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Phloroglucinols, depsidones and xanthones from the twigs of *Garcinia parvifolia*

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Abstract—Seven phloroglucinols, named parvifoliols A–G (**1**–**7**), two depsidones, named parvifolidones A, B (**8**, **9**), and three xanthones, named parvifolixanthones A–C (**10**–**12**), were isolated from the twigs of *Garcinia parvifolia* along with seven known compounds: garcidepsidone B, mangostinone, rubraxanthone, dulxanthone D, 1,3,5,6-tetrahydroxyxanthone, norathyriol, and (2*E*,6*E*,10*E*)-(+)-4β-hydroxy-3-methyl-5β-(3,7,11,15-tetramethylhexadeca-2,6,10,14-tetraenyl)cyclohex-2-en-1-one. Their structures were proposed on the basis of spectroscopic data. The antibacterial and antioxidation activities were evaluated.

1. Introduction

Plants of the genus *Garcinia*, widely distributed in tropical Africa, Asia, New Caledonia, and Polynesia, have yielded an abundance of biologically active and structurally intriguing natural products.[1,2] As part of our ongoing research program on the identification of antibacterial constituents from plants in the genus *Garcinia*, we have investigated the twigs of *Garcinia parvifolia* belonging to the Guttiferae family. Phytochemical investigation on the latex,[3] leaves,[4] and bark[5] of *G. parvifolia* resulted in the isolation of ten xanthones and four depsidones. In this paper, we describe the isolation and characterization of seven phloroglucinols, parvifoliols A–G (**1**–**7**), two depsidones, parvifolidones A, B (**8**, **9**), and three xanthones, parvifolixanthones A–C (**10**–**12**), along with seven known compounds, garcidepsidone B,[4] mangostinone,[6] rubraxanthone,[3] dulxanthone D,[7] 1,3,5,6-tetrahydroxyxanthone,[8] norathyriol,[9] and (2*E*,6*E*,10*E*)-(+)-4β-hydroxy-3-methyl-5β-(3,7,11,15-tetramethylhexadeca-2,6,10,14-tetraenyl)cyclohex-2-en-1-one[10] from the twigs of *G. parvifolia*. The isolated compounds were examined for the antibacterial activity against methicillin-resistant *Staphylococcus aureus* (MRSA) and the antioxidation effect based on the scavenging activity study of the stable 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radical.

2. Results and discussion

Parvifoliol A (**1**) was isolated as a colorless gum whose molecular formula $C_{19}H_{26}O_5$ was deduced by HREIMS. The UV absorption bands at 223, 268, and 317 nm indicated the presence of an aromatic moiety while the IR spectrum showed hydroxyl (3433 cm^{-1}) and conjugated ester carbonyl (1662 cm^{-1}) stretching bands. The ^1H NMR spectrum (Table 1) displayed resonances for one aromatic proton (δ 6.07, s), one geranyl unit [δ 5.16 (1H, mt, J=6.9 Hz), 5.07 (1H, mt, J=6.9 Hz), 3.26 (2H, d, J=6.9 Hz), 2.00 (4H, m), 1.76 (3H, s) 1.64 (3H, s), and 1.58 (3H, s)], and two methoxyl groups (δ 4.03, s and 3.83, s). The carbonyl carbon resonance at δ 170.0 together with its HMBC correlation with the methoxy protons at δ 4.03 established the presence of a methyl ester group. The geranyl unit, the other methoxyl group (δ 3.83), and the aromatic proton were located at C-3 (δ 93.5), C-4 (δ 164.2), and C-5 (δ 91.6), respectively, on the basis of HMBC correlations from the methylene protons (H_2-7, δ 3.26) of the geranyl unit to C-2 (δ 158.6), C-3, and C-4, from the methoxy protons to C-4, and from the aromatic proton to C-1 (δ 109.0), C-3, C-4, and C-6 (δ 160.8). Signal enhancement of H-5 and H_2-7 after irradiation at 4-OMe in the NOEDIFF experiment

Keywords: *Garcinia parvifolia*; Phloroglucinols; Depsidones; Xanthones; Antibacterial activity; Antioxidant activity.
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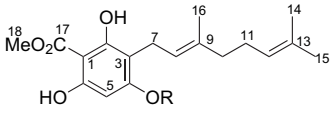
Table 1. ^{1}H and ^{13}C NMR data of compounds **1–4**

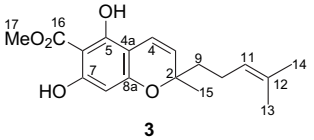
Position	1		2		3		4	
	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C
1	—	109.0, s	—	93.7, s	—	—	—	—
2	—	158.6, s	5.99, s	162.3, s	—	80.2, s	—	73.7, s
3	—	93.5, s	—	106.0, s	5.41, d, 10.0	124.7, d	4.73, t, 8.7	91.0, d
4	—	164.2, s	—	162.3, s	6.65, dd, 10.0, 0.6	116.4, d	3.03, d, 8.7	26.7, t
4-OMe	3.83, s	55.6, q	—	—	—	—	—	—
4a	—	—	—	—	—	102.1, s	—	105.1, s
5	6.07, s	91.6, d	6.00, s	96.0, d	—	161.0, s	—	167.1, s
6	—	160.8, s	—	162.3, s	—	93.4, s	—	93.0, s
7	3.26, d, 6.9	21.5, t	3.35, d, 7.2	21.6, t	—	161.0, s	—	167.1, s
8	5.16, mt, 6.9	122.5, d	5.23, mt, 7.2	121.7, d	5.96, br s	96.5, d	6.00, s	90.8, d
8a	—	—	—	—	—	161.0, s	—	167.1, s
9	—	134.8, s	—	138.7, s	1.69, m	41.7, t	1.60, m	36.7, t
10	2.00, m	39.8, t	2.07, m	39.7, t	2.06, m	22.6, t	2.11, m	21.9, t
11	2.00, m	26.8, t	2.07, m	26.4, t	5.08, mt, 7.0	123.9, d	5.12, mt, 7.2	124.0, d
12	5.07, mt, 6.9	124.5, d	5.05, mt, 6.9	123.8, d	—	131.8, s	—	132.2, s
13	—	131.4, s	—	132.0, s	1.57, s	17.6, q	1.63, s	17.7, q
14	1.58, s	17.7, q	1.59, s	17.7, q	1.66, s	25.7, q	1.68, s	25.7, q
15	1.64, s	25.7, q	1.67, s	25.6, q	1.39, s	27.1, q	1.29, s	22.7, q
16	1.76, s	16.0, q	1.80, s	16.2, q	—	169.8, s	—	169.8, s
17	—	170.0, s	—	170.0, s	4.03, s	52.5, q	4.03, s	52.4, q
18-OMe	4.03, s	52.4, q	4.04, s	52.4, q	—	—	—	—

