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New Halogenated Furanones from the Marine Alga *Delisea pulchra* (cf. *fimbriata*)[1]

Rocky de Nys[2], Anthony D. Wright, Gabriele M. König, and Otto Sticher

Department of Pharmacy, Swiss Federal Institute of Technology (ETH) Zürich, Winterthurerstrasse 190, CH-8057 Zürich, Switzerland

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ABSTRACT.-An investigation of the natural products chemistry of the red alga *Delisea pulchra*, collected from the Cape Banks, New South Wales, Australia, yielded eight new polyhalogenated furanones (**1-7**) and the previously reported metabolites **8-24**. The structures of **1-8** were determined from the interpretation of their 1D and 2D NMR, UV, IR and mass spectral data. For the first time, complete ^{1}H and ^{13}C NMR data for compounds **14**, **18**, and **20-23** are reported.

INTRODUCTION

The investigation of the natural products chemistry of *Delisea pulchra* (Greville) Montage (Bonnemaisonales, Bonnemaisoniaceae) (cf. *Delisea fimbriata* [3]) was carried out as part of an on-going study of the chemical and pharmacological properties of marine natural products[4-6]. *Delisea* species are somewhat special when compared to many other algal species, in their apparent ability to stave off colonisation by common epiphytes and also to be a food source which is generally not preferred by obligate herbivores.

D. pulchra, the subject of the current investigation, has already been the focus of some chemical, biological activity and ecological studies. These have yielded new chemistry[7-11], some interesting biological activity[12,13] and useful preliminary ecological observations[13]. The current collection and extraction of *D. pulchra* from Cape Banks, New South Wales, Australia resulted in the isolation and structural elucidation of the new halogenated furanones **1-7**, and the re-isolation of the previously

reported metabolites cholesterol and **8-24**. For the first time, complete ^{1}H and ^{13}C NMR data for compounds **14**, **18**, and **20-23** are reported.

RESULTS AND DISCUSSION

Compound **1** was shown, by accurate mass measurement, to have the molecular formula $C_{12}H_{16}BrIO_5$. Of the four degrees of unsaturation implied by the molecular formula of **1**, three were present in the form of multiple bonds; one carbon-carbon double bond (136.1 (s), 142.3 (s) ppm) and two carbon-oxygen double bonds (164.9 (s), 170.5 (s) ppm), indicating **1** to be monocyclic.

Table 1. ^{13}C-NMR (75.5 MHz, $CDCl_3$) data[a] for compounds **1-7**.

Carbon	1	2	3	4	5	6	7
C-2	164.9 s	166.7 s	166.8 s	165.6 s	165.6 s	164.4 s	165.2 s
C-3	136.1 s	139.6 s	139.4 s	133.4 s	133.4 s	136.8 s	138.3 s
C-4	142.3 s	138.5 s[b]	138.9 s	144.8 s	144.2 s	140.6 s	136.8 s
C-5	106.1 s	106.6 s	106.8 s	107.5 s	107.7 s	106.0 s	106.3 s
C-6	4.9 t	4.4 t	5.0 t	23.5 q	23.2 q	42.0 d	41.9 d
C-7	52.3 q	52.1 q	52.8 q	50.8 q	50.8 q	52.8 q	52.7 q
C-1'	68.9 d	67.6 d	67.8 d	68.8 d	68.7 d	68.9 d	68.7 d
C-2'	33.7 t	38.1 t	38.0 t	33.7 t	33.9 t	33.5 t	33.7 t
C-3'	18.6 t	18.7 t	18.6 t	18.5 t	18.5 t	18.5 t	18.5 t
C-4'	13.6 q	13.7 q	13.7 q	13.6 q	13.6 q	13.6 q	13.6 q
OAc	170.5 s					170.5 s	170.0 s
	20.6 q					20.6 q	20.3 q

[a]All assignments are based on the results of ^{1}H-^{13}C one bond (HMQC, J 150 Hz) and ^{1}H-^{1}H correlated spectra. [b]Double boxes represent chemical shift differences between compounds **2** and **3**, **4** and **5**, and **6** and **7** which are 0.3 ppm or larger.

