Taylor & Francis
Taylor & Francis Group

Natural Product Research
Formerly Natural Product Letters

ISSN: 1478-6419 (Print) 1478-6427 (Online) Journal homepage: https://www.tandfonline.com/loi/gnpl20

Two new phenylpropanoids and a new dihydrostilbenoid from the flower buds of *Magnolia biondii* pamp and their acetylcholinesterase inhibitory activities

Yan-Gang Cao, Hong-Wei Li, Bing Cao, Jian-Chao Wang, Yan-Li Zhang, Xuan Zhao, Xiao-Ke Zheng & Wei-Sheng Feng

To cite this article: Yan-Gang Cao, Hong-Wei Li, Bing Cao, Jian-Chao Wang, Yan-Li Zhang, Xuan Zhao, Xiao-Ke Zheng & Wei-Sheng Feng (2019): Two new phenylpropanoids and a new dihydrostilbenoid from the flower buds of *Magnolia biondii* pamp and their acetylcholinesterase inhibitory activities, Natural Product Research, DOI: 10.1080/14786419.2019.1693567

To link to this article: https://doi.org/10.1080/14786419.2019.1693567

NATURAL PRODUCT RESEARCH
https://doi.org/10.1080/14786419.2019.1693567

Taylor & Francis
Taylor & Francis Group

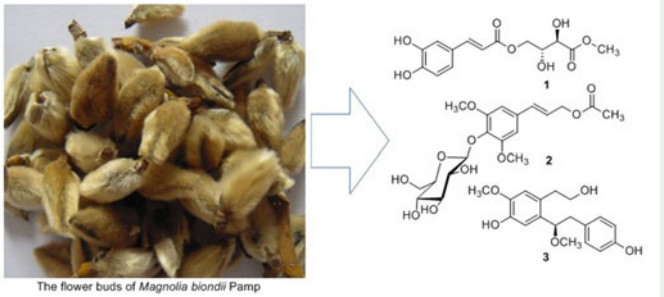
Two new phenylpropanoids and a new dihydrostilbenoid from the flower buds of *Magnolia biondii* pamp and their acetylcholinesterase inhibitory activities

Yan-Gang Cao[a,b], Hong-Wei Li[a,b], Bing Cao[a,b], Jian-Chao Wang[a], Yan-Li Zhang[a,b], Xuan Zhao[a], Xiao-Ke Zheng[a,b] and Wei-Sheng Feng[a,b]

[a]School of Pharmacy, Henan University of Chinese Medicine, Zhengzhou, P.R. China;
[b]Co-construction Collaborative Innovation Center for Chinese Medicine and Respiratory Diseases by Henan & Education Ministry of P.R. China, Zhengzhou, P.R. China

ABSTRACT

Two new phenylpropanoids, named (2′*R**,3′*R**)-2′,3′-dihydroxy-4′-methoxy-caffeoyl butyrate (**1**), 9-acetoxy syringin (**2**), and a new dihydrostilbene, named (8′*R*)-4′,5-dihydroxy-4,8′-dimethoxy-2-hydroxyethyl diphenylethane (**3**), together with five analogues (**4**–**8**), were isolated from the flower buds of *Magnolia biondii* Pamp. Their structures were elucidated by extensive spectroscopic analyses and comparison with literature data. The absolute configurations were deduced by comparison of experimental and calculated gauge-independent atomic orbital (GIAO) 1 D NMR data. Moreover, the isolated compounds (**1**–**8**) were evaluated *in vitro* for their acetylcholinesterase (AChE) inhibitory activities.



The flower buds of *Magnolia biondii* Pamp

ARTICLE HISTORY
Received 11 September 2019
Accepted 10 November 2019

KEYWORDS
Magnolia biondii Pamp; Magnoliaceae; phenylpropanoids; dihydrostilbenoids; acetylcholinesterase inhibitory activity

1. Introduction

Magnolia biondii Pamp from the Magnoliaceae family is widely distributed in Korea, China, and Japan (Nguyen et al. 2017). The dried flower buds of *M. biondii*, commonly known as Xin-yi in China, have been used in Chinese medicine to treat allergic rhinitis,

CONTACT Xiao-Ke Zheng zhengxk.2006@163.com; Wei-Sheng Feng fwsh@hactcm.edu.cn School of Pharmacy, Henan University of Chinese Medicine, Zhengzhou 450046, P.R. China.

