Cytotoxic and antibacterial depsidones from the endophytic fungus *Chaetomium brasiliense* isolated from Thai rice

Trinop Promgool<sup>a</sup>, Kwanjai Kanokmedhakul<sup>a</sup>, Thianrat Leewijit<sup>b</sup>, Jiaojiao Song<sup>b</sup>, Kasem Soytong<sup>b</sup>, Jantana Yahuafai<sup>c</sup>, Tomas Kudera<sup>d</sup>, Ladislav Kokoska<sup>d</sup> and Somdej Kanokmedhakul<sup>a</sup>

<sup>a</sup>Faculty of Science, Natural Products Research Unit, Department of Chemistry and Center of Excellence for Innovation in Chemistry, Khon Kaen University, Khon Kaen, Thailand; <sup>b</sup>Faculty of Agricultural Technology, King Mongkut’s Institute of Technology Ladkrabang, Bangkok, Thailand; <sup>c</sup>Natural Products Research Section, Research Division, National Cancer Institute, Bangkok, Thailand; <sup>d</sup>Department of Crop Sciences and Agroforestry, Faculty of Tropical Agrisciences, Czech University of Life Sciences Prague, Prague, Czech Republic

**ABSTRACT**

Four new depsidones, mollicellins V-Y (1-4), together with eight known depsidones (5-12) were isolated from the endophytic fungus, *Chaetomium brasiliense*, detached from stems of Thai rice. Their structures were determined by extensive spectroscopic methods. Mollicellins X, H, and F (3, 8 and 10) showed potent cytotoxicity against the human oral epidermoid carcinoma (KB) cell line, and mollicellin F (10) also showed a potent cytotoxicity against the human hepatocellular carcinoma (HepG2) cell line. Besides, mollicellin B (11) exhibited cytotoxicity against the colorectal adenocarcinoma (HT-29) cell line. Moreover, most of the isolated depsidones displayed potent antibacterial activity against Gram-positive bacteria, *Bacillus cereus* and *Bacillus subtilis*, and several of them showed moderate activity against Methicillin-resistant *Staphylococcus aureus* (MRSA) and clinical isolates of *S. aureus*. In addition, a few of them also showed moderate activity against a Gram-negative bacteria *Pseudomonas aeruginosa*.

**ARTICLE HISTORY**

Received 5 August 2021
Accepted 20 October 2021

**KEYWORDS**

*Chaetomium brasiliense*; Chaetomiaceae; endophytic fungus; depsidone; mollicellins V-Y; cytotoxicity; antibacterial

CONTACT Somdej Kanokmedhakul somdej@kku.ac.th

Supplemental data for this article can be accessed online at https://doi.org/10.1080/14786419.2021.1999947.

This article has been republished with minor changes. These changes do not impact the academic content of the article.
1. Introduction