The ^{1}H and ^{13}C NMR, UV and IR data of **1** indicated the presence of an acetate-function (2.09 (s), 170.5 (s) ppm, 1785 cm^{-1}), an α,β-unsaturated γ-lactone (164.9 (s), 142.3 (s), 136.1 (s) ppm, 230 (ε 7960) nm, 1740 cm^{-1}), a methoxyl-function (3.25 (s), 52.3 (q) ppm) an iodomethyl-function (3.43 (d, J 11.1 Hz), 3.64 (d, J 11.1 Hz), 4.9 (t) ppm) and an olefinic bromo-function (142.3 (s) ppm). From the ^{1}H-^{1}H 2D NMR COSY and the ^{1}H-^{13}C 2D NMR (HMQC) one bond spectra of **1** it was also possible to delineate the C-1' to C-4' molecular fragment. Thus in the ^{1}H-^{1}H 2D NMR COSY spectrum of **1** cross peaks were observed between H_3-4' (δ 0.97) and H_2-3' (δ 1.46), and between H_2-3' and H_2-2' (δ 1.86, 2.03). A cross peak was also observed between the resonances at δ 1.86

and 2.03. From the same spectrum it was also clear that H_2-6 (δ 3.34, 3.64) coupled with H_3-7 (δ 3.35), indicating both the methoxyl group and the iodomethyl-function to reside at C-5, which must be at least doubly oxygenated based on its ^{13}C NMR chemical shift, 106.1 (s) ppm.

These data clearly indicated **1** to have the structure **1** or **1a**. Structure **1a** was ruled out as a possibility on the basis of ^{13}C NMR data comparisons made between **1** and compounds having similar functionalities[9,10] as well as the fact that no NOEs were observed between protons in the C-1' to C-4' side chain and the protons of the methoxyl group and/or the protons of the iodomethyl-function. Compound **1** is thus 3-(1'-acetoxybutyl)-4-bromo-5-iodomethyl-5-methoxyl-2(5*H*)-furanone.

Compounds **2** and **3** both had a molecular formula of $C_{10}H_{14}BrIO_4$, by mass spectrometry. The NMR spectra of both compounds were almost identical to those of **1**, with the exception of the resonances for the acetoxyl-function at C-1'. In both **2** and **3** C-1' was substituted with a secondary alcohol function instead of the acetoxyl-function found in **1**. Consistent with this change of functionality a deshielding of H-1' (δ 5.41 in **1**, δ 3.68 in **2**, δ 3.67 in **3**), and the loss of resonances in the NMR spectra of **2** and **3** for the acetoxyl-function were observed. Thus **2** and **3** were the 1'-deacetoxyl derivatives of **1**. The difference between **2** and **3** was most evident from their optical rotations; +8.0° for **2**, +39.0° for **3**, which indicated them to be diastereomers. Comparison of the ^{13}C NMR data of both compounds (Table 1) revealed that the largest differences in chemical shifts occurred in the region around C-5, suggesting **2** and **3** to be epimeric at this center. Compounds **2** and **3** are thus 3-(1'-hydroxybutyl)-4-bromo-5-iodomethyl-5-methoxyl-2(5*H*)-furanone and 5-*epi*-3-(1'-hydroxybutyl)-4-bromo-5-iodomethyl-5-methoxyl-2(5*H*)-furanone, respectively.

Mass spectral analysis determined **4** and **5** to both have a molecular formula of $C_{12}H_{17}BrO_5$. Structurally, after consideration of their spectroscopic data in comparison with those of compound **1** (see Tables 1 and 2 and the Experimental section), it was clear that these two compounds were related to **1** by the substitution of the iodomethyl-function at C-5 of **1** with a methyl group. The specific optical rotations obtained for **4** and **5** revealed them to be diastereomers. Based on ^{13}C NMR data comparisons it was concluded that **4** and **5**, as in the case of **2** and **3**, are epimeric at C-5 (Table 1). Compound **4** is 3-(1'-acetoxybutyl)-4-bromo-5-methyl-5-methoxyl-2(5*H*)-furanone, while **5** is 5-*epi*-3-(1'-acetoxybutyl)-4-bromo-5-methyl-5-methoxyl-2(5*H*)-furanone.