confirmed the assigned location. The carbon chemical shifts of C-2 and C-6 established the attachment of hydroxyl groups at these carbons. Consequently, the methyl ester moiety was linked at C-1. Parvifoliol A was thus determined to be **1**.

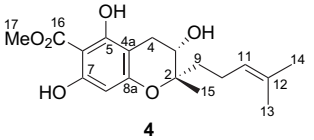


1 R = Me
2 R = H

Parvifoliol B (**2**) was isolated as a colorless gum. The molecular formula $C_{18}H_{24}O_5$ determined by HREIMS showed that it was lower than that of **1** by one methylene unit. The UV and IR bands were almost identical to those of **1**. The ^{1}H and ^{13}C NMR spectra (Table 1) were similar to those of **1** except for the disappearance of the aromatic methoxyl resonance in **2**, indicating the presence of a hydroxyl group instead of the methoxyl group at C-4 (δ 162.3) in **2**. The identical location of the geranyl side chain and the aromatic proton to that of **1** was confirmed by the following HMBC correlations: 2-OH (δ 5.99, s)/C-1 (δ 93.7), C-2 (δ 162.3), and C-3 (δ 106.0), H_2-7 (δ 3.35, d, J=7.2 Hz)/C-2, C-3, and C-4, and H-5 (δ 6.00, s)/C-1, C-3, C-4, and C-6 (δ 162.3). Consequently, parvifoliol B had the structure **2**.



3

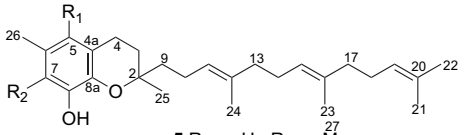


4

Parvifoliol C (**3**) was isolated as a colorless gum and the molecular formula of **3** was established as $C_{18}H_{22}O_5$ by HREIMS. The UV spectrum revealed bands at 227, 254, 262, 278, and 333 nm while the IR spectrum was similar to that of **1**. The ^{1}H NMR data (Table 1) were similar to those of **1** except for the fact that the geranyl resonances in **1** were replaced by signals of two *cis*-olefinic protons of the chromene ring [δ 6.65 (dd, J=10.0 and 0.6 Hz) and 5.41 (d, J=10.0 Hz)], one 4-methyl-3-pentenyl unit [δ 5.08 (1H, mt, J=7.0 Hz), 2.06 (2H, m), 1.69 (2H, m), 1.66 (3H, s), and 1.57 (3H, s)], and one oxyquaternary methyl group (δ 1.39, s) in **3**. ^{3}J HMBC correlations between the higher field olefinic proton (H-3, δ 5.41) with C-4a (δ 102.1) and C-9 (δ 41.7) of the 4-methyl-3-pentenyl unit and C-15 (δ 27.1) of the oxyquaternary methyl group established the fusion of the chromene ring at C-4a and C-8a (δ 161.0) with an ether linkage at C-8a and also revealed the linkage of both 4-methyl-3-pentenyl unit and Me-15 at C-2 of the chromene ring. Signal enhancement of H-4 (δ 6.65), H_2-9 (δ 1.69), and Me-15 (δ 1.39), upon irradiation of H-3 in the NOEDIFF experiment, supported the assignment. In addition, H-8 (δ 5.96, br s) showed a zig-zag coupling with H-4 in the COSY spectrum. Parvifoliol C was thus assigned to be **3**.

Parvifoliol D (**4**) was isolated as a colorless gum. The molecular formula was determined to be $C_{18}H_{24}O_6$ by HREIMS. The UV and IR absorption bands were similar to those of **1**. The ^{1}H NMR data (Table 1) revealed the replacement of the *cis*-olefinic proton resonances of the chromene unit in **3** with resonances of one oxymethine proton (δ 4.73, t, J=8.7 Hz) and methylene protons (δ 3.03, d, J=8.7 Hz) in **4**. ^{3}J HMBC correlations of the oxymethine proton/C-9 (δ 36.7) and C-15 (δ 22.7) as well as those of the methylene protons/C-2 (δ 73.7) and C-8a (δ 167.1) established the location of these protons at C-3 and C-4 of the chroman unit, respectively. The relative orientation of the methyl group at C-2 and the hydroxyl group at C-3 was assigned as trans since irradiation of H-3 enhanced the signal intensity of

Me-15 in the NOEDIFF experiment. Therefore, parvifoliol D had the structure **4**.