The Chaetomium genus belongs to the Chaetomiaceae family. It is widely distributed in soil, air, water, paper, plants and animals (Pinheiro et al. 2019; Tantapakul et al. 2020). It has been reported to produce various types of bioactive metabolites such as cytochalasin, depsidone, xanthone, sterigmatocystin, chromone, xanthoquinodin and dimeric epidithiodiketopiperazine (ETP) alkaloid. Many of these have shown bioactivities such as antimalarial, antibacterial, and antifungal, as well as cytotoxicity towards the properties of cancer cell lines (Li et al. 2008; Khumkomkhet et al. 2009; Zhang et al. 2013; Ouyang et al. 2018; Tantapakul et al. 2020; Zhao et al. 2021). Among bioactive compounds, depsidone is one of the groups that have attracted attention by natural product chemists, due to their biological activities and pharmaceutical applications (Li et al. 2008; Khumkomkhet et al. 2009; Ouyang et al. 2018; Zhao et al. 2021). Although depsidones have been known to be present in lichens (Elix et al. 1997; 1999; Elix and Wardlaw 1999; Rezanka and Guschina 1999; Elix et al. 2000; Pejin et al. 2012; Stojanovic et al. 2012; Bui et al. 2020; Nguyen et al. 2020), many of them have also been found in other sources such as fungi: Chaetomium brasiliense (Li et al. 2008; Khumkomkhet et al. 2009; Zhao et al. 2021), Preussia aurantiaca (Poch and Gloer 1991), Emericella unguis (Kawahara et al. 1988), Lasiodiplodia theobromae (Umeokoli et al. 2019), an endophytic fungus BCC 8616 (Pittayakhajonwut et al. 2006), a mangrove endophytic fungus Aspergillus sp. GXNU-A9 (Hao et al. 2020), a mushroom Pilobolus heterosporus (Rajachan et al. 2014) and leaves of Garcinia plants (Ito et al. 2001; Lannang et al. 2018). Our previous investigation on C. brasiliense revealed ten cytotoxic depsidones, including four new mollicellins K–N and six known mollicellins B, C, E, F, H and J (Khumkomkhet et al. 2009). Therefore, further search for new bioactive depsidones from C. brasiliense, an endophytic fungus isolated from Thai rice was our focus. Based on our primary screening of this fungus, it was found that the n-hexane and EtOAc extracts from the cultured biomass showed cytotoxicity against five cancer cell lines: Human oral epidermoid carcinoma (KB), Human cervical carcinoma (Hela), Human hepatocellular carcinoma (HepG2), Colorectal adenocarcinoma (HT-29) and Human breast adenocarcinoma (MCF-7) with IC50 values in the range of 4.31-39.08 μg/mL. Moreover, these crude extracts exhibited antibacterial activity against Gram-positive bacteria (Bacillus cereus, Bacillus subtilis and Staphylococcus aureus) with MICs in the range of 5-640 μg/mL and Gram-negative bacteria (Pseudomonas aeruginosa) with MICs in the range of 160-1,280 μg/mL. Consequently, the isolation, structural elucidation and bioactivities evaluation of isolated metabolites of crude n-hexane and EtOAc extracts from C. brasiliense are described.

2. Results and discussion

Chromatographic separation of n-hexane and EtOAc extracts of air-dried biomass of C. brasiliense yielded four new depsidones, mollicellins V–Y (1–4), eight known depsidones (5–12) (Figure 1), and an ergosterol. Structures of the known compounds were identified by physical and spectroscopic data (IR, 1H and 13C NMR, 2D NMR) and by comparison of the data obtained with published values to be mollicellins R, C, E, H, N, F, B and M (5–12) (Khumkomkhet et al. 2009; Zhao et al. 2021) and an ergosterol.
The structure elucidation of four new depsidones together with their antibacterial and cytotoxicity activities are presented as follows.

Compound 1 was obtained as a white amorphous solid, and its molecular formula, C_{21}H_{20}O_{7}, was deduced from HRESI-TOF-MS m/z 407.1108 [M + Na]^+ and $^{13}$C NMR data. The data indicated 12 degrees of unsaturation. The IR spectrum showed the absorption bands of a hydroxyl (3336 cm$^{-1}$), conjugated carbonyl ester (1736 cm$^{-1}$), aromatic aldehyde (1684 cm$^{-1}$), aromatic ketone (1659 cm$^{-1}$), and aromatic (1601 cm$^{-1}$) functionalities. The $^1$H NMR data (Table S1) showed two singlet signals of aromatic protons at $\delta$ 6.73 (H-2) and 6.70 (H-6), as well as two methyl groups attached to aromatics at $\delta$ 2.54 (CH$_3$-10) and 2.55 (CH$_3$-8), and two methyl groups of an isobutane unit at $\delta$ 0.94 (CH$_3$-6') and 0.92 (CH$_3$-7'), with a hydroxyl group at C-7 at $\delta$ 10.83. The low-field singlet signal ($\delta$ 12.07) was assigned as a chelated OH involving the carbonyl of an aldehyde group ($\delta$ 10.53) at its ortho-position of the aromatic ring. The $^1$H and $^{13}$C NMR spectroscopic data of 1 were similar to those of a depsidone, mollicellin K (Khumkomkhet et al. 2009), except for the double bond at C-4'/C-5', which was replaced by a single bond [d $H/C$ 2.77 (d, $J$ = 6.8 Hz, H-4')/53.4 and $\delta_{H/C}$ 2.28 (m, H-5')/26.0] in 1. The COSY spectrum showed correlations of the side chain unit, H-4'/H-5'/H-6'/H-7' (Figure S1 in the Supplementary Material). The HMBC spectrum of 1 displayed correlations of H-1' to C-1, C-2 and C-11a; H-2 to C-4 and C-11a; H-6 to C-5a, C-7, C-8, and C-9a; the OH proton at C-3 to C-2, C-3, and C-4; the aldehyde proton (H-2') to C-3 and C-4; H-6' to C-4', C-5' and C-7'; and H-7' to C-4', C-5' and C-6' confirming the connectivity in the molecule (Figure S1). Based on the above data, the structure of 1 was defined as a new depsidone and has been named mollicellin V.