The two remaining new compounds, **6** and **7**, also had identical molecular formulae, $C_{12}H_{15}Br_3O_5$. Their spectroscopic data revealed them both to be C-5 dibromomethylderivatives of **4** and **5**. Their optical rotations and ^{13}C NMR data clearly indicated that they were C-5 epimers, compound **6** being 3-(1'-acetoxybutyl)-4-bromo-5-dibromomethyl-5-methoxyl-2(5*H*)-furanone and **7** being 5-*epi*-3-(1'-acetoxybutyl)-4-bromo-5-dibromomethyl-5-methoxyl-2(5*H*)-furanone.

For compounds **1**-**7** it was not possible to propose any relative stereochemistry for the centers C-1' and C-5 as there was no way of relating the two centers, even if the relative or absolute

configuration at either one or the other had been known. To resolve these stereochemical problems attempts are currently underway to crystallise at least one of the new compounds.

Table 2. ^{1}H-NMR (300 MHz, $CDCl_3$) data[a] for compounds **1-7**.

Proton	1	2	3	4
6	3.43 (d, *J* 11.1 Hz)	3.45 (d, *J* 11.2 Hz)	3.46 (d, *J* 11.4 Hz)	1.65 (s)
	3.64 (d, *J* 11.1 Hz)	3.68 (d, *J* 11.2 Hz)	3.67 (d, *J* 11.4 Hz)	
7	3.25 (s)	3.28 (s)	3.31 (s)	3.16 (s)
1'	5.41 (dd, *J* 6.3, 7.9 Hz)	4.60 (br)	4.57 (dd, *J* 6.2, 7.6 Hz)	5.41 (dd, *J* 6.3, 8.0 Hz)
2'	1.86 (m), 2.03 (m)	1.77 (m), 1.87 (m)	1.77 (m), 1.84 (m)	1.84 (m), 1.96 (m)
3'	1.46 (m)	1.45 (m)	1.53 (m)	1.31 (m), 1.35 (m)
4'	0.97 (t, *J* 7.3 Hz)	0.98 (t, *J* 7.4 Hz)	0.97 (t, *J* 7.4 Hz)	0.95 (t, *J* 7.4 Hz)
OAc	2.09 (s)			2.09 (s)

Proton	5	6	7
6	1.64 (s)	5.75 (s)	5.75 (s)
7	3.16 (s)	3.31 (s)	3.31 (s)
1'	5.44 (dd, *J* 6.3, 8.0 Hz)	5.38 (dd, *J* 6.3, 7.9 Hz)	5.39 (dd, *J* 6.0, 7.9 Hz)
2'	1.84 (m), 1.98 (m)	1.86 (m), 1.94 (m)	1.86 (m), 1.93 (m)
3'	1.31 (m), 1.34 (m)	1.45 (m)	1.45 (m)
4'	0.95 (t, *J* 7.4 Hz)	0.96 (t, *J* 7.5 Hz)	0.96 (t, *J* 7.5 Hz)
OAc	2.09 (s)	2.10 (s)	2.11 (s)

[a]All assignments are based on the results of ^{1}H-^{13}C one bond (HMQC, *J* 150 Hz) and ^{1}H-^{1}H correlated spectra.

Together with the seven new compounds a further seventeen, **8-24**, were isolated and spectroscopically characterised. For compounds **14**, **18** and **20-23** complete ^{1}H and ^{13}C NMR data are provided for the first time. For compounds **15**, **17**, **19** and **24** no optical rotations are reported as all of these compounds rapidly isomerise after isolation to give the $\Delta^{5,6}$ *Z* isomer.

All metabolites demonstrated antimicrobial activities, which will be reported in greater detail elsewhere.

EXPERIMENTAL

GENERAL EXPERIMENTAL PROCEDURES.- As per reference (14).

PLANT MATERIAL.- The alga *Delisea pulchra* was collected from Cape Banks, Sydney, New South Wales, Australia in October 1991, at a depth of 3-5 meters. A herbarium specimen of the alga is lodged with the Biological Sciences Department, University of New South Wales, Australia.