5 R_1 = H, R_2 = Me
6 R_1 = R_2 = H
7 R_1 = Me, R_2 = OH
28

Parvifoliol E (**5**), isolated as a colorless gum, had the molecular formula $C_{28}H_{42}O_2$ determined by HREIMS. It exhibited UV absorption bands at 208, 227, and 298 nm while a hydroxyl stretching band (3420 cm^{-1}) was the only significant absorption observed in the IR spectrum. The ^{1}H NMR spectrum (Table 2) displayed resonances of one aromatic proton (δ 6.36, br s), one hydroxyl group (δ 4.35, br s), four methylene protons of a chroman ring [δ 2.67 (2H, t, J=6.6 Hz) and 1.75 (2H, m)], one 4,8,12-trimethyltrideca-3,7,11-trienyl unit [δ 5.12 (3H, m), 2.12 (2H, m), 2.07 (6H, m), 1.96 (2H, m), 1.66 (1H, m), 1.54 (1H, m), 1.68 (3H, s), 1.61 (3H, s), 1.60 (3H, s), and 1.58 (3H, s)], two aromatic methyl groups (δ 2.13, 6H, s), and one oxyquaternary methyl group (δ 1.26, 3H, s). The presence of the 4,8,12-trimethyltrideca-3,7,11-trienyl moiety was established by COSY, HMQC, and HMBC correlations. The singlet aromatic proton at δ 6.36 was assigned as H-5, according to its ^3J HMBC correlations with C-4 (δ 22.3), C-7 (δ 125.8), C-8a (δ 145.7), and C-26 (δ 11.8). In the HMQC spectrum, C-4 and C-26 were correlated with H_2-4 (δ 2.67) of the chroman ring and Me-26 (δ 2.13), respectively. These results also indicated the attachment of Me-26 at C-6 (δ 121.7) and the fusion of the chroman ring at C-4a (δ 118.2) and C-8a. The HMBC cross peaks between the other methylene protons (H_2-3, δ 1.75) of the chroman ring and C-4a, C-9 (δ 39.8), and C-25 (δ 24.0) confirmed the fusion of the chroman ring at C-4a with an ether linkage at C-8a and further established the linkage of both the oxyquaternary methyl and 4,8,12-trimethyltrideca-3,7,11-trienyl groups at C-2 of the chroman skeleton. This assigned location was supported by signal enhancement of H_2-3 and H_2-10 after irradiation of Me-25 in NOEDIFF experiment. The remaining aromatic methyl group was assigned at C-7 (δ 125.8) on the basis of the chemical shifts of C-8 (δ 146.3) and C-8a, which indicated the presence of two adjacent oxy-substituents. Thus, parvifoliol E was determined to be **5**.

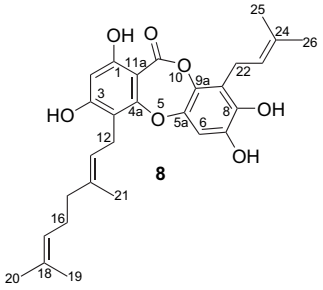
Parvifoliol F (**6**), isolated as a colorless gum, had the molecular formula $C_{27}H_{40}O_2$ assigned by HREIMS. It exhibited UV and IR absorption bands almost identical to those of **5**. The ^{1}H NMR spectrum (Table 2) was similar to that of **5** except that resonances for the singlet aromatic proton and one of the aromatic methyl groups in **5** were replaced by signals of two *meta*-aromatic protons [δ 6.47 (d, J=2.7 Hz) and 6.37 (d, J=2.7 Hz)] in **6**. The higher field aromatic proton was attributed to H-5 according to its ^3J HMBC correlations with C-4 (δ 22.5), C-7 (δ 115.7), C-8a (δ 146.0), and C-26 (δ 16.0). The other *meta*-aromatic proton was then located at C-7. Signal enhancement of both H-5 and H-7 after irradiation of Me-26 in the NOEDIFF experiment supported the position of two *meta*-aromatic protons. Accordingly, parvifoliol F was characterized as **6**.

Table 2. ^{1}H and ^{13}C NMR data of compounds **5–7**

Position	5		6		7	
	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C
2	—	75.2, s	—	75.3, s	—	75.0, s
3	1.75, m	31.4, t	1.76, m	31.4, t	1.68, m	31.3, t
4	2.67, t, 6.6	22.3,[a] t	2.69, t, 6.6	22.5, t	2.32, m	20.6, t
4a	—	118.2, s	—	121.3, s	—	117.3, s
5	6.36, br s	112.2, d	6.37, d, 2.7	112.6, d	—	115.2, s
6	—	121.7, s	—	127.4, s	—	122.2, s
7	—	125.8, s	6.47, d, 2.7	115.7, d	—	144.7, s
8	4.35, br s	146.3, s	4.45, br s	147.8, s	4.44, br s	126.9, s
8a	—	145.7, s	—	146.0, s	—	145.9, s
9	1.66, m, 1.54, m	39.8, t	1.69, m, 1.53, m	39.7, t	1.59, m	39.8, t
10	2.07, m	22.2,[a] t	2.12, m	22.2, t	2.11, m	22.2, t
11	5.12, m	124.4,[b] d	5.11, m	124.3,[a] d	5.10, m	124.2, d
12	—	135.1,[c] s	—	135.1,[b] s	—	135.2, s
13	2.12, m	39.8, t	1.97, m	39.7, t	2.00, m	39.7, t
14	2.07, m	26.6,[d] t	2.07, m	26.6, t	2.07, m	26.8,[a] t
15	5.12, m	124.4,[b] d	5.11, m	124.4,[a] d	5.14, m	124.2, d
16	—	135.0,[c] s	—	135.0,[b] s	—	135.0, s
17	1.96, m	39.7, t	1.97, m	39.7, t	2.00, m	39.7, t
18	2.07, m	26.8,[d] t	2.01, m	26.8, t	2.07, m	26.7,[a] t
19	5.12, m	124.2,[b] d	5.11, m	124.3,[a] d	5.10, m	124.4, d
20	—	131.3, s	—	131.3, s	—	131.2, s
21	1.61, s	17.7, q	1.60, s	17.7, q	1.60, br s	17.7, q
22	1.68, s	25.7, q	1.68, s	25.7, q	1.68, s	25.7, q
23	1.58, s	16.0, q	1.59, s	15.9, q	1.59, s	15.9,[b] q
24	1.60, s	15.9, q	1.58, s	16.0, q	1.59, s	16.0,[b] q
25	1.26, s	24.0, q	1.26, s	24.3, q	1.26, s	23.8, q
26	2.13, s	11.8,[e] q	2.12, s	16.0, q	2.20,[a] s	12.3, q
27	2.13, s	11.9,[c] q	—	—	—	—
28	—	—	—	—	2.19,[a] s	12.0, q

[a,b,c,d,e] Chemical shifts with the same index in the same column may be interchanged.

