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Xanthones and benzophenones from *Garcinia griffithii* and *Garcinia mangostana*

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Abstract

A new polyisoprenylated benzophenone, guttiferone I, together with the known compounds cambogin, 1,7-dihydroxyxanthone, 1,3,6,7-tetrahydroxyxanthone and 1,3,5,6-tetrahydroxyxanthone were isolated from the stem bark of *Garcinia griffithii*. The acetone extract of the heartwood of *Garcinia mangostana* contained one new diprenylated xanthone (mangoxanthone) and a new benzophenone (3′,6-dihydroxy-2,4,4′-trimethoxybenzophenone) as well as the known xanthones dulxanthone D, 1,3,7-trihydroxy-2-methoxyxanthone, 1,3,5-trihydroxy-13,13-dimethyl-2H-pyran[7,6-*b*]xanthen-9-one. Their structures were established on the basis of spectroscopic studies and chemical correlation.

Keywords: Guttiferae; *Garcinia griffithii*; *Garcinia mangostana*; Polyisoprenylated benzophenones; Xanthones

1. Introduction

The genus *Garcinia* (Guttiferae) is known to produce a variety of biologically active metabolites such as polyisoprenylated benzophenones (Gustafson et al., 1992; Williams et al., 2003) and xanthones (Bennett and Lee, 1989). *Garcinia griffithii* T. Anders. is a medium-sized tree found in South East Asia (Whitmore, 1972). No medicinal uses are recorded for this species although it has been used as a fruit tree (Burkill, 1966; Perry and Metzger, 1980). As part of a phytochemical study of South East Asian plants, we have previously reported the presence of a cytotoxic bixanthone, griffipavixanthone, which is common to *G. griffithii* and *Garcinia parvifolia* (Xu et al., 1998) and now describe the isolation and structural elucidation of further constituents of the stem bark of *G. griffithii* collected in Singapore.

Garcinia mangostana L. is commonly found throughout South and South East Asia where it is the source of the mangosteen fruit as well as being utilised in traditional treatments for skin diseases (Burkill, 1966; Perry and Metzger, 1980). We have previously reported the isolation of 12 new xanthones from the hexane extract of the heartwood of *G. mangostana* L. collected in Myanmar (Nilar and Harrison, 2002). In a continuation of our study of this species, we have now examined the acetone extract and have obtained three known xanthones along with a new xanthone and a new benzophenone.

2. Results and discussion

Both hexane and EtOAc extracts of the stem bark of *G. griffithii* were analysed. The latter gave the known polyisoprenylated benzophenone, cambogin (Gustafson et al., 1992) and three known xanthones, 1,7-dihydroxyxanthone (Delle Monache et al., 1983), 1,3,6,7-tetra-