Compound 2 was obtained as a white amorphous solid, and its molecular formula, C_{22}H_{22}O_{8}, was deduced from HRESI-TOF-MS m/z 437.1212 [M + Na]^+, indicating 12 degrees of unsaturation. The IR spectrum of 2 showed the absorption bands of hydroxyl (3395 cm$^{-1}$), carbonyl ester (1736 cm$^{-1}$), aromatic aldehyde (1712 cm$^{-1}$), aromatic ketone (1648 cm$^{-1}$), and aromatic (1607 cm$^{-1}$) functionalities. The $^1$H and $^{13}$C NMR spectroscopic data of 2 (Table S1) were similar to those of the isolated depsidone, mollicellin C (Khumkomkhet et al. 2009), except that the double bond at C-4'/C-5' was reduced to a single bond [d $H/C$ 2.64 (d, $J$ = 6.4 Hz, H-4')/53.8 and $\delta_{H/C}$ 2.28 (m, H-5')/26.0] in 2. The COSY and HMBC correlations of 2 confirmed the connectivity in the molecule (Figure S1). Thus, compound 2 was identified as a new depsidone and has been named mollicellin W.

Compound 3 was obtained as a white amorphous solid, and its molecular formula, C_{22}H_{21}ClO_{8}, was deduced from HRESI-TOF-MS m/z 471.0752 [M + Na]^+ and 473.0755 [M + 2 + Na]^+ in the ratio of 3:1, as well as $^{13}$C NMR data, indicating a chlorine atom in the molecule and possessing 12 degrees of unsaturation. The IR spectrum of 3 showed absorption bands as in mollicellin W (2). The $^1$H and $^{13}$C NMR spectral data of 3 (Table S1) were similar to those of 2, except for the presence of a chlorine atom at C-2 ($\delta_C$ 122.0), which was determined by comparing its $^{13}$C NMR data with those reported for known isolates mollicellins E (7), F (10), and M (12) (Khumkomkhet et al. 2009). The HMBC spectrum showed correlations of H-1' ($\delta_H$ 2.59) to C-2, and C-11a, and a hydroxyl proton at C-3 ($\delta_H$ 3.52) to C-3, C-2 and C-4 revealing a substituted
chlorine at C-2 (Figure S1). Thus, compound 3 was identified as a new depsidone and has been named mollicellin X.

Compound 4 was obtained as a white amorphous solid, and its molecular formula, C_{22}H_{22}O_{8}, was deduced from HRESI-TOF-MS m/z 345.1679 [M + Na]^+ and $^{13}$C NMR data, indicating 12 degrees of unsaturation. The IR spectrum showed the presence of OH (3261 cm$^{-1}$), an $\alpha,\beta$-unsaturated carbonyl ester (1700 cm$^{-1}$), aromatic ketone (1656 cm$^{-1}$), and aromatic (1606 cm$^{-1}$) functionalities. The $^1$H and $^{13}$C NMR spectral data of 4 (Table S1) were similar to those of mollicellin W (2), except that 4 has a double bond at C-4' ($\delta_{HH}$ 6.32/126.0)/C-5' ($\delta_{CC}$164.9) and a hydroxyl methyl group at C-4 ($\delta_{H}$ 5.08/55.2, H/C-2'). These were confirmed by the HMBC correlations of H-1 to C-2, C-11a; H-2' to C-3, C-4a; H-4' to C-3'; H-4' to C-6' and C-7' (Figure S1). Based on the above data, compound 4 was deduced as another new depsidone and has been named mollicellin Y.