Supplemental data for this article can be accessed at https://doi.org/10.1080/14786419.2019.1693567.

sinusitis, and headache (Park et al. 2012). Phytochemical studies of this plant have resulted in the identification of various metabolites such as esstenial oils (Hu et al. 2018), lignans (Ma et al. 1996; (Zhang et al. 2017)), neolignans (Ma et al. 1996; Chung et al. 2012), monoterpends (Feng et al. 2016), sesquiterpends (Nguyen et al. 2017), and alkaloids (Talapatra et al. 1982). Extracts of *M. biondii* have been reported to possess anti-inflammatory (Qi et al. 2011; Nguyen et al. 2017), anti-allergenic (Tsuruga et al. 1991; Zhang et al. 2017), and anti-platelet-activating factor (anti-PAF) (Jung et al. 1998).

Alzheimer's disease (AD), a neurodegenerative disorder, is the leading cause of dementia among the elderly. Therapeutic approach to enhance cholinergic neurotransmission by the use of cholinesterase (AChE) inhibitors is the most successful treatment for AD according to the cholinergic hypothesis and evidences from the clinical trials (Bhadra et al. 2012). Natural products were the important sources of new drugs ((Newman and Cragg 2016)) and many natural phenolic compounds were evaluated as AChE inhibitors for potential application in the treatment of AD (Lu et al. 2017; Posri et al. 2019). In our effort to discover diverse constituents with AChE inhibitory activities, two new phenylpropanoids, named (2′*R**,3′*R**)-2′,3′-dihydroxy-4′-methoxy-caffeoyl butyrate (**1**), 9-acetoxy syringin (**2**), and a new dihydrostilbene, named (8′*R*)-4′,5-dihydroxy-4,8′-dimethoxy-2-hydroxyethyl diphenylethane (**3**), together with five known compounds (**4**–**8**), were isolated from the flower buds of *M. biondii* and their AChE inhibitory effects were evaluated.

2. Results and discussion

Compound **1** was isolated as a white amorphous powder with a molecular formula of $C_{14}H_{16}O_8$ determined by the HRESIMS and NMR data. In the ^{1}H NMR spectrum of **1**, the signals suggested the presence of an 1,3,4-trisubstituted benzene ring [δ_H 7.04 (1H, d, $J = 2.0$ Hz, H-2), 6.95 (1H, dd, $J = 8.2$, 2.0 Hz, H-6), and 6.78 (1H, d, $J = 8.2$ Hz, H-5)], a conjugated olefinic group [δ_H 7.58 (1H, d, $J = 16.0$ Hz, H-7) and 6.26 (1H, d, $J = 16.0$, H-8)], two oxymethines [δ_H 4.23 (1H, d, $J = 3.8$ Hz, H-3′) and 4.11 (1H, m, H-2′)], an oxygenated methylene [δ_H 4.30 (1H, dd, $J = 11.3$, 5.2 Hz, H-1′a) and 4.25 (1H, dd, $J = 11.3$, 6.2 Hz, H-1′b)], and a methoxy group [δ_H 3.75 (3H, s, 4′-OCH_3)]. In its ^{13}C NMR spectrum, fourteen carbon signals, including two carboxylic carbons [δ_C 174.3 (C-4′) and 168.9 (C-9)], three sp^2 quaternary carbons [δ_C 149.7 (C-4), 146.9 (C-3) and 127.7 (C-1)], five sp^2 methine carbons [δ_C 147.3 (C-7), 123.0 (C-6), 116.5 (C-5), 115.1 (C-2), and 114.8 (C-8)], two sp^3 oxygenated methine carbons [δ_C 73.5 (C-3′), and 72.0 (C-2′)], a sp^3 oxymethlene carbon [δ_C 65.4 (C-1′)], and a methoxy group [δ_C 52.5 (4′-OCH_3)] were observed. The 1 D NMR data of **1** were similar to those of caffeoyl ester of apionic acid (Braca et al. 2001) with the mian difference being the absence of a hydroxymethyl moiety and the presence of a methoxy group attached to the C-4′, which was determined by the HMBC correlation of methoxy group protons with C-4′. Thus, the planar structure of **1** was elucidated.

