Note

Morinlongosides A–C, Two New Naphthalene Glycoside and a New Iridoid Glycoside from the Roots of *Morinda longissima*

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Two new naphthalene glycosides, morinlongosides A and B (1, 2) and a new iridoid glycoside, morinlongoside C (3), together with four known ones, geniposidic acid (4), (3*R*)-3-*O*-[*β*-D-xylopyranosyl-(1→6)-*β*-D-glucopyranosyl]-l-octen-3-ol (5), lucidin-3-*O*-*β*-primeveroside (6), and morindone-6-*O*-*β*-gentiobioside (7), were isolated from the roots of *Morinda longissima* Y. Z. RUAN. The structures of all isolated compounds (1–7) were elucidated on the basis of spectroscopic data (high resolution (HR)-MS, one and two dimensional (1/2D)-NMR).

Key words morinlongoside A; morinlongoside B; morinlongoside C; naphthalene glycoside; iridoid glycoside

The Rubiaceae family in Vietnam is comprised of approximately 64 genera, several of which are very common and widely distributed throughout the country such as *Prismatomeris*, *Xanthophytum*, *Randia*, and *Morinda*.[1] The species *Morinda longissima* Y. Z. RUAN (local name "Nho dong") was designated as a newly taxonomical plant in 2004 and is widely used as a hepatoprotective herb by several ethnic minorities such as the Tay and Thai in the mountainous areas of northern Vietnam.[2] Previous investigations of various parts of the *Morinda* plant led to the isolation and structural elucidation of mono anthraquinones and anthraquinone glucosides,[3,4] iridoids,[5,6] iridoid glucosides,[7,8] flavonoids and flavonoid glucosides.[9]

In previous papers, we reported the isolation of mono anthraquinones from *M. longissima* roots.[10] In this study, we describe the isolation and structural determination of three new compounds, including two naphthalene glycosides, morinlongosides A and B (**1**, **2**) and an iridoid glycoside morinlongoside C (**3**), along with four known ones, geniposidic acid (**4**), (3*R*)-3-*O*-[*β*-D-xylopyranosyl-(1→6)-*β*-D-glucopyranosyl]-l-octen-3-ol (**5**), lucidin-3-*O*-*β*-primeveroside (**6**), and morindone-6-*O*-*β*-gentiobioside (**7**) from the roots of *M. longissima*. The structures of all isolated compounds (**1**–**7**) were elucidated on the basis of spectroscopic data (high resolution (HR)-MS, one and two dimensional (1/2D)-NMR) as well as by comparison with spectral values published in the literature.

Results and Discussion

The dried powdered roots of *M. longissima* were extracted with 96% EtOH and concentrated under decreased pressure to yield EtOH extract. The EtOH extract was then suspended in MeOH–H_2O and then partitioned with EtOAc, successively. The resulting fractions were concentrated to give the EtOAc- and water-soluble fractions. Otherwise, the dried powdered roots of *M. longissima* were decocted in hot water and concentrated under reduced pressure to get aqueous extract. Repeated column chromatography of the water-soluble fraction of the EtOH extract and aqueous extract resulted in the isolation of three new compounds, morinlongosides A–C (**1**–**3**), as well as four known ones (**4**–**7**).

