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TWO MINOR DITERPENES RELATED TO DICTYODIAL A FROM THE BROWN ALGA *DICTYOTA CRENULATA*

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Key Word Index—*Dictyota crenulata*; Dictyotaceae; brown alga; diterpenes; structure determination.

Abstract—4β-Hydroxydictyodial A and 18,*O*-dihydro-4β-hydroxydictyodial A 18-acetate are two minor aldehydic diterpenes in the brown alga *Dictyota crenulata*. ^{1}H NMR and lanthanide-induced chemical shift studies indicate that the relative stereochemistry of both compounds is 2*R**,3*R**,4*S**,10*S**.

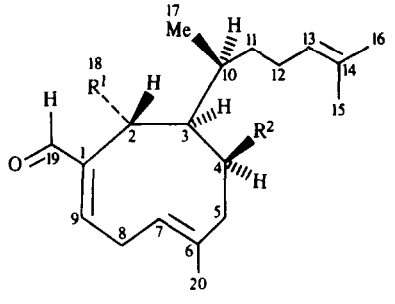
INTRODUCTION

Dictyodial A (**1**) is the major diterpene in the lipophilic extract of the marine brown alga *Dictyota crenulata* (Kutzig) from Hawaii [1]. During the winter months this seaweed produces minor amounts of a novel aldehydic diterpene, β-crenulal [2], along with two diterpenes that are related to dictyodial A. We report here the structures and relative stereochemistries of the two dictyodial A-related diterpenes.

RESULTS AND DISCUSSION

One diterpene has been identified as 4β-hydroxydictyodial A (**2**). Mass spectrometry indicates that the molecular formula is $C_{20}H_{30}O_3$ and the IR spectrum shows that a hydroxyl group is present (3440 cm^{-1}). The ^{13}C NMR and ^{1}H NMR spectra of **2** (Table 1) closely resemble those of dictyodial A [1]. Signals are present for two aldehydic functionalities, one of which is in a conjugated enal system (λ_{max} 231 nm); the chemical shift of the proton (H-18) in the unconjugated aldehyde group of **2**, however, is 0.5 ppm higher field than that of **1**, suggesting that the OH group is close to H-18. Detailed analysis (spin–spin decoupling) has established that the OH group is attached β to C-4, since the proton on C-4 (δ 4.32) shows small to nil couplings (0–4 Hz) to all of its vicinal neighbors. Inspection of a Dreiding model of **2** (in the conformation suggested from X-ray crystallographic analysis of dictyodiol and dictyolactone, two derivatives of **1** [1]) shows that when the OH on C-4 is β, the dihedral angles between H-4 and H-3, H-4 and H-5β, and H-4 and H-5α are in the 30–90° range, in perfect agreement for the 0–4 Hz couplings that are seen between these pairs of protons. Zero coupling is seen between H-2 and H-3, indicating that the dihedral angle between these two protons is *ca* 90°, as it is in **1**. H-3 resonates as a broad singlet at δ 1.60, showing nil coupling to not only H-2 and H-4, but to H-10 as well ($J_{3,10}$ for **1** is ~ 0.5 Hz [1]). The relative stereochemistry of **2**, therefore, appears to be the same as **1** at C-2, C-3 and C-10. Since the optical rotations are almost the same for **2** ($[\alpha]_D - 121°$) and **1** ($[\alpha]_D - 95°$) and since the ^{1}H NMR data strongly suggest that both diterpenes have virtually the same conformation in solution, the absolute stereochemistry of **2** is probably the same as that of **1** (the absolute stereochemistry of **1**, however, is presently unknown).

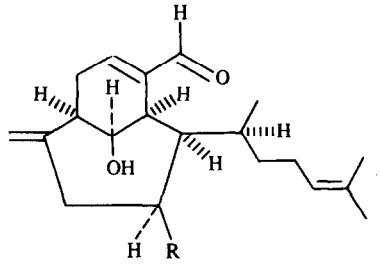
The second diterpene has structure **3**. Mass spectrometry establishes its elemental composition as $C_{22}H_{34}O_4$. The presence of OH and acetoxyl groups are indicated by