EXTRACTION AND ISOLATION.- The alga (5.1 kg) was frozen on collection and freeze dried. The freeze dried tissue (873.6 g) was extracted with dichloromethane (CH_2Cl_2) to afford 7.8 g (0.89 %) of CH_2Cl_2 soluble material. 5.1 g of the

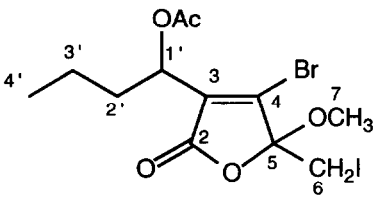
CH_2Cl_2 extract was separated by vacuum liquid chromatography (VLC) over silica gel using hexane containing increasing proportions of ethyl acetate as eluent and afforded 25 fractions each of approximately 90 ml.

HPLC separation (LiChrosorb Si60, 5 µm, EtOAc:hexane (1:45)) of combined VLC fractions 5 and 6 yielded compounds **10**, **12** and **13**.

1,1,2-Tribromo-oct-1-en-3-one (**10**): (82 mg, 0.009 %), a yellow mobile oil with ^1H and ^{13}C NMR data identical to those previously reported[7].

3-Butyl-4-bromo-5-(dibromomethylidene)-2(5*H*)-furanone (**12**): (245 mg, 0.028 %), a yellow mobile oil with ^1H and ^{13}C NMR data identical to those previously reported[8].

(5*Z*)-3-Butyl-4-bromo-5-(bromomethylidene)-2(5*H*)-furanone (**13**): (67 mg, 0.008 %), a yellow mobile oil with ^1H and ^{13}C NMR data identical to those previously reported[8,11].



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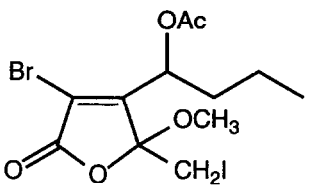

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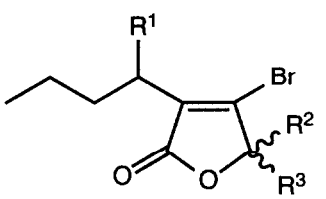

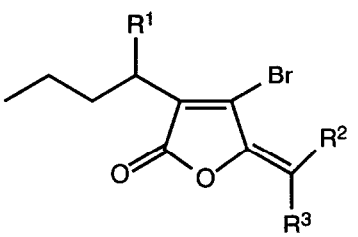

	R^1	R^2	R^3
2	OH	CH_2I	OCH_3
3	OH	OCH_3	CH_2I
4	OAc	CH_3	OCH_3
5	OAc	OCH_3	CH_3
6	OAc	$CHBr_2$	OCH_3
7	OAc	OCH_3	$CHBr_2$

	R^1	R^2	R^3
12	H	Br	Br
13	H	H	Br
14	OH	H	Br
15	OH	Br	H
16	OAc	H	Br
17	OAc	Br	H
18	OH	H	I

	R^1	R^2	R^3
19	OH	I	H
20	OAc	H	I
21	OH	Br	Br
22	OAc	Br	Br
23	OH	H	Cl
24	OH	Cl	H

HPLC separation (LiChrosorb Si60, 5 µm, EtOAc:hexane (1:45)) of VLC fractions 9 yielded compounds **9**, **11**, **16**, **17**, **20** and **22**.

(2*S*)-1,1,3-Tribromododec-3-en-2-ol (**9**) (24 mg, 0.003 %), yellow mobile oil with ^1H and ^{13}C NMR data and physical properties identical to those previously reported[11].

(*R*,*S*)-6-Acetoxy-1,1,2-tribromooct-1-en-3-one (**11**) (69 mg, 0.008 %), yellow mobile oil with ^1H and ^{13}C NMR data and physical properties identical to those previously reported[11].

(1'*R*,5*E*)-3-(1'-Acetoxybutyl)-4-bromo-5-(bromo-methylidene)-2(5*H*)-furanone (**16**): (265 mg, 0.03 %), with identical physical and spectroscopic properties to those reported for[9].