Compound **1** was isolated as a white amorphous powder, with negative optical rotation of $[\alpha]_D^{22}$ −1.34 (*c*=1.00, MeOH). In the positive HR-electrospray ionization (ESI)-MS spectra, the quasi-molecular ion peaks at *m*/*z* 649.2127 $[M+Na]^+$ determined the molecular formula of compound **1** as $C_{29}H_{38}O_{15}$. The IR spectrum showed absorption bands at 3368 and 1704 cm^{-1}, attributed to hydroxyl and carbonyl groups, respectively. The ^{1}H-NMR spectrum exhibited four aromatic proton signals [δ_H 8.59 (d, *J*=9.0 Hz, H-5, H-8), δ_H 7.56 (t, *J*=8.5 Hz, H-6), δ_H 7.61 (t, *J*=8.5 Hz, H-7)], which represented an *ortho*-substituted phenyl group pattern.[11] The signals of a 1-hydroxy-2-methyl-2(*Z*)-pentenyl group at [δ_H 4.00 (dd, *J*=9.0, 15.0 Hz, H_a-9), δ_H 3.68 (m, H_b-9), δ_H 5.34 (t-like, *J*=7.5 Hz, H-10), δ_H 1.78 (s, H-12), δ_H 4.30 (d, *J*=12.0 Hz, H_a-13), δ_H 4.20 (d, *J*=12.0 Hz, H_b-13)], two anomeric protons at [δ_H 4.68 (d, *J*=7.5 Hz, H-1′), δ_H 4.88 (overlap, H-1″)] and one methoxy group at δ_H 3.90 (s, OCH_3) were also observed in ^{1}H-NMR spectrum (Table 1). The ^{13}C-NMR/distortionless enhancement by polarization transfer (DEPT) and heteronuclear single quantum coherence (HSQC) spectra of **1** exhibited 29 carbon signals, including 10 aromatic carbons at δ_C 124.4–148.2, a methyl carbon at δ_C 21.5 (C-12), and a methyl ester carbon at [δ_C 53.2, δ_C 171.3], belonging to one naphthalenyl nucleus, and a methyl ester group. In addition, the carbon signals at [δ_C 106.3 (C-1′), δ_C 63.3–77.9 (C-2′–C-6′)] and [δ_C 106.5 (C-1″), δ_C 62.4–78.2 (C-2″–C-6″)] indicate the presence of two sugar units (Table 1). Acid hydrolysis of **1** yielded D-glucose, which were confirmed by GC analysis according to published paper.[12] The linkage of glucose was determined as *β* on the basis of the $J_{1,2}$ value (7.5 Hz) of the anomeric proton.[11,13] Furthermore, the strong cross-peaks between

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Table 1. ^{1}H- and ^{13}C-NMR Spectroscopic Data of Compounds **1**–**3**

Position	**1**		**2**		**3**	
	δ_C (ppm)[a]	δ_H (ppm)[a]	δ_C (ppm)[b]	δ_H (ppm)[b]	δ_C (ppm)[a]	δ_H (ppm)[a]
1	148.2		149.4		97.4	5.37, d, 5.5
2	127.7		110.5	6.95, s		
3	130.1		130.9		153.0	7.48, d, 1.0
4	148.5		143.4		111.8	
4a	128.8		124.8			
5	124.4	8.59, d, 9.0	122.0	8.50, d, 8.5	40.5	3.65, dt, 2.0, 8.0
6	127.5	7.56, t, 8.5	124.6	7.43, t, 8.5	135.7	6.01, dt, 2.0, 5.5
7	128.6	7.61, t, 8.5	126.1	7.49, t, 9.0	131.4	5.68, dt, 2.0, 5.5
8	124.6	8.59, d, 9.0	122.5	8.24, d, 9.0	48.5	3.08, m
8a	131.0		128.2			
9	27.3	4.00, dd, 9.0, 15.0	28.0	3.68, m	45.0	2.47, ddd, 2.0, 5.5, 8.0
		3.68, m		3.60, m		
10	127.4	5.34, t-like, 7.5	124.9	5.44, t, 7.5	72.3	3.85, m 3.73, m
11	136.2		135.8		170.7	
12	21.5	1.78, s	21.2	1.74, s		
13	61.9	4.30, d, 12.0	59.6	4.12, m		
		4.20, d, 12.0				
1′	106.3	4.68, d, 7.5	101.0	4.91, d, 8.0	100.2	4.67, d, 8.0
2′	75.6	3.57, m	74.1	3.42, m	74.6[d]	3.27, m
3′	77.8	3.46, m	76.6	3.27, m	77.9[d]	3.37, m
4′	71.9	3.32[c]	69.9	3.18, m	71.6	3.34, m
5′	77.9	3.13, m	77.0	2.97, m	78.3	3.30, m
6′	63.3	3.77, dd, 2.0, 13.5	61.0	3.61, dd, 4.5, 10.0	62.7	3.90, dd, 2.5, 10.0
		3.65, dd, 7.0, 13.5		3.40, dd, 7.5, 10.0		3.71, dd, 5.0, 10.0
1″	106.5	4.88[c]	105.0	4.62, d, 8.0	103.7	4.35, d, 8.0
2″	75.8	3.68, m	73.2	3.38, m	75.1[d]	3.25, m
3″	77.9	3.42, m	76.4	3.24, m	77.9[d]	3.39, m
4″	71.4	3.48, m	69.5	3.29, m	71.5	3.32, m
5″	78.2	3.13, m	76.8	3.31, m	78.1	3.28, m
6″	62.4	3.75, dd, 1.5, 13.5	60.4	3.68, dd, 7.0, 14.0	62.6	3.86, dd, 2.0, 12.0
		3.64, dd, 6.5, 13.5		3.53, dd, 5.5, 14.0		3.69, dd, 8.5, 12.0
CO	171.3					
OCH_3	53.2	3.90, s				
13-OH				4.64, t, 8.0		
2′-OH				5.40, d, 5.0		
3′-OH				5.09, d, 5.0		
4′-OH				5.07, d, 5.5		
6′-OH				4.23, t, 5.5		
2″-OH				5.81, d, 5.0		
3″-OH				4.92, d, 4.0		
4″-OH				5.01, d, 5.0		
6″-OH				4.58, t, 5.5		