1 R^1 = CHO, R^2 = H

2 R^1 = CHO, R^2 = OH

3 R^1 = CH_2OAc, R^2 = OH



4 R = H

5 R = OH

Table 1. NMR spectral data for 4β-hydroxydictyodial A (**2**) in $CDCl_3$

^{13}C δ*	Assignment	^1H δ†
203.6 (*d*)	18	9.69 (1H, *s*)
194.2 (*d*)	19	9.39 (1H, *s*)
157.8 (*d*)	9	7.06 (1H, *dd*)
147.9 (*s*)	1	
138.1 (*s*)	6	
131.2 (*s*)	14	
124.6 (*d*)	13	5.00 (1H, *tm*)
124.2 (*d*)	7	5.33 (1H, *ddm*)
73.6 (*d*)	4	4.32 (1H, *br m*)
52.0 (*t*)	8_β	3.43 (1H, *ddd*)
	8_α	3.10 (1H, *ddd*)
50.5 (*d*)	3	1.60 (1H, *br s*)
47.9 (*t*)	5_α	2.46 (1H, *dd*)
	5_β	2.09 (1H, *dd*)
39.59 (*t*)	11	1.10 (2H, *br m*)
33.25 (*d*)	10	2.11 (1H, obscured *m*)
29.55 (*d*)	2	3.58 (1H, *br s*)
25.68 (*t*)	12	1.82 (2H, *m*)
25.68 (*q*)	16	1.58 (3H, *br m*)
20.22 (*q*)	17	1.13 (3H, *d*)
17.58 (*q*)	15	1.68 (3H, *br m*)
17.58 (*q*)	20	1.98 (3H, *br m*)

*25.2 MHz, TMS as internal standard = 0.

†220 and 100 MHz, TMS as internal standard = 0.

J(Hz): 2, 3 = 0; 3, 4 = 1; 3, 5_α = 1; 4, 5_β = 1; 4, 5_α = 2.5; 5_α, 5_β = −13; 7, 8_β = 11; 7, 8_α = 3.5; 7, 20 = 1.5; 8_α, 8_β = −16; 8_β, 9 = 3.5; 8_α, 9 = 8; 10, 17 = 7; 11, 12 = 7; 12, 13 = 7; 13, 15 = 1.5; 13, 16 = 1.5.

Table 2. ^1H NMR spectral and lanthanide-induced chemical shift data for **3**

	δ*	Δδ†		δ*	Δδ†
H-19	9.32 *d*	2.80	$H\text{-}5_\alpha$	*br d*	
H-9	6.84 *dd*	1.73	$H\text{-}5_\beta$	*dd*	
H-7	5.25 *ddq*	2.18	AcO	*s*	
H-13	5.04 *t septets*		3H-20	*br m*	2.70
H-18	4.65 *dd*	7.30	2H-12	*br m*	
H-18′	4.54 *dd*	7.95	3H-15	*br s*	
H-4	4.29 *m*	5.63	3H-16	*br s*	
$H\text{-}8_\beta$	3.34 *ddd*		H-3	*br m*	
$H\text{-}8_\alpha$	3.01 *ddd*		2H-11	*br m*	
H-2	3.24 *ddd*	6.50	3H-17	*d*	
H-10	2.32 *m*				

*220 MHz, $CDCl_3$, TMS = 0 as internal reference.

†100 MHz, $CDCl_3$, 1 molar equivalent $Eu(fod)_3$.

J(Hz): 2, 3 = 0; 2, 18 = 7; 2, 18′ = 9; 2, 19 = 2; 3.4 ~ 0; 3, 10 ~ 0; 4, 5_α = 2; 4, 5_β = 4; 5_α, 5_β = −13; 7, 8_α = 3.5; 7, 8_β = 11; 7, 20 = 1.5; 8_α, 8_β = −15; 8_α, 9 = 8; 8_β, 9 = 3.5; 10, 17 = 7; 11, 12 = 7.5; 12, 13 = 7.5; 12, 15 = 1.5; 12, 16 = 1.5; 13, 15 = 1.5; 13, 16 = 1.5; 18, 18′ = −12.

the mass spectrum since fragment ions are observed for successive losses of H_2O and HOAc from the molecular ion. The IR spectrum provides further evidence for the presence of these OH (3500 cm^{-1}) and acetoxyl (1730 cm^{-1}) functionalities. The UV spectrum shows that an enal group is present (λ_{max} 244 nm). The ^1H NMR spectrum of **3** (Table 2) is very similar to that of **2**, except that acetoxymethyl signals are found instead of the signal for the unconjugated aldehyde group. The coupling constants for the various ring protons in **3** are identical with those in **2**. Lanthanide-induced chemical shift studies of **3** (Table 2) prove that the OH on C-4 is β. H-18, H-18′ and H-2 shift very rapidly, in fact faster than H-4, and much faster than the protons on C-7, C-9, C-19 and C-20, when $Eu(fod)_3$ is added to the NMR sample, establishing that the OH on C-4 is very close to H-2, H-18 and H-18′. A Dreiding model shows that this is possible only when **3** has the same conformation indicated by X-ray analysis for dictyodiol and dictyolactone [1] and when the OH on C-4 is β. Diterpene **3** also has a laevorotatory optical rotation ($[\alpha]_D$ −187°), suggesting that its absolute stereochemistry is probably the same as that of **1** and **2**.