All isolated depsidones, 1–12, were evaluated for their cytotoxicity and antibacterial activities and the results are shown in Tables S2 and S3 (Supplementary Material), respectively. Mollicellins V–X (1–3), R, C, E, H, N, F, B and M (5–11) showed cytotoxicity against KB, Hela, HepG2, HT-29 and MCF-7 cell lines with IC$_{50}$ values in the range of 4.79–92.11 μM. Among these, mollicellins X, H and F (3, 8 and 10) showed potent cytotoxicity against KB cell lines with IC$_{50}$ values of 9.83, 10.64 and 4.79 μM, respectively. Mollicellins X, F and B (3, 10 and 11) showed potent cytotoxicity against the HepG2 cell line with IC$_{50}$ values of 11.69, 7.10 and 10.66 μM, respectively. All depsidones, except mollicellin Y (4), were cytotoxic to Vero cells with IC$_{50}$ values in the range of 5.65–54.06 μM. These results show that most depsidones containing an aldehyde group

Figure 1. Structures of the isolated depsidones 1–12.
at C-4 show cytotoxicity toward most of the cell lines tested. In contrast, mollicellin Y (4), having a hydroxyl methyl group at C-4, was not cytotoxic towards any cell lines, except a weak activity against the HT-29 cell (IC_{50} value of 80.47 \mu M). Therefore, an aldehyde group at C-4 in the depsidone core should be crucial to the cytotoxic activity. However, structure activity relationship of depsidones (2, 6, 9 and 11) and their chlorinated depsidones pairs (3, 7, 10 and 12) remains unclear. In addition, mollicellins V, W, R, C and M (1, 2, 5, 6, 8 and 12) exhibited weak antibacterial activity against a Gram-negative bacteria, \textit{P. aeruginosa}, with MIC values in the range of 64-128 \mu g/mL. Moreover, mollicellins V, W and C-F (1, 2 and 6–10) exhibited strong antibacterial activity against Gram-positive bacteria \textit{B. cereus} and \textit{B. subtilis} with MIC values in the range of 2–8 \mu g/mL, which are close to the standard drug kanamycin (MIC value of 2 \mu g/mL). They also exhibited activity against \textit{S. aureus} ATCC 25923, with MIC values in the range of 16–64 \mu g/mL. Mollicellins X, Y, C, H and B (3, 4, 6, 8 and 11) showed moderate antibacterial activity against MRSA ATCC 33591, MRSA ATCC 33592, and MRSA ATCC 43300 with MIC values in the range of 32-128 \mu g/mL, which are close to a standard drug, oxacillin (MIC value of 32-128 \mu g/mL). In addition, mollicellins C and B (6 and 11) displayed moderate antibacterial activity against clinical isolates \textit{S. aureus} (SA1-3), with MIC values in the range of 32-128 \mu g/mL. Similarly for cytotoxic activity, an aldehyde group at C-4 in the depsidone core should be significant in antibacterial activity against all Gram-positive bacteria. In addition, a chlorine atom at C-2 of the depsidones has no or less effect than the antibacterial activity of their unchlorinated depsidone pairs. Overall, the complete lactone ring in the depsidone structure plays an important role in both cytotoxic and antibacterial activities (Zhang et al. 2014).

3. Experimental

3.1. General experimental procedures

Melting points were determined on a Gallenkamp SANYO melting point apparatus. UV spectra were measured by an Agilent 8453 UV-visible spectrophotometer. IR spectra were taken on a Bruker Tenser 27 spectrophotometer. NMR spectra were recorded in CDCl$_3$ and CD$_3$OD on a Varian Mercury Plus 400 spectrometer. HR-ESI-TOF-MS data were recorded on a Micromass Q-TOF-2 spectrometer. Column chromatography was carried out on Merck silica gel 60 (230 – 400 mesh). TLC was performed with pre-coated Merck silica gel 60 PF$_{254}$ on aluminium sheets. Preparative TLC was carried out on silica gel 60 PF$_{254}$ (0.5 mm, Merck) plates.