a) NMR (in methanol-d_4, δ values) spectroscopic data. *b*) NMR (in DMSO-d_6, δ values) spectroscopic data. *c*) Overlapped. *d*) May be exchangeable.

anomeric protons at δ_H 4.68 (H-1′) and δ_C 148.2 (C-1), δ_H 4.88 (H-1″) and δ_C 148.5 (C-4) in the heteronuclear multiple bond connectivity (HMBC) spectrum suggested that two sugar moieties are located at C-1 and C-4 of the naphthalenyl ring. The ^{1}H- and ^{13}C-NMR of compound **1** were similar to those of 2-carbomethoxy-3-prenyl-1,4-naphthohydroquinone 1,4-di-*O*-*β*-D-glucopyranoside,[14] except for the presence of a methylene hydroxyl group located at C-13 (Fig. 1), which had HMBC correlations to double-bonded carbons C-10 (δ_C 127.4) and C-11 (δ_C 136.2) (Fig. 2). The locations of the methoxycarbonyl group and 1-hydroxy-2-methyl-2(*Z*)-pentenyl group at C-2 and C-3, respectively, were confirmed by the HMBC correlations of the methoxy proton (δ_H 3.90) with the carbonyl carbon (δ_C 171.3) and of the proton H-9 (δ_H 4.00) with carbons C-2 (δ_C 127.7), C-3 (δ_C 130.1), and C-4 (δ_C 148.5) (Table 1, Fig. 2). The geometrical configuration of **1** was determined to have a *Z*-configuration by analysis of its nuclear Overhauser effect spectroscopy (NOESY) spectra. From the NOESY spectrum, the olefinic proton resonance at δ_H 5.34 (H-10) displayed a nuclear Overhauser effect (NOE) with the methyl proton at δ_H 1.78 (H-12) (Fig. 2). Based on these findings, compound **1** was determined to be 2-methoxycarbonyl-3-(1-hydroxy-2-methyl-2(*Z*)-pentenyl)-1,4-naphthohydroquinone 1,4-di-*O*-*β*-D-glucopyranoside, named morinlongoside A.

Compound **2** was obtained as a white amorphous powder with negative optical rotation of $[\alpha]_D^{22}$ −1.32 (*c*=1.00, MeOH). The quasi-molecular ion peaks in the positive HR-ESI-MS spectra at *m*/*z* 591.2049 $[M+Na]^+$ determined the molecular

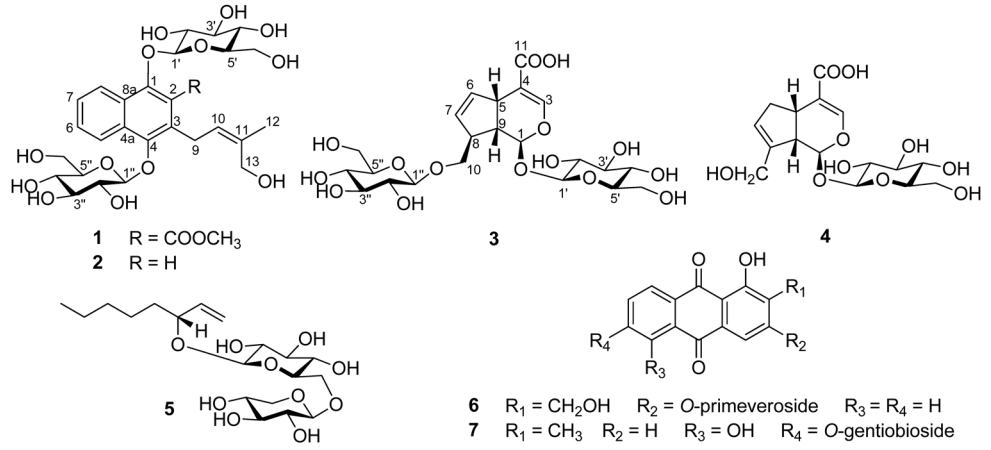

Fig. 1. The Structures of Isolated Compounds **1**–**7** from *Morinda longissima*