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hydroxyxanthone (Carpenter et al., 1969) and 1,3,5,6-tetrahydroxyxanthone (Frahm and Chaudhuri, 1979) which were identified by comparison of their physical properties with reported values. The hexane extract of the stem bark afforded mixtures of lipids and sterols as well as griffipavixanthone (Xu et al., 1998) and a new polyisoprenylated benzophenone, guttiferone I (**1**). The mass spectrum of compound **1** showed a molecular ion (*m*/*z* 602.3616) which established the molecular formula as $C_{38}H_{50}O_6$. UV absorptions at λ_{max} 280 and 232 nm revealed aromatic and conjugated carbonyl chromophores. The IR spectrum exhibited bands for hydroxyl (3350 cm^{-1}) and both non-conjugated (1724 cm^{-1}) and conjugated (1639 cm^{-1}) carbonyl groups. The ^1H NMR spectrum in $CDCl_3$ was quite complex, but when the spectrum was recorded in CD_3OD/TFA only one set of signals was obtained. This behaviour has been observed for polyisoprenylated benzophenones from *Garcinia* and *Allanblackia* species which undergo keto-enol tautomerism (Gustafson et al., 1992; Fuller et al., 1999; Williams et al., 2003). The ^1H NMR spectrum (Table 1) revealed the presence of a 1,2,4-trisubstituted benzene ring [δ_H 7.19 (1H, *d*, J = 1.9 Hz, H-12), 6.98 (1H, *dd*, J = 8.3 and 1.9 Hz, H-16), and 6.68 (1H, *d*, J = 8.3 Hz, H-15)]. There were also resonances for two tertiary methyl groups [δ_H 1.24 (3H, *s*, H_3-22) and 1.02 (3H, *s*, H_3-23)], four trisubstituted double bonds [δ_H 4.90 (1H, *br t*, J = 9.1 Hz, H-18), 5.05 (1H, *m*, H-25), 5.17 (1H, *m*, H-30), and 5.09 (1H, *m*, H-35)], seven vinylic methyl groups [δ_H 1.69 (3H, *s*, H_3-38), 1.68 (3H, *s*, H_3-21), 1.65 (6H, *s*, H_3-20 and H_3-27), 1.58 (3H, *s*, H_3-36), 1.53 (3H, *s*, H_3-37), and 1.48 (3H, *s*, H_3-28)] and 10 allylic methylene protons [δ_H 2.0–2.2 & 2.5–2.75 (10H, *m*)] which suggested the presence of two 3-methylbut-2-enyl and one 3,7-dimethylocta-2,6-dienyl side chains. The ^{13}C NMR spectrum (Table 1) showed resonances for six aromatic carbons [δ_C 152.5 (C-14), 146.2 (C-13), 129.6 (C-11), 125.2 (C-16), 117.3 (C-12), and 115.1 (C-15)] and a conjugated carbonyl group at δ_C 196.0 (C-10), which indicated the presence of a 3,4-dihydroxybenzoyl group. This was supported by ^1H NMR signals for a 1,2,4-trisubstituted benzene ring (see above) and a peak at *m*/*z* 137.0256 ($C_7H_5O_3$) in the mass spectrum. The presence of these structural features was supported by the HMBC spectrum (see Table 1). The ^{13}C NMR spectrum also showed resonances for a non-conjugated ketone [δ_C 209.8 (C-9)], two quaternary carbons [δ_C 68.1 (C-4) and 61.8 (C-8)] and an enolised 1,3-diketone [δ_C 194.9 (C-1), 118.4 (C-2) and 195.4 (C-3)] which along with quaternary [δ 47.9 (C-5)], methine [δ 41.0 (C-6)] and methylene [δ 40.7 (C-7)] carbons were characteristic of the bicyclo[3.3.1]nonane ring system characteristic of a polyisoprenylated benzophenone (Gustafson et al., 1992).

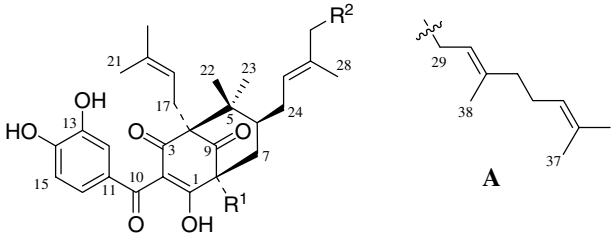
The positions of the side chains were assigned from the HMBC spectrum (Table 1) and nOe interactions.

Table 1
^1H (500 MHz), HMBC and ^{13}C (125 MHz) NMR data for **1** in CD_3OD/TFA (J in Hz in parentheses)