Parvifoliol G (**7**) was isolated as a colorless gum. The HREIMS showed the molecular formula $C_{28}H_{42}O_3$, which was higher than that of **5** by one oxygen atom. Its UV and IR absorption bands were almost identical to those of **5**. The ^{1}H NMR data (Table 2) were similar to those of **5** except for the disappearance of the aromatic proton in **7**, suggesting the replacement of the aromatic proton with a hydroxyl group. The HMBC correlations from H_2-4 (δ 2.32, m) to C-4a (δ 117.3), C-5 (δ 115.2), and C-8a (δ 145.9), and from Me-28 (δ 2.19 or 2.20) to C-4a, C-5, and C-6 (δ 122.2) revealed the linkage of Me-28 at C-5. The other aromatic methyl group (Me-26, δ 2.20 or 2.19) was attached at C-6 on the basis of HMBC correlations of Me-26/C-5, C-6, and C-7 (δ 144.7). The oxygenated C-8 resonated at much higher field (δ 126.9) due to the shielding effect of two *ortho* oxy-substituents at C-7 and C-8a. The structure of parvifoliol G was thus assigned to be **7**.



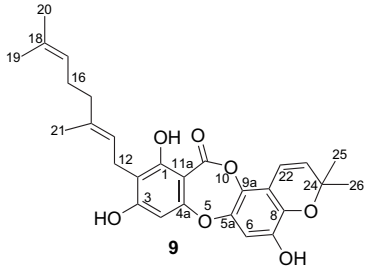
8

The molecular formula of parvifolidone A (**8**), isolated as a yellow gum, was established as $C_{28}H_{32}O_7$ by HREIMS. It exhibited UV and IR absorption bands similar to those of garcidepsidone B.[4] The ^{1}H, ^{13}C NMR (Table 3), and HMBC data were similar to those of garcidepsidone B except for the differences in the HMBC correlations observed in left hand ring. ^3J HMBC correlations of the aromatic proton (δ 6.29, s)/C-4 (δ 111.2) and C-11a (δ 99.3) and those of the methylene protons (δ 3.57, d, J=6.9 Hz) of the geranyl unit/C-3 (δ 162.6) and C-4a (δ 158.7) established the attachment of the aromatic proton and the geranyl side chain at C-2 (δ 100.9) and C-4, respectively. Signal enhancement of H_2-12 and Me-21 (δ 1.86, s) in the NOEDIFF experiment after irradiation of H-6 (δ 6.69, s) confirmed the close proximity of H-6 and the geranyl group. Therefore, parvifolidone A was determined to be **8**.

Table 3. ^{1}H and ^{13}C NMR data of compounds **8** and **9**

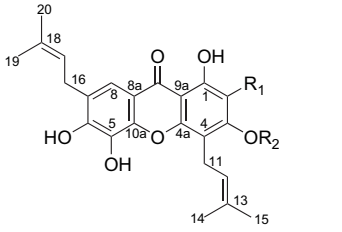
Position	**8**		**9**	
	δ_H	δ_C	δ_H	δ_C
1	10.72, s	163.2, s	11.36, s	162.4, s
2	6.29, s	100.9, d	—	110.8, s
3	6.23, br s	162.6, s	6.26, br s	162.4, s
4	—	111.2, s	6.29, s	100.5, d
4a	—	158.7, s	—	160.1, s
5a	—	143.4, s	—	142.2, s
6	6.69, s	105.4, d	6.69, s	106.4, d
7	5.53, br s	142.0, s	5.39, br s	143.1, s
8	5.59, br s	139.8, s	—	136.5, s
9	—	120.0, s	—	113.8, s
9a	—	135.9, s	—	132.6, s
11	—	168.3, s	—	168.5, s
11a	—	99.3, s	—	98.5, s
12	3.57, d, 6.9	22.4, t	3.41, d, 7.2	22.0, t
13	5.20, mt, 6.9	121.3, d	5.23, mt, 7.2	120.7, d
14	—	139.4, s	—	140.3, s
15	2.13, m	39.7, t	2.08, m	39.7, t
16	2.13, m	26.3, t	2.08, m	26.3, t
17	5.05, mt, 6.9	123.6, d	5.04, mt, 6.6	123.6, d
18	—	132.2, s	—	132.3, s
19	1.60, s	17.7, q	1.59, s	17.7, q
20	1.67, s	25.7, q	1.68, s	25.7, q
21	1.86, s	16.4, q	1.80, s	16.2, q
22	3.57, d, 6.9	23.9, t	6.76, d, 10.2	116.2, d
23	5.25, mt, 6.9	120.2, d	5.75, d, 10.2	132.1, d
24	—	136.7, s	—	77.2, s
25	1.83, s	18.0, q	1.46, s	27.7, q
26	1.76, s	25.8, q	1.46, s	27.7, q

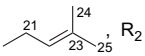
Parvifolidone B (**9**) was isolated as a yellow gum whose molecular formula was determined as $C_{28}H_{30}O_7$ by HREIMS. The UV and IR absorption bands indicated the presence of the depsidone chromophore. The ^{1}H NMR data (Table 3) were similar to those of garcidepsidone B.[4] The differences were proton resonances in the right hand ring. The prenyl resonances in garcidepsidone B were replaced by characteristic signals of the dimethylchromene ring [δ 6.76 (1H, d, J=10.2 Hz), 5.75 (1H, d, J=10.2 Hz), and 1.46 (6H, s)] in **9**. The HMBC correlations from the *cis*-olefinic proton at δ 6.76 (H-22) to C-8 (δ 136.5) and C-9a (δ 132.6) and from the other *cis*-olefinic proton (H-23) to C-9 (δ 113.8) established the fusion of the dimethylchromene ring at C-8 and C-9 with an ether linkage at C-8. Consequently, parvifolidone B had the depsidone structure **9**.