(1'*R*,5*Z*)-3-(1'-Acetoxybutyl)-4-bromo-5-(bromo-methylidene)-2(5*H*)-furanone (**17**): (290 mg, 0.03 %), yellow mobile oil with ^1H and ^{13}C NMR data and optical properties identical to those previously reported[9].

(1'*R*,5*Z*)-3-(1'-Acetoxybutyl)-4-bromo-5-(iodomethylidene)-2(5*H*)-furanone (**20**): (10 mg, 0.001 %), was obtained as a clear oil with $[\alpha]_D^{25}$ +23.2° (c, 0.5 $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 0.96 (t, *J* 7.5, 7.5 Hz, 3H, H-4'), 1.31 (m, 1H, H-3'), 1.36 (m, 1H, H-3'), 1.84 (m, 1H, H-2'), 1.96 (m, 1H, H-3'), 2.09 (s, 3H, H-1''), 5.51 (dd, *J* 6.6, 7.5 Hz, 1H, H-1'), 6.60 (s, 1H, H-6); ^{13}C NMR (75.5 MHz, $CDCl_3$) 13.5 (q, C-4'), 18.6 (t, C-3'), 20.6 (t, C-1''), 33.8 (t, C-2'), 68.5 (d, C-1'), 64.3 (d, C-6), 131.1 (s, C-3), 131.1 (s, C-4), 153.8 (s, C-4), 164.0 (s, C-2), 170.2 (s, C-2'') ppm; EIMS, m/z (% rel. int.) 416, 414 (M^+, 4), 373 (24), 371 (23), 355 (4), 331 (11), 329 (13), 289 (33), 287 (33), 247 (8), 245 (8), 229 (11), 227 (11), 43 (100).

(1'*R*,5*Z*)-3-(1'-Acetoxybutyl)-4-bromo-5-(dibromomethylidene)-2(5*H*)-furanone (**22**): (39 mg, 0.005 %), was obtained as an oil; $[\alpha]_D^{25}$ +6.6° (c, 1.0 $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 0.96 (t, *J* 7.5, 7.5 Hz, 3H, H-4'), 1.31 (m, 1H, H-3'), 1.36 (m, 1H, H-3'), 1.84 (m, 1H, H-2'), 1.96 (m, 1H, H-3'), 2.09 (s, 3H, H-1''), 5.58 (dd, *J* 6.3, 7.8 Hz, 1H, H-1'); ^{13}C NMR (75.5 MHz, $CDCl_3$) 13.6 (q, C-4'), 18.5 (t, C-3'), 20.6 (t, C-1''), 33.5 (t, C-2'), 68,9 (d, C-1'), 84.3 (s, C-6), 130.0 (s, C-4), 134.2 (s, C-3), 144.3 (s, C-4), 162.3 (s, C-2), 170.3 (s, C-2'') ppm; EIMS, m/z (% rel. int.); 450 (M^+, 1), 448 (2), 446 (2), 444 (1), 407 (7), 406 (15), 405 (18), 404 (16), 403 (17), 402 (5), 367 (13), 365 (10), 363 (12), 361 (13), 327 (11), 325 (21), 323 (11), 307 (9), 43 (100).

HPLC separation (LiChrosorb Si60, 5 µm, EtOAc:hexane (1:10)) of VLC fraction 11 yielded compounds **1**, **4**-**7** as well as further **16**, **17** and **20**

3-(1'-Acetoxybutyl)-4-bromo-5-iodomethyl-5-methoxyl-2(5*H*)-furanone (**1**): (30 mg, 0.003 %), an oil, $[\alpha]_D^{25}$ +27° (c, 1.0 $CHCl_3$); IR υ_{max} 2960, 1785, 1740, 1225 cm^{-1}; UV λ_{max} 230 (ε 7960) nm; ^1H NMR see Table 1; ^{13}C NMR see Table 2; EIMS, m/z (% rel. int.); 448, 446 (M^+, 1), 417 (1), 415 (1), 375 (1), 373 (1), 363 (6), 361 (6), 307 (65), 305 (65), 265 (35), 263 (35), 261 (25), 259 (25), 247 (15), 245 (15), 233 (15), 231 (15), 155 (60); HREIMS obsd 445.9175, $C_{12}H_{16}{}^{79}BrIO_5$ req 445.9227.

