Cytotoxic and antibacterial xanthones from the roots of *Maclura cochinchinensis*

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Three new furanoxanthones, macochinxanthones A–C (1–3) and sixteen known xanthones (4–19) were isolated from the roots of *Maclura cochinchinensis*. Their structures were elucidated by spectroscopic analysis including NMR, UV and IR, as well as mass spectrometry. Chiral-phase HPLC analysis of 1–3 revealed that they were scalemic mixtures with an enantiomeric excess (ee) of 0.05%, 36.8% and 8%, respectively. Most of the isolated xanthones exhibited potent cytotoxicity against four cancer cell lines (KB, HelaS3, A549 and HepG2) with IC50 values in the range of 1.29–90.15 μM. In addition, many of them displayed antibacterial activity against Gram-positive bacteria and Methicillin resistant *Staphylococcus aureus* (MRSA) with MIC values in the range of 4–128 μg/mL.

1. Introduction

*Maclura cochinchinensis* (Lour.) Corner (Syn. *Maclura amboinensis* and *Cudrania cochinchinensis*) belongs to the Moraceae family. It is widely distributed in most of Asia districts such as India, Sri Lanka, China, Japan, Taiwan, Burma, Laos, Vietnam, Cambodia,
Thailand, Malaysia, Indonesia, Philippines and Papua New Guinea, as well as Australia (Berg et al. 2011; Siripong et al. 2012). It has been used in folk medicines for hepatitis, rheumatism and neuralgia (Nakashima et al. 2015), wound healing, bruising, boils, scabies, oedema, blood stasis, dysmenorrhea and contusions (Chien et al. 2019). In Thailand, *M. cochinchinensis* is known as ‘Kae Lae’ and can be found throughout the country, where in remote areas people use it for treating chronic fever, diarrhea, fainting, skin infection, abnormality of the lymph nodes (Bunyapraphatsara et al. 2000; Kongkiatpaiboon et al. 2017). This medicinal plant has been reported as a source of bioactive compounds such as xanthenes (Chang et al. 1989a, 1989b; Nakashima et al. 2015, 2017) and flavonoids (Chien et al. 2019; Polbuppha et al. 2021). Most of these compounds demonstrate a variety of biological activities including antifungal (Fukai et al. 2003), antimicrobial (Polbuppha et al. 2021), anticancer (Siripong et al. 2012; Chien et al. 2019), anti-inflammation (Nakashima et al. 2017), anti-lipid peroxidation (Chang et al. 1994) and antidiabetic (Chewchinda et al. 2021). To further search for bioactive compounds from the roots of *M. cochinchinensis*, the bioassay screening of *n*-hexane and EtOAc extracts showed antibacterial activities with minimum inhibitory concentration (MIC) values in the range of 20–160 μg/mL, and cytotoxicity against KB and HelaS3 cell lines with IC50 values in the range of 2.97–10.07 μg/mL. Herein the phytochemical study of the roots of *M. cochinchinensis* and their biological activities are presented.

2. Results and discussion

Chromatographic separation of *n*-hexane and EtOAc extracts from the roots of *Maclura cochinchinensis* obtained three new furanoxanthenes (1–3), along with sixteen known xanthenes (4–19). Structures of new compounds were analysed by spectroscopic methods and mass spectrometry, whereas the structures of the known compounds were identified by comparing their spectral data with published values as being gerontoxanthon A (4) (Chang et al. 1989a), gerontoxanthon C (5) (Chang et al. 1989a; Nakashima et al. 2015), gerontoxanthenes E, G and I (6–8) (Chang et al. 1989b), macluraxanthon (9) (Iinuma et al. 1994), macluraxanthon C (10) (Groweiss et al. 2000), 1,3,5,6-tetrahydroxy-2-prenylxanthon (11) (Jackson et al. 1966), toxyloxanthon C (12) (Fukai et al. 2003), toxyloxanthon D (13) (Deshpande et al. 1973), cudraxантон F (14) (Hano et al. 1990), 6-deoxyjacareubin (15) (Cheng et al. 2004), cudraniaxanthone (16) (Murti et al. 1972; Nakashima et al. 2015), isocudraniaxanthone A (17) (Kobayashi et al. 1997), 2-depyrenyllumidoxanthone B (18) and 5-O-methyl-2-depyrenylmumidoxanthone (19) (Rath et al. 1996) as shown in Figure 1.