The gauge-independent atomic orbital (GIAO) 1 D NMR calculations for four isomers [(2′*R*,3′*R*)-**1**, (2′*R*,3′*S*)-**1**, (2′*S*,3′*R*)-**1**, and (2′*S*,3′*S*)-**1**] were conducted at the mPW1PW91/6-31G(d,p) level in MeOH and the calculated NMR and experimental data were analysed by the DP4+ probability method. As a result, (2′*R*,3′*R*)-**1** (50.24% probability) and

(2′*S*,3′*S*)-**1** (49.76% probability) were probably the right structure (See supplementary information, Figure S39). Therefore, the structure of **1** was elucidated as (2′*R**,3′*R**)-2′,3′-dihydroxy-4′-methoxy-caffeoyl butyrate.

Compound **2** was isolated as a white amorphous powder. The molecular formula of **2** was determined to be $C_{19}H_{26}O_{10}$ by the HRESIMS and NMR data. The ^{1}H NMR spectrum displayed resonances for an 1,3,4,5,-tetrasubsituted aromatic ring [δ_H 6.77 (2H, s, H-2, 6)], a conjugated olefinic group [δ_H 6.59 (1H, d, J = 16.0 Hz, H-7) and 6.35 (1H, dt, J = 16.0, 6.2 Hz, H-8)], an oxygenated methylene [δ_H 4.67 (2H, t, J = 6.2 Hz, H-9)], two methoxy groups [δ_H 3.76 (6H, s, 3, 5-OCH_3)], and a methyl group [δ_H 2.05 (3H, s, H-2′)]. Furthermore, an anomeric proton resonance was observed at δ_H 4.94 (1H, d, J = 6.6 Hz, H-1″), together with additional sugar signals appeared at δ_H 3.01–3.59 (6H, m). Nineteen carbon signals in the ^{13}C NMR and DEPT135 spectra were attributed to a carboxylic carbon [δ_C 170.2 (C-1′)], four sp^2 quaternary carbons [δ_C 152.7 (C-3, 5), 134.4 (C-4), and 131.6 (C-1)], four sp^2 methine carbons [δ_C 133.1 (C-7), 123.2 (C-8), and 104.8 (C-2, 6)], an oxygenated methylene carbon [δ_C 64.3 (C-9)], two methoxy carbons [δ_C 56.4 (3, 5-OCH_3)], and a methyl group [δ_C 20.8 (C-2′)], as well as six monosaccharide carbon atoms [δ_C 102.4 (C-1″), 77.2 (C-5″), 76.6 (C-3″), 74.2 (C-2″), 69.9 (C-4″), and 60.9 (C-6″)]. The above NMR data resembled to those of syringin (Li et al. 2015) with the exception of an extra acetyl group, which attached to the C-9 based on the HMBC correlation of H-9 with C-1′. Acid hydrolysis of **2** yielded D-glucose, which was detected in the hydrolysate by chiral HPLC analysis (See supplementary information, Figure S41). The β-configuration of D-glucose was determined based on the coupling constant (J = 6.6 Hz) of the anomeric proton. Thus, the structure of **2** was assigned as 9-acetoxy syringin.

Compound **3** was isolated as a white amorphous powder with a molecular formula of $C_{18}H_{22}O_5$ determined by the HRESIMS and NMR data. The ^{1}H NMR data of **3** revealed signals for an 1,2,4,5-tretasubstituted aromatic ring [δ_H 6.76 (1H, s, H-3) and 5.73 (1H, s, H-6)], an 1,4-bisubstituted aromatic ring [δ_H 6.87 (2H, d, J = 8.5 Hz, H-2′, 6′) and 6.70 (2H, d, J = 8.5 Hz, H-3′, 5′)], an oxygenated methine [δ_H 4.10 (1H, d, J = 11.8 Hz, H-8′)], an oxymethylene [δ_H 3.75 (1H, dd, J = 12.5, 9.0 Hz, H-8a) and 3.43 (1H, dd, J = 12.5, 6.5 Hz, H-8b)], and two methylenes [δ_H 4.05 (1H, dd, J = 12.2, 2.4 Hz, H-7′a), 3.15 (2H, m, H-7), and 2.59 (1H, dd, J = 12.2, 10.0 Hz, H-7′b)]. Its ^{13}C NMR data indicated the presence of six sp^2 quaternary carbons [δ_C 157.4 (C-4′), 149.4 (C-4), 145.7 (C-5), 129.0 (C-1′), 127.1 (C-1), and 120.7 (C-2)], six sp^2 methine carbons [δ_C 132.2 (C-2′, 6′), 116.3 (C-3′, 5′), 115.8 (C-6), and 112.5 (C-3)], a sp^3 oxymethine carbon [δ_C 79.9 (C-8′)], an oxymethlene carbon [δ_C 60.7 (C-8)], two methylene carbons [δ_C 38.6 (C-7′) and 27.1 (C-7)], and two methoxy groups [δ_C 56.5 (8′-OCH_3) and 56.4 (4-OCH_3)]. The above NMR data resembled those of 1-(2-(2-hydroxyethyl)-4,5-dimethoxyphenyl)-2-(4-methoxyphenyl) ethanol (Ivanov et al. 2007), but for the absence of a methoxy group. The methoxy groups were located at C-4 and C-8′, respectively, based on the HMBC correlations from protons of 4-OCH_3 to C-4 and from protons of 8′-OCH_3 to C-8′.