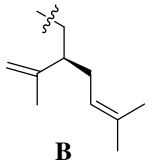
Position	δ_H	HMBC		δ_C
		^2J	^3J	
1	–			194.9
2	–			118.4
3	–			195.4
4	–			68.1
5	–			47.9
6	1.98 *m*	C-5, C-24	C-25	41.0
7	2.04 *m*	C-8	C-1, C-29	40.7
8	–			61.8
9	–			209.8
10	–			196.0
11	–			129.6
12	7.19 *d* (1.9)	C-11, C-13	C-10, C-14, C-16	117.3
13	–			146.2
14	–			152.5
15	6.68 *d* (8.3)	C-14, C-16	C-11, C-13	115.1
16	6.98 *dd* (1.9, 8.3)	C-11, C-15	C-10, C-12, C-14	125.2
17	2.54 *m* 2.75 *br dd* (9.1, 13.5)	C-4, C-18	C-5, C-9, C-19	27.1
18	4.90 *br t* (9.1)		C-20, C-21	120.8
19	–			135.7
20	1.65 *s*	C-19, C-21	C-18	25.9
21	1.68 *s*	C-19, C-20	C-18	18.2
22	1.24 *s*	C-5	C-4, C-6, C-23	23.2
23	1.02 *s*	C-5	C-4, C-6, C-22	27.3
24	2.09 *m*	C-6, C-25	C-26	30.1
25	5.05 *m*	C-24	C-28	125.4
26	–			133.7
27	1.65 *s*			26.3
28	1.48 *s*	C-26	C-25, C-27	18.1
29	2.52 *m*	C-8, C-30	C-31	31.8
30	5.17 *m*		C-38	120.5
31	–			139.2
32	2.00 *m*			27.7
33	1.99 *m*			27.8
34	5.09 *m*		C-36, C-37	125.1
35	–			132.2
36	1.58 *s*	C-35	C-34, C-37	25.9
37	1.53 *s*	C-35	C-34	17.8
38	1.69 *s*	C-31	C-30	16.8

The C-17 methylene protons showed five correlations (^2J: C-4, C-18; ^3J: C-5, C-9 and C-19) which required the placement of one of the 3-methylbut-2-enyl groups at C-4. The *gem*-dimethyl group at C-5 was indicated by correlations between each set of methyl protons with C-4, C-5 and C-6. The correlations of the C-24 methylene protons (^2J: C-6, C-25; ^3J: C-26) required the placement of the other 3-methylbut-2-enyl group at C-6. Assignment of the relative stereochemistry of this group was made by comparison of the ^{13}C chemical shifts of the methyl groups at C-22 and C-23 with those of guttiferones B (**2**), E (**3**) and F (**4**) (Gustafson et al., 1992; Fuller et al., 1999). In guttiferone B (**2**), where the geranyl side chain at C-6 is equatorial, the C-22 and C-23 methyl resonances appeared at δ 23.8 and 16.5, the C-23 methyl

being shielded by a γ-gauche interaction with the geranyl group. In both guttiferones E (**3**) and F (**4**), where the 3-methylbut-2-enyl group at C-6 is axial, this shielding interaction is absent for C-23 and hence the C-22 and C-23 methyl signals appeared at δ 23.2 and 27.3. In the case of **1**, the corresponding methyl resonances [δ_C 23.2 (C-22) and 27.3 (C-23)] established the axial nature of the 3-methylbut-2-enyl group at C-6. The C-29 methylene protons showed two ^2J couplings to C-8 and C-30 and a ^3J coupling to C-31. They also showed an nOe interaction with the C-38 methyl, while the C-30 olefinic proton showed a correlation with C-38 and showed nOe enhancements with the C-32 methylene protons. This established that the 3,7-dimethylocta-2,6-dienyl group was attached to C-8. The bicyclic ring system in compound **1** requires that the C-4 and C-8 substituents be equatorial. The absolute configuration of **1** remains undetermined.

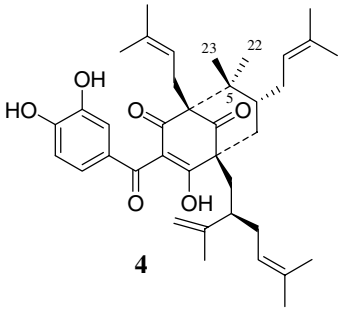


A



B

1 R^1=A, R^2=H
2 R^1=A, R^2=preny1
3 R^1=B, R^2=H



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From *G. mangostana*, two compounds which have previously been reported as natural products were isolated. The first compound was a prenylated xanthone, dulxanthone D (**5**), which has been isolated from *G. dulcis* and was identified by comparison with the literature values (Ito et al., 1997). Methylation of **5** with diazomethane gave a trimethyl ether (**6**) [δ_H 3.97, 3.87 and 3.80 (each 3H, *s*)] which possessed a chelated hydroxyl [δ_H 13.44 (1H, *s*, 1-OH)] and was therefore the previously unknown 1-hydroxy-3,6,7-trimethoxy-8-(3-methylbut-2-enyl)-xanthone. The second known compound was 1,3,7-trihydroxy-2-methoxyxanthone (**7**) which has been obtained from *Polygala cyparissias* (Pinheiro et al., 1998).

