Journal of Natural Medicines (2021) 75:871–876
https://doi.org/10.1007/s11418-021-01527-9

ORIGINAL PAPER

Four new xanthones and their cytotoxicity from the stems of *Garcinia schomburgkiana*

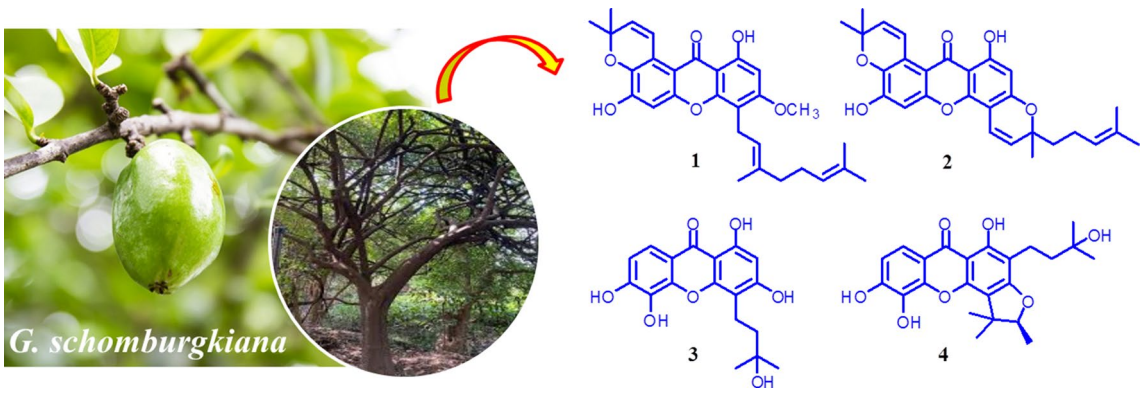
Sutin Kaennakam[1] · Edwin Risky Sukandar[2] · Thanawan Juntagoot[3] · Pongpun Siripong[4] · Santi Tip-pyang[2]

Received: 11 March 2021 / Accepted: 6 May 2021 / Published online: 17 May 2021

Abstract

Four new xanthones, named schomburgones C-F (**1–4**), along with six known xanthones (**5–10**) were isolated from the stems of *Garcinia schomburgkiana*. Their structures were determined by spectroscopic analysis especially 1D and 2D NMR spectroscopies. The isolated compounds were evaluated for their cytotoxicity against five human cancer cell lines. Furanoxanthones **4–6** showed potent cytotoxicity against four cell lines (KB, HeLa S3, MCF-7 and Hep G2) with IC_{50} values in the range of 0.18−9.95 μM.

Graphic abstract



Keywords Schomburgones C-F · *Garcinia schomburgkiana* · Clusiaceae · Xanthone · Cytotoxicity

✉ Sutin Kaennakam
sutin.k@sci.kmutnb.ac.th

✉ Santi Tip-pyang
santi.ti@chula.ac.th

[1] Department of Agro-Industrial, Food, and Environmental Technology, Faculty of Applied Science, King Mongkut's University of Technology North Bangkok (KMUTNB), Bangkok 10800, Thailand

[2] Department of Chemistry, Center of Excellence in Natural Products Chemistry, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand

[3] The Demonstration School, Faculty of Education, Phetchaburi Rajabhat University, Phetchaburi 76000, Thailand

[4] Natural Products Research Section, Research Division, National Cancer Institute, Bangkok 10400, Thailand

Introduction

Garcinia schomburgkiana (Clusiaceae) is an edible plant distributed in Thailand. It has been traditionally used for the treatment of diabetes, cough, laxative, menstrual disturbances and expectorant [1]. Previous chemical and biological studies on chemical constituents of *Garcinia* showed the presence of xanthones, biphenyls, flavonoids, triterpenoids, depsidones, and phloroglucinols, some of which exhibited significant cytotoxicity [2–4]. Herein, we reported four new xanthones, named schomburgones C-F (**1–4**), along with six known xanthones (**5–10**) which were isolated from the stems of this plant. The structures of all isolated compounds were elucidated using spectroscopic methods especially 1D

and 2D NMR spectroscopies and compared with their ^{1}H and ^{13}C NMR spectroscopic data from the literature. Previous researches revealed that xanthones from *Garcinia* displayed potent cytotoxicity [5]. Therefore, all the isolated compounds (**1**–**10**) were evaluated against human cancer cell lines, including KB and HeLa S3 cells. The tested compounds with IC_{50} values lower than 10 μM against these two cells were further evaluated against MCF-7, Hep G2, and HT-29 cells.