3.2. Fungal material

The fungus \textit{Chaetomium brasiliense} Bat. & Pontual was isolated from stems of Thai rice (Pathum Thani 80) (Leewijit et al. 2016) and a voucher specimen No. PT302 was deposited at the Faculty of Agricultural Technology, King Mongkut’s Institute of Technology. It was confirmed by a molecular phylogenetic study as having nuclear ribosomal DNA (rDNA) in the regions of the internal transcribed spacer (ITS), at the position of ITS-5.8S-ITS2 in primers ITS1 and ITS 4. The fungus was cultured in conical flasks (200 mL each, 75 flasks) with potato dextrose broth (50 mL/flask) and incubated
in a standing condition at 30°C for 4 weeks. The culture broth was filtered to give a wet biomass which was then air-dried at room temperature.

### 3.3. Extraction and isolation

Air-dried biomass of *C. brasiliense* (88 g) was ground and extracted successively at room temperature with *n*-hexane (3 x 1 L), EtOAc (3 x 1 L) and MeOH (3 x 1 L) to give three crude extracts, *n*-hexane (1.8 g, 2.0%), EtOAc (4.1 g, 4.7%) and MeOH (7.1 g, 8.1%), respectively. The crude hexane extract (1.8 g) was separated by silica gel FCC, eluting with a gradient system of *n*-hexane-EtOAc (100:0 to 100:1) to give 10 fractions (H1-10). Fraction H4 (170 mg) was further separated by CC, eluting with a gradient system of *n*-hexane-CH2Cl2 (50:50 to 0:100) to give a white solid of compound 5 (1.8 mg). The solid in fraction H5 (360 mg) was crystallized from MeOH/acetone to give a white amorphous solid of compound 11 (249 mg). Fraction H7 (250 mg) was separated by CC, eluting with a gradient system CH2Cl2-EtOAc (100:0, 95:5, 93:7) to give three subfractions (H7.1-7.3). Subfraction H7.2 (20 mg) was separated by preparative TLC (CH2Cl2-MeOH, 95:5) to obtain a white solid of compound 9 (11 mg). Fraction H9 (110 mg) was purified by Sephadex LH-20 CC, eluted with MeOH, to give three subfractions (H9.1-9.3). The subfraction H9.2 (50 mg) was separated by preparative TLC using CH2Cl2-MeOH (98:2) as eluent, to give a white solid of compound 10 (10 mg). The EtOAc extract (3.9 g) was separated by silica gel FCC, eluting with a gradient system of *n*-hexane-EtOAc (100:0 to 100:1) to give 10 fractions (E1-10). Fraction E3 (26 mg) was isolated by preparative TLC using CH2Cl2-MeOH (90:10, developed 3 times) as eluent, to obtain an additional amount of compound 5 (3.4 mg). Solid in fraction E4 (440 mg) was crystallized from acetone to give a white solid of compound 6 (148 mg) and the filtrate was evaporated to yield a residue (240 mg), which was further purified by silica gel FCC, eluting with a gradient system of *n*-hexane-CH2Cl2 (90:10 to 20:80) to give five subfractions (E4.1-4.5). Subfraction E4.2.2 (36 mg) was purified by preparative TLC (CH2Cl2-MeOH, 98:2) to obtain a white solid of ergosterol (15 mg). Solid in fraction E5 (270 mg) was crystallized from acetone to give a white amorphous solid of compound 8 (37 mg). Fraction E6 (220 mg) was isolated by FCC, eluting with a gradient system of *n*-hexane-CH2Cl2 (50:50 to 0:100) and CH2Cl2-EtOAc (90:10 to 0:100) to give five fractions (E6.1-6.5). Subfraction E6.4 (100 mg) was purified by preparative TLC using CH2Cl2 as eluent (developed 2 times), to give a white amorphous solid of compound 10 (10 mg). Fraction E6.5 (52 mg) was purified by preparative TLC using CH2Cl2-EtOAc (85:15, developed 7 times) as eluent, to obtain a white solid compound 2 (5.2 mg). Fraction E7 was purified by silica gel FCC, eluting with a gradient system with *n*-hexane-CH2Cl2 (50:50 to 0:100) and CH2Cl2-EtOAc (95:5 to 0:100) to give eight subfractions (E7.1-7.8). Subfraction E7.7 (34 mg) was purified by preparative TLC using CH2Cl2-EtOAc (85:15) as eluent, to yield a white amorphous solid of compound 3 (12 mg). Fraction E7.8 (63 mg) was purified by FCC, eluting with a gradient system of CH2Cl2-EtOAc (95:5 to 75:25) to give five subfractions (E7.8.1-7.8.5). Subfraction E7.8.5 (19.0 mg) was purified by Sephadex LH-20 CC, eluted with MeOH to give a white solid of compound 7 (10 mg). Fraction E8 (490 mg) was purified by silica gel CC, eluting with a gradient system of *n*-hexane-EtOAc (80:20 to 0:100) to give six subfractions
(E8.1-8.6). Subfraction E8.2 (110 mg) was separated on silica gel CC, eluted with an isocratic system of CH₂Cl₂ to give three subfractions (E8.2.1-8.2.3). Subfraction E8.2.3 (43 mg) was isolated by preparative TLC (CH₂Cl₂-MeOH, 95:5) to give a pale yellow solid of compound 4 (25 mg).