The GIAO NMR data of (8′*R*)-**3** and (8′*S*)-**3** were calculated and the simulated and experimental data were used for DP4+ probability analysis. The results indicated that (8′*R*)-**3** with 100% probability was the better suitable for **3** (See supplementary information, Figure S40). Therefore, the structure of **3** was elucidated as (8′*R*)-4′,5-dihydroxy-4,8′-dimethoxy-2-hydroxyethyl diphenylethane.

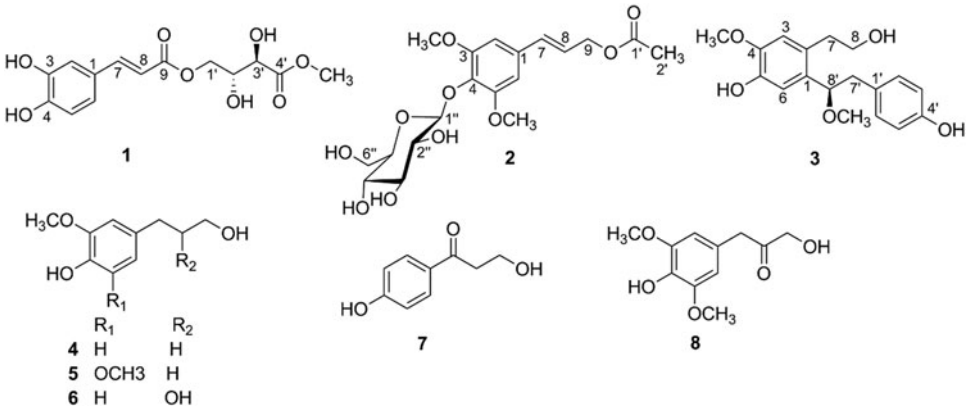


Figure 1. Structures of compounds **1**–**8** from *Magnolia biondii* Pamp.

By comparison of the NMR data with those reported in the literatures, five known compounds were identified as dihydroconiferylalcohol (**4**) (Huang et al. 2014), dihydrosyringenin (**5**) (Rustaiyan et al. 1991), 3-(4-hydroxy-3-methoxyphenyl) propane-1,2-diol (**6**) (Kikuzaki et al. 1999), β-hydroxypropiovanillone (**7**) (Karonen et al. 2004), 3-hydroxy-1-(4-hydroxy-3,5-dimethoxyphenyl) propan-1-one (**8**) (Jones et al. 2000).

The isolated compounds (**1**–**8**) were evaluated *in vitro* for their AChE inhibitory activities. As a result, compounds **3**–**6**, and **8** exhibited slightly inhibitory effects with the values from 25.7–43.1 μM (See supplementary information, Table S1) (Figure 1).