9

Parvifolixanthone A (**10**), isolated as a yellow gum, had the molecular formula $C_{28}H_{32}O_6$ determined by HREIMS. It exhibited UV absorption bands of a xanthone chromophore at 256, 286, and 329 nm while hydroxyl and conjugated carbonyl absorption bands were observed at 3346 and 1641 cm^{-1}, respectively, in the IR spectrum. The ^{1}H NMR spectrum (Table 4) displayed signals of one chelated hydroxyl group (δ 13.32, s), one aromatic proton (δ 7.58, s), three prenyl units: unit 1 [δ 5.28 (1H, mt, J=7.2 Hz),



10 R_1 =  , R_2 = H

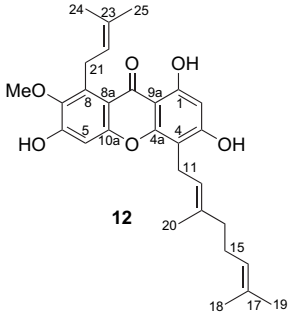
11 R_1 = H, R_2 = Me

Table 4. ^{1}H and ^{13}C NMR data of compounds **10–12**

Position	**10**		**11**		**12**	
	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C
1	13.32, s	158.6, s	13.12, s	162.2, s	13.35, s	161.7, s
2	—	108.9, s	6.37, s	94.4, d	6.25, s	98.5, d
3	6.43, s	160.3, s	—	163.6, s	5.97, br s	138.8, s
3-OMe	—	—	3.91, s	56.1, q	—	—
4	—	105.2, s	—	107.3, s	—	104.1, s
4a	—	152.6, s	—	153.8, s	—	154.0, s
5	5.67, br s	130.1, s	5.61, s	130.1, s	6.88, s	101.6, d
6	6.15, br s	147.7, s	6.12, s	147.8, s	6.33, br s	155.8, s
7	—	125.3, s	—	125.4, s	—	142.7, s
7-OMe	—	—	—	—	3.82, s	62.1, q
8	7.58, s	117.1, d	7.60, s	117.1, d	—	137.1, s
8a	—	113.4, s	—	113.3, s	—	112.2, s
9	—	180.7, s	—	180.7, s	—	182.4, s
9a	—	102.9, s	—	103.0, s	—	104.1, s
10a	—	143.7, s	—	143.8, s	—	154.6, s
11	3.52, d, 6.6	22.0, t	3.49, d, 5.7	21.7, t	3.53, d, 6.6	21.6, t
12	5.25, mt, 6.6	122.3, d	5.22, br s	122.9, d	5.28, mt, 6.6	121.3, d
13	—	133.5, s	—	131.7, s	—	138.8, s
14	1.85, s	18.0, q	1.85, s	17.9, q	2.09, m	39.7, t
15	1.73, s	25.7, q	1.71, s	25.6, q	2.09, m	26.4, t
16	3.41, d, 7.5	28.5, t	3.42, d, 7.5	28.4, t	5.03, mt, 6.6	123.7, d
17	5.34, mt, 7.5	121.1, d	5.35, mt, 7.5	121.1, d	—	124.3, s
18	—	134.4, s	—	134.3, s	1.60, d, 0.9	18.0, q
19	1.75, s	17.9, q	1.76, s	17.9, q	1.66, d, 0.9	25.7, q
20	1.77, s	25.9, q	1.77, s	25.8, q	1.89, d, 0.9	18.2, q
21	3.46, d, 7.2	21.6, t	—	—	4.10, d, 6.0	26.6, t
22	5.28, mt, 7.2	121.4, d	—	—	5.27, mt, 6.0	123.1, d
23	—	135.8, s	—	—	—	135.7, s
24	1.85, s	18.0, q	—	—	1.83, d, 1.2	18.2, q
25	1.78, d, 1.2	25.8, q	—	—	1.70, d, 1.2	25.8, q