3-(1'-Acetoxybutyl)-4-bromo-5-methyl-5-methoxyl-2(5*H*)-furanone (**4**): (12 mg, 0.001 %), an oil, $[\alpha]_D^{25}$ +38° (c, 0.9 $CHCl_3$); IR υ_{max} 2940, 1775, 1755, 1225 cm^{-1}; UV λ_{max} 229 (ε 6880) nm; ^1H NMR see Table 1; ^{13}C NMR see Table 2; EIMS, m/z (% rel. int.); 322, 320 (M^+, 1), 307 (1), 305 (1), 291 (4), 289 (4), 262 (10), 260 (10), 237 (11), 235 (11), 181 (40), 167 (85); HREIMS obsd 322.0047, $C_{12}H_{17}{}^{81}BrO_5$ req 322.0240, obsd 259.9992, $C_{10}H_{13}{}^{79}BrO_3$ req 260.0045.

5-*epi*-3-(1'-Acetoxybutyl)-4-bromo-5-methyl-5-methoxyl-2(5*H*)-furanone (**5**): (19 mg, 0.001 %), an oil, $[\alpha]_D^{25}$ +3° (c, 1.2 $CHCl_3$); IR υ_{max} 2960, 1775, 1745, 1230 cm^{-1}; UV λ_{max} 231 (ε 8500) nm; ^1H NMR see Table 1; ^{13}C NMR see Table 2; EIMS, m/z (% rel. int.); 322, 320 (M^+, <1), 307 (<1), 305 (<1), 291 (1), 289 (1), 262 (1), 260 (1), 237 (11), 235 (11), 181 (40), 167 (95); HREIMS obsd 322.0189, $C_{12}H_{17}{}^{81}BrO_5$ req 322.0240.

3-(1'-Acetoxybutyl)-4-bromo-5-dibromomethyl-5-methoxyl-2(5*H*)-furanone (**6**): (19 mg, 0.001 %), an oil, $[\alpha]_D^{25}$ +10° (c, 0.5 $CHCl_3$); IR υ_{max} 2960, 1790, 1740, 1225 cm^{-1}; UV λ_{max} 208 (ε 7125), 233 (ε 8500) nm; ^1H NMR see Table 1; ^{13}C NMR see Table 2; EIMS, m/z (% rel. int.); 482, 480, 478, 476 (M^+, <1), 463, 461, 459, 457 (<1), 439, 437, 435, 433 (1), 397 (1), 395 (3), 393 (3), 391 (1), 359 (7), 357 (12), 355 (6), 341 (7), 339 (15), 337 (8), 307 (35), 305 (33), 265 (43), 263 (40), 155 (60); HREIMS obsd 434.8325, $C_{10}H_{12}{}^{81}Br^{79}Br_2O_4$ req 434.8265.

5-*epi*-3-(1'-Acetoxybutyl)-4-bromo-5-dibromomethyl-5-methoxyl-2(5*H*)-furanone (**7**): (15 mg, 0.002 %), an oil, $[\alpha]_D^{25}$ +27° (c, 0.5 $CHCl_3$); IR υ_{max} 2960, 1790, 1740, 1225 cm^{-1}; UV λ_{max} 208 (ε 7125), 233 (ε 8500) nm; ^1H NMR see Table 1; ^{13}C NMR see Table 2; EIMS, m/z (% rel. int.); 482, 480, 478, 476 (M^+, <1), 463, 461, 459, 457 (<1), 439, 437, 435, 433 (1), 397 (1), 395 (3), 393 (3), 391 (1), 359 (1), 357 (2), 355 (1), 341 (7), 339 (15), 337 (8), 307 (18), 305 (17), 265 (30), 263 (30), 155 (45); HREIMS obsd 434.8328, $C_{10}H_{12}{}^{81}Br^{79}Br_2O_4$ req 434.8265.

HPLC separation (LiChrosorb Si60, 5 µm, EtOAc-hexane (1:10)) of VLC fraction 12 afforded **21**.

