

## Rhodolaureol and Rhodolauradiol, Two New Halogenated Tricyclic Sesquiterpenes from a Marine Alga

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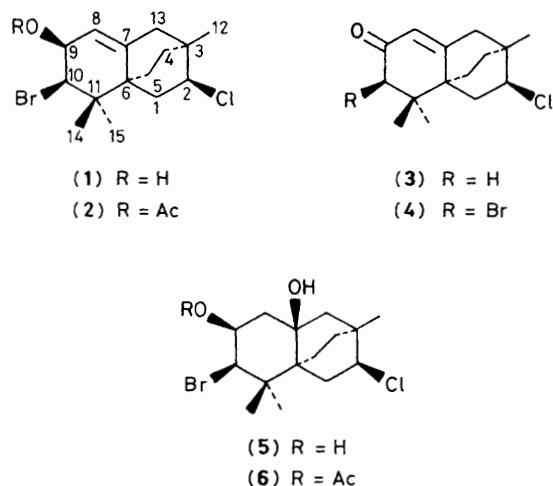
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The structures of two closely related halogenated sesquiterpenes: rhodolaureol (**1**) and rhodolauradiol (**5**), isolated from a marine alga of the genus *Laurencia*, have been determined by X-ray diffraction analysis.

We report herein the structural elucidation of two new minor sesquiterpenes having a carbon skeleton not found previously among naturally occurring terpenoids, which are isolated from extracts of an alga of the genus *Laurencia* (Rhodomelaceae, Rhodophyta).

Freshly gathered algae were extracted with cold ether under an inert atmosphere and quickly chromatographed on silica gel at low temperature under anhydrous conditions with a variety of eluants. Fractions eluted with light petroleum-ether (80:20) yielded rhodolaureol (**1**) (120 mg, 0.21% of lipid weight), m.p. 57–58 °C (from n-hexane),  $[\alpha]_D^{25} +139^\circ$  (c 1.2, CHCl<sub>3</sub>). High-resolution electron-impact mass spectrometry established, by peak matching, the elemental composition

C<sub>15</sub>H<sub>22</sub><sup>79</sup>Br<sup>35</sup>ClO (obs. 332.0546; calc. 332.0542); fragment peaks were observed at *m/z* 253.1353 (*M*<sup>+</sup>-Br), 235.1255 (*M*<sup>+</sup>-Br-H<sub>2</sub>O), and 217.1593 (*M*<sup>+</sup>-Br-HCl). The i.r. spectrum of (**1**) showed absorptions at  $\nu_{\max}$  (KBr) 3470, 1670, 1370, 1230, 1190, 1030, 870, and 810 cm<sup>-1</sup>, and its <sup>1</sup>H n.m.r. spectrum resonances at  $\delta$  (CDCl<sub>3</sub>) 5.67 (m, 8-H), 4.52 (d, *J* 5 Hz, 10-H), 4.20 (m, 9-H), 4.05 (m, 2-H), 1.50 (br. s, 4- and 5-H<sub>2</sub>), and 1.02, 0.95, and 0.93 (each s, 12-, 14-, and 15-H<sub>3</sub>). The <sup>13</sup>C n.m.r. (CDCl<sub>3</sub>) data for (**1**) assisted by off-resonance and selective proton-noise decoupling techniques showed the presence of 3 Me groups:  $\delta$  20.5 (C-14), 24.1 (C-15), and 24.5 (C-12); four CH<sub>2</sub> groups: 27.3 (C-1), 33.4 (C-5), 36.1 (C-4), and 39.7 (C-13); three heteroatom-bearing CH groups: 65.3

