

Chemical Constituents from *Berchemia polyphylla* var. *Leioclada*Wen-Li Xie,<sup>||</sup> Zheng-Yang Lu,<sup>||</sup> Jing Xu, Yu Chen, Hong-Li Teng,\* and Guang-Zhong Yang\*Cite This: *ACS Omega* 2024, 9, 3942–3949

Read Online

ACCESS |



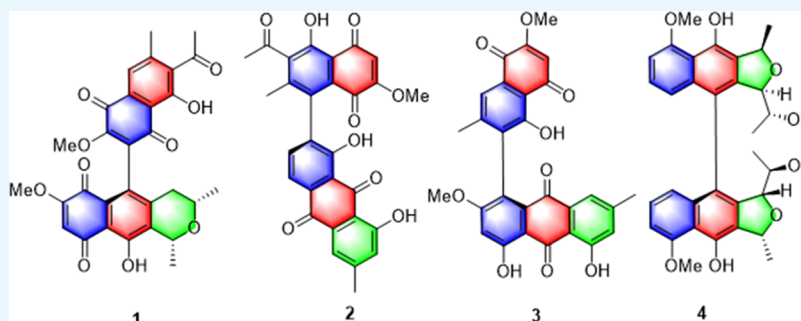
Metrics &amp; More



Article Recommendations



Supporting Information



**ABSTRACT:** One previously undescribed naphthoquinone-benzisochromanquinone dimer berpolydiquinone A (1), along with two previously undescribed naphthoquinone-anthraquinone dimers berpolydiquinones B and C (2–3), and one previously undescribed dimeric naphthalene berpolydinaphthalene A (4), were isolated from the stems and leaves of *Berchemia polyphylla* var. *leioclada*. The chemical structures of these compounds were determined using high-resolution electrospray ionization mass spectroscopy (HR-ESI-MS), spectroscopic data, the exciton chirality method (ECM), and quantum chemical calculation. Notably, compounds (1–2 and 5) are dimeric quinones that share the same naphthoquinone moiety, specifically identified as 2-methoxystypantron. Compound (4) is a derivative of dimeric naphthalene with a symmetrical structure, which is a new structure type isolated from *B. polyphylla* var. *leioclada* for the first time. These findings suggest that *B. polyphylla* var. *leioclada* serves as a significant reservoir of structurally diverse phenolic compounds. This study provides a scientific foundation for regarding *B. polyphylla* var. *leioclada* as a potential source of “Tiebaojin”.

## INTRODUCTION

The genus *Berchemia*, belonging to the family Rhamnaceae, consists of 31 species worldwide. These species are primarily found in temperate and tropical regions across east to southeast Asia. Approximately 18 species are distributed in the southern part of China. Medicinally, the roots, stems, or leaves of some *Berchemia* species are utilized for their ability to dispel wind and dampness, promote blood circulation, relieve pain, and alleviate cough and phlegm. Natural products derived from *Berchemia* plants include flavonoids, glycosides, lignans, quinones, and terpenes. Notably, dimeric quinones extracted from this genus exhibit significant biological activity, highlighting their distinctive role as key components.<sup>1</sup> “Tiebaojin” is a frequently used traditional medicine in Guangxi Zhuang and southwest minority areas of China. After conducting investigations, it has been found that “Tiebaojin” is derived from four species of the *Berchemia* genus, namely, *Berchemia lineata*, *Berchemia floribunda*, *Berchemia polyphylla* Wall. ex Laws., and *B. polyphylla* var. *leioclada*. According to the “Guangxi Standards of Chinese Medicinal Materials” and the “Dictionary of Traditional Chinese Medicine”, *B. lineata* has been identified as the primary plant source of “Tiebaojin”.<sup>2,3</sup> Due to the extensive use of *B. lineata* in Zhuang medicine compound preparations, its resources are depleting rapidly.

Therefore, it is imperative to intensify research efforts on the other three plant sources of “Tiebaojin”.<sup>4</sup>

Previous studies have focused on phytochemical investigations of the stems and leaves of *B. lineata*, which have identified several new phenolic compounds including naphthopyrones, flavonoids, and bibenzyls.<sup>5</sup> However, there is limited research on the chemical constituents of *B. polyphylla* var. *leioclada*, which is another source of “Tiebaojin”.<sup>6</sup> This study aims to compare the chemical components of *B. lineata* and *B. polyphylla* var. *leioclada* to provide a scientific basis for the use of the latter as “Tiebaojin” and to expand the medicinal plant resources associated with it. In this study, we have identified and characterized three new dimeric quinones named berpolydiquinones A–C (1–3) and one new dimeric naphthalene named berpolydinaphthalene A (4). Additionally, we have isolated 21 known phenolic compounds (8–25) with