The third compound, 1,3,5-trihydroxy-13,13-dimethyl-2H-pyran[7,6-*b*]xanthen-9-one (**8**) has been reported only as a transformation product of 1,3,5-trihydroxy-6,6′-dimethylpyrano-(2′,3′:6,7)-4-(1,2-dimethylprop-2-enyl)-xanthone (**9**). This is the first report of **8** as a natural product. 2D NMR studies (see Fig. 1) confirmed the structure and allowed the assignment of the ^{13}C NMR spectrum (see Section 3) which has not previously been determined.

3′,6-Dihydroxy-2,4,4′-trimethoxybenzophenone (**10**) was obtained as a pale yellow solid, $C_{16}H_{16}O_6$ (*m*/*z* 304.0919), m.p. 161–162 °C with UV (228, 280 and 312 nm) and IR absorptions [3400 (OH), 1618 (a cross-conjugated C=O) and 1579 and 1514 (aromatic rings) cm^{-1}] which were suggestive of an oxygenated benzophenone. The ^{1}H NMR spectrum contained signals for a chelated hydroxyl group [δ_H 11.72 (1H, *s*, 6-OH)], two *meta*-coupled aromatic protons [δ_H 6.15 (1H, *d*, J = 2.3 Hz, H-5) and 5.95 (1H, *d*, J = 2.3 Hz, H-3)], a 1,2,4-trisubstituted benzene ring [δ_H 7.17 (1H, *dd*, J = 2.0 and 8.8 Hz, H-6′), 7.17 (1H, *d*, J = 2.0 Hz, H-2′) and 6.83 (1H, *d*, J = 8.8 Hz, H-5′)] and three methoxyl groups [δ_H 3.93, 3.83 and 3.52 (3 · 3H, *s*, 4′-OMe, 4-OMe and 2-OMe)]. The ^{13}C NMR spectrum (see Section 3) revealed the presence of sixteen carbon resonances due to a carbonyl carbon, 12 aromatic carbons and three methoxyl groups. These spectral data indicated that **10** was a benzophenone comprising 1,2,4-trisubstituted and 1,2,3,5-tetrasubstituted benzene rings. Methylation afforded a pentamethyl ether (**11**) which was identical to that obtained by methylation of 4′,6-dihydroxy-2,3′,4-trimethoxybenzophenone (**12**) from *G. subelliptica* (Minami et al., 1994). The positions of the methoxyl groups on **10** were determined using difference NOE spectroscopy. The trisubstituted ring had only one methoxyl since H-5′ was enhanced upon irradiation of the C-4′ methoxyl group. Irradiation of the most shielded methoxyl (2-OMe) enhanced H-3 whilst both H-3 and H-5 were affected when the 4-OMe was irradiated. The natural product was therefore 3′,6-dihydroxy-2,4,4′-trimethoxybenzophenone (**10**).

The final compound, mangoxanthone (**13**) was isolated as yellow needles, m.p. 195–197 °C, $[\alpha]_D$ −40.0. A positive test with alcoholic $FeCl_3$ showed it to be a

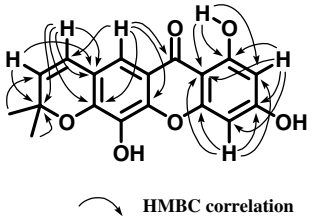


Fig. 1. HMBc correlations of 8.