Compound 1 was isolated as a pale yellow solid and its molecular formula C19H18O6 was deduced from the 13C NMR and HRESI-MS, m/z 343.1176 [M + H]+ (calcd. 343.1182) implying 11 degrees of unsaturation. The UV spectrum showed absorption maxima at 253, 280 and 313 nm, corresponding with a 1,3,5,6-tetraoxygenated xanthon skeleton (Nakashima et al. 2015). The IR spectrum showed absorption bands of hydroxyl (3344 cm−1) and carbonyl (1623 cm−1) functionalities. The 1H and 13C NMR spectroscopic data of 1 (Table S1 in Supplementary material) showed signals of two ortho-coupled aromatic protons at δH 7.61 (d, J = 8.8 Hz, H-7)/δC 111.4
and 6.87 (d, $J = 8.8$ Hz, H-8)/$\delta_C$ 115.8, a singlet signal of aromatic proton at $\delta_H$ 6.70 (s, H-4)/$\delta_C$ 91.2, an oxymethine at $\delta_H$ 4.57 (q, $J = 6.6$ Hz, H-14)/$\delta_C$ 90.4, a methoxy group at $\delta_H$ 3.97/$\delta_C$ 54.3 and the methyl groups at $\delta_H$ 1.44 (s, H$_3$-12)/$\delta_C$ 23.9, $\delta_H$ 1.20 (s, H$_3$-13)/$\delta_C$ 19.0 and $\delta_H$ 1.46 (d, $J = 6.6$ Hz, H$_3$-15)/$\delta_C$ 12.3. The HMBC correlations of H-4 to C-2, C-3 and C-9a; H-12 and H-13 to C-2; H-14 to C-2; and the methoxy protons to C-3 indicated that 2,3,3-trimethyl dihydofuran moiety fused with the A-ring at C-1 and C-2 (Figure S1). Furthermore, the correlations of H-7 to C-5 and C-9a; H-8 to C-6, C-9 and C-10a confirmed two hydroxy groups were located at

Figure 1. Structures of xanthones isolated from roots of *Maclura cochinchinensis*. 
C-5 and C-6. The planar structure of 1 was similar to a known cudracuspixanthone C isolated from the roots of Cudrania tricuspidata (Jo et al. 2014), except for the absence of a prenyl unit at C-4 in 1.

It appeared that the chemical shift values for C-2 ($\delta_C$ 118.2) and OMe ($\delta_C$ 54.3) of 1 were more shielded than those of cudracuspixanthone, C-2 ($\delta_C$ 124.4) and OMe ($\delta_C$ 62.0), suggesting the effect of the isoprene group at C-4 in cudracuspixanthone C. This was supported by the chemical shift value for C-2 ($\delta_C$ 118.8) of its analogue, cudratrixanthone H isolated from Cudrania tricuspidata (Kwon et al. 2014). Thus, 1 was identified as a new furanoxanthone, and it has been named macochinxanthone A. In the proposed biosynthesis, compound 1 could be derived from the isolated precursor crudraniaxanthone (16) by a ring closure of the 1,1-dimethyl-2-propenyl group at C-2, to form a dihydrofuran ring fused with the A-ring at C-1 and C-2. It was found that the specific rotation value of 1 was almost zero [0.0198 (c 0.08, MeOH)] which corresponded with the absence of the Cotton effect signal in its ECD spectrum. This data suggests that 1 was a mixture of enantiomers. Further chiral-phase HPLC analysis of 1 revealed that it was a scalemic mixture with an enantiomeric excess (ee) of 0.05% (Figure S2). However, the attempt to separate this enantiomer pair by chiral HPLC was unsuccessful.

Compound 2 was isolated as a light brown powder and its molecular formula C$_{23}$H$_{24}$O$_8$ was established from the $^{13}$C NMR and HRESI-MS, m/z 429.1550 [M + H]$^+$ (calcd. 429.1549), revealing 12 degrees of unsaturation. The IR spectrum showed absorption bands of hydroxyl (3311 m$^{-1}$) and carbonyl (1631 cm$^{-1}$) functionalities. The UV spectrum showed absorption maxima of the xanthone core similar to that of 1.