3. Experimental

3.1. General experimental procedures

Optical rotations were record by a Rudolph AP-IV polarimeter (Rudolph, Hackettstown, NJ, USA). ECD spectra were obtained using an Applied Photophysics Chirascan qCD spectropolarimeter (AppliedPhotophysics, Leatherhead, Surrey, UK). UV spectra were measured by a Thermo EVO 300 spectrometer (Thermo, Waltham, MA, USA). IR spectra were recorded on a Thermo Nicolet IS 10 spectrometer (Thermo, Waltham, MA, USA). NMR spectra were measured by a Bruker Avance III 500 spectrometer (Bruker, Germany). MS spectra were acquired using a Bruker maXis HD mass spectrometer (Bruker, Germany). Semipreparative HPLC separations were conducted on a Saipuruisi LC 50 HPLC system, equipped with an UV/VIS 50 detector (Saipuruisi, Beijing, China). Monosaccharide elucidation was performed on a Waters 2695 separation module equiped with an evaporative light scattering detector (ELSD) (Waters, Milford, MA, USA) using a CHIRALPAK AD-H column (250 × 4.6 mm) (Daicel Chiral Technologies Co., Ltd., China). Column chromatographies were performed using MCI gel CHP-20 (TOSOH Corp., Tokyo, Japan), ODS gel (50 μm) (YMC Group, Kyoto, Japan), Sephadex LH-20 (40–70 μm) (Amersham Pharmacia Biotech AB, Uppsala, Sweden), Toyopearl HW-40C (TOSOH Corp., Tokyo, Japan), and silica gel (160–200 mesh) (Marine Chemical Industry, Qingdao, China).

3.2. Plant material

The flower buds of *M. biondii* gathered in Nanzhao, Henan province, China, were identified by Professor Chengming Dong, School of Pharmacy, Henan University of Chinese Medicine, Zhengzhou, China. A voucher specimen (20140609) was deposited at the Department of Pharmaceutical Chemistry, Henan University of Chinese Medicine.

3.3. Extraction and isolation

The flower buds of *M. biondii* (5.0 kg) were extracted with 50% aqueous acetone (20 $L \times 3$, smashed tissue extraction) at room temperature. The combined solutions were evaporated under vacuum to give a crude extract (463 g), which was suspended in H_2O (2 L) and then successively extracted with petroleum ether, EtOAc and *n*-BuOH (2 $L \times 5$), respectively. The *n*-BuOH fraction (60.0 g) was subjected to Diaion HP-20 column chromatography (CC) and eluted with EtOH-H_2O (0:100, 20:80, 40:60, 80:20, 95:5, v/v) to give five subfractions (Fr. I–Fr. V). Fr. II (14.0 g) was then applied to ODS CC eluted with a MeOH-H_2O (0:100, 5:95, 10:90, 15:85, 20:80, 25:75, 35:65,45:55, 100:0, v/v) gradient to give nine fractions (Fr. 1–Fr. 9). Fr. 3 (20.5 mg) was purified by preparative HPLC eluted by MeOH-H_2O (25:75) to give **1** (1.4 mg, $t_R = 72.9$ min) and **3** (3.5 mg, $t_R = 96.6$ min). Fr. IV (50.2 g) was subjected to silica gel eluted with a CH_2Cl_2-MeOH (100:0, 80:20, 60:40, 40:60, 20:80, 0:100) gradient to yield nine subfractions (Fr. A–Fr. I). Fr. B (55.8 mg) was purified by preparative HPLC eluted by MeOH-H_2O (15:85) to give **6** (6.3 mg, $t_R = 27.8$ min) and **5** (4.3 mg, $t_R = 35.7$ min). Fr. C (221.8 mg) was purified by preparative HPLC eluted by MeOH-H_2O (35:65) to give **2** (30.4 mg, $t_R = 39.5$ min). Fr. D (82.4 mg) was chromatographied by preparative HPLC eluted by MeOH-H_2O (30:70) to give **7** (4.9 mg, $t_R = 49.8$ min) and **8** (8.3 mg, $t_R = 67.2$ min). Fr. F (34.6 mg) was purified by preparative HPLC eluted by MeOH-H_2O (25:75) to give **4** (4.6 mg, $t_R = 24.3$ min).