phenol. The molecular formula was deduced to be $C_{23}H_{24}O_6$ from the HREI-MS (*m/z* 396.1602). The ^1H and ^{13}C NMR spectra (see Table 2) of **13** had signals due to a chelated hydroxyl group [δ_H 13.08 (1H, *s*, exchangeable with D_2O, 1-OH)] with the corresponding chelated carbonyl carbon [δ_C 182.2 (C-9)], a free phenolic hydroxyl group [δ_H 9.00 1H, *br s*, exchangeable with D_2O, 7-OH], a 1,2,4-trisubstituted benzene ring [δ_H 7.56 (1H, *d*, J = 2.9 Hz, H-8), 7.48 (1H, *d*, J = 9.0 Hz, H-5) and 7.34 (1H, *dd*, J = 9.0 and 2.9 Hz, H-6); δ_C 125.5 (C-6), 120.4 (C-5) and 109.9 (C-8)], a 3-methylbut-2-enyl group [δ_H 5.30 (1H, *t* sept, J = 7.5 and 1.2 Hz, H-17), 3.48 and 3.41 (1H each, *dd*, J = 14.4 and 7.5 Hz, H_2-16), 1.86 (3H, *br s*, H_3-20) and 1.66 (3H, *br s*, H_3-19); δ_C 132.7 (C-18), 123.5 (C-17), 23.3 (C-16), 18.7 (C-20) and 26.5 (C-19)], a 2,3-dioxygenated-3-methylbutyl group [δ_H 4.85 (1H, *dd*, J = 9.4 and 7.5 Hz, H-12), 3.22 (1H, *dd*, J = 15.6 and 7.5 Hz, H-11) and 3.16 (1H, *dd*, J = 15.6 and 9.4 Hz, H-11), 1.28 (3H, *s*, H_3-14) and 1.27 (3H, *s*, H_3-15); δ_C 93.2 (C-12), 72.3 (C-13), 28.0 (C-11)], 26.8 (C-14) and 25.9 (C-15)], a hydroxyl group [δ_H 3.82 (1H, *br s*, exchangeable with D_2O, 13-OH)], and nine substituted aromatic carbons, five of which were oxygenated. The UV spectrum exhibited maxima at 236, 266, 322, and 380 nm, characteristic of a oxygenated xanthone.

Table 2
^1H (500 MHz) and ^{13}C (75 MHz) NMR data for **9** in acetone-d_6 (J in Hz in parentheses)

Position	δ_H	δ_C
1	–	157.3
2	–	109.0
3	–	167.5
4	–	103.2
4a	–	156.5
5	7.48 *d* (9.0)	120.4
6	7.34 *dd* (9.0, 2.9)	125.5
7	–	155.5
8	7.56 *d* (2.9)	109.9
8a	–	122.3
9	–	182.2
9a	–	104.9
10a	–	151.5
11	3.22 *dd* (15.6, 7.5) 3.16 *dd* (15.6, 9.4)	28.0
12	4.85 *dd* (9.4, 7.5)	93.2
13	–	72.3
14	1.27 *s*[a]	26.8[a]
15	1.28 *s*[a]	25.9[a]
16	3.48 *dd* (14.4, 7.5) 3.41 *dd* (14.4, 7.5)	23.3
17	5.30 *t* sept (7.5, 1.2)	123.5
18	–	132.7
19	1.66 *br s*	26.5
20	1.86 *br s*	18.7
1-OH	13.08 *s*	
7-OH	9.00 *br s*	
18-OH	3.82 *br s*	

[a] Assignments within the same column are interchangeable.

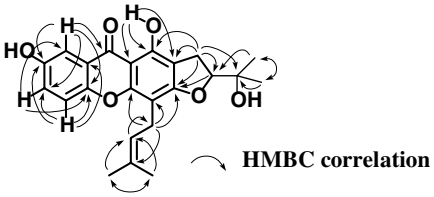
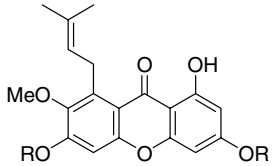
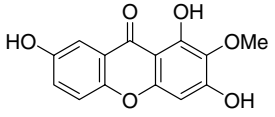


Fig. 2. HMBC correlations of 13.