Experimental

General experimental procedures

1D and 2D NMR spectra were recorded on Bruker 400 AVANCE spectrometer. HRESIMS spectra were obtained using a Bruker MICROTOF model mass spectrometer. IR data was obtained using Nicolet 6700 FT-IR spectrometer using KBr discs. UV–visible absorption spectra were taken on UV-2550 UV–Vis spectrometer (Shimadzu, Kyoto, Japan). The optical rotation was determined using Jasco P-1010 Polarimeter.

Plant material

The stems of *G. schomburgkiana* were collected from Bang Ramat Road, Khwaeng Bang Ramat, Khet Taling Chan, Bangkok Thailand, in October 2019. The plant material was identified by Dr. Suttira Sedlak, a botanist at the Walai Rukhavej Botanical Research Institute, Mahasarakham University, and a specimen retained as a reference (Khumkratok no. 92-08).

Extraction and isolation

The air-dried stems of *G. schomburgkiana* (5.0 kg) were macerated with CH_2Cl_2 over a period of 5 days at room temperature (2 × 10 L). Removal of the solvent under reduced pressure provided CH_2Cl_2 crude extract (85.0 g) which was further separated by column chromatography over silica gel and eluted with a gradient of hexane–EtOAc (100% hexane, 80%, 60%, 40% and 20% hexane–EtOAc, each 5 L) to give ten fractions (A−J). Fraction D (3.5 g) was purified by a Sephadex LH-20 column (250 g) with 80% CH_2Cl_2–MeOH (2 L) and further applied to a radial chromatography (chromatotron) with 90% hexane–EtOAc (200 mL) to afford compounds **1** (8.5 mg) and **2** (3.0 mg). Fraction F (1.2 g) was purified by a chromatotron with 80% hexane–EtOAc (200 mL) to obtain compounds **5** (7.4 mg), **6** (5.4 mg), and **8** (6.2 mg). Compounds **3** (8.8 mg), **4** (6.7 mg), and **10** (6.2 mg) were obtained from fraction H (3.5 g) by a Sephadex LH-20 column (250 g) with 80% CH_2Cl_2–MeOH (2 L) followed by a chromatotron with 70% hexane–EtOAc (200 mL). Finally, Fraction J (2.5 g) was applied to a Sephadex LH-20 column (250 g) using 80% CH_2Cl_2–MeOH (2 L) to provide compounds **7** (5.7 mg) and **9** (7.2 mg).

*Schomburgone C (**1**)* Yellow amorphous powder; UV ($CHCl_3$) λ_{max} (log ε): 336 (0.2), 266 (0.7), and 211 (0.8) nm.; IR ν_{max} (KBr): 3386, 2915, 1648, and 1428 cm^{-1}; for ^{1}H (400 MHz, $CDCl_3$) and ^{13}C NMR (100 MHz, $CDCl_3$) spectroscopic data, see Table 1; HRESIMS *m/z* 499.2077 $[M+Na]^+$ (calcd. for $C_{26}H_{32}O_6Na$, 499.2097).

*Schomburgone D (**2**)* Yellow amorphous powder; $[a]_D^{20}$ +35.5 (*c* 1.0, MeOH); UV ($CHCl_3$) λ_{max} (log ε): 327 (0.1), 285 (0.2), and 217 (0.5) nm.; IR ν_{max} (KBr): 3396, 2919, 1646, and 1467 cm^{-1}; for ^{1}H (400 MHz, $CDCl_3$) and ^{13}C NMR (100 MHz, $CDCl_3$) spectroscopic data, see Table 1; HRESIMS *m/z* 483.1767 $[M+Na]^+$ (calcd. for $C_{28}H_{28}O_6Na$, 483.1784).

*Schomburgone E (**3**)* Yellow amorphous powder; UV (MeOH) λ_{max} (log ε): 359 (0.2), 274 (0.5), and 232 (0.5) nm.; IR ν_{max} (KBr): 3442, 2965, 1648, and 1494 cm^{-1}; for ^{1}H (400 MHz, Acetone d_6) and ^{13}C NMR (100 MHz, Acetone-d_6) spectroscopic data, see Table 1; HRESIMS *m/z* 369.0955 $[M+Na]^+$ (calcd. for $C_{18}H_{18}O_7Na$, 369.0950).