The $^1$H and $^{13}$C NMR spectroscopic data of 2 (Table S1) exhibited two singlet signals of aromatic protons at $\delta_H$ 6.38 (H-4)/$\delta_C$ 89.1 and 7.68 (H-8)/$\delta_C$ 111.8, four singlet resonances of methyl groups at $\delta_H$ 1.46 (s, H$_3$-12)/$\delta_C$ 24.2, $\delta_H$ 1.22 (s, H$_3$-13)/$\delta_C$ 13.2, $\delta_H$ 1.48 (s, H$_3$-19)/$\delta_C$ 25.7 and $\delta_H$ 1.46 (s, H$_3$-20)/$\delta_C$ 25.1, a doublet signal of a methyl group at $\delta_H$ 1.35 (d, $J$ = 5.2 Hz, H-15)/$\delta_C$ 19.6 and three oxymethine protons at $\delta_H$ 4.48 (q, $J$ = 5.2 Hz, H-14)/$\delta_C$ 90.9, $\delta_H$ 5.37 (d, $J$ = 4.8 Hz, H-16)/$\delta_C$ 71.4 and $\delta_H$ 4.38 (d, $J$ = 4.8 Hz, H-17)/$\delta_C$ 92.0. The COSY spectrum of 2 showed correlations between H-14 and H-15, and H-16 and H-17, supporting the partial connection in the molecule. The HMBC spectrum of 2 displayed correlations of H-8 to C-6, C-16, C-10a and C-9; H-16 to C-2, C-3 and C-18; H-17 to C-16, C-18, C-19 and C-20; and H-19 to C-17 and C-20, indicating that the 2-(isopropyl-2-ol)-3-hydroxyhydrofuran moiety fused with the B-ring at C-6 and C-7. This moiety was similar to a known xanthone 1,2,5,4$^{-}$-tetrahydroxy-4-(1,1-dimethallyl)-5$^{-}$-(2-hydroxypropan-2-yl)-4$'$,5$'$-dihydrofurano(2$'$,3$'$:6,7) xanthone isolated from Garcinia xanthochymus (Chen et al. 2010). Furthermore, correlations of H-4 to C-2, C-3 and C-9a; H-12 and H-13 to C-2; H-14 to C-2, C-3 and C-15; and H-15 to C-11 and C-14 indicated a 2,3,3-trimethylidihydrofuran unit fused with the A-ring at C-2 and C-3 (Figure S1) similar to those of isolated gerontoxanthone G (7). The small coupling constant values (4.8 Hz) of vicinal protons, H-16 and H-17 suggested that the two protons were in cis orientation (Minch 1994). Thus, 2 was discovered as a new furanoxanthone and it has been named macochinxanthone B. Among isolated compounds, gerontoxanthone G (7) could be proposed as a precursor of 2 by ring closure involving oxidation of a prenyl unit at C-7 to form a hydroxy hydrofuran fused with...
the B-ring at C-6 and C-7 in the biosynthesis pathway. Since the specific rotation value of 2 was almost zero [-0.0003 (c 0.2, MeOH)], and the ECD spectrum showed no signal for a Cotton effect, the chiral HPLC analysis of 2 was performed and the result displayed as a scalemic mixture with an ee of 36.8% (Figure S3). An attempt to separate this enantiomer pair by chiral HPLC was unsuccessful.

Compound 3 was isolated as a light brown solid and its molecular formula was established from the $^{13}$C NMR and HRESI-MS, $m/z$ 443.1708 [M + H]$^+$ (calcd. 443.1706) to be $C_{24}H_{26}O_8$, having 12 degrees of unsaturation. The UV, IR and NMR spectroscopic data of 3 were similar to those of 2, except that a hydroxyl group at C-5 was replaced by a methoxy group ($\delta$H/C 4.08/$\delta$C 59.3) in 3. The HMBC correlation of methoxy protons to C-5 revealed that a methoxy group was substituted at C-5 (Figure S1). Therefore, 3 was identified as a new furanoxanthone analogue and it has been named macochin-xanthone C. The structure of 3 could be proposed to derive from the isolated precursor gerontoxanthon E (6) by involving oxidation and the ring closure of a prenyl group at C-7, the same as 2. Similar to that of 2, the specific rotation value of 3 was almost zero [-0.0003 (c 0.08, MeOH)], and the ECD spectrum showed no signal for a Cotton effect. Consequently, the chiral HPLC analysis of 3 (Figure S4) indicated as a scalemic mixture with an ee of 8%, and this enantiomer pair could not be separated by chiral HPLC.