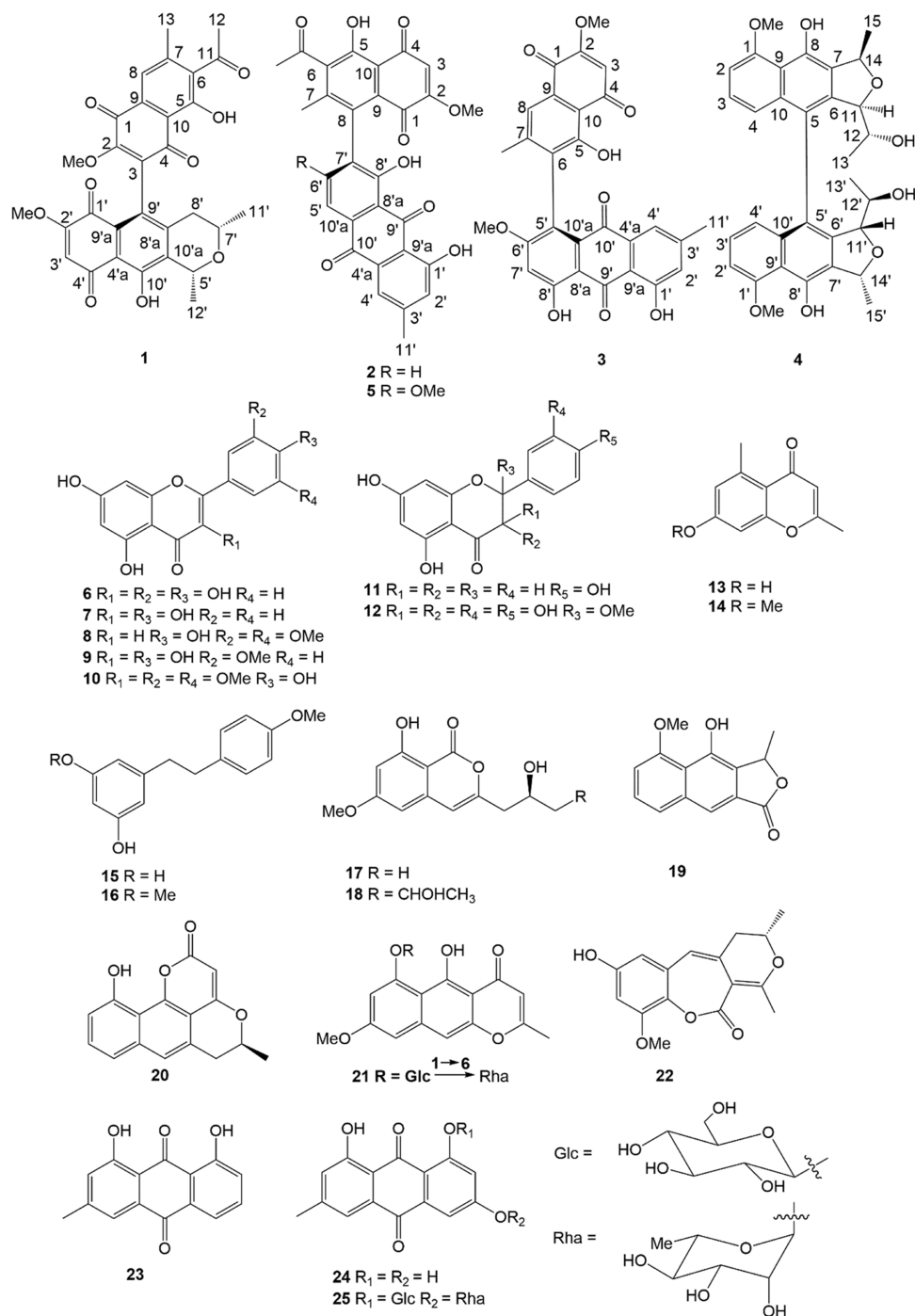
Received: October 23, 2023

Revised: December 16, 2023

Accepted: December 26, 2023

Published: January 5, 2024





**Figure 1.** Structures of compounds 1–25.

diverse carbon skeletons from the stems and leaves of *B. polyphylla* var. *leioclada*. The isolation and structural elucidation of these previously undescribed dimeric quinones and naphthalene are presented in this article (Figure 1).

## RESULTS AND DISCUSSION

Compound **1** was obtained as a yellow, amorphous powder. The molecular formula was assigned as C<sub>30</sub>H<sub>26</sub>O<sub>10</sub> based on high-resolution electrospray ionization mass spectroscopy (HR-ESI-MS) ( $m/z$  547.16008 [M + H]<sup>+</sup>, calcd for C<sub>30</sub>H<sub>27</sub>O<sub>10</sub>, 547.15987). The <sup>1</sup>H NMR spectrum (Table 1) of compound **1** showed the presence of various groups, including two methoxy groups at  $\delta_{\text{H}}$  3.89 (3H, s, 2-OCH<sub>3</sub>) and

3.87 (3H, s, 2'-OCH<sub>3</sub>), four methyl groups at  $\delta_{\text{H}}$  1.62 (3H, d,  $J$  = 6.6 Hz, CH<sub>3</sub>-12'), 1.26 (3H, d,  $J$  = 6.0 Hz, CH<sub>3</sub>-11'), 2.57 (3H, s, CH<sub>3</sub>-12), and 2.38 (3H, s, CH<sub>3</sub>-13). Additionally, there was a double-bonded proton at  $\delta_{\text{H}}$  6.26 (1H, s, H-3'), an isolated aromatic proton at  $\delta_{\text{H}}$  7.58 (1H, s, H-8), two oxymethines at  $\delta_{\text{H}}$  3.67 (1H, m, H-7') and 5.13 (1H, q,  $J$  = 6.6 Hz, H-5'), and a methylene group at  $\delta_{\text{H}}$  2.61 (1H, m, H<sub>a</sub>-8'), 2.28 (1H, m, H<sub>b</sub>-8'). The <sup>13</sup>C NMR, DEPT, and HSQC spectra confirmed the presence of 30 carbons, including 4 CH<sub>3</sub> groups, 2 OMe groups, 2 sp<sup>2</sup> CH groups, 1 sp<sup>3</sup> CH<sub>2</sub> group, 2 sp<sup>3</sup> CH groups, and 5 conjugated carbonyl groups at  $\delta_{\text{C}}$  181.6 (C-1'), 192.9 (C-4'), 181.6 (C-1), 191.1 (C-4), 205.1 (C-11). In addition, there are 14 sp<sup>2</sup> nonprotonated carbons. A