*Schomburgone F (**4**)* Yellow amorphous powder; $[a]_D^{20}$ −65.5 (*c* 1.0, MeOH); UV (MeOH) λ_{max} (log ε): 336 (0.2) and 258 (0.5) nm.; IR ν_{max} (KBr): 3423, 2923, 1652, and 1579 cm^{-1}; for ^{1}H (400 MHz, Methanol-d_4) and ^{13}C NMR (100 MHz, Methanol-d_4) spectroscopic data, see Table 1; HRESIMS *m/z* 437.1582 $[M+Na]^+$ (calcd. for $C_{23}H_{26}O_7Na$, 437.1576).

Cytotoxicity assay

All isolated compounds (**1–10**) were subjected to cytotoxic evaluation against KB (human epidermoid carcinoma), HeLa S3 (human cervical carcinoma), HT-29 (human colon adenocarcinoma), MCF-7 (human breast adenocarcinoma) and Hep G2 (human liver carcinoma) cell lines employing the MTT colorimetric method by incubating cells for 72 h, as described previously [6]. The results are expressed as the mean values of three independent experiments. Doxorubicin was used as the positive control.

Results and discussion

Phytochemical investigation of CH_2Cl_2 crude extract from the stems of *G. schomburgkiana* led to the isolation of four new xanthones, schomburgone C-F (**1–4**) together with six known xanthones (**5**−**10**) (Fig. 1), formoxanthone C (**5**) [7], 2-deprenylrheediaxanthone B (**6**) [8], cycloderivativexanthone (**7**) [9], toxyloxanthone B (**8**) [10], 1,3,5,6-tetrahydroxyxanthone (**9**) [11], 1,5,6-trihydroxy-3-methoxyxanthone

Table 1 ^{1}H (400 MHz) and ^{13}C (100 MHz) NMR data for **1**–**4**

No	**1**[a]		**2**[a]		**3**[b]		**4**[c]	
	δ_H (J in Hz)	δ_C	δ_H (J in Hz)	δ_C	δ_H (J in Hz)	δ_C	δ_H (J in Hz)	δ_C
1		162.3		163.3		163.4		165.5
2	6.34 (s)	94.4	6.20 (s)	99.0	6.30 (s)	98.8		108.4
3		163.8		160.3		162.6		162.0
4		107.6		100.4		109.0		113.7
4a		154.1		151.1		156.2		152.5
5	6.86 (s)	102.9	6.86 (s)	102.5		133.8		134.1
6		153.8		153.2		152.4		153.0
7		137.2		137.6	6.96 (d, 8.7)	114.1	6.86 (d, 8.5)	113.3
8		120.3		199.7	7.60 (d, 8.7)	117.5	7.56 (d, 8.5)	117.6
8a		108.8		108.7		114.9		115.1
9		183.4		182.6		181.8		182.0
9a		104.2		104.0		103.5		103.8
10a		151.4		151.1		147.3		147.8
1′	3.45 (d, 7.1)	21.9	6.81 (d, 10.2)	115.7	2.99 (m)	17.9	2.63 (dd, 5.1, 9.9)	18.7
2′	5.19 (t, 6.8)	122.7	5.52(d, 10.2)	125.8	1.80 (m)	43.2	1.68 (t, 8.6)	43.4
3′		135.5		80.7		72.2		71.6
4′	1.97 (m)	40.2	1.80 (m)	41.8	1.33 (s)	29.9	1.25 (s)	28.9
5′	2.04 (m)	27.2	2.10 (m)	22.8	1.33 (s)	29.9	1.25 (s)	28.9
6′	5.04 (t, 6.8)	124.8	5.09 (t, 6.3)	123.9				
7′		131.8		132.1				
8′	1.54 (s)	26.1	1.57 (s)	25.8				
9′	1.60 (s)	18.1	1.66 (s)	17.9				
10′	1.85 (s)	16.7	1.44 (s)	27.2				
1″	8.03 (d, 10.2)	121.5	8.02 (d, 10.2)	121.1				45.3
2″	5.83 (d, 10.2)	132.8	5.83 (d, 10.2)	132.6			4.51 (q, 6.5)	91.9
3″		77.7		77.4			1.40 (d, 6.5)	14.7
4″	1.50 (s)	27.8	1.50 (s)	27.5			1.32 (s)	21.5
5″	1.50 (s)	27.8	1.50 (s)	27.5			1.61 (s)	26.0
1-OH	13.39 (s)		13.39 (s)					
6-OH	6.25 (s)		6.24 (s)					
3-OCH_3	3.90 (s)	56.4						

[a]In $CDCl_3$, [b] in Acetone-d_6, and [c] in Methanol-d_4

(**10**) [12]. The structures of the known compounds were determined and confirmed by comparison of their ^{1}H and ^{13}C NMR spectroscopic data with those previously published data.