Compounds obtained with a sufficient amount, including 1–13, 15, 16 and 18, were evaluated for their cytotoxicity against four cancer cell lines including human epidermoid carcinoma (KB), human cervical carcinoma (HelaS3), human lung carcinoma cell line (A549) and human hepatocellular carcinoma (HepG2) (Table S2 in Supplementary material). All xanthones, except 2, displayed cytotoxicity against all cell lines tested. Most of them, including compounds 1, 4, 5, 7–11, 13, 16 and 18, showed potent cytotoxicity toward the KB cell line with IC$_{50}$ values of 3.10, 4.82, 4.85, 5.60, 1.29, 1.30, 2.52, 7.11, 1.89, 3.81 and 4.28 $\mu$M, respectively. In a similar trend, compounds 4, 5, 7–11, 13, 16 and 18 exhibited cytotoxic activity against the HelaS3 cell line with IC$_{50}$ values of 4.68, 2.14, 2.87, 2.97, 1.59, 3.15, 4.09, 6.31, 5.04 and 2.66 $\mu$M, respectively. Moreover, compounds 7–10, 13, 16, and 18 showed selective cytotoxicity against the A549 cell line with IC$_{50}$ values of 3.20, 2.70, 6.46, 4.13, 4.89, 3.61 and 4.49 $\mu$M, respectively. In addition, compounds 5, 9, 10, 11, 13, 16, and 18 displayed moderate cytotoxicity against HepG2 cell line, with IC$_{50}$ values ranging from 6.67, 5.26, 5.89, 7.49, 7.00, 5.15 and 5.98 $\mu$M, respectively. It was found that only 2, 15 and 18 were not toxic to normal cells (Vero) at IC$_{50}$ values $<$100 $\mu$M. All compounds, except for 17 and 19, were evaluated for antibacterial activity against Gram-negative bacteria (Escherichia coli, Pseudomonas aeruginosa, and Shigella sonnei) and Gram-positive bacteria (Bacillus cereus, Bacillus subtilis, and Staphylococcus aureus) as well as Methicillin resistant S. aureus (MRSA) (Table S3 in supplementary material). Several compounds showed antibacterial activity against only Gram-positive bacteria, B. cereus, B. subtilis and S. aureus with MICs values ranging from 4–28 $\mu$g/mL. Among them, compounds 8, 11 and 13 exhibited potent activity at MICs values ranging from 4–8 $\mu$g/mL. In addition, compounds 8–11 and 18 showed activities towards MRSA at MICs values ranging from 4–16 $\mu$g/mL. It should be noted that a major isolate, 2-deprenylrheediaxanthone (18) (1.34 g, 0.083%), showed bioactivities not only in our
bioassay tests but also that had previously been reported with antifungal activity against *Candida albicans* (Rath et al. 1996) and inducing cell death in colorectal cancer cells (Mittermair et al. 2020). The structure activity relationship (SAR) among isolated xanthones, the existence of 1,5,6-trihydroxyl groups in 1, 4, 5, 7–11, 13, 16 and 18 played important roles in their cytotoxicity toward several cell lines tested. Besides, the lack of a hydroxyl group at C-6 in compound 15 led to reduced cytotoxicity for all cell lines tested (Teh et al. 2013, Kaennakam et al. 2021). Moreover, the replaced of a methoxy group at C-5 in 6 decreased cytotoxicity comparing to those of C-5 hydroxyl analogues. Similarly, a methoxy group at C-5 in the diprenylated xanthone 14 abolished antibacterial activity against *B. cereus*, *B. subtilis*, *S. aureus* and MRSA compared to its hydroxyl analogue 13.

3. Experimental (see also supplementary material)

3.1. Plant material

Roots of *Maclura cochinchinensis* were collected from Pattani province, Thailand in April 2018. The specimens were identified by Prof. Dr. Pranom Chantaranothai, Department of Biology, Khon Kaen University, Thailand, where a voucher specimen (SK 17) was deposited.