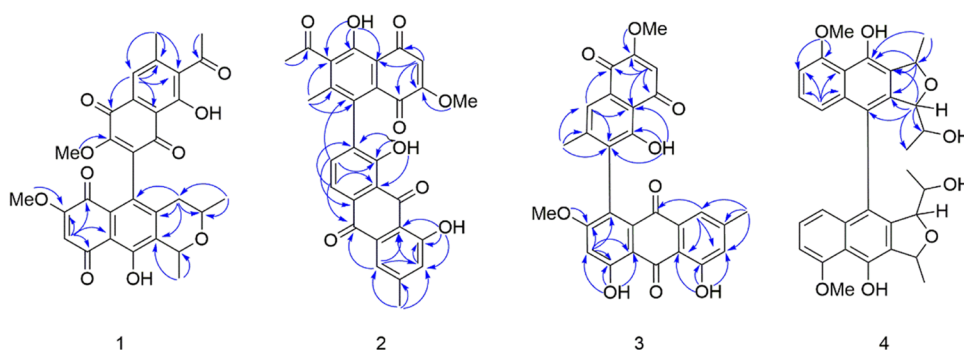
**Table 1.**  $^1\text{H}$  and  $^{13}\text{C}$  NMR Data of Compounds 1–3 (1 in  $\text{CD}_3\text{OD}$ , 2–3 in  $\text{CD}_3\text{Cl}$ ,  $\delta$  in ppm,  $J$  in Hz)

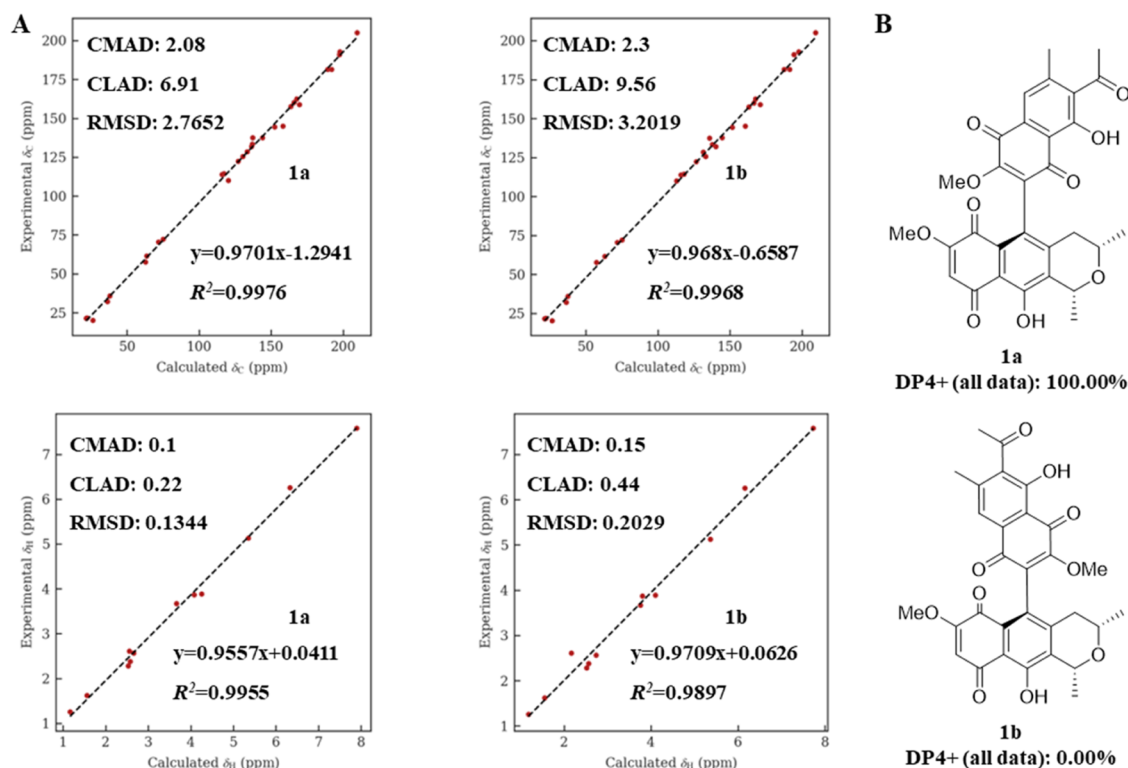
no.	1		2		3	
	$^1\text{H}$ NMR	$^{13}\text{C}$ NMR	$^1\text{H}$ NMR	$^{13}\text{C}$ NMR	$^1\text{H}$ NMR	$^{13}\text{C}$ NMR
1		181.6		179.3		179.9
2		157.5		161.0		161.3
3		132.0	6.11 (s)	108.8	6.08 (s)	109.6
4		191.1		190.9		190.8
5		159.0	13.07 (s)	158.2	12.38 (s)	158.9
6		137.5		138.2		133.7
7		145.1		142.6		144.9
8	7.58 (s)	122.4		130.7	7.68 (s)	121.7
9		133.4		128.4		129.5
10		114.4		113.4		112.2
11		205.1		203.5		
12	2.57 (s)	32.1	2.65 (s)	32.2		
13	2.38 (s)	20.2	2.01 (s)	17.8	2.07 (s)	20.6
1'		181.6	12.0 (s)	163.0	12.05 (s)	162.4
2'		162.5	7.13 (d, 1.2)	124.5	7.07 (s)	124.3
3'	6.26 (s)	110.1		149.7		148.8
4'		192.9	7.70 (d, 1.2)	121.7	7.42 (s)	121.6
4'a		113.8		133.6		132.3
5'	5.13 (q, 6.6)	72.2	7.92 (d, 7.8)	120.6		120.3
6'			7.33 (d, 7.8)	136.3		164.3
7'	3.67 (m)	70.6		135.8	6.84 (s)	105.0
8'	2.28, 2.61 (m)	35.9	12.37 (s)	160.0	13.04 (s)	166.3
8'a		144.4		116.0		110.7
9'		125.6		193.0		191.3
9'a		128.5		114.0		113.6
10'		160.1		182.0		182.8
10'a		137.6		133.2		132.3
11'	1.26 (d, 6.0)	21.8	2.50 (s)	22.5	2.37 (s)	22.3
12'	1.62 (d, 6.6)	21.5				
2'-OMe	3.89 (s)	61.6	3.85 (s)	57.0	3.94 (s)	56.8
2''-OMe	3.87 (s)	57.7				
6''-OMe					3.83 (s)	56.9