Schomburgone C (**1**) was obtained as a yellow amorphous powder. Its molecular formula was determined as $C_{29}H_{32}O_6$ by the positive HRESIMS measurement through the ion peak at *m/z* 499.2077 $[M+Na]^+$ (calcd. for $C_{29}H_{32}O_6Na$, 499.2097). The UV spectrum displayed absorption bands at λ_{max} 336, 266 and 211 nm. The IR spectrum showed absorption bands for a phenolic hydroxyl and a hydrogen-bonded carbonyl groups at 3386 and 1648 cm^{-1}. The ^{1}H NMR spectrum showed the signals of a hydrogen-bonded hydroxyl proton, two aromatic protons, a hydroxyl proton, and a methoxy proton which appeared as five singlets at δ_H 13.39 (1H, s, OH-1), 6.86 (1H, s, H-5), 6.34 (1H, s, H-2), 6.25 (1H, s, OH-6), and 3.90 (3H, s, OCH_3-3), respectively. The signals at δ_H 8.03 (1H, d, J = 10.2 Hz, H-1″), 5.83 (1H, d, J = 10.2 Hz, H-2″), and 1.50 (6H, s, H-4″ and H-5″) in the spectrum were indicated of a pyran ring. In addition, a geranyl group showed signals at δ_H 5.19 (1H, t, J = 6.8 Hz, H-2′), 5.04 (1H, t, J = 6.8 Hz, H-6′), 3.45 (2H, d, J = 7.1 Hz, H-1′), 2.04 (2H, m, H-5′), 1.97 (2H, m, H-4′), 1.85 (3H, s, H-10′), 1.60 (3H, s, H-9′), and 1.54 (3H, s, H-8′). The ^{1}H and ^{13}C NMR spectroscopic data of **1** (Table 1) were shown to be similar to those of the known xanthone, virgataxanthone B [12], except for the hydroxyl group at C-3 was replaced by a methoxy group in **1**. In the HMBC correlations (Fig. 2), the methoxy proton at δ_H 3.90 showed a cross-peak with δ_C 163.8 (C-3), an aromatic proton at δ_H 6.34 showed cross-peak with δ_C 107.6 (C-4) and 104.2 (C-9a), and a hydrogen-bonded hydroxyl proton at δ_H 13.39 showed cross-peaks