3.46 (2H, d, J=7.2 Hz), 1.85 (3H, s), and 1.78 (3H, d, J=1.2 Hz)], unit 2 [δ 5.25 (1H, mt, J=6.6 Hz), 3.52 (2H, d, J=6.6 Hz, 2H), 1.85 (3H, s), and 1.73 (3H, s)], and unit 3 [δ 5.34 (1H, mt, J=7.5 Hz), 3.41 (2H, d, J=7.5 Hz), 1.77 (3H, s), and 1.75 (3H, s)], and three hydroxyl groups [δ 6.43 (s), 6.15 (br s), and 5.67 (br s)]. The ^{13}C NMR, DEPT, and HMQC data indicated that **10** consisted of 15 quaternary, four methine, three methylene, and six methyl carbons. The location of all substituents was established by HMBC data as follows. The chelated hydroxyl group was placed at C-1 (δ 158.6), a *peri*-position of the xanthone carbonyl group, and gave cross peaks with C-1, C-2 (δ 108.9), and C-9a (δ 102.9). ^{3}J HMBC correlations between the methylene protons (H_2-21, δ 3.46) of the prenyl unit 1 and C-1 and C-3 (δ 160.3) and those between the methylene protons (H_2-11, δ 3.52) of the prenyl unit 2 and C-3 and C-4a (δ 152.6) established the attachment of the prenyl units 1 and 2 at C-2 and C-4 (δ 105.2), respectively. The singlet aromatic proton at δ 7.58 was attributed to H-8 on the basis of the proton chemical shift and ^{3}J HMBC correlations of H-8/C-6 (δ 147.7), C-9 (δ 180.7), and C-10a (δ 143.7). The prenyl unit 3 was linked at C-7 due to HMBC correlations between the methylene protons (H_2-16, δ 3.41) with C-6, C-7 (δ 125.3), and C-8 (δ 117.1). Furthermore, HMBC correlations from the hydroxy proton at δ 6.43 to C-2, C-3, and C-4 and from the hydroxy proton at δ 6.15 to C-5, C-6, and C-7 established the linkage of these hydroxyl groups at C-3 and C-6, respectively. Thus, the remaining hydroxy proton at δ 5.67 belonged to the C-5 hydroxyl group. Signal enhancement of H-12 and H_2-21 in the NOEDIFF experiment upon irradiation of 3-OH and that of H_2-16 after irradiation of H-8 supported the assigned location of all prenyl substituents. Therefore, parvifolixanthone A was characterized as **10**.

The molecular formula of parvifolixanthone B (**11**), isolated as a yellow gum, was deduced as $C_{24}H_{26}O_6$ by HREIMS. The UV and IR absorption bands similar to those of **10** indicated that **11** had a xanthone chromophore. The ^{1}H NMR spectrum (Table 4) was similar to that of **10** except that one of the prenyl resonances in **10** was replaced by a singlet signal of an aromatic proton at δ 6.37 in **11**. This proton was attributed to H-2 due to HMBC correlations of H-2/C-1 (δ 162.2), C-3 (δ 163.6), C-4 (δ 107.3), and C-9a (δ 103.0). An additional methoxyl group resonating at δ 3.91 in the ^{1}H NMR spectrum of **11** was located at C-3 according to its HMBC correlation with C-3. Signal enhancement observed between H-2 and the methoxy protons in the NOEDIFF experiment confirmed the assignment. Parvifolixanthone B was thus determined to be **11**.



Parvifolixanthone C (**12**), isolated as a yellow gum, had the molecular formula $C_{29}H_{34}O_6$ determined by HREIMS. The

UV and IR absorption revealed the presence of a xanthone chromophore. The ^{1}H NMR data (Table 4) were similar to those of dulxanthone D[7] except that one of the aromatic protons on the right hand ring in dulxanthone D was replaced by the geranyl signal in **12**. The geranyl unit was located at C-4 (δ 104.1) on the basis of HMBC correlations between methylene protons H_2-11 (δ 3.53, d, J=6.6 Hz) with C-3 (δ 138.8), C-4, and C-4a (δ 154.0). Accordingly, parvifolixanthone C had the tetraoxygenated xanthone structure **12**.

All isolated compounds except for **1**, **4**, **9**, 1,3,5,6-tetrahydroxyxanthone, and (2*E*,6*E*,10*E*)-(+)-4β-hydroxy-3-methyl-5β-(3,7,11,15-tetramethylhexadeca-2,6,10,14-tetraenyl)cyclohex-2-en-1-one for which insufficient material was available were tested for antibacterial activity against MRSA. Rubraxanthone, previously reported as a strong antibacterial substance against both normal and penicillin-resistant strains,[3] showed the best antibacterial activity with a minimum inhibitory concentration (MIC) value of 19.5 μM while parvifoliol B (**2**) displayed much less activity with a MIC value of 100 μM. However, both exhibited much weaker antibacterial activity than the standard vancomycin (a MIC value of 0.6 μM). The remaining compounds were inactive against MRSA. In addition, the isolated compounds were examined for antioxidant effect with DPPH assay as xanthones and phloroglucinols have been reported as radical scavengers.[11] Parvifoliol E (**5**) showed high radical scavenging potency with a 50% inhibitory concentration (IC_{50}) value of 0.02 μM, which was much lower than that of the reference 2,6-di-*tert*-butyl-4-hydroxyanisole (BHT) having an IC_{50} value of 0.13 μM. The less active compounds were norathyriol and parvifoliol F (**6**) of which IC_{50} values were 0.08 and 0.10 μM, respectively. Garcidepsidone B gave an equal IC_{50} value to BHT while **7**, **8**, **10**, **11**, and **13** exhibited weaker antioxidant activity than BHT with IC_{50} values in the range of 0.18–0.38 μM. Other compounds gave no activity.

The genus *Garcinia* is known to be rich in a variety of compounds, for example, polyprenylated xanthones[5] and benzophenones.[12] However, only twelve depsidones,[4,13–16] three phloroglucinols of tocotrienol type,[11,17] and one methyl ester of a benzopyran derivative[18] have been isolated from *Garcinia* plants. We now add new members to the lists of compounds of these types. This is also the first report on the isolation of methyl esters of phloroglucinols from the genus *Garcinia*.

3. Experimental

3.1. General experimental procedures

Infrared spectra (IR) were determined on a Perkin–Elmer 783 FTS165 FTIR spectrometer. Ultraviolet (UV) absorption spectra were determined by using MeOH on a Shimadzu UV-160A spectrophotometer. Optical rotations were measured on a Jasco P-1020 polarimeter. ^{1}H and ^{13}C NMR spectra were recorded in $CDCl_3$ on a 300 MHz Bruker FTNMR Ultra Shield™ spectrometer. Mass spectra were obtained on a MAT 95 XL mass spectrometer (Thermofinnigan). Thin-layer chromatography (TLC) and precoated TLC were performed on silica gel GF_{254} (Merck). Column chromatography (CC) was performed on silica gel (Merck) type 100 (70–230 Mesh ASTM) eluted either with gradient system A (CH_2Cl_2–MeOH) or B (light petroleum–EtOAc) or on Sephadex LH-20 eluted with MeOH or on reverse-phase silica gel C-18 eluted with a gradient of MeOH–H_2O, unless otherwise stated. Light petroleum had bp 40–60 °C.