comparison of the NMR data of compound 1 with those of floribundiquinones A–C revealed that these compounds contained the same benzisochromanquinone moiety, which

was identified the subunit as 7-dehydroxyventiloquinone H with an additional quaternary carbon at C-9'.<sup>7,8</sup> Apart from the signals of the 7-dehydroxyventiloquinone H moiety, the remaining signals included one methyl group [ $\delta_{\text{H}}$  2.38 (3H, s),  $\delta_{\text{C}}$  20.2 (q)], one methoxy group [ $\delta_{\text{H}}$  3.89 (3H, s),  $\delta_{\text{C}}$  61.6 (q)], one acetyl group [ $\delta_{\text{H}}$  2.57 (3H, s, H-12),  $\delta_{\text{C}}$  32.1 (q), 205.1 (s)], one  $\text{sp}^2$  methine [ $\delta_{\text{H}}$  7.58 (1H, s, H-8),  $\delta_{\text{C}}$  122.4 (d)], two conjugated carbonyls [ $\delta_{\text{C}}$  181.6 (s), 191.1 (s)] and seven  $\text{sp}^2$  nonprotonated carbons. The additional NMR data indicated the presence of a naphthoquinone unit with a methoxy, a methyl, an acetyl, and a hydroxyl group. By comparing the remaining NMR data with the literature on 2-methoxystypantron,<sup>9,10</sup> it was observed that the quinone ring did not have a double-bonded proton and had an extra nonprotonated carbon. These findings suggested that the substituent pattern of the benzene ring in the naphthoquinone unit was consistent with that of 2-methoxystypantron, which was further confirmed by HMBC correlations (Figure 2). Due to the lack of relevant ROESY correlations, the methoxy group can be attached to either C-2 or C-3 on the quinone ring, allowing for a nonbiaryl connectivity between the two units through C-9' to C-2 or C-9' to C-3. Through ROESY correlation of H-5' and H-7', it was determined that they are in the *cis* orientation, consistent with the literature reports on floribundiquinones A–D. This suggests that the benzisochromanquinones isolated from Rhamnaceae plants exhibit the same chirality from a biogenetic perspective. Additionally, we successfully isolated 7-dehydroxyventiloquinone H and confirmed its absolute configuration through equivalent circulating density (ECD) calculations, which aligns with the biosynthetic analysis. Thus, the absolute configurations of C-5' and C-7' were determined as *R* and *S*, respectively.<sup>7</sup>

Although compound (1) consisted of two structurally and electronically different electronic transition dipole moments (TDMs), the exciton chirality method (ECM) was still applicable to determine the absolute configuration of the nonbiaryl axis. According to the ECM rule, the coupling of the transition dipole moments (TDMs) resulted in a negative first cotton effect (CE) at longer wavelengths and a positive second CE at shorter wavelengths, indicating a negative chirality. Conversely, a positive first CE and a negative second CE indicated a positive chirality. The positive chirality suggests that the TDMs of the two chromophores are oriented in a clockwise manner, while the negative chirality suggests that the TDMs of the two chromophores are oriented in an anticlockwise manner.<sup>11,12</sup> In the ECD spectrum of compound 1, a negative CE is observed around 307 nm, while a positive CE is observed around 286 nm. These CE values indicate the