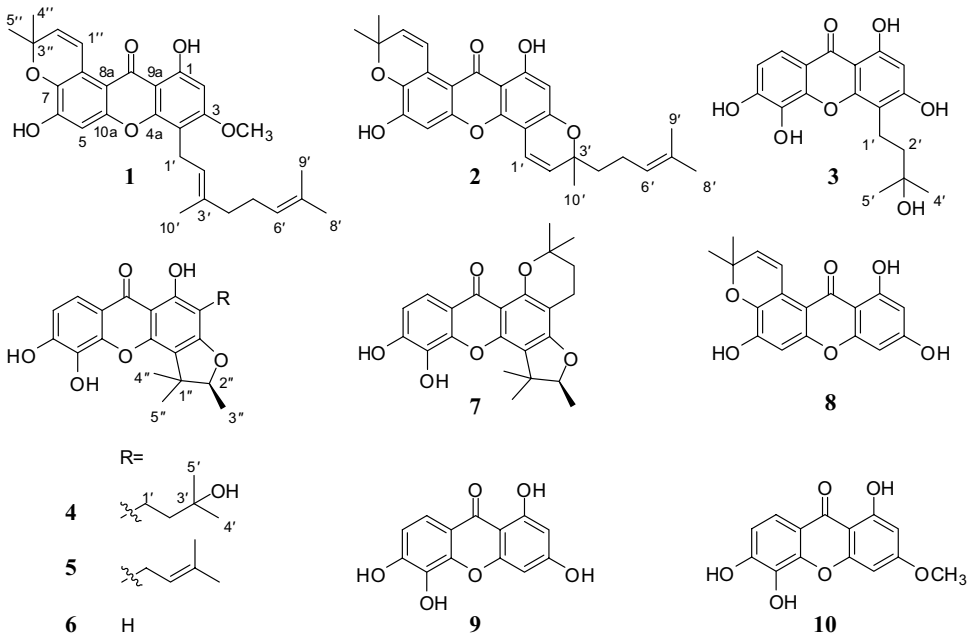


Fig. 1 Chemical structures of **1**–**10**

with δ_C 162.3 (C-1), 104.2 (C-9a), and 94.4 (C-2). In addition, a methylene proton at δ_H 3.45 showed cross-peaks with δ_C 163.8 (C-3), 154.1 (C-4a), and 135.5 (C-3'), indicated that a geranyl group was attached to C-4. Thus, the complete assignment of schomburgone C was determined as **1**.

Schomburgone D (**2**) was obtained as a yellow amorphous powder and optically active $[a]_D^{20}$+35.5 (*c* 1.0, MeOH). Its molecular formula was determined as $C_{28}H_{28}O_6$ by the positive HRESIMS measurement through the ion peak at *m/z* 483.1767 $[M+Na]^+$ (calcd. for $C_{28}H_{28}O_6Na$, 483.1784). The UV, IR, ^1H and ^{13}C NMR data of **2** (Table 1) were closely related to those of **1**. The major difference was the cyclization of geranyl group at C-4 to C-3 by ether linkage to form pyran ring in **2**. the ^1H NMR signals showed three methine protons at δ_H 6.81 (1H, d, J = 10.2 Hz, H-1′), 5.52 (1H, d, J = 10.2 Hz, H-2′), and 5.09 (1H, t, J = 6.3 Hz, H-6′), two methylene protons at δ_H 2.10 (2H, m, H-5′) and 1.80 (2H, m, H-4′), and three methyl protons at δ_H 1.66 (3H, s, H-9′), 1.57 (3H, s, H-8′), and 1.44 (3H, s, H-10′). The location of a pyran ring was deduced by HMBC correlations (Fig. 2) of methine protons at H-1′ to C-3 (δ_C 160.3), C-4a (δ_C 151.1), and C-3′ (δ_C 80.7), and H-2′ to C-4 (δ_C 100.4), C-3′ (δ_C 80.7), C-4′ (δ_C 41.8), and C-10′ (δ_C 27.2). From these data, the structure of schomburgone D was assigned as **2**.

Schomburgone E (**3**) was obtained as a yellow amorphous powder. Its molecular formula was determined as $C_{18}H_{18}O_7$ by the positive HRESIMS measurement through the ion peak at *m/z* 369.0955 $[M+Na]^+$ (calcd. for $C_{18}H_{18}O_7Na$, 369.0950). The UV spectrum displayed absorption bands at λ_{max} 359, 274 and 232 nm. The IR spectrum exhibited the signals of phenolic hydroxyl groups and a hydrogen-bonded carbonyl group at 3442 and 1648 cm^{-1}. The ^1H NMR spectrum showed the presence of three aromatic proton signals at δ_H 7.60 (1H, d, J = 8.7 Hz, H-8), 6.96 (1H, d, J = 8.7 Hz, H-7), and 6.30 (1H, s, H-2), two methylene proton signals at δ_H 2.99 (2H, m, H-1′) and 1.80 (2H, m, H-2′), and two methyl proton signals at δ_H 1.33 (6H, s, H-4′ and H-5′). The 1D NMR data (Table 1) were closely to those of the known xanthone, 1,5,6-trihydroxy-3-methoxy-4-(3-hydroxyl-3-methylbutyl)xanthone [14], except for the methoxy group at C-3 was replaced by a hydroxyl group. In the HMBC correlations of **3** (Fig. 2), the aromatic proton at δ_H 6.30 showed cross-peaks with δ_C 163.4 (C-1) and 162.6 (C-3), the methylene proton at δ_H 2.99 showed cross-peaks with δ_C 162.6 (C-3), 156.2 (C-4a), and 72.2 (C-3′), indicated that a 3-hydroxyl-3-methylbutyl group was located at C-4. Accordingly, the structure of schomburgone E was determined as **3**.