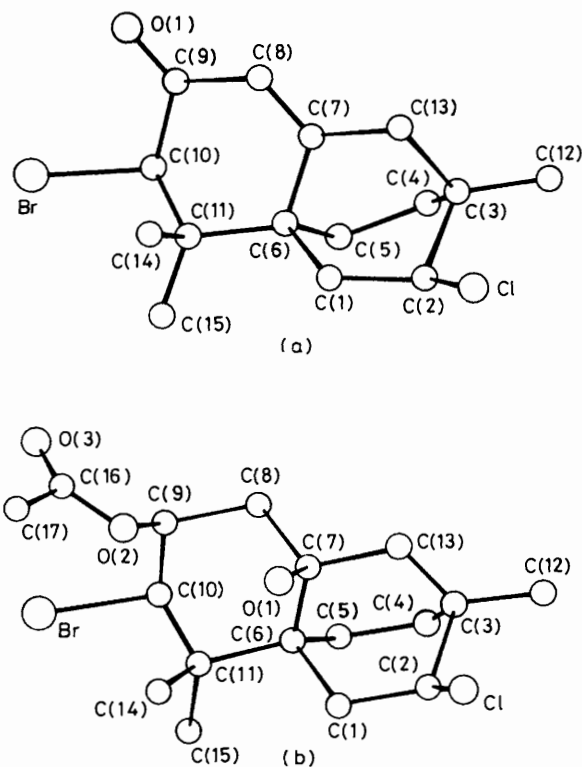


(C-2), 67.3 (C-9), and 69.8 (C-10); 3 fully substituted C atoms: 35.0 (C-3), 38.5 (C-6), and 43.1 (C-11); and one trisubstituted double bond: 118.4 (C-8) and 144.2 (C-7).

Treatment of (1) with  $\text{Ac}_2\text{O}$ -pyridine gave the acetate (2)<sup>†</sup> which on mild hydrolysis with  $\text{K}_2\text{CO}_3$  in tetrahydrofuran (THF)- $\text{H}_2\text{O}$  produced the alcohol (1) and the  $\alpha,\beta$ -unsaturated ketone (3).<sup>†</sup> Compound (3) was also obtained when an ethereal solution of rhodolaureol (1) was stirred with neutral alumina at room temperature.<sup>1</sup> Treatment of (1) with pyridinium chlorochromate (2 equiv.) in dry methylene chloride gave (4).<sup>†</sup> Reduction of (4) with  $\text{Zn}$ - $\text{AcOH}$  in ether yielded the debrominated ketone (3). The acetate (6) was isolated following acetylation of the non-resolved and more polar chromatographic fractions: m.p. 124–126 °C,  $[\alpha]_{\text{D}} +45^\circ$  (*c* 1.12,  $\text{CHCl}_3$ ).<sup>†</sup> The crystal structures of (4) and (6) were determined.

**Crystal data:** (4),  $\text{C}_{15}\text{H}_{20}\text{BrClO}$ , monoclinic,  $a = 8.383(2)$ ,  $b = 7.898(1)$ ,  $c = 11.064(2)$  Å,  $\beta = 92.75(2)^\circ$ ,  $Z = 1$ , space group  $P2_1$  (from systematic absences). Data were collected to  $2\theta = 114^\circ$  using graphite-monochromated  $\text{Cu-K}\alpha$  radiation (1.541 78 Å) and the  $\omega$ -scan technique. 2451 Reflections were collected, and the 1892 with  $I > 3\sigma(I)$  used in the structure