3.4. Physical and spectroscopic data of mollicellins V-Y (1-4)

**Mollicellin V (1):** white amorphous solid; mp 142-141 °C; Rf 0.31 (20% EtOAc-n-hexane); UV (MeOH) \( \lambda_{\text{max}} \) (log e) 250 (4.25), 301 (3.82) nm; IR (film) \( \nu_{\text{max}} \): 3336, 2957, 2872, 1736, 1684, 1659, 1601, 1570 cm⁻¹; for \(^1\)H and \(^{13}\)C NMR, see Table S1; HRESI-TOF-MS m/z 407.1108 [M + Na]⁺ (calcd. for C₂₁H₂₀O₇Na⁺, 407.1107).

**Mollicellin W (2):** white amorphous solid; mp 150-152 °C; Rf 0.29 (20% EtOAc-n-hexane); UV (MeOH) \( \lambda_{\text{max}} \) (log e) 264 (4.31), 305 (4.01), 372 (3.59) nm; IR (film) \( \nu_{\text{max}} \): 3395, 2959, 2931, 2871, 1736, 1712, 1648, 1607, 1567 cm⁻¹; for \(^1\)H and \(^{13}\)C NMR, see Table S1; HRESI-TOF-MS m/z 437.1275 [M + Na]⁺ (calcd. for C₂₂H₂₂O₈Na⁺, 437.1212).

**Mollicellin X (3):** white amorphous solid; Rf 0.21 (70% EtOAc-n-hexane); mp 159-160 °C; Rf 0.21 (70% EtOAc-n-hexane); UV (MeOH) \( \lambda_{\text{max}} \) (log e) 224 (4.14), 258 (3.95), 307 (3.49) nm; IR (film) \( \nu_{\text{max}} \): 3380, 2957, 2928, 2872, 1735, 1701, 1649, 1591 cm⁻¹; for \(^1\)H and \(^{13}\)C NMR, see Table S1; HRESI-TOF-MS m/z 471.0752 [M + Na]⁺ (calcd. for C₂₂H₂₁ClO₈Na⁺, 471.0823) and 473.0755 [M + 2Na]⁺ (calcd. for C₂₂H₂₁ClO₈₂Na⁺, 473.0793).

**Mollicellin Y (4):** white amorphous solid; mp 109-111 °C; Rf 0.55 (70% EtOAc-n-hexane); UV (MeOH) \( \lambda_{\text{max}} \) (log e) 227 (4.49), 263 (4.25), 318 (3.55) nm; IR (film) \( \nu_{\text{max}} \): 3261, 2936, 1700, 1656, 1606 cm⁻¹; for \(^1\)H and \(^{13}\)C NMR, see Table S1; HRESI-TOF-MS m/z 437.1217 [M + Na]⁺ (calcd. for C₂₂H₂₂O₈Na⁺, 437.1213).

3.5. Biological activity procedures

Cytotoxicity and Antibacterial assays are provided in Supplementary Material.