Schomburgone F (**4**) was obtained as yellow amorphous powder and optically active $[a]_D^{20}$−65.5 (*c* 1.0, MeOH). Its molecular formula was deduced as $C_{23}H_{26}O_7$ by the positive HRESIMS measurement through the ion peak at *m/z* 437.1582 $[M+Na]^+$ (calcd. for $C_{23}H_{26}O_7Na$, 437.1576). The UV spectrum displayed absorption bands at λ_{max} 336 and 258 nm. The IR spectrum showed O–H and C–O stretching bands at 3423 and 1652 cm^{-1}, respectively. The ^1H NMR spectrum showed the presence of two aromatic proton signals at δ_H 7.56 (1H, d, J = 8.4 Hz, H-8) and 6.86 (1H, d, J = 8.4 Hz, H-7), two methylene proton signals at δ_H 2.63 (2H, dd, J = 5.1 and 9.9 Hz, H-1′) and 1.68 (2H, t, J = 8.6 Hz, H-2′), a vinylic proton signal at δ_H 4.51 (1H, q, J = 6.5 Hz,

H-2″), and five methyl proton signals at δ_H 1.61 (3H, s, H-5″), 1.40 (3H, d, J = 6.5 Hz, H-3″), 1.32 (3H, s, H-4″), and 1.25 (6H, s, H-4′ and H-5′). The ^{1}H and ^{13}C NMR data (Table 1) were nearly identical to those of the known xanthone, formoxanthone C (**5**) [7] except for the prenyl group at C-3 was hydrated to be a 3-hydroxyl-3-methylbutyl group in **4**. In the HMBC correlations of **4** (Fig. 2), the methylene proton at δ_H 2.63 showed cross-peaks with δ_C 165.5 (C-1), 162.0 (C-3), and 71.6 (C-3') indicated that the 3-hydroxyl-3-methylbutyl unit was located at C-2. The absolute configuration at C-2″ was assigned as *S* based on the negative value of optical rotation and comparison with reference [7]. Thus, the structure of schomburgone F was defined as **4**.

The cytotoxicity of all isolated compounds against five human cancer cell lines (KB, HeLa S3, HT-29, MCF-7 and Hep G2) were shown in Table 2. Furanoxanthones **4–6** showed potent cytotoxicity against four cell lines including KB, HeLa S3, MCF-7, and Hep G2 with IC_{50} values in the range of 0.18−9.95 μM. The SAR study (Fig. 1 and Table 2) suggest that the presence of the ortho hydroxy groups at C-5 and C-6, and the trimethylfuran ring at C-3 and C-4 might

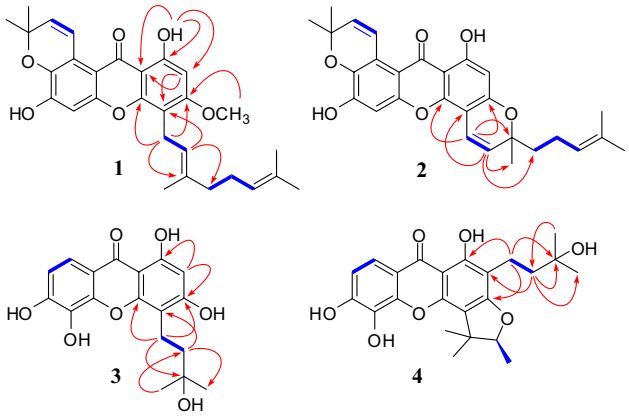


Fig. 2 Key HMBC (arrow curves) and COSY (bold lines) correlations of **1–4**

Table 2 In vitro cytotoxicity of compounds **1**−**10** against five human cancer cell lines

Compounds	IC_{50} (μM) ± SD				
	KB	HeLa S3	HT-29	MCF-7	Hep G2
1	> 100	> 100	NT	NT	NT
2	> 100	> 100	NT	NT	NT
3	16.74 ± 1.41	17.07 ± 1.49	NT	NT	NT
4	1.78 ± 0.08	2.96 ± 0.24	25.61 ± 0.42	4.72 ± 0.08	3.32 ± 0.16
5	0.18 ± 0.01	0.27 ± 0.02	21.89 ± 1.16	4.90 ± 0.42	3.81 ± 0.53
6	5.11 ± 0.42	5.96 ± 0.53	63.60 ± 3.94	6.47 ± 0.22	9.95 ± 0.21
7	23.66 ± 1.35	19.76 ± 1.27	NT	NT	NT
8	14.37 ± 0.16	10.95 ± 0.81	NT	NT	NT
9	28.59 ± 0.57	18.37 ± 2.81	NT	NT	NT
10	24.73 ± 0.82	12.22 ± 3.85	NT	NT	NT
Doxorubicin[a]	0.57 ± 0.14	0.53 ± 0.33	0.22 ± 0.02	1.47 ± 0.21	0.93 ± 0.04