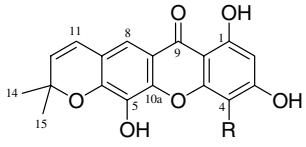
The HMBC correlations of **13** (see Fig. 2) clearly identified a 7-hydroxylated xanthone B ring and established that the other ring was fully substituted. They also confirmed the presence of a 3-methylbut-2-enyl group and a 2,3-dioxygenated-3-methylbutyl group. Correlations of the methylene protons of the latter group and of the chelated hydroxyl proton established that C-2 was alkylated and a correlation from H-12 to C-3 revealed that this alkyl group formed a 2-(1-hydroxy-1-methylethyl)-2,3-dihydrofuran ring moiety with the oxygen at C-3. The 3-methylbut-2-enyl group must by default be attached to C-4 and this was confirmed by the presence of a ^3J correlation from the C-16 methylene protons and C-3. The chemical shifts of the fully substituted ring agreed well with those of morusignin G (**14**) (Hano et al., 1991). The compound was, therefore, mangoxanthone (**13**) which is a new natural product.



5 R=H
6 R=Me

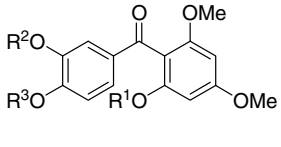


7

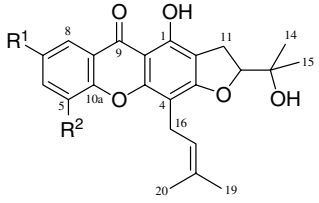


8 R=H

9 R=



10 R^1=R^2=H, R^3=Me
11 R^1=R^2=R^3=Me
12 R^1=R^3=H, R^2=Me



13 R^1=OH, R^2=H
14 R^1=H, R^2=OH

3. Experimental

3.1. General experimental details

Mp uncorr. IR: $CHCl_3$ unless otherwise specified. UV: EtOH. ^1H NMR and ^{13}C NMR: Bruker DPX300, Bruker AMX500 or Bruker DRX500 relative to TMS at δ 0.0. EIMS: 70 eV Finnigan TSQ-7000 LC/triple quadrupole MS.

CC was carried out on normal phase silica gel 60 (Merck, 63–200 μm) or reversed phase silica gel (Baker C_{18}, 40 μm). GPC: Sephadex LH-20 ($CHCl_3$–MeOH 1:1 as eluant). HPLC: Lichrosorb silica, 10 μm, 4.5 × 250 mm or 9.0 × 250 mm, RI detection.

3.2. Plant material

Stem bark of *G. griffithii* was collected in Singapore and identified by Prof. Le Cong Kiet of the Botany Department, University of Ho Chi Minh City, Vietnam. A herbarium sample (LJHGG1) is deposited in the National University of Singapore Herbarium (SINU). Hexane-extracted *G. mangostana* heartwood (1 kg) was available from an earlier study of the hexane soluble material (Nilar and Harrison, 2002).

3.3. Extraction and isolation of compounds from *G. griffithii*

Air-dried and ground bark (950 g) was extracted with hot hexane (35 g of extract) and then hot EtOAc (30 g of extract). CC of the hexane extract over silica gel yielded 7 frs. ^1H NMR showed that frs 1–2 contained triglycerides and β-sitosterol and they were not investigated further. Frs 4–7 showed a single spot on TLC and after RP-CC over C_{18} silica gel [Me_2CO–H_2O–TFA (74.95:24.95:0.1)] yielded *guttiferone I* (**1**) (40 mg). CC of the EtOAc extract over silica gel (EtOAc–hexane gradient) gave, in order of elution, cambogin (35 mg), 1,7-dihydroxyxanthone (10 mg), 1,3,6,7-tetrahydroxyxanthone (12 mg) and 1,3,5,6-tetrahydroxyxanthone (15 mg).

3.3.1. Guttiferone I (1)

Bright yellow solid, m.p. 60–62°. $[\alpha]_D$ −68 (*c* 1.2, $CHCl_3$); UV λ_{max} nm (ε): 280 (26,700), 232 (20,600); IR ν_{max} 3350, 1724, 1639, 1505 cm^{-1}; ^1H NMR and ^{13}C NMR (CD_3OD/0.1% TFA) (Table 1); HR-EIMS *m/z* (rel. int.) 602.36158 [M^+] (6), 533.15925 (10), 465.20163 (35), 231.98515 (21), 137.02560 (30), 69.07056 (100).