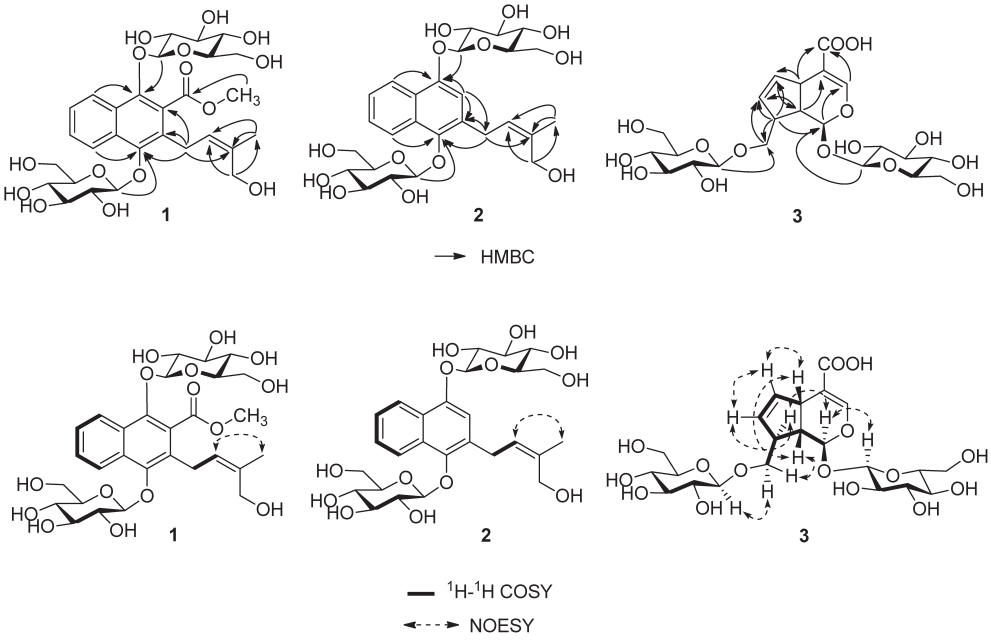

Fig. 2. Selected (COSY, NOESY, and HMBC) Correlations of Compounds **1**–**3**

formula of **2** as $C_{27}H_{36}O_{13}$. The ^{1}H- and ^{13}C-NMR spectra of compound **2** were similar to those of compound **1** except for the presence of an aromatic proton at δ_H 6.95 (H-2) instead of the methyl ester group at C-2 as in **1** (Table 1). The presence of aromatic proton H-2 was identified by the HMBC correlations between δ_H 6.95 (H-2) and δ_C 149.4 (C-1), 130.9 (C-3), and 28.0 (C-9) (Fig. 2). The geometrical configuration of **2** was analyzed to have a *Z*-configuration by comparison of ^{1}H- and ^{13}C-NMR between compound **2** and compound **1** and published data.[15] Again, in the NOESY spectrum of **2**, the olefinic proton resonance at δ_H 5.44 (H-10) displayed a NOE with the methyl proton at δ_H 1.74 (H-12) (Fig. 2). Therefore, the structure of compound **2** was established as 3-(1-hydroxy-2-methyl-2(*Z*)-pentenyl)-1,4-naphthohydroquinone 1,4-di-*O*-*β*-D-glucopyranoside, named morinlongoside B.