(1'*R*)-3-(1'-Hydroxybutyl)-4-bromo-5-(dibromomethylidene)-2(5*H*)-furanone (**21**): (61 mg, 0.007 %), a clear oil, $[\alpha]_D^{25}$ +16° (c, 1.0 $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 0.96 (t, *J* 7.2 Hz, 3H, H-4'), 1.40 (m, 1H, H-3'), 1.48 (m, 1H, H-3'), 1.70 (m, 1H, H-2'), 1.84 (m, 1H, H-3'), 4.59 (dd, *J* 6.3, 8.1 Hz, 1H, H-1'); ^{13}C NMR (75.5 MHz, $CDCl_3$) 13.7 (q, C-4'), 18.6 (t, C-3'), 37.7 (t, C-2'), 68.0 (d, C-1'), 84.2 (d, C-6), 127.0 (s, C-4), 137.2 (s, C-2), 144.3 (s, C-4), 164.0 (s, C-2) ppm; EIMS, m/z (% rel. int.); 408 (M^+, 1), 406 (4), 404 (4), 402 (1), 389 (2), 387 (2), 379 (3), 377 (8), 375 (8), 373 (3), 365 (31), 363 (93), 361 (100), 359 (34), 283 (10), 43 (13).

HPLC separation (LiChrosorb Si60, 5 μm, EtOAc:hexane (3:20)) of VLC fraction 13 yielded further **22** as well as cholesterol and compounds **14**, **15**, **18**, **19**, **23** and **24**.

Cholesterol: (34 mg, 0.0039 %) a white crystalline solid with identical physical and spectroscopic properties to an authentic sample.

(1'*R*,5*Z*)-3-(1'-Hydroxybutyl)-4-bromo-5-(bromomethylidene)-2(5*H*)-furanone (**14**): (217 mg, 0.025 %), a yellow mobile oil, $[\alpha]_D^{25}$ +15.0° (c, 0.4 $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 0.95 (t, *J* 7.5 Hz, 3H, H-4'), 1.43 (m, 2H, H-3'), 1.72 (m, 1H, H-2'), 1.83 (m, 1H, H-3'), 3.22 (br s, 1H, OH), 4.58 (dd, *J* 6.3, 7.5 Hz, 1H, H-1'), 6.38 (s, 1H, H-6); ^{13}C NMR (75.5 MHz, $CDCl_3$) 13.7 (q, C-4'), 18.6 (t, C-3'), 37.8 (t, C-2'), 67.4 (d, C-1'), 93.4 (d, C-6), 129.6(s, C-4), 133.4 (s, C-2), 149.7 (s, C-4), 165.3 (s, C-2) ppm; EIMS, *m/z* (% rel. int.): 328 (M^+, 1), 326 (3), 324 (1), 402 (1), 311 (1), 309 (2), 307 (1), 299 (3), 297 (7), 295 (3), 285 (48), 283 (100), 281 (54), 247 (5), 245 (5), 203 (4), 205 (5), 175 (3), 173 (3).

(1'*R*,5*E*)-3-(1'-Hydroxybutyl)-4-bromo-5-(bromomethylidene)-2(5*H*)-furanone (**15**): (173 mg, 0.02 %), a yellow mobile oil with identical physical and spectroscopic data as those reported for **14**[8].

(1'*R*,5*Z*)-3-(1'-Hydroxybutyl)-4-bromo-5-(iodomethylidene)-2(5*H*)-furanone (**18**): (19 mg, 0.002 %) a yellow mobile oil with $[\alpha]_D^{25}$ +3° (c, 0.25 $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 0.96 (t, *J* 7.2 Hz, 3H, H-4'), 1.40 (m, 2H, H-3'), 1.74 (m, 1H, H-2'), 1.86 (m, 1H, H-3'), 4.56 (dd, *J* 6.6, 7.8 Hz, 1H, H-1'), 6.60 (s, 1H, H-6); ^{13}C NMR (75.5 MHz, $CDCl_3$) 13.6 (q, C-4'), 18.6 (t, C-3'), 37.8 (t, C-2'), 64.2 (d, C-6'), 67.6 (d, C-1'), 129.4 (s, C-4), 133.9 (s, C-2), 153.8 (s, C-4), 165.0 (s, C-2) ppm; EIMS, m/z (% rel. int.): 374 (M^+, 9), 372 (9), 345 (6), 343 (6), 331 (95), 329 (100), 303 (5), 301 (5), 43 (26).