4. Conclusion

Phytochemical investigation on biomass of an endophytic fungus *C. brasiliense* isolated from Thai rice led to the isolation of four new depsidones, mollicellins V-Y (1–4), along with eight known depsidones namely mollicellins R, C, E, H, N, F, B and M (5–12). Most of the isolated depsidones exhibited cytotoxicity towards five cancer cell lines (KB, Hela, HepG2, HT-29 and MCF-7) and Vero cell lines. In addition, they also displayed potent antibacterial activity against Gram-positive bacteria, *B. cereus* and *B. subtilis* and several of them showed moderate antibacterial activity against MRSA. These finding support that the fungus *C. brasiliense* is an alternative source for bioactive depsidones.

Acknowledgements

We are grateful for the financial support from the Thailand Research Fund via Direct Basic Research Grant (Grant no. DBG6180092). Partial support from the Center of Excellence for
Innovation in Chemistry (PERCH-CIC), Ministry of Higher Education, Science, Research and Innovation is gratefully acknowledged. We would like to thank Assoc. Prof. Sophon Boonlue, Department of Microbiology, Faculty of Science, Khon Kaen University, Thailand for providing some bacterial cultures and laboratory facilities.

Disclosure statement
No potential conflict of interest was reported by the authors.

Funding
This research was funded by the Thailand Research Fund via Direct Basic Research Grant (Grant no. DBG6180029).

ORCID
Kwanjai Kanokmedhakul http://orcid.org/0000-0002-3237-2920
Ladislav Kokoska http://orcid.org/0000-0002-5677-692X
Somdej Kanokmedhakul http://orcid.org/0000-0001-8481-2636

References
Bui VM, Duong TH, Chavasiri W, Nguyen KPP, Huynh BL. 2020. A new depsidone from the lichen Usnea ceratina Arch. Nat Prod Res. :1–7. doi.org/10.1080/14786419.2020.1828405
Elix JA, Wardlaw JH. 1999. The structure of chalybaeizanic acid and quaesitic acid, two new lichen depsidones related to salazinic acid. Aust J Chem. 52(7):3–6.
Elix JA, Wardlaw JH, Archer AW, Obermayer W. 1999. 2-Methoxypsoromic acid, a new lichen depsidone from Pertusaria and Sulcaria species. Aust J Chem. 52(7):717–719.
Elix JA, Wardlaw JH, Obermayer W. 2000. 2-Hydroxyvirensic acid, a new depsidone from the lichen Sulcaria sulcata. Aust J Chem. 53:3–6.
Elix JA, Wardlaw JH, Yoshimura I. 1997. Sublobaric acid and oxolobaric acid, two new depsidones from the lichen Anzia hypoleucoides. Aust J Chem. 50(7):763–766.
Hao L, Zhou D, Qin X, Zhang W, Yang R, Li J, Huang X. 2020. A new depsidone derivative from mangrove endophytic fungus Aspergillus sp. GXNU-A9. Nat Prod Res. :1–5. doi.org/10.1080/14786419.2020.1809400
Ito C, Itoigawa M, Mishina Y, Tomiyasu H, Litaudon M, Cosson JP, Mukainaka T, Tokuda H, Nishino H, Furukawa H. 2001. Cancer chemopreventive agents. New depsidones from Garcinia plants. J Nat Prod. 64(2):147–150.
Kawahara N, Nozawa K, Nakajima S, Kawai KI, Yamazaki M. 1988. Isolation and structures of novel fungal depsidones, emequisins A, B, and C, from Emericella unguis. J Chem Soc Perkin Trans. 1(9):2611–2614.
Khumkomkhet P, Kanokmedhakul S, Kanokmedhakul K, Hahnvajanawong C, Soytong K. 2009. Antimalarial and cytotoxic depsidones from the fungus Chaetomium brasiliense. J Nat Prod. 72(8):1487–1491.
Lannang AM, Sema DK, Tatsimo SJN, Tankeu VFT, Tegha HF, Wansi JD, Shiono Y, Sewald N. 2018. A new depsidone derivative from the leaves of Garcinia polyantha. Nat Prod Res. 32(9):1033–1038.
Leewijit T, Pongnak W, Soytong K. 2016. Isolation of soil and endophytic fungi from rice (Oryza sativa L.). Int J Agric Technol. 12(7):2191–2202.
Li GY, Li BG, Yang T, Liu GY, Zhang GL. 2008. Secondary metabolites from the fungus Chaetomium brasiliense. Helv Chim Acta. 91(1):124–129.