**Figure 2.** Key HMBC correlations of compounds 1–4.



**Figure 3.** (A) Calculated  $^{13}\text{C}$  and  $^1\text{H}$  NMR data of four possible isomers (compounds 1a–1b). The data were obtained at the mPW1PW91/6-311+G (2d, p) level in  $\text{CD}_3\text{OD}$ . (B) DP4+ probabilities based on the  $^1\text{H}$  and  $^{13}\text{C}$  NMR chemical shifts of compound 1.

presence of negative chirality, which can be attributed to the anticlockwise arrangement of the two naphthoquinone chromophores. Taking into account the position of the nonbiaryl axis, compound 1 could potentially have two diastereomers (*P*)-3, 9'-linkage 1a and (*M*)-2, 9'-linkage 1b. To confirm the structure of compound 1, we conducted NMR calculations with DP4+ analysis on two possible diastereomers: [(*P*)-3, 9'-linkage]-1a and [(*M*)-2, 9'-linkage]-1b.<sup>13,14</sup> The DP4+ analysis showed that [(*P*)-3, 9'-linkage]-1a, with a 100% DP4+ probability, was the most likely structure for compound 1 (Figure 3). As a result, the structure of compound 1 was determined and was named berpolydiquinone A.

Compound 2 was obtained as a yellow amorphous powder. The molecular formula was determined to be  $\text{C}_{29}\text{H}_{20}\text{O}_9$  based on HR-ESI-MS ( $m/z$  513.11841 [ $\text{M} + \text{H}$ ]<sup>+</sup>, calcd for  $\text{C}_{29}\text{H}_{21}\text{O}_9$ , 513.11801). A comparison of the NMR data of compound 2 with those of 2-methoxystyphandron and chrysophanol indicated that compound 2 is a naphthoquinone-anthraquinone dimer consisting of two subunits: 2-methoxystyphandron and chrysophanol.<sup>10,15</sup> When compared to the NMR data of floribundiquinone E,<sup>16</sup> compound 2 lacks the signal of a methoxy group and an isolated aromatic proton but exhibits a pair of *ortho*-coupled aromatic proton signals at  $\delta_{\text{H}}$  7.92 (1H, d,  $J = 7.8$  Hz) and 7.33 (1H, d,  $J = 7.8$  Hz), indicating that the two subunits are connected through C-8 to C-7'. HMBC correlations from H-6' to 130.7 (s, C-8), H-5' to 135.8 (s, C-7') and from  $\text{CH}_3$ -13 to 130.7 (s, C-8) confirmed this deduction. The ECD spectrum of compound 2 exhibited a negative chirality, indicating that the two chromospheres in space rotated in an anticlockwise manner. This observation establishes the axial chirality as the absolute *M*-configuration.<sup>17</sup>

Based on these findings, the structure of compound 2 was determined and named berpolydiquinone B.

Compound 3 was obtained as a yellow, amorphous powder. The molecular formula was determined to be  $\text{C}_{28}\text{H}_{20}\text{O}_9$  based on HR-ESI-MS ( $m/z$  501.11768 [ $\text{M} + \text{H}$ ]<sup>+</sup>, calcd for  $\text{C}_{28}\text{H}_{21}\text{O}_9$ , 501.11801). A comparison of the NMR data of compound 3 with those of 3-methoxy-7-methyljuglone and physcion revealed that compound 3 is a naphthoquinone-anthraquinone dimer composed of two subunits: 3-methoxy-7-methyljuglone and physcion.<sup>18,19</sup> When comparing the NMR data of 3-methoxy-7-methyljuglone and physcion with compound 3, it was observed that compound 3 lacks two pairs of *meta*-coupled aromatic proton signals but exhibits two isolated aromatic protons at  $\delta_{\text{H}}$  7.68 (1H, s) and 6.84 (1H, s). In the HMBC spectrum, the S-OH signal at  $\delta_{\text{H}}$  12.38 (1H, s) showed correlations with  $\delta_{\text{C}}$  112.2 (s, C-10), 158.9 (s, C-5), and 133.7 (s), and the  $\text{CH}_3$ -13 signal at  $\delta_{\text{H}}$  2.07 (3H, s) showed correlations with  $\delta_{\text{C}}$  121.7 (d, C-8), 144.9 (s, C-7), and 133.7 (s). These correlations suggested that the chemical shift at  $\delta_{\text{C}}$  133.7 (s) corresponded to C-6. In the same way, the chemical shift at  $\delta_{\text{C}}$  120.3 (s) was assigned to C-5'. This assignment was supported by the HMBC spectrum. These findings indicate that the biaryl connectivity of two subunits is determined at the C-6 and C-5' positions. The ECD spectrum of compound 3 also showed a negative chirality, suggesting the axial chirality as the absolute *M*-configuration.<sup>17</sup> Based on these findings, the structure of compound 3 was determined and named berpolydiquinone C.