(1'*R*,5*E*)-3-(1'-Hydroxybutyl)-4-bromo-5-(iodomethylidene)-2(5*H*)-furanone (**19**): (8 mg, 0.001 %) was obtained as a yellow mobile oil and had identical physical and spectroscopic properties to **18**[8].

(1'*R*,5*Z*)-3-(1'-Hydroxybutyl)-4-bromo-5-(chloromethylidene)-2(5*H*)-furanone (**23**): (17 mg, 0.002 %), was obtained as a yellow mobile oil, $[\alpha]_D^{25}$ +9° (c, 0.5 $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 0.96 (t, *J* 7.2 Hz, 3H, H-4'), 1.39 (m, 2H, H-3'), 1.74 (m, 1H, H-2'), 1.86 (m, 1H, H-3'), 4.63 (dd, *J* 6.6, 7.8 Hz, 1H, H-1'), 6.39 (s, 1H, H-6); ^{13}C NMR (75.5 MHz, $CDCl_3$) 13.6 (q, C-4'), 18.6 (t, C-3'), 37.8 (t, C-2'), 66.3 (d, C-1'), 92.1 (d, C-6), 129.9 (s, C-4), 140.1 (s, C-3), 148.8 (s, C-5), 165.0 (s, C-2) ppm; EIMS, m/z (% rel. int.); 285 (M^++1, 8), 283 (18), 281 (10), 241 (24), 239 (100), 237 (80), 159 (7), 43 (9).

(1'*R*,5*E*)-3-(1'-Hydroxybutyl)-4-bromo-5-(chloromethylidene)-2(5*H*)-furanone (**24**): (9 mg, 0.001 %), was obtained as a yellow mobile oil and had identical physical and spectroscopic properties to **23**[8].

Reverse phase VLC (MeOH:H_2O (1:5)) of original VLC fraction 15 afforded six fractions. HPLC separation of combined fractions 1 and 2 (LiChrosorb Si60, 5 μm, EtOAc-hexane (3:20)) afforded further **14** and **15** as well as **2**, **3** and **8**.

3-(1'-Hydroxybutyl)-4-bromo-5-iodomethyl-5-methoxyl-2(5*H*)-furanone (**2**): (36 mg, 0.004 %), an oil, $[\alpha]_D^{25}$ +8° (c, 0.8 $CHCl_3$); IR υ_{max} 3440, 2960, 1770 cm^{-1}; UV λ_{max} 231 (ε 8500) nm; ^1H NMR see Table 1; ^{13}C NMR see Table 2; EIMS, m/z (% rel. int.); 407, 405 (M^++1, <1), 389, 387 (<1), 363 (90), 361 (100), 281 (20), 155 (15); HREIMS obsd 406.9151, $C_{10}H_{15}{}^{81}BrIO_4$ req 406.9178.

5-*epi*-3-(1'-Hydroxybutyl)-4-bromo-5-iodomethyl-5-methoxyl-2(5*H*)-furanone (**3**): (18 mg, 0.002 %), an oil, $[\alpha]_D^{25}$ +39° (c, 1.0 $CHCl_3$); IR υ_{max} 3440, 2960, 1770 cm^{-1}; UV λ_{max} 230 (ε 8500) nm; ^1H NMR see Table 1; ^{13}C NMR see Table 2; EIMS, m/z (% rel. int.); 407, 405 (M^++1, <1), 389, 387 (<1), 375, 373 (<1), 363 (98), 361 (100), 331 (5), 329 (4), 281 (12), 265 (6), 263 (4), 155 (15); HREIMS obsd 406.9188, $C_{10}H_{15}{}^{81}BrIO_4$ req 406.9178.

(*R*,*S*)-3-Butyl-4-bromo-5-(dibromomethyl)-5-hydroxy-2-(5*H*)-furanone (**8**): (15 mg, 0.002 %), a yellow mobile oil with physical and spectroscopic data identical to those previously reported[10].

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