Compound **3** was isolated as a colorless liquid, with positive optical rotation of $[\alpha]_D^{22}$ +0.48 (*c*=1.60, MeOH). The molecular formula of **3** was determined as $C_{22}H_{32}O_{15}$ from the quasi-molecular ion peak at *m*/*z* 559.1653 $[M+Na]^+$ in the positive HR-ESI-MS spectrum. The IR absorption bands at 3371 and 1652 cm^{-1} suggested the presence of hydroxyl groups and a carbonyl group. The ^{1}H-NMR spectrum of **3** exhibited three olefinic protons [δ_H 7.48 (d, *J*=1.0 Hz, H-3), δ_H 6.01 (dt, *J*=2.0, 5.5 Hz, H-6), δ_H 5.68 (dt, *J*=2.0, 5.5 Hz, H-7)], an oxygenated methylene group [δ_H 3.85 (m, H_a-10), δ_H 3.73 (m, H_b-10)], three methine proton signals [δ_H 3.65 (dt, *J*=1.5, 8.0 Hz, H-5), δ_H 3.08 (m, H-8), δ_H 2.47 (ddd, *J*=2.0, 5.0, 8.0 Hz, H-9)], an acetal proton at δ_H 5.37 (d, *J*=5.5 Hz, H-1) assigned to an iridoid ring, and oxygenated protons at [δ_H 4.67 (d, *J*=8.0 Hz, H-1′), δ_H 3.27–3.90 (6H, H-2′–H-6′), δ_H 4.35 (d, *J*=8.0 Hz, H-1″), δ_H 3.25–3.86 (6H, H-2″–H-6″)] belonging to two sugar moieties (Table 1). Acid hydrolysis of **3** yielded D-glucose, which were confirmed by GC analysis. The linkage of glucose was determined as *β* on the basis of the $J_{1,2}$ value (8.0 Hz) of the anomeric proton.[11,13] The ^{13}C-NMR and HSQC spectra of **3** exhibited 22 signals due to a carboxylic carbon at δ_C 170.7 (4-COOH), four olefinic carbons at [δ_C 153.0 (C-3), 111.8 (C-4), 135.7 (C-6), 131.4 (C-7)], three methine carbon signals at [δ_C 40.5 (C-5), 48.5 (C-8), 45.0 (C-9)], an oxymethylene carbon at δ_C 72.3 (C-10), an acetal carbon at δ_C 97.4 (C-1), as

well as sugar carbon signals at [δ_C 100.2 (C-1′), δ_C 62.7−78.3 (C-2′−C-6′), δ_C 103.7 (C-1″), δ_C 62.6–78.1 (C-2″–C-6″)], suggesting that **3** is an iridoid glucoside[16,17] (Table 1). In the HMBC, the correlations between H-8 and C-1/C-6/C-7/C-10, and the cross-peak between H-8 and H-6, H-7, H-9, and H-10 in the correlation spectroscopy (COSY) spectra were observed (Fig. 2). The HMBC correlations between the anomeric proton δ_H 4.35 (H-1″) and carbon signal at δ_C 72.3 (C-10), and between the anomeric proton δ_H 4.67 (H-1′) and carbon signal at δ_C 97.4 (C-1) confirmed that two sugar units are located at C-10 and C-1 of **3** (Fig. 2). The relative configurations of **3** were examined from its difference NOESY spectra and coupling constant. The appearance of H-5 as a double triplet revealed a small coupling constant with H-6 ($J_{5,6}$=2.0 Hz) indicating the β-position of proton H-5.[18,19] The NOEs were observed between H-9 of aglycone and H-5, between H-5 and H-6, between H-6 and H-7 (Fig. 2), while no NOEs observed between H-9 and H-1, and between H-9 and H-8. All those evidences indicated that the H-9 was β-orientation, whereas the H-1 and H-8 were all α-orientation. The configuration of the oxymethylene (C-10) of **3** was confirmed as β on the basis of an NOE difference experiment. Irradiation of H-1 (δ_H 5.37) caused an enhancement of H-8 (δ_H 3.08) (Fig. 2) as previously observed.[20] Thus, the structure of compound **3** was deduced as shown (Fig. 1) and named morinlongoside C.

In addition, from the roots of *M. longissima*, four known compounds were isolated and identified as geniposidic acid (**4**),[21] (3*R*)-3-*O*-[β-D-xylopyranosyl-(1→6)-β-D-glucopyranosyl]-L-octen-3-ol (**5**),[22] lucidin-3-*O*-β-primeveroside (**6**),[13,23] and morindone-6-*O*-β-gentiobioside (**7**)[24] by comparison of the physicochemical and spectroscopic data (IR, UV, MS, 1/2D-NMR) with those reported in the literature (Fig. 1). Although many publications reported the chemical constituents of various compounds, such as iridoids, coumarins, anthraquinones from *M. longissima*, however the biological activities of isolated compounds are needed to further study.

