ($c = 9.3$; CH_2Cl_2). Its IR spectrum contained a hydroxyl absorption band ($\nu_{OH} = 3400\ cm^{-1}$). Its acyclic nature was established by the presence in the ^{1}H NMR spectrum of four olefinic protons and five olefinic methyl groups (Table 1), a combination which requires four unsaturations. Structure **1** was supported by ^{1}H NMR decoupling experiments, by comparison with related substances [5–7]. The terminal vinyl proton at δ5.04 (*t* (*br*), 1H) was coupled (long range $J = 1$–2 Hz) to two methyl singlets at δ1.60 and 1.68 and to a methylene signal at δ2.20 (*dd*, 2H), which was in turn coupled to the signal at δ3.92 (t, $J = 6.7$ Hz, 1H). The ^{13}C NMR spectrum contained signals for eight olefinic carbons (Table 1). The olefin geometries (*E*) were assigned based upon the methyl resonances being observed at higher than δ20 and the two oxygen atoms were accomodated by primary and secondary hydroxyl groups, δ59.21 (*t*) and 77.1 (*d*) respectively.

Confirmation of the proposed structure (**1**) and total assignment of the ^{13}C NMR spectrum were accomplished by 2D-NMR [8, 9]. In the J_{CH} correlation, the methyl signals at δ1.56, 1.57, 1.60, 1.63 and 1.68 were observed to correlate with the carbon resonances at δ15.92, 11.63, 17.89, 16.17 and 25.76 respectively. In a similar fashion the assignment of the four sp^2 tertiary carbons, the C-1 and C-13 methylene carbons and the C-12 carbon was also accomplished. In order to complete the total assignment of the structure, experimental conditions were set up to enhance the signals of carbons weakly coupled to protons ($J_{CH} \simeq 4$–8 Hz). The correlations obtained by this method were the C-3/H-20, C-7/H-19, C-11/H-18 and C-15/H-16/17 geminal couplings and the C-2/H-20, C-6/H-19, C-10/H-18 and C-14/H-17 vicinal couplings. The signals at δ134.20, 136.71, 134.89 and 139.09 were identified as the sp^2 quaternary carbons C-15, C-11, C-7 and C-3 respectively by long range heteronuclear δ–δ ^{1}H–^{13}C correlation. The remaining methylene carbons C-5, C-9 and C-4, C-8 were observed to correlate with the ethylenic protons H-6, H-10 respectively (two-bond couplings) and the methyl protons H-20, H-19 (three-bond couplings), thus providing a total assignment. Returning to the problem associated with the position of the secondary hydroxyl group, the 2-D long range δ_C/δ_H correlations showed that the δ77.14 resonance was coupled to H-18 methyl protons whereas specific decouplings in ^{1}H NMR spectrum indicated couplings between H-12/H-13 and H-13/H-14. Given the C-14/H-14 correlation, C-14/H-17 vicinal coupling and C-15/H-16, C-15/H-17 geminal couplings, the location of the secondary hydroxyl group at C-12 was unequivocally confirmed.

A Horeau determination [10] of the absolute configuration of the alcohol indicated *S* configuration for the hydroxyl-bearing carbon.

EXPERIMENTAL

Bifurcaria bifurcata was collected in 1984 (Atlantic Coast, Morocco). The freeze-dried material (29 g) was ground and extracted with EtOH–$CHCl_3$ (1 : 1). After filtration and evapor-

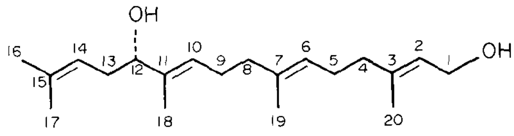

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Table 1. ^1H and ^{13}C NMR data of compound **1** [360 MHz (^1H) and 90.5 MHz (^{13}C), $CDCl_3$, TMS as internal standard]

C	^1H NMR	^{13}C NMR	C	^1H NMR	^{13}C NMR
1	4.09 *d* (6.8)*	59.21 *t* (106)†	11		136.71 *s*
2	5.35 *t* (6.8)	123.53 *d* (153)	12	3.92 *t* (6.7)	77.14 *d* (109)
3		139.09 *s*	13	2.20 *dd* (6.7, 7)	34.17 *t* (96)
4	1.99 *m*	39.40 *t* (94)	14	5.04 *t* (7)	120.23 *d* (151)
5	2.07 *m*	26.71 *t* (92)	15		134.20 *s*
6	5.07 *t* (6.8)	123.98 *d* (150)	16	1.68 *s*	25.76 *q* (70)
7		134.89 *s*	17	1.60 *s*	17.89 *q* (95)
8	1.99 *m*	39.18 *t* (94)	18	1.57 *s*	11.63 *q* (92)
9	2.07 *m*	26.00 *t* (94)	19	1.56 *s*	15.92 *q* (96)
10	5.32 *t* (6.8)	125.80 *d* (151)	20	1.63 *s*	16.17 *q* (96)

*J_{HH} (Hz) in parentheses.
†J_{CH} (Hz) in parentheses.

ation, the extract was partitioned between H_2O and Et_2O. The Et_2O-soluble material was dried over $MgSO_4$ and filtered, and the filtrate was evaporated to yield 440 mg of a crude extract which was subjected to CC on silica gel eluted with a solvent gradient from hexane to EtOAc. The new compound was eluted with hexane–EtOAc (2:3) and was subsequently purified by HPLC (EtOAc–*iso*-octane, 2:3) to give 250 mg of pure product.

12-(*S*)-*Hydroxygeranylgeraniol*. $[\alpha]_D = -12.47°$ ($c = 9.3$; CH_2Cl_2). IR ν_{max}^{film}: 3400 cm^{-1}; ^1H and ^{13}C NMR see Table 1; EIMS (70 eV) m/z: 288, 189, 153, 135, 121, 85 and 69.

^1H–^{13}C *shift correlation*. The applied pulse sequence was ($\pi/2$, ^1H)-($t_{1/2}$)-(π, ^{13}C)-($t_{1/2}$)-τ_1-($\pi/2$, ^1H; $\pi/2$, ^{13}C)-τ_2-(BB, ^1H; FID, t_2) with $\tau_1 = 3.3$ msec and $\tau_2 = 1.67$ msec. Spectral width in F_1 was $W_1 = \pm 500$ Hz and in F_2, $W_2 = 6024$ Hz. ^1H–^{13}C *long range shift correlation*. Identical to ^1H–^{13}C shift correlation except: $\tau_1 = \tau_2 = 41.7$ msec.

Absolute configuration at C-12. The alcohol (15 mg) in dry C_5H_5N (150 μl) was treated with (±)-2-phenylbutyric anhydride (50 mg) and left overnight at room temp. H_2O (500 μl) was added and the mixture warmed for 30 min until a homogeneous soln was obtained. H_2O (2 ml) and C_6H_6 (3 ml) were added and the mixture was titrated with NaOH (0.1 M) until alkaline (phenolphthalein). C_6H_6 (10 ml) was added and the layers separated. The C_6H_6 layer was washed with H_2O and the combined aq. phases acidified (pH 1.5) with HCl (10 M) and extracted with C_6H_6 (2 × 10 ml). The C_6H_6 extracts were washed with H_2O (10 ml), dried over $MgSO_4$ and concd. The rotation was measured to be −0.03. As the acid excess was laevorotatory, the molecule had 12*S* configuration.

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