The relative stereochemistry of both **2** and **3** is apparently 2*R**, 3*R**, 4*S**, 10*S**.

β-Crenulal (**4**) is readily formed when dictyodial A is treated with boron trifluoride etherate in benzene at 5° [2]. Attempted cyclization of **2** to **5** under the same conditions leads to anomalous products.

EXPERIMENTAL

Isolation. Wet *Dictyota crenulata* (Kutzig) (397 g dry wt) collected at Kualoa Beach Park, Oahu, Hawaii in January 1977 was extracted with Me_2CO and CH_2Cl_2. The dried extract was distributed between H_2O and CH_2Cl_2 and the organic phase was evapd to 35.6 g of a dark green oil which was chromatographed on a 70 cm × 6.5 cm column of silica gel with hexane, hexane–$CHCl_3$ and $CHCl_3$. The fraction eluted with $CHCl_3$ (4.71 g) was then subjected to gel permeation chromatography in 500 mg portions on a 120 cm × 3 cm column of Biobeads SX-8, a porous styrene–divinylbenzene copolymer, with C_6H_6. HPLC of the material eluted after the pigments on a Whatman Partisil 10/50 M-9 column with 5% EtOAc–$CHCl_3$ gave 278 mg of β-crenulal, 100 mg of 4β-hydroxydictyodial A (**2**, 0.28%) and 125 mg of 18,*O*-dihydro-4β-hydroxydictyodial A 18-acetate (**3**, 0.35%). Purification of **2** and **3** was also achieved by reverse-phase HPLC on a Whatman Partisil 10/50 ODS-2 column with 15% H_2O–MeCN.

4β-Hydroxydictyodial A (**2**) was isolated as an oil, $[\alpha]_D^{25}$ −121° (*c* 0.33; EtOH); IR ν_{max}^{neat} cm^{-1}: 3440 (OH), 2940, 2890, 2710, 1695 (sh), 1670, 1610, 1440, 1380, 1180, 1110, 840; UV λ_{max}^{EtOH} nm (ε): 232 (4000); EIMS (probe) 70 eV, *m/z* (rel. int.): 318.219 $[M]^+$ (4) $C_{20}H_{30}O_3$, 300 $[M-H_2O]^+$ (12), 262 (7), 261 (7), 201 (8), 189 (11), 177 (8), 176 (7), 165 (11), 161 (26), 147 (15), 135 (19), 109 (38), 95 (25), 93 (25), 91 (23), 82 (22), 69 $[Me_2C{=}CH{-}CH_2]^+$ (100), 67 (23), 45 (18), 43 (15).

18,*O*-*Dihydro-4β-hydroxydictyodial A 18-acetate* (**3**) was isolated as a colorless oil, $[\alpha]_D^{25}$ −187° (*c* 0.80; EtOH); IR ν_{max}^{neat} cm^{-1}: 3500, 2940, 2900, 2840, 2700, 1735, 1690, 1445, 1370, 1240, 1110, 1030, 800; UV λ_{max}^{EtOH} nm (ε): 244 (2500), 270 (sh, 1560); EIMS (probe) 70 eV, *m/z* (rel. int.): 362.217 $[M]^+$ (6) $C_{22}H_{34}O_4$, 344 $[M-H_2O]^+$ (5), 318 (5), 302 $[M{-}HOAc]^+$ (16), 284 $[M-H_2O-HOAc]^+$ (14), 149 (46), 109 (47), 107 (30), 105 (34), 95 (38), 93 (34), 91 (38), 81 (68), 69 $[Me_2C{=}CH{-}CH_2]^+$ (100), 55 (48), 43 (56), 41 (70).

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REFERENCES

1. Finer, J., Clardy, J., Fenical, W., Minale, L., Riccio, R., Battaile, J., Kirkup, M. and Moore, R. E. (1979) *J. Org. Chem.* **44**, 2044.
2. Kirkup, M. P. and Moore, R. E. (1978) 175th National Meeting of the American Chemical Society, Anaheim, California, March 1978, Abstract No. ORGN 187.