3.2. Plant material

The twigs of *G. parvifolia* were collected at Trang Province, Thailand. A voucher specimen is deposited in the Herbarium of the Department of Biology, Faculty of Science, Prince of Songkla University, Hat Yai, Songkhla, Thailand.

3.3. Extraction and isolation

The dried and chopped twigs of *G. parvifolia* (2.4 kg) were extracted with MeOH (7 L) for 5 days at room temperature three times. Filtration and subsequent evaporation of the combined MeOH extracts to dryness in vacuo afforded a dark brown gum (102.5 g), which was subjected to silica gel CC with a gradient of $CHCl_3$–hexane followed by a gradient of $CHCl_3$–MeOH to give 11 fractions (A–K). Fraction B (299.6 mg) was further purified by silica gel CC with a gradient of $CHCl_3$–light petroleum to afford **1** (3.6 mg) and **3** (9.3 mg). Fraction C (283.9 mg) was then separated by silica gel CC with gradient system B to give **5** (18.3 mg) and **7** (21.9 mg). Fraction E (1.06 g), upon purification with Sephadex LH-20 CC, yielded three subfractions (E1–E3). Subfraction E3 was further purified by repeated Sephadex LH-20 CC to give **2** (12.9 mg) and **4** (3.5 mg). Fraction G (3.20 g) was subjected to silica gel CC using gradient system A to yield seven subfractions (G1–G7). Subfraction G2 (203.0 mg) was purified by Sephadex LH-20 CC to give **6** (44.3 mg), **10** (17.9 mg) and **11** (9.2 mg). Subfractions G3 (182.8 mg), G5 (238.3 mg), and G6 (148.2 mg) were subjected to Sephadex LH-20 CC to yield **12** (4.8 mg), and (2*E*,6*E*,10*E*)-(+)-4β-hydroxy-3-methyl-5β-(3,7,11,15-tetramethylhexadeca-2,6,10,14-tetraenyl)cyclohex-2-en-1-one (3.6 mg) from subfractions G3, G5, and G6, respectively. Fraction I (3.05 g) was purified by silica gel CC with gradient system A to give four subfractions (I1–I4). Subfraction I2 contained **9** (3.2 mg). Subfraction I3 (206.3 mg) was separated by silica gel CC using gradient system A to afford **8** (34.5 mg). Subfraction I4 (523.8 mg) was subjected to silica gel CC with acetone–light petroleum (1:9) to yield mangostinone (6.6 mg), rubraxanthone (11.3 mg), dulxanthone D (5.3 mg), and garcidepsidone B (9.2 mg). Fraction J (1.64 g) was purified by reverse-phase silica gel CC to afford three subfractions (J1–J3). Subfraction J2 (132.5 mg) was further separated by Sephadex LH-20 CC to afford 1,3,5,6-tetrahydroxyxanthone (2.1 mg) and norathyriol (5.3 mg).

3.3.1. Parvifoliol A (1). Colorless gum; UV (MeOH) λ_{max} (log ε) 223 (4.36), 268 (4.15), 317 (3.40) nm; IR (neat) ν_{max} 3433, 1662 cm^{-1}; HREIMS *m*/*z* [M]$^+$ 334.1788 (calcd for $C_{19}H_{26}O_5$, 334.1780); ^{1}H NMR ($CDCl_3$, 300 MHz), see Table 1; ^{13}C NMR ($CDCl_3$, 75 MHz), see Table 1.

3.3.2. Parvifoliol B (2). Colorless gum; UV (MeOH) λ_{max} (log ε) 224 (4.38), 271 (4.20), 315 (3.42) nm; IR (neat) ν_{max} 3433, 1660 cm^{-1}; HREIMS *m*/*z* [M]$^+$ 320.1625 (calcd for $C_{18}H_{24}O_5$, 320.1624); ^{1}H NMR ($CDCl_3$, 300 MHz), see Table 1; ^{13}C NMR ($CDCl_3$, 75 MHz), see Table 1.

3.3.3. Parvifoliol C (3). Colorless gum; $[\alpha]_D^{29}$ −36.4 (*c* 0.06, MeOH); UV (MeOH) λ_{max} (log ε) 227 (3.17), 254 (4.39), 262 (4.49), 278 (3.25), 333 (2.82) nm; IR (neat) ν_{max} 3431, 1668 cm^{-1}; HREIMS *m/z* $[M]^+$ 318.1474 (calcd for $C_{18}H_{22}O_5$, 318.1462); ^1H NMR ($CDCl_3$, 300 MHz), see Table 1; ^{13}C NMR ($CDCl_3$, 75 MHz), see Table 1.

3.3.4. Parvifoliol D (4). Colorless gum; $[\alpha]_D^{29}$ −21.2 (*c* 0.07, MeOH); UV (MeOH) λ_{max} (log ε) 232 (4.16), 272 (4.37), 311 (2.32) nm; IR (neat) ν_{max} 3430, 1662 cm^{-1}; HREIMS *m/z* $[M]^+$ 336.1564 (calcd for $C_{18}H_{24}O_6$, 336.1573); ^1H NMR ($CDCl_3$, 300 MHz), see Table 1; ^{13}C NMR ($CDCl_3$, 75 MHz), see Table 1.