<sup>†</sup> Compound (2), oil,  $[\alpha]_{\text{D}} + 218^\circ$  (*c* 2.5,  $\text{CHCl}_3$ ),  $M^+$ ,  $m/z$  374, 376, 378;  $\nu_{\text{max}}$  (KBr) 2940, 1735, 1370, 1235, 1030, and 815  $\text{cm}^{-1}$ ;  $^1\text{H}$  n.m.r. ( $\text{CDCl}_3$ )  $\delta$  0.98 (s, 6H), 1.02 (s, 3H), 1.50 (br. s, 4H), 2.08 (s, 3H), 4.06 (m, 1H), 4.50 (d,  $J$  5 Hz, 1H), and 5.45 (m, 2H);  $^{13}\text{C}$  n.m.r. 20.0 (q), 21.0 (q), 24.0 (q), 27.2 (t), 33.3 (t), 35.0 (s), 36.0 (t), 38.5 (s), 39.4 (t), 43.0 (s), 61.6 (d), 65.2 (d), 68.3 (d), 116.1 (d), and 146.1 (s). Compound (3), oil,  $[\alpha]_{\text{D}} + 35^\circ$  (*c* 1.3,  $\text{CHCl}_3$ ),  $M^+$ ,  $m/z$  252, 254;  $\nu_{\text{max}}$  (KBr) 2970, 1660, 1460, 1370, 1280, 890, and 805  $\text{cm}^{-1}$ ;  $^1\text{H}$  n.m.r. ( $\text{CDCl}_3$ )  $\delta$  0.90 (s, 6H), 1.02 (s, 3H), 1.60 (br. s, 2H), 2.22 (br. s, 2H), 4.05 (m, 1H), and 5.88 (s, 1H). Compound (4), m.p. 144–146 °C,  $[\alpha]_{\text{D}} + 128^\circ$  (*c* 0.46,  $\text{CHCl}_3$ ),  $M^+$ ,  $m/z$  330, 332, 334;  $\nu_{\text{max}}$  (KBr) 2970, 2295, 1660, 1640, 1365, 1240, 1170, and 870  $\text{cm}^{-1}$ ;  $^1\text{H}$  n.m.r. ( $\text{CDCl}_3$ )  $\delta$  0.97 (s, 3H), 1.03 (s, 3H), 1.07 (s, 3H), 1.65 (br. s, 2H), 4.09 (m, 1H), 4.80 (s, 1H), and 5.99 (s, 1H);  $^{13}\text{C}$  n.m.r. 19.1 (q), 24.0 (q), 24.1 (q), 26.0 (t), 32.7 (t), 35.5 (s), 37.0 (t), 39.1 (t), 42.2 (s), 43.8 (s), 64.2 (d), 66.2 (d), 121.4 (d), 140.0 (s), and 189.5 (d). Analytical data for rhodolauradiol acetate (6) indicated the formula  $\text{C}_{17}\text{H}_{26}\text{BrClO}_3$ ;  $m/z$  295, 297 ( $M^+ - \text{Br} - \text{H}_2\text{O}$ );  $\nu_{\text{max}}$  (KBr) 3540, 1760, 1070, 825, and 700  $\text{cm}^{-1}$ ;  $^1\text{H}$  n.m.r. ( $\text{CDCl}_3$ )  $\delta$  5.36 (dd,  $J$  6 and 4 Hz, 9-H), 4.41 (d,  $J$  4 Hz, 10-H), 4.10 (d of dd,  $J$  11, 4, and 0.5 Hz, 2-H), 2.1 (s,  $\text{MeCO}_2$ ), and 1.34, 0.96, and 0.92 (each s, 14-, 12-, and 15- $\text{H}_3$ );  $^{13}\text{C}$  n.m.r. ( $\text{CDCl}_3$ )  $\delta$  73.2 (C-9), 72.9 (C-7), 66.2 (C-2), 63.2 (C-10), 47.9 (C-13), 44.1 (C-11), 41.0 (C-6), 40.6 (C-8), 35.7 (C-4), 34.2 (C-3), 32.9 (C-5), 27.8 (C-12), 25.0 (C-15), 24.1 (C-1), and 21.9 (C-14).



**Figure 1.** Crystal structures of (a) the tricyclic ketone (4); (b) the acetate (6).

solution. A phasing model was achieved by the heavy-atom method, but was slightly complicated by the nearly identical  $y$ -co-ordinates of Br and Cl.<sup>2</sup> Full-matrix least-squares refinement with fixed isotropic hydrogen and anisotropic non-hydrogen atoms, and anomalous scattering corrections for Br and Cl have converged to  $R = 0.073$ . The structure is shown in Figure 1(a).<sup>‡</sup>

Compound (6),  $\text{C}_{17}\text{H}_{26}\text{BrClO}_3$ , orthorhombic,  $a = 11.750(3)$ ,  $b = 9.553(4)$ ,  $c = 15.510(6)$  Å,  $Z = 1$ , space group  $P2_12_12_1$  (from systematic absences). 1367 Reflections were collected as for (4), and the 1326 'observed' used in the solution. Full-matrix least-squares refinement with fixed isotropic hydrogen and anisotropic non-hydrogen atoms, and anomalous dispersion corrections for Br and Cl converged to  $R = 0.080$ . The structure is shown in Figure 1(b).<sup>‡</sup>

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- 2 The programs used are as described by E. Arnold and J. Clardy, *J. Am. Chem. Soc.*, 1981, **103**, 1243.

<sup>‡</sup> The atomic co-ordinates for this work are available on request from the Director of the Cambridge Crystallographic Data Centre, University Chemical Laboratory, Lensfield Road, Cambridge CB2 1EW. Any request should be accompanied by the full literature citation for this communication.