3.2. Extraction and isolation

Air-dried roots of *M. cochinchinensis* (1.6 Kg) were ground and extracted successively at room temperature with *n*-hexane (3 × 10 L) and EtOAc (3 × 10 L) for 3 days each to give crude hexane (15 g, 0.94%) and EtOAc (84 g, 5.2%) extracts, respectively. The *n*-hexane extract (15 g) was separated by silica gel column chromatography (CC), eluted with a gradient system of *n*-hexane-EtOAc (100:0–0:100) and EtOAc-MeOH (100:0–0:100) to afford 12 fractions, designated as H1–H12. Fraction H2 was subjected to CC, using a gradient elution with *n*-hexane-EtOAc (100:0–0:100) to give a yellow solid of compound 6 (27.9 mg). Solid from fraction H4 was filtered to give yellow crystals of compound 9 (232.3 mg) and the filtrate was further purified by CC, eluted with an isocratic solution of *n*-hexane-CH$_2$Cl$_2$ (70:30) to give seven subfractions, H4.1–H4.7. Subfraction H4.6 was further purified by Sephadex LH-20 CC, eluted with MeOH, to give yellow crystals of compound 4 (1.6 mg) and a yellow solid of compound 15 (0.4 mg). Solid in subfraction H4.7 was filtered out to provide a yellow solid of compound 7 (3.8 mg). Solid in fraction H5 was filtered out to yield an addition of compound 9 (264.8 mg), and the filtrate was further purified by CC, eluted with an isocratic solution of *n*-hexane-CH$_2$Cl$_2$ (60:40) to give five subfractions, H5.1–H5.5. Subfraction H5.5 was purified by preparative TLC using *n*-hexane-CH$_2$Cl$_2$ (50:50) as eluent, to give a yellow solid of compound 19 (6.3 mg). Fraction H7 was purified by preparative TLC using *n*-hexane-CH$_2$Cl$_2$ (50:50) as eluent, to give yellow solid of compounds 5 (20.3 mg) and 8 (81.7 mg).

The EtOAc extract (84 g) was separated by silica gel CC, using the same solvent system as that of crude *n*-hexane above to yield 13 fractions, E1–E13. Fraction E4 was purified by CC, eluted with an isocratic solution of n-hexane-CH$_2$Cl$_2$ (80:20) to give an
additional amount of compound 4 (10.2 mg). Fraction E5 was subjected to CC, eluted with an isocratic solution of n-hexane-CH₂Cl₂ (50:50) to obtain seven subfractions, E5.1–E5.7. Subfraction E5.4 gave an additional amount of compound 4 (14.7 mg). Subfraction E5.5 was purified by preparative TLC using CH₂Cl₂-MeOH (97:3) as eluent, to yield an additional amount of compound 15 (2.5 mg). The solid in subfraction E5.6 was recrystallized from CH₂Cl₂ to give an additional amount of compound 9 (44.7 mg). The filtrate of subfraction E5.6 was further purified by preparative TLC, eluted with CH₂Cl₂-MeOH (97:3) to yield a pale yellow solid of compounds 14 (8.0 mg) and 15 (18.0 mg). Fraction E6 was fractionated by CC, eluted with CH₂Cl₂ to obtain eight subfractions, E6.1–E6.8. Subfraction E6.3 gave an additional amount of compound 9 (174.2 mg). Subfraction E6.4 gave an additional amount of compound 7 (198.7 mg). Subfraction E6.5 gave an additional amount of compound 8 (39.4 mg). Subfraction E6.6 was purified on a Sephadex LH-20 CC, eluted with MeOH to yield five subfractions, E6.6.1–E6.6.5. Subfraction E6.6.5 gave an additional amount of compound 5 (51.5 mg). Fraction E7 was filtered out to give yellow crystals of compounds 12 (158.1 mg) and 18 (1,344.4 mg) and the filtrate was purified by Sephadex LH-20 CC, eluted with MeOH to obtain three subfractions E7.1–E7.3. Subfraction E7.2 was further purified by MPLC using a prepacked normal phase column, eluted with CH₂Cl₂-MeOH (99:1) to give a yellow solid of compound 13 (34.2 mg). Subfraction E7.2 was purified on a Sephadex LH-20 CC, eluted with MeOH to give a yellow solid of compound 17 (7.3 mg). Fraction E8 was purified by CC, eluted with a gradient system of CH₂Cl₂-MeOH (100:0–0:100) to obtain six subfractions, E8.1–E8.6. Subfraction E8.3 was further purified by preparative TLC using CH₂Cl₂-MeOH (97:3) as eluent, to give compound 10 (29.6 mg). Fraction E9 was subjected to CC, eluted with an isocratic solution of CH₂Cl₂ to obtain fourteen subfractions, E9.1–E9.14. Subfraction E9.8 was purified by Sephadex LH-20 CC, eluted with MeOH to give a yellow solid of compound 1 (55.9 mg). Subfraction E9.9 was purified by Sephadex LH-20 CC, eluted with MeOH to give a yellow solid of compound 11 (62.7 mg). Fraction E10 was subjected to CC, eluted with a gradient system of CH₂Cl₂-MeOH (100:0–0:100) to obtain six subfractions, E10.1–E10.6. Subfraction E10.2 gave a yellow solid of compound 16 (14.3 mg). Solid in subfraction E10.3 was filtered out to give an additional amount of compound 1 (244.5 mg) and the filtrate was purified by Sephadex LH-20 CC, eluted with MeOH to obtain four subfractions, E10.3.1–E10.3.4. Subfraction E10.3.3 was further purified by preparative TLC using CH₂Cl₂-MeOH (95:5) as eluent, to give a brown solid of compounds 2 (12.0 mg) and 3 (14.0 mg).