Compound **1**: white amorphous powder; [α] + 42.8 (c 0.03, MeOH); UV (MeOH) λ_{max} 204,301,330 nm; IR (iTR) ν_{max}: 335,323,602,341,173,000,000,000,000,000,000,000 cm^{-1}; HRESIMS *m/z* 335.0731 $[M + Na]^+$ (calcd for 335.0737, $C_{14}H_{16}O_8Na$); ^1H NMR (500 MHz, CD_3OD): δ_H 7.58 (1H, d, $J = 16.0$ Hz, H-7), 7.04 (1H, d, $J = 2.0$ Hz, H-2), 6.95 (1H, dd, $J = 8.2$, 2.0 Hz, H-6), 6.78 (1H, d, $J = 8.2$ Hz, H-5), 6.26 (1H, d, $J = 16.0$ Hz, H-8), 4.30 (1H, dd, $J = 11.3$, 5.2 Hz, H-1'a), 4.25 (1H, dd, $J = 11.3$, 6.2 Hz, H-1'b), 4.23 (1H, d, $J = 3.8$ Hz, H-3'), 4.11 (1H, m, H-2'), 3.75 (3H, s, 4'-OCH_3); ^{13}C NMR (125 MHz, CD_3OD): δ_C 174.3 (C-4'), 168.9 (C-9), 149.7 (C-4), 147.3 (C-7), 146.9 (C-3), 127.7 (C-1), 123.0 (C-6), 116.5 (C-5), 115.1 (C-2), 114.8 (C-8), 73.5 (C-3'), 72.0 (C-2'), 52.5 (4'-OCH_3).

Compound **2**: white amorphous powder; [α] –43.5 (c 0.24, MeOH); UV (MeOH) λ_{max} 201,223,268 nm; IR (iTR) ν_{max}: 341,917,331,653,105,000,000,000 cm^{-1}; HRESIMS *m/z* 449.1215 $[M + Cl]^-$ (calcd for 449.1209, $C_{19}H_{26}O_{10}Cl$); ^1H NMR (500 MHz, DMSO-d_6): δ_H 6.77 (2H, s, H-2, 6), 6.59 (1H, d, $J = 15.9$ Hz, H-7), 6.35 (1H, dt, $J = 15.9$, 6.2 Hz, H-8), 4.94 (1H, d, $J = 6.6$ Hz, H-1''), 4.67 (2H, t, $J = 6.2$ Hz, H-9), 3.76 (6H, s, 3, 5-OCH_3), 3.59 (1H, d, $J = 11.3$ Hz, H-6''a), 3.41 (1H, dd, $J = 11.3$, 4.6 Hz, H-6''b), 3.20 (1H, m, H-2''), 3.18 (1H, m, H-3''), 3.17 (1H, m, H-4''), 3.04 (1H, m, H-5''), 2.05 (3H, s, H-2'); ^{13}C NMR (125 MHz, DMSO-d_6): δ_C 170.2 (C-1'), 152.7 (C-3, 5), 134.4 (C-4), 133.1 (C-7), 131.6 (C-1),123.2 (C-8), 104.8 (C-2, 6) 102.4 (C-1''), 77.2 (C-5''), 76.6 (C-3''), 74.2 (C-2''), 69.9 (C-4''), 64.3 (C-9), 60.9 (C-6''), 56.4 (3, 5-OCH_3), 20.8 (C-2').

Compound **3**: white amorphous powder; [α] −36.5 (c 0.07, MeOH); UV (MeOH) λ_{max} 211,228,286,319 nm; IR (iTR) ν_{max}: 3,466,295,629,242,850,000,000,000,000,000,000,000,000 cm^{-1}; HR-ESI-MS *m/z* 341.1357 $[M + Na]^+$ (calcd for 341.1359, $C_{18}H_{22}O_5Na$); ^{1}H NMR (500 MHz, CD_3OD): δ_H 6.87 (2H, d, $J = 8.5$ Hz, H-2′, 6′), 6.76 (1H, s, H-3), 6.70 (2H, d, $J = 8.5$ Hz, H-3′, 5′), 5.73 (1H, s, H-6), 4.10 (1H, d, $J = 11.8$ Hz, H-8′), 4.05 (1H, dd, $J = 12.2$, 2.4 Hz, H-7′a), 3.81 (3H, s, 4-OCH_3), 3.75 (1H, dd, $J = 12.5$, 9.0 Hz, H-8a), 3.43 (1H, dd, $J = 12.5$, 6.5 Hz, H-8b), 3.15 (2H, m, H-7), 3.14 (3H, s, 8′-OCH_3), 2.59 (1H, dd, $J = 12.2$, 10.0 Hz, H-7′b); ^{13}C NMR (125 MHz, CD_3OD): δ_C 157.4 (C-4′), 149.4 (C-4), 145.7 (C-5), 132.2 (C-2′, 6′), 129.0 (C-1′), 127.1 (C-1), 120.7 (C-2), 116.3 (C-3′, 5′), 115.8 (C-6), 112.5 (C-3), 79.9 (C-8′), 60.7 (C-8), 56.5 (8′-OCH_3), 56.4 (4-OCH_3), 38.6 (C-7′), 27.1 (C-7).