Experimental

General Experimental Procedures ^{1}H-NMR (500 MHz) and ^{13}C-NMR (125 MHz) were measured on a Bruker Avance 500 MHz spectrometer. HR-ESI-MS were obtained from a Varian FT-MS spectrometer and MicroQ-TOF III (BrukerDaltonics, Germany). IR spectroscopy was fulfilled on Nicolet Impact 410 spectrometer. UV was performed in spectroscopic V-630 UV-VIS instrument. HPLC was carried out using a Water system with a UV detector and an YMC Pak ODS-A column (20×250 mm, 5 μm particle size, YMC Co., Ltd., Japan) and HPLC solvents were from Burdick & Jackson, U.S.A. Column chromatography was carried out on silica gel (Si 60 F_{254}, 40–63 mesh, Merck). All solvents were redistilled before use. Pre-coated TLC plates (Si 60 F_{254}) were used for analytical purposes. Compounds were visualized under UV radiation (254, 365 nm) and by spraying plates with 10% H_2SO_4 followed by heating with a heat gun.

Plant Materials Roots of *M. longissima* were collected in Son La Province, North Vietnam in 2013. The plants were identified by botanist Dr. Ngo Van Trai, Institute of Medicinal Materials, Hanoi, Vietnam. A voucher specimen (C-520) was deposited in the Herbarium of the Institute of Natural Products Chemistry, VAST, Hanoi, Vietnam.

Extraction and Isolation The dried powdered roots of *M. longissima* (0.5 kg) were extracted with 96% EtOH over the period of 2 d at room temperature and concentrated under decreased pressure to yield a black crude EtOH extract (20.0 g). The crude EtOH extract was then suspended in MeOH–H_2O (1 : 1, v/v) and then partitioned with EtOAc and H_2O. The resulting fractions were concentrated under decreased pressure to give the corresponding solvent-soluble fractions EtOAc (5.0 g) and H_2O (10.0 g). The H_2O fraction was subjected on Diaion HP-20 column with gradient solvents of H_2O–MeOH (75 : 25→0 : 100, v/v, 1.5 L each) to afford 4 fractions (frs.) (WA–WD). The WA fr. (2.57 g) was separated on a silica gel column, eluting with a gradient of $CHCl_3$–MeOH (6 : 1, v/v), to afford 6 sub-frs. (WA1–WA6). White crystal was separated from the WA5 sub-fr. (1.27 g), and then was washed with MeOH to afford compound **1** (3.3 mg). The WA4 sub-fr. (280 mg) was further chromatographed on a silica gel column eluting with a solvent mixture of EtOAc–MeOH (6 : 1, v/v) to afford WA4a sub-fr. (100 mg). White crystal was separated from this fr., and then was washed with MeOH to afford compound **2** (15.0 mg). The WB fr. (1.38 g) was subjected to silica gel column (40–63 mesh, Merck) with gradient solvents of $CHCl_3$–MeOH–H_2O (3 : 1 : 0.1, v/v/v) to afford 6 sub-frs. (WB1–WB6). The WB3 sub-fr. (0.45 g) was purified on a silica gel column, eluting with $CHCl_3$–MeOH–H_2O (6 : 1 : 0.1, v/v/v), to produce compound **6** (70.0 mg). The WC sub-fr. (0.9 g) was further chromatographed on a silica gel column (40–63 mesh, Merck) eluting with a gradient of $CHCl_3$–MeOH–H_2O (1 : 1 : 0.1, v/v/v) to afford 5 sub-frs. (WC1–WC6). The WC4 sub-fr. (120 mg) was then rechromatographed on RP 18 column, eluting with MeOH–H_2O (1.5 : 1, v/v) to get 3 sub-frs. (WC4a–c). The WC4b sub-fr. (50.0 mg) was re-crystallization to yield compound **7** (23.0 mg).