3.4. Extraction and isolation of compounds from *G. mangostana*

The dried and powdered plant material was extracted by continuous percolation with hot Me_2CO. Removal of the solvent gave a crude extract (29.1 g) which was subjected to CC (silica gel, acetone–hexane step gradient) to give 19 frs. TLC and ^1H NMR spectroscopy showed that only fr 7 was worth further examination. The fr (3.56 g) was subjected to GPC, CC (silica gel, 30% EtOAc–hexane) and HPLC (silica gel, 30% EtOAc - hexane) to give dulxanthone D (**5**) (7 mg), 3′6-*dihydroxy*-244′-*trimethoxybenzophenone* (**10**) (55 mg), 1,3,7-trihydroxy-2-methoxyxanthone (**7**) (10 mg), 1,3,5-trihydroxy-13,13-dimethyl-2H-pyran[7,6-b]-xanthen-9-one (**8**) (8 mg), and *mangoxanthone* (**13**) (6.2 mg).

3.4.1. 1-Hydroxy-3,6,7-trimethoxy-8-(3-methylbut-2-enyl)-xanthone (6)

Dulxanthone D (**5**) (4 mg) was methylated with ethereal CH_2N_2 to give the trimethyl ether (**6**) as a pale yellow gum. UV λ_{max} nm (log ε): 244 (4.33), 254 (4.37), 308 (4.17), 346 (3.75). IR ν_{max} cm^{-1}: 1649 (C=O), 1596 (Ar), 1457, 1427, 1269, 1208, 1160, 1128. ^1H NMR (500 MHz, $CDCl_3$) δ_H 13.44 (1H, *s*, 1-OH), 6.76 (1H, *s*, H-5), 6.32 (1H, *d*, *J* = 2.3 Hz, H-4), 6.31 (1H, *d*, *J* = 2.3 Hz, H-2), 5.25 (1H, *t* sept, *J* = 6.6 and 1.3 Hz, H-12), 4.13 (2H, *br d*, *J* = 6.6 Hz, H_2-11), 3.97 (3H, *s*, OMe), 3.87 (3H, *s*, OMe), 3.80 (3H, *s*, OMe), 1.85 (3H, *s*, H_3-15), 1.69 (3H, *br s*, H_3-14). ^{13}C NMR (125 MHz, $CDCl_3$) δ_C 182.1 (C), 165.8 (C), 163.7 (C), 158.3 (C), 156.8 (C), 155.6 (C), 144.2 (C), 137.4 (C), 132.0 (C), 123.1 (CH), 112.0 (C), 104.1 (C), 98.4 (CH), 96.8 (CH), 91.9 (CH), 61.0 (CH_3), 56.1 (CH_3), 55.7 (CH_3), 26.2 (CH_2), 25.9 (CH_3), 18.2 (CH_3). EIMS *m/z* (rel. int.): 370 [$M]^+$ (39), 355 (36), 341 (8), 327 (100), 313 (9), 299 (11), 283 (8), 257 (5), 195 (23), 170 (11), 135 (2), 77 (44), 41 (5). HR-EIMS *m/z* 370.1410 ($C_{21}H_{22}O_6$ requires *m/z* 370.1416).

3.4.2. 1,3,5-Trihydroxy-13,13-dimethyl-2H-pyran[6,7-b]-xanthen-9-one (8)