3.4. Acid hydrolysis of compound 2

Compound **2** (1.0 mg) was hydrolyzed with 2 M HCl (2.5 mL) (80 °C, 3 h). The mixture was dried and the residue was dissolved in H_2O (2 mL) and extraction with ethyl acetate (3 × 2 mL) (Kang et al. 2017). The dry aqueous was subjected to chiral HPLC equipped with a Chiralpack AD-H column (250 × 4.6 mm) and an evaporative light scattering detection (ELSD), using hexane:alcohol:trifluoroacetic acid mixture (750:250:0.25) as the mobile phase (0.5 mL·min^{-1}) (Lopes and Gaspar, 2008). Retention time of the sugar derivative obtained from compound **2** was similar to that of D-glucose (t_R = 17.0 min), so the sugar was identified as D-glucose.

3.5. Acetylcholinesterase inhibition assays

AChE inhibition was determined using a modified Ellman's method (Rhee et al. 2001; Zhang et al. 2015).

4. Conclusion

In this study, two new phenylpropanoids, (2′*R**,3′*R**)-2′,3′-dihydroxy-4′-methoxy-caffeoyl butyrate, 9-acetoxy syringin, and a new dihydrostilbenoid, (8′*R*)-4′,5-dihydroxy-4,8′-dimethoxy-2-hydroxyethyl diphenylethane, together with five known compounds, were isolated from flower buds of *M. biondii*. The AChE inhibitory bioassay indicated that compounds **4**–**6**, and **8** exhibited slightly AChE inhibitory activities with IC_{50} values 25.7–43.1 μM.

Disclosure statement

The authors declare no conflicts of interest.

Funding

This work was supported by the Central Leading Local Science and Technology Development Special Foundation ([2016]149) and Science and Technology Key Project of Henan Province (182102410080).

References

Bhadra S, Mukherjee PK, Bandyopadhyay A. 2012. Cholinesterase inhibition activity of *Marsilea quadrifolia* Linn. an edible leafy vegetable from West Bengal, India. Nat Prod Res. 26(16): 1519–1522.

Braca A, Tommasi ND, Bari LD, Bari LD, Pizza C, Politi M, Morelli I. 2001. Antioxidant principles from *Bauhinia tarapotensis*. J Nat Prod. 64(7):892–895.

Chung CY, Fang SY, Chang YY, Hwang TL, Chung MI, Chen JJ. 2012. Two new biphenyl-type neolignan derivatives from the flower buds of *Magnolia biondii*. Planta Med. 78(11): 1195–1195.

Feng WS, He YH, Zheng XK, Wang JC, Cao YG, Zhang YL, Song K. 2016. Four new monoterpenoid glycosides from the flower buds of *Magnolia biondii*. Molecules. 21(6):728.

Hu ML, Bai M, Ye W, Wang YL, Wu H. 2018. Variations in volatile oil yield and composition of "Xin-yi" (*Magnolia biondii* pamp. flower buds) at different growth stages. J Oleo Sci. 67(6): 779–787.

Huang YH, Zeng WM, Li GY, Liu GQ, Zhao DD, Wang J, Zhang YL. 2014. Characterization of a new sesquiterpene and antifungal activities of chemical constituents from *Dryopteris fragrans* (L.) Schott. Molecules. 19(1):507–513.

Ivanov I, Nikolova S, Kochovska E, Statkova-Abeghe S. 2007. Application of *ortho*-acylated phenylacetic acid esters to the synthesis of 1-substituted isochromanes. Arkivoc. 15:31–44.

Jones L, Bartholomew B, Latif Z, Sarker SD, Nash RJ. 2000. Constituents of *Cassia laevigata*. Fitoterapia. 71(5):580–583.

Jung KY, Kim DS, Oh SR, Park SH, Lee IS, Lee JJ, Shin DH, Lee HK. 1998. Magnone A and B, novel anti-PAF tetrahydrofuran lignans from the flower buds of *Magnolia fargesii*. J Nat Prod. 61(6): 808–811.