3.3. Physical and spectroscopic data of three new compounds 1–3

3.3.1. Macochinxanthone A (1)

Yellow solid; [α]D25 +0.0198 (c 0.08, MeOH); UV (MeOH) λmax (log ε) 211 (4.35), 253 (4.71), 280 (4.13), 313 (4.27) nm; IR (Neat) νmax 3344, 1623, 1592, 1441, 1204, 1068 cm⁻¹; ¹H and ¹³C NMR data see Table S1; HRESI-MS m/z 343.1176 [M+H]⁺ (calcd. for C₁₉H₁₉O₆⁺ 343.1182).
3.3.2. Macochinxanthone B (2)
Pale yellow solid; $[\alpha]_{D}^{24} = -0.0003$ (c 0.2, CH3OH); UV (MeOH) $\lambda_{\text{max}}$ (log $\varepsilon$) 253(4.46), 284 (3.95), 326 (4.20) nm; IR (Neat) $\nu_{\text{max}}$ 3311, 2958, 2923, 2855, 1631, 1447, 1151, 1099 cm$^{-1}$; $^1$H and $^{13}$C NMR data see Table S1; HRESI-MS $m/z$ 429.1550 [M + H]$^+$ (calcd. for C23H25O8$^+$ 429.1549).

3.3.3. Macochinxanthone C (3)
Pale yellow solid; $[\alpha]_{D}^{25} = -0.0003$ (c 0.08, MeOH); UV (MeOH) $\lambda_{\text{max}}$ (log $\varepsilon$) 251 (4.38), 278 (3.79), 323 (4.12) nm; IR (Neat) $\nu_{\text{max}}$ 3372, 2975, 2932, 1655, 1610, 1440, 1304, 1152, 1108 cm$^{-1}$; $^1$H and $^{13}$C NMR data see Table S1; HRESI-MS $m/z$ 443.1708 [M + H]$^+$ (calcd. for C24H27O8$^+$ 443.1706).

4. Conclusion

Nineteen xanthones (1–19) were isolated from the roots of Maclura cochinchinensis. Their structures were determined by spectroscopic methods. Three of them were new furanoxanthones, macochinxanthones A–C (1–3), and each of them was analysed by chiral-phase HPLC to be a scalemic mixture of enantiomers. However, attempts to separate these enantiomer pairs by chiral-phase HPLC were not successful. The biosynthesis of 1–3 was proposed. This is the first report of xanthones 10, 11, 13, 14 and 19 from M. cochinchinensis and C. cochinchinensis. All tested compounds, except 2, were cytotoxic towards four cancer cell lines, KB, HelaS3, A549 and HepG2. Several of them displayed potent cytotoxicity towards KB, HelaS3 and A549 cancer cell lines with IC$_{50}$ values in the range of 1.29–4.58 μM. In addition, several of them showed moderate or potent antibacterial activity against Gram-positive bacteria, B.cereus, B. subtilis, S. aureus and MRSA with MICs values in the range of 4–128 μg/mL. These findings support that roots of M. cochinchinensis are a rich source of bioactive xanthones, especially a major isolate 2-deprenylrheedixanthone (18).

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Disclosure statement

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