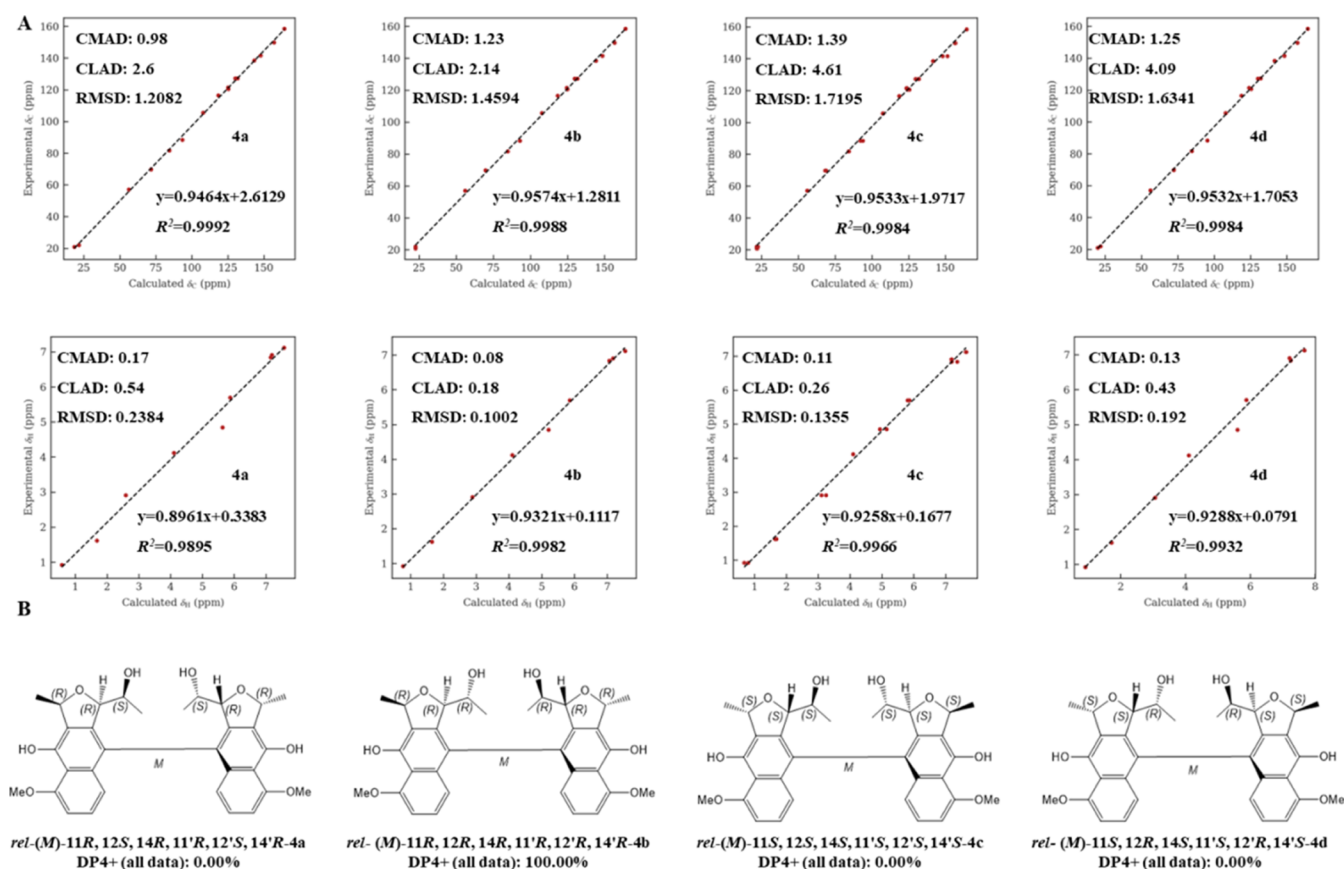
Compound 4 was obtained as a brown powder. The molecular formula was determined to be  $\text{C}_{32}\text{H}_{34}\text{O}_8$  based on HR-ESI-MS ( $m/z$  569.21399 [ $\text{M} + \text{Na}$ ]<sup>+</sup>, calcd for  $\text{C}_{32}\text{H}_{34}\text{O}_8\text{Na}$ , 569.21459). The  $^{13}\text{C}$  and DEPT NMR spectra (Table 2) displayed 16 carbon signals, including three  $\text{sp}^2$

**Table 2.**  $^1\text{H}$  and  $^{13}\text{C}$  NMR Data of Compound 4 ( $\text{CD}_3\text{OD}$ ,  $\delta$  in ppm,  $J$  in Hz)

no.	4	
	$^1\text{H}$ NMR	$^{13}\text{C}$ NMR
1		158.5
2	6.91 (d, 7.5)	105.6
3	7.12 (dd, 8.5, 8.5)	127.3
4	6.84 (dd, 8.5, 1.0)	121.5
5		120.6
6		141.6
7		127.2
8		149.8
9		116.5
10		138.5
11	4.85 (t, 1.5)	88.4
12	2.91 (q, 6.5)	69.8
13	0.92 (d, 6.5)	20.9
14	5.70 (qd, 6.5, 1.5)	81.7
15	1.62 (d, 6.5)	22.0
OMe	4.12 (s)	57.1

methines, seven  $\text{sp}^2$  quaternary carbons, one methoxy group, two methyl groups, and three oxygenated  $\text{sp}^3$  methines. Based on the HR-ESI-MS data, it can be deduced that compound 4 is a derivative of dimeric naphthalene with a symmetrical structure. The  $^1\text{H}$ - $^1\text{H}$  COSY correlations of H-2/H-3/H-4; HMBC correlations from H-2 to  $\delta_{\text{C}}$  158.5 (s, C-1), 116.5 (s, C-9); as well as MeO to  $\delta_{\text{C}}$  158.5 (s, C-1) suggested that