Kang KB, Park EJ, Kim J, Sung SH. 2017. Berchemiosides A – C, 2-acetoxy-ω-phenylpentaene fatty acid triglycosides from the unripe fruits of *Berchemia berchemiifolia*. J Nat Prod. 80(10): 2778–2786.

Karonen M, Hamalainen M, Nieminen R, Klika KD, Loponen J, Ovcharenko VV, Moilanen E, Pihlaja K. 2004. Phenolic extractives from the bark of *Pinus sylvestris* L. and their effects on inflammatory mediators nitric oxide and prostaglandin E_2. J Agric Food Chem. 52(25):7532–7540.

Kikuzaki H, Hara S, Kawai Y, Nakatani N. 1999. Antioxidative phenylpropanoids from berries of *Pimenta dioica*. Phytochemistry. 52(7):1307–1312.

Li J, Yang GZ, Mei ZY, Huang XJ, Zhang HL. 2015. Study on C6-C3 skeleton derivatives from the flower buds of *Magnolia denudate*. Asian J Chem. 27(2):463–466.

Lopes JF, Gaspar E. 2008. Simultaneous chromatographic separation of enantiomers, anomers and structural isomers of some biologically relevant monosaccharides. J Chromatogr A. 1188(1):34–42.

Lu HX, Wu FY, Jiang MX, Liang WJ. 2017. Tzumin A and B, two new lignan derivatives from the barks of *Sassafras tzumu*. Nat Prod Res. 31(7):829–834.

Ma YL, Huang QL, Han GQ. 1996. A neolignan and lignans from *Magnolia biondii*. Phytochemistry. 41(1):287–288.

Newman DJ, Cragg GM. 2016. Natural products as sources of new drugs from 1981 to 2014. J Nat Prod. 79(3):629–661.

Nguyen TTM, Lee HS, Nguyen TT, Ngo TQM, Jun CD, Min BS, Kim JA. 2017. Four new lignans and IL-2 inhibitors from *Magnoliae flos*. Chem Pharm Bull. 65(9):840–847.

Park CS, Kim TB, Lee JY, Park JY, Lee YC, Jeong SS, Lee YD, Cho YS, Moon HB. 2012. Effects of add-on therapy with NDC-052, an extract from *Magnoliae flos*, in adult asthmatic patients receiving inhaled corticosteroids. Korean J Intern Med. 27(1):84–90.

Posri P, Suthiwong J, Takomthong P, Wongsa C, Chuenban C, Boonyarat C, Yenjai C. 2019. A new flavonoid from the leaves of *Atalantia monophylla* (L.) DC. Nat Prod Res. 33(8): 1115–1121.

Qi YP, Qu LP, Wu YT, Fan GR. 2011. A plasma metabonomic investigation into the intervention of volatile oil of *Magnolia biondii* Pamp on rat model of acute inflammation. J Ethnopharmacol. 137(1):487–494.

Rhee IK, Meent M, Ingkaninan K, Verpoorte R. 2001. Screening for acetylcholinesterase inhibitors from Amaryllidaceae using silica gel thin-layer chromatography in combination with bioactivity staining. J Chromatogr A. 915(1–2):217–223.

Rustaiyan A, Saberi M, Habibi Z, Jakupovic J. 1991. Melampolides and other constituents from *Jurinea leptoloba*. Phytochemistry. 30(6):1929–1932.

Talapatra B, Chaudhuri PK, Talapatra SK. 1982. (–)Maglifloenone, a novel spirocyclohexadienone neolignan and other constituents from *Magnolia liliflora*. Phytochemistry. 21(3):747–750.

Tsuruga T, Ebizuka Y, Nakajima J, Chun Y-T, Noguchi H, Iitaka Y, Sankawa U. 1991. Biologically active constituents of *Magnolia salicifolia*: inhibitors of induced histamine release from rat mast cells. Chem Pharm Bull. 39(12):3265–3271.

Zhang X, Qian F, Tan JJ, Guo FJ, Kulka M, Xu JW, Li YM. 2017. Bioassay-guided isolation of bisepoxylignans from the flower buds of *Magnolia biondii* Pamp and their antiallergic effects. RSC Adv. 54(7):34236–34243.

Zhang JJ, Yang XW, Liu X, Ma JZ, Liao Y, Xu G. 2015. 1,9-*seco*-Bicyclic polyprenylated acylphloroglucinols from *Hypericum uralum*. J Nat Prod. 78(12):3075–3079.