3.3.5. Parvifoliol E (5). Colorless gum; $[\alpha]_D^{29}$ −3.2 (*c* 0.27, MeOH); UV (MeOH) λ_{max} (log ε) 208 (4.23), 227 (3.14), 298 (3.09) nm; IR (neat) ν_{max} 3420 cm^{-1}; HREIMS *m/z* $[M]^+$ 410.3184 (calcd for $C_{28}H_{42}O_2$, 410.3185); ^1H NMR ($CDCl_3$, 300 MHz), see Table 2; ^{13}C NMR ($CDCl_3$, 75 MHz), see Table 2.

3.3.6. Parvifoliol F (6). Colorless gum; $[\alpha]_D^{29}$ +26.2 (*c* 0.31, MeOH); UV (MeOH) λ_{max} (log ε) 206 (4.17), 223 (3.21), 297 (2.41) nm; IR (neat) ν_{max} 3387 cm^{-1}; HREIMS *m/z* $[M]^+$ 396.3015 (calcd for $C_{27}H_{40}O_2$, 396.3028); ^1H NMR ($CDCl_3$, 300 MHz), see Table 2; ^{13}C NMR ($CDCl_3$, 75 MHz), see Table 2.

3.3.7. Parvifoliol G (7). Colorless gum; $[\alpha]_D^{29}$ +53.0 (*c* 0.16, MeOH); UV (MeOH) λ_{max} (log ε) 207 (4.24), 226 (3.11), 301 (3.10) nm; IR (neat) ν_{max} 3431 cm^{-1}; HREIMS *m/z* $[M]^+$ 426.3116 (calcd for $C_{28}H_{42}O_3$, 426.3134); ^1H NMR ($CDCl_3$, 300 MHz), see Table 2; ^{13}C NMR ($CDCl_3$, 75 MHz), see Table 2.

3.3.8. Parvifolidone A (8). Yellow gum; UV (MeOH) λ_{max} (log ε) 223 (3.59), 276 (3.43), 319 (2.82) nm; IR (neat) ν_{max} 3373, 1656 cm^{-1}; HREIMS *m/z* $[M]^+$ 480.2110 (calcd for $C_{28}H_{32}O_7$, 480.2143); ^1H NMR ($CDCl_3$, 300 MHz), see Table 3; ^{13}C NMR ($CDCl_3$, 75 MHz), see Table 3.

3.3.9. Parvifolidone B (9). Yellow gum; UV (MeOH) λ_{max} (log ε) 221 (4.09), 272 (3.16), 281 (3.15), 327 (2.59) nm; IR (neat) ν_{max} 3363, 1657 cm^{-1}; HREIMS *m/z* $[M]^+$ 478.1993 (calcd for $C_{28}H_{30}O_7$, 478.1986); ^1H NMR ($CDCl_3$, 300 MHz), see Table 3; ^{13}C NMR ($CDCl_3$, 75 MHz), see Table 3.

3.3.10. Parvifolixanthone A (10). Yellow gum; UV (MeOH) λ_{max} (log ε) 256 (4.46), 286 (3.68), 329 (3.60) nm; IR (neat) ν_{max} 3346, 1641 cm^{-1}; HREIMS *m/z* $[M]^+$ 464.2197 (calcd for $C_{28}H_{32}O_6$, 464.2199); ^1H NMR ($CDCl_3$, 300 MHz), see Table 4; ^{13}C NMR ($CDCl_3$, 75 MHz), see Table 4.

3.3.11. Parvifolixanthone B (11). Yellow gum; UV (MeOH) λ_{max} (log ε) 236 (4.19), 254 (4.48), 285 (3.65), 328 (3.60) nm; IR (neat) ν_{max} 3410, 1644 cm^{-1}; HREIMS *m/z* $[M]^+$ 410.1751 (calcd for $C_{24}H_{26}O_6$, 410.1729); ^1H NMR ($CDCl_3$, 300 MHz), see Table 4; ^{13}C NMR ($CDCl_3$, 75 MHz), see Table 4.

3.3.12. Parvifolixanthone C (12). Yellow gum; UV (MeOH) λ_{max} (log ε) 241 (4.01), 257 (3.82), 317 (3.15), 359 (2.59) nm; IR (neat) ν_{max} 3394, 1646 cm^{-1}; HREIMS *m/z* $[M]^+$ 478.2371 (calcd for $C_{29}H_{34}O_6$, 478.2350); ^1H NMR ($CDCl_3$, 300 MHz), see Table 4; ^{13}C NMR ($CDCl_3$, 75 MHz), see Table 4.

3.4. Antibacterial activity testing

MICs were determined by the agar microdilution method.[19] The test substances were dissolved in DMSO (Merck, Germany). Serial two-fold dilutions of the test substances were mixed with melted Mueller–Hinton agar (Difco) in the ratio of 1:100 in microtiter plates with flat-bottomed wells (Nunc, Germany). Final concentration of the test substances in agar ranged from 200 to 0.39 μg/mL. MRSA isolated from a clinical specimen, Songklanakarin Hospital, was used as test strain. Inoculum suspensions (10 μL) were spotted on agar-filled wells. The inoculated plates were incubated at 35 °C for 18 h. MICs were recorded by reading the lowest substance concentration that inhibited visible growth. Growth controls were performed on agar containing DMSO.

3.5. Free radical scavenging activity

This was carried out according to that of Yen and Hsieh.[20] To different concentrations of a sample in methanol (0.5 mL each) was added 1 mL of a methanolic solution of 0.2 mM DPPH. After mixing thoroughly, the mixture was allowed to stand in the dark for 30 min and the absorbance at 523 nm was measured using methanol for the baseline correction. The results were then compared with that of the control prepared as above but without any sample. Radical scavenging activity was expressed as percentage and was calculated using the following formula: %Scavenging= $[(A_{control}-A_{sample})/A_{control}]\times 100$. For each sample, the result was presented as IC_{50} (sample concentration that produced 50% scavenging of DDPH radical).

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Supplementary data

Supplementary data associated with this article can be found in the online version, at doi:10.1016/j.tet.2006.06.059.

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