$IC_{50} \leq 10$ = good activity, $10 < IC_{50} \leq 30$ = moderate activity, $IC_{50} > 100$ = inactive, NT = Not tested

[a]Doxorubicin is used as the positive control

improve the cytotoxicity as inferred from the comparison with their cytotoxicity of compounds **1**–**10**.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11418-021-01527-9.

Acknowledgements This research was funded by the Faculty of Applied Science, King Mongkut's University of Technology North Bangkok (KMUTNB), Contract no. 641069. We also thank Ms. Suttira Khumkratok, Walai Rukhavej Botanical Research Institute, Mahasarakham University, Mahasarakham 44000, Thailand for the identification and deposition of the plant material.

References

1. Mungmee C, Sitthigool S, Suttisri R, Buakeaw A (2012) Xanthones and biphenyls from *Garcinia schomburgkiana* wood and their cytotoxicity. Thai J Pharm Sci 36:6–9
2. Kaennakam S, Mudsing K, Rassamee K, Siripong P, Tip-Pyang S (2019) Two new xanthones and cytotoxicity from the bark of *Garcinia schomburgkiana*. J Nat Med 73:257–261
3. Sukandar ER, Siripong P, Khumkratok S, Tip-pyang S (2016) New depsidones and xanthone from the roots of *Garcinia schomburgkiana*. Fitoterapia 111:73–77
4. Sukandar ER, Kaennakam S, Aree T, Nöst X, Rassamee K, Bauer R (2020) Picrorhizones A-H, polyprenylated benzoylphloroglucinols from the stem bark of *Garcinia picrorhiza*. J Nat Prod 83:2102–2111
5. Vo HT, Nguyen NTT, Nguyen HT, Do KQ, Connolly JD, Maas G (2012) Cytotoxic tetraoxygenated xanthones from the bark of *Garcinia schomburgkiana*. Phytochemistry Lett 5:553–557
6. Kongkathip N, Kongkathip B, Siripong P, Sangma C, Luangkamin S, Niyomdecha M (2003) Potent antitumor activity of synthetic 1,2-naphthoquinones and 1,4-naphthoquinones. Bioorg Med Chem 11:3179–3191
7. Boonsri S, Karalai C, Ponglimanont C, Kanjana-opas A, Chantrapromma K (2006) Antibacterial and cytotoxic xanthones from the roots of *Cratoxylum formosum*. Phytochemistry 67:723–727
8. Rath G, Potterat O, Mavi S, Hostettmann K (1996) Xanthones from *Hypericum roeperanum*. Phytochemistry 43:513–520
9. Monache FD, Botta B, Nicoletti M, de Barros Coêlho JS, de Andrade Lyra FD (1981) Three new xanthones and macluraxanthone from *Rheedia benthamiana* Pl. Triana (guttiferae). J Chem Soc Perkin 1:484–488
10. Sukandar ER, Kaennakam S, Rassamee K, Ersam T, Siripong P, Tip-pyang S (2019) Tetrandraxanthones A-I, prenylated and geranylated xanthones from the stem bark of *Garcinia tetrandra*. J Nat Prod 82:1312–1318
11. Sia GL, Bennett GJ, Harrison LJ, Sim KY (1995) Minor xanthones from the bark of *Cratoxylum cochinchinense*. Phytochemistry 38:1521–1528
12. Nielsen H, Arends P (1979) Xanthone constituents of *Hypericum androsaemum*. J Nat Prod 42:301–304
13. Merza J, Aumond MC, Rondeau D, Dumontet V, Le Ray AM, Séraphin D (2004) Prenylated xanthones and tocotrienols from *Garcinia virgata*. Phytochemistry 65:2915–2920
14. Shen J, Yang JS (2006) Two new xanthones from the stems of *Garcinia cowa*. Chem Pharm Bull 54:126–128