Yellow solid; m.p. 275–277 °C. UV λ_{max} nm (log ε): 274 (4.79), 328 (4.29), 362 (4.19). IR ν_{max} cm^{-1} 3438 (OH), 1654 (C=O), 1578 (Ar), 1474, 1340, 1253, 1167, 1136. ^1H NMR (500 MHz, acetone-d_6) δ_H 13.10 (*s*, 1-OH, exchangeable with D_2O), 7.41 (*s*, H-8), 6.56 (*d*, *J* = 9.9 Hz, H-11), 6.44 (*d*, *J* = 2.1 Hz, H-4), 6.23 (*d*, *J* = 2.1 Hz, H-2), 5.88 (*d*, *J* = 9.9 Hz, H-12), 1.49 (*s*, H_3-14 and H_3-15); ^{13}C NMR (125 MHz, acetone-d_6) δ_C 180.9 (C-9), 164.6 (C-1), 166.1 (C-3), 158.7 (C-4a), 146.8 (C-10a), 146.6 (C-6), 134.3 (C-5), 132.4 (C-12), 122.1 (C-11), 119.3 (C-7), 115.3 (C-8a), 113.2 (C-8), 103.2 (C-9a), 98.9 (C-2), 94.8 (C-4), 78.8 (C-13), 28.3 (C-14), 28.3 (C-15). EIMS *m/z* (rel. int.): 326 [$M]^+$ (57), 311 (100), 297 (5), 274 (17), 259 (22), 231 (14), 203 (6), 156 (40), 141 (7), 115 (3), 69 (5), 59 (14), 43 (32). HR-EIMS *m/z* 326.0791 ($C_{18}H_{14}O_6$ requires *m/z* 326.0790).

3.4.3. 3′,6-Dihydroxy-2,4,4′-trimethoxybenzophenone (10).

Pale yellow solid; m.p. 161–162 °C. UV λ_{max} nm (log ε): 228 (4.26), 280 (4.01), 312 (4.02). IR ν_{max} cm^{-1}: 1621 (C=O), 1581 (Ar), 1280, 1206, 1158, 1111. ^1H NMR (500 MHz, $CDCl_3$) δ_H 11.72 (1H, *s*, 6-OH), 7.17 (1H, *d*, *J* = 2.0 Hz, H-2′), 7.17 (1H, *dd*, *J* = 2.0 and 8.8 Hz, H-6′), 6.83 (1 H, *d*, *J* = 8.8 Hz, H-5′), 6.15 (1H, *d*, *J* = 2.3 Hz, H-5), 5.95 (1H, *d*, *J* = 2.3 Hz, H-3), 3.93 (3H, *s*, 4′-OMe), 3.83 (3H, *s*, 4-OMe), 3.52 (3H, *s*, 2-OMe). ^{13}C NMR (125 MHz, $CDCl_3$) δ_C 197.5 (C), 166.0 (C), 165.1 (C), 161.7 (C), 149.5 (C), 144.8 (C), 134.7 (C), 121.7 (CH), 115.1 (CH), 109.4 (CH), 106.0 (C), 93.8 (CH), 91.5 (CH), 56.0 (CH_3), 55.6 (CH_3), 55.3 (CH_3). EIMS *m/z* (rel. int.): 304 $[M]^+$ (78), 303 (100), 287 (23), 273 (4), 259 (6), 243 (3), 215 (2), 181 (90), 167 (8), 151 (27), 138 (19), 123 (13), 108 (6), 95 (6), 69 (7), 58 (7), 43 (18). HRMS *m/z* 304.0919 ($C_{16}H_{16}O_6$ requires *m/z* 304.0947).

3.4.4. Methylation of 3′,6-dihydroxy-2,4,4′-trimethoxybenzophenone (10)

3′,6-Dihydroxy-2,4,4′-trimethoxybenzophenone (**10**) (20 mg) was methylated with CH_3I–K_2CO_3 The crude product was chromatographed over silica gel (30% EtOAc–hexane) to afford 2,3′,4,4′,6-pentamethoxybenzophenone (**11**) which was identical with that reported (Minami et al., 1994).

3.4.5. Mangoxanthone (13)

Yellow needles, m.p. 195–197 °C (acetone–hexane), $[\alpha]_D$ −40.0 (*c* 0.62 in acetone); UV λ_{max} nm 236 (4.21), 266 (4.23), 322 (3.96), and 380 (3.54). IR ν_{max} cm^{-1} 3450 (OH), 1657 (C=O), 1578 (Ar), 1479, 1337, 1257, 1139. ^1H NMR and ^{13}C NMR (CD_3OD/0.1% TFA) (Table 2). EIMS *m/z* (rel. int.) 396 ($[M]^+$, 55), 363 (42), 323 (50), 309 (49), 269 (51), 167 (8), 149 (24), 69 (47), 43(100). HREI-MS *m/z* 396.1602 ($C_{23}H_{24}O_6$ requires 396.1573).

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