Again the dried powdered roots of *M. longissima* (1.5 kg) were decocted in hot water (2.5 L) and concentrated under reduced pressure to get black crude aqueous extract. The extract (30.0 g) was subjected to chromatography on Diaion HP-20 column, eluting with H_2O–MeOH (100 : 0→0 : 100, v/v, each 2.5 L), to give 4 frs. (W1–W4). The W3 fr. (8.2 g) was chromatographed on RP 18 column, using MeOH–H_2O (1 : 3, v/v, each 500 mL) as mobile phase to afford 12 sub-frs. (W3.1–W3.12). The W3.1 sub-fraction was further purified by semi-preparative HPLC [YMC Pack ODS-A column; mobile phase MeOH–H_2O (25 : 75→70 : 30); flow rate 5 mL/min; 90 min; UV detection at 210 nm] to yield compounds **3** (20.0 mg), **4** (12.0 mg) and **5** (10.0 mg), respectively.

Morinlongoside A (**1**)

White amorphous powder; $[\alpha]_D^{22}$ −1.34 (c=1.00, MeOH); UV λ_{max} (MeOH): 235.0 nm; IR (KBr) ν_{max} 3368, 2943, 2862, 1704, 1633, 1521, 1439, 1351, 1290, 1244, 1064, 1016 cm^{-1}; HR-ESI-MS (+): *m/z* 649.2127 $[M+Na]^+$ (Calcd for $C_{29}H_{38}O_{15}Na$ 649.2109); ^{1}H-NMR (500 MHz, methanol-d_4) and ^{13}C-NMR (125 MHz, methanol-d_4) spectroscopic data, see Table 1.

Morinlongoside B (**2**)

White amorphous powder; $[\alpha]_D^{22}$ −1.32 (c=1.00, MeOH); UV λ_{max} (MeOH): 235.0 nm; IR (KBr) ν_{max} 3370, 2941, 2860, 1701, 1635, 1521, 1440, 1290, 1245, 1065, 1017 cm^{-1}; HR-ESI-MS (+): *m/z* 591.2049 $[M+Na]^+$ (Calcd for $C_{27}H_{36}O_{13}Na$ 591.2053); ^{1}H-NMR (500 MHz, DMSO-d_6) and ^{13}C-NMR (125 MHz, DMSO-d_6) spectroscopic data, see Table 1.

Morinlongoside C (**3**)

Colorless liquid; $[\alpha]_D^{22}$ +0.48 (c=1.60, MeOH); UV λ_{max}

(MeOH): 236.0 nm; IR (film) ν_{max} 3371, 2956, 2843, 1652, 1450, 1410, 1114, 1023 cm^{-1}; HR-ESI-MS (+): *m/z* 559.1653 $[M+Na]^+$ (Calcd for $C_{22}H_{32}O_{15}Na$ 559.1638); ^{1}H-NMR (500 MHz, methanol-d_4) and ^{13}C-NMR (125 MHz, methanol-d_4) spectroscopic data, see Table 1.

Acid Hydrolysis of Compounds 1–3 The monosaccharide subunits of **1–3** were obtained by acid hydrolysis. Compounds **1–3** (2 mg each) in 10% HCl–dioxane (1 : 1, 1 mL) were each heated at 80°C for 4 h in a water bath. The reaction mixtures were neutralized with Ag_2CO_3, filtered, and then extracted with $CHCl_3$ (1 mL×2). After concentration, each water layer (monosaccharide portion) was examined by TLC with $CHCl_3$–MeOH–H_2O (50 : 50 : 10) and compared with authentic samples. Each sugar residue was then dissolved in 1 mL of H_2O, 10 mg of $NaBH_4$ was added, and the mixture was left to stand for 2 h at ambient temperature. Several drops of 25% HOAc were added until the pH value was 4 and 5. After co-distillation with CH_3OH to remove the extra boracic acid and water, the resulting products were put into vacuum-desiccators overnight and then heated at 110°C for 15 min to further remove the water. Next, 1.0 mL of acetic anhydride was added and the solution was kept at 100°C for 1 h. Then the solution was cooled and co-distillated with toluene several times. The acetate derivatives were dissolved in $CHCl_3$, washed with distilled water and then anhydrous sodium sulfate, filtered, and concentrated to 0.1 mL. The acetate derivatives were subjected to GC analysis to identify the sugars. Column temperature 210°C; injection temperature 250°C; carrier gas N_2 at a flow rate of 25 μL/min; D-glucose, 17.40 min, respectively.

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Conflict of Interest The authors declare no conflict of interest.

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