compound 4 contained a 1,2,3-trisubstituted benzene ring with a methoxy group at the C-1 position. Based on the  $^1\text{H}$ - $^1\text{H}$  COSY and HSQC experiments, it can be deduced that there are two structural fragments: a  $\text{CH}_3(\text{CH})\text{O}$ - and b  $-\text{CH}(\text{O})\text{CH}(\text{O})\text{CH}_3$ . The HMBC correlations from H-11 to  $\delta_{\text{C}}$  81.7 (d, C-14) indicate that these two fragments are connected through an ether bond at the C-11 and C-14 positions, resulting in the formation of a 1-methyl-2-(2-hydroxy-propyl)-dihydrofuran ring. Furthermore, the HMBC correlations from H-14 to  $\delta_{\text{C}}$  149.8 (s, C-8), 127.2 (s, C-7), and 141.6 (s, C-6), along with the correlations from H-11 to  $\delta_{\text{C}}$  120.6 (s, C-5) and 141.6 (s, C-6), suggest that the C-8 position of the naphthalene ring is substituted by a hydroxyl group and that the furan ring is fused to the C-6 and C-7 positions of the naphthalene ring. The biaryl connectivity at the C-5 positions was determined based on the fact that C-5 is a quaternary carbon and its chemical shift is downfield. Compound 4 was identified as a dimer of naphthofuran, formed by the polymerization of two identical monomers at the C-5-C-5' position through a  $\sigma$  bond. The relative configuration of compound 4 was deduced by using the ROESY spectrum and DP4+ analysis. The *cis* orientation between H-11 and H-14 was determined based on the ROESY correlations of H-14 ( $\delta_{\text{H}}$  5.70)/H-11 ( $\delta_{\text{H}}$  4.85). As the biaryl axis and the configuration of C-12 have not been determined, compound 4 may have four diastereoisomers, including [(*M*)-11*R*\*, 12*S*\*, 14*R*\*, 11'*R*\*, 12'*S*\*, 14'*R*\*]-4a, [(*M*)-11*R*\*, 12*R*\*, 14*R*\*, 11'*R*\*, 12'*R*\*, 14'*R*\*]-4b, [(*M*)-11*S*\*, 12*S*\*, 14*S*\*, 11'*S*\*, 12'*S*\*, 14'*S*\*]-4c, and [(*M*)-11*S*\*, 12*R*\*, 14*S*\*, 11'*S*\*, 12'*R*\*, 14'*S*\*]-4d. To



**Figure 4.** (A) Calculated  $^{13}\text{C}$  NMR and  $^1\text{H}$  NMR data of four possible isomers (compounds 4a, 4b, 4c, and 4d). The data were obtained at the mPW1PW91/6-311+G (2d, p) level in  $\text{CD}_3\text{OD}$ . (B) DP4+ probabilities based on the  $^1\text{H}$  NMR and  $^{13}\text{C}$  NMR chemical shifts of compound 4.

verify the relative configuration of compound **4**, NMR calculations were performed with DP4+ analysis on the four possible isomers. According to DP4+ analysis, it was determined with a 100% probability that the structure of compound **4** is [(*M*)-11*R*\*, 12*R*\*, 14*R*\*, 11'*R*\*, 12'*R*\*, 14'*R*\*]-**4b** (Figure 4). Compound **4** is classified as a member of 1,1'-binaphthyl. The ECM rule can also be used to determine the absolute configuration of the biaryl axis. In the ECD spectrum of compound **4**, a negative CE at 244 nm and a positive CE at 226 nm were observed, indicating a negative chirality. The absolute *M*-configuration was assigned to the biaryl axis.<sup>20</sup> Therefore, the compound was determined and named berpolydinaphthalene A.

Additionally, the remaining phenolic compounds were identified as floribundiquinone E (**5**),<sup>16</sup> quercetin (**6**),<sup>21</sup> kaempferol (**7**),<sup>22</sup> tricetin (**8**),<sup>23</sup> isorhamnetin (**9**),<sup>24</sup> 5,7,4'-trihydroxy-3,3',5'-trimethoxyflavone (**10**),<sup>25</sup> naringenin (**11**),<sup>26</sup> 5,7,3',4'-tetrahydroxy-2-methoxy-3,4-flavandione-3-hydrate (**12**),<sup>27</sup> 2,5-dimethyl-7-hydroxychromone (**13**),<sup>28</sup> 2,5-dimethyl-7-methoxychromone (**14**),<sup>29</sup> vittarin-B (**15**),<sup>30</sup> 3-methoxy-5-[2-(4-methoxyphenyl)ethyl]phenol (**16**),<sup>31</sup> (11*S*)-diaprothin (**17**),<sup>32</sup> citreoisocoumarinol (**18**),<sup>33</sup> eleutherol (**19**),<sup>34</sup> bercheminol C (**20**),<sup>5</sup> rubrofusarin-6-*O*- $\alpha$ -*L*-rhamnosyl-(1  $\rightarrow$  6)-*O*- $\beta$ -*D*-glucopyranoside (**21**),<sup>35</sup> bercheminol A (**22**),<sup>5</sup> chrysophanol (**23**),<sup>36</sup> emodin (**24**),<sup>37</sup> and glucofrangulin A (**25**)<sup>38</sup> by comparisons of their spectroscopic data with reported values.