Martinez M, Alvarez ST, Campi MG, Bravo JA, Vila JL. 2015. Ergosterol from the mushroom Laetiporus sp.; isolation and structural characterization. Rev Boliv Quim. 32:90–94.

Nguyen T-H-T, Nguyen T-M-N, Nguyen T-T, Nguyen H-H, Mai D-T, Huynh B-L-C, Tran C-L, Duong T-H. 2020. Parmosidine K, a new meta-depsidone from the lichen Parmotrema tsavoense. Nat Prod Res.:1–6. doi.org/10.1080/14786419.2020.1844697

Ouyang J, Mao Z, Guo H, Xie Y, Cui Z, Sun J, Wu H, Wen X, Wang J, Shan T. 2018. Mollicellins O–R, four new depsidones isolated from the endophytic fungus Chaetomium sp. EEF-10. Molecules. 23(12):3218–3211.

Pejin B, Tommonaro G, Iodice C, Tesevic V, Vajs V. 2012. Acetylcholinesterase inhibition activity of acetylated depsidones from Lobaria pulmonaria. Nat Prod Res. 26(17):1634–1637.

Pinheiro AC, Sequeira SO, Macedo MF. 2019. Fungi in archives, libraries, and museums: a review on paper conservation and human health. Crit Rev Microbiol. 45(5–6):686–700.

Pittayakhajonwut P, Dramae A, Madla S, Lartpommatulee N, Boonyuen N, Tanticharoen M. 2006. Depsidones from the endophytic fungus BCC 8616. J Nat Prod. 69(9):1361–1363.

Poch G, Gloer JB. 1991. Auranticins A and B: Two new depsidones from a mangrove isolate of the fungus preussia aurantiaca. J Nat Prod. 54(1):213–217.

Rajachan O. a, Kanokmedhakul S, Kanokmedhakul K, Soytong K. 2014. Bioactive depsidones from the fungus Pilobolus heterosporus. Planta Med. 80(17):1635–1640.

Rezanka T, Guschina IA. 1999. Brominated depsidones from Acarospora gobiensis, a lichen of Central asia. J Nat Prod. 62(12):1675–1677.

Stojanovic G, Stojanovic I, Smelcerovic A. 2012. Lichen depsidones as potential novel pharmacologically active compounds. Mini-Rev Org Chem. 9(2):178–184.

Tantapakul C, Promgool T, Kanokmedhakul K, Soytong K, Song J, Hadsadee S, Jungsuttiwong S, Kanokmedhakul S. 2020. Bioactive xanthoquinodins and epipolythiodioxopiperazines from Chaetomium globosum 7s-1, an endophytic fungus isolated from Rhapis cochinchinensis (Lour.) Mart. Nat Prod Res. 34(4):494–502.

Umeokoli BO, Ebrahim W, El-Neketi M, Müller WEG, Kalscheuer R, Lin W, Liu Z, Proksch P. 2019. A new depsidone derivative from mangrove sediment derived fungus Lasiodiplodia theobromae. Nat Prod Res. 33(15):2215–2222.

Zhang Y, Mu J, Feng Y, Wen L, Han J. 2014. Four chlorinated depsidones from a seaweed-derived strain of Aspergillus unguis and their new biological activities. Nat Prod Res. 28(7):503–506.

Zhang G, Zhang Y, Qin J, Qu X, Liu J, Li X, Pan H. 2013. Antifungal metabolites produced by Chaetomium globosum No.04, an endophytic fungus isolated from Ginkgo biloba. Indian J Microbiol. 53(2):175–180.

Zhao P, Yang M, Zhu G, Zhao B, Wang H, Liu H, Wang X, Qi J, Yin X, Yu L, et al. 2021. Mollicellins S-U, three new depsidones from Chaetomium brasiliense SD-596 with anti-MRSA activities. J Antibiot (Tokyo). 74(5):317–323.