In this study, 25 phenolic compounds were isolated and identified from the stems and leaves of *B. polyphylla* var. *leioclada*. These compounds can be categorized into four dimeric quinone (**1–3**, **5**), two naphthalenes (**4**, **19**), seven flavonoids (**6–12**), two chromones (**13–14**), two bibenzyls (**15–16**), two isocoumarins (**17–18**), two naphthopyrones (**20–21**), a phenolic compound with a novel carbon skeleton (**22**), and three anthraquinones (**23–25**). Notably, compounds **4**, **17–19** have not been previously found in the family Rhamnaceae. Compound (**4**) is particularly interesting as it is a new structure type of dimeric naphthalene with a symmetrical structure. Flavonoids, a large class of polyphenols, were also found in the genus *Berchemia* plant. In this work, seven flavonoids (**6–12**) were isolated from *B. polyphylla* var. *leioclada*. Among them, compounds **6–7** and **9–10** were flavonols, compound **8** was a flavone, compound **11** was a dihydroflavone, and compound **12** was a hydrate of flavonoids. Flavonoids are considered to be the traditional active ingredients of the genus *Berchemia* plant, with quercetin being a representative compound used for quality control of “Tiebaojin” due to its wide range of biological activities. In addition, quercetin was isolated from two species of the genus *Berchemia* plant (*B. polyphylla* var. *leioclada* and *B. lineata*), both of which are used as “Tiebaojin” in Zhuang medicine. Furthermore, compounds **7**, **11**, **13**, **15**, **20–22**, and **24** were also isolated from *B. polyphylla* var. *leioclada* and *B. lineata*. These findings provide a scientific basis for considering *B. polyphylla* var. *leioclada* as a source of “Tiebaojin” and expand the range of medicinal plants for the traditional medicine “Tiebaojin”. Dimeric quinones are distinctive chemical constituents found in plants belonging to the genus *Berchemia*. In this study, we have identified one novel naphthoquinone-benzisochromanquinone dimer, as well as two new naphthoquinone-anthraquinone dimers. These discoveries contribute to the existing repertoire of quinone compounds found in this particular genus of plants. Consequently, our findings

highlight the significance of *B. polyphylla* var. *leioclada* as a valuable source of diverse phenolic compounds, warranting further investigation.

## EXPERIMENTAL SECTION

**General Experimental Procedures.** Optical rotations were determined in MeOH by using a Rudolph Autopol IV polarimeter. Ultraviolet (UV) spectra were obtained with a UHS300 double-beam UV–visible (UV–vis) spectrophotometer. ECD spectra were obtained on an Applied Photophysics Chirascan-Plus spectrometer. One-dimensional (1D) and two-dimensional (2D) NMR spectra were recorded with a Bruker Avance III 500 or 600 MHz spectrometer in CDCl<sub>3</sub> using tetramethylsilane (TMS) as the internal standard. Chemical shifts ( $\delta$ ) are reported in ppm, and the coupling constants (*J*) are expressed in hertz. High-resolution electrospray ionization mass spectroscopy (HR-ESI-MS) data were obtained using a Thermo Scientific Q Exactive Orbitrap MS System. High-performance liquid chromatography (HPLC) was conducted using an Ultimate 3000 HPLC system. The system consisted of an Ultimate 3000 pump and Ultimate 3000 Variable Wavelength detector. A semipreparative YMC-Pack ODS-A column and CHIRALPAK AD-H column (250  $\times$  10 mm, 5 mm) were utilized. Silica gel for column chromatography (CC) (200–300 mesh) was obtained from Qingdao Hai Yang Chemical Group Co. Ltd.

**Plant Material.** The stems and leaves of *B. polyphylla* var. *leioclada* were obtained from Nanning, Guangxi Zhuang Autonomous Region, P. R. China. Prof. Hongli Teng from Guangxi Zhuang Medicine International Hospital identified the plant material. A voucher specimen was deposited in the herbarium of the School of Pharmaceutical Sciences, South Central Minzu University for Nationalities.

**Extraction and Isolation.** The dried stems and leaves of *B. polyphylla* (9.31 kg) were crushed and extracted 3 times with 70% EtOH for 24 h each time, resulting in an EtOH extract (700 g). The EtOH extract was then suspended in water and sequentially extracted with petroleum ether (P.E.) (50.1 g), ethyl acetate (EtOAc) (170 g), and *n*-BuOH (208.4 g), respectively. The EtOAc extract was further subjected to silica gel column chromatography (CC) using different ratios of PE/EtOAc (9:1, 8:2, 7:3, 6:4, 1:1, and 0:1), which yielded nine subfractions (Fr. B.1 ~ Fr. B.9).

Compound **23** (15.4 mg) was obtained directly in crystal form from Fr. B.1. Fr.B.3 (5.1 g) was purified using octadecylsilyl (ODS) CC with MeOH/H<sub>2</sub>O (3:7, 1:1, 7:3, 9:1, 1:0) as the mobile phase, resulting in 14 fractions (Fr.B.3.1–Fr. B.3.14). Fr.B.3.6 (45.3 mg) was further separated using normal-phase and reversed-phase silica gel columns and then purified using semipreparative HPLC to obtain compound **19** (0.7 mg, MeCN–H<sub>2</sub>O, 55:45, *t*<sub>R</sub> = 19.63 min, 3 mL/min). Fr.B.3.8 (1.32 g) was separated by using ODS CC with MeOH/H<sub>2</sub>O (3:7, 1:1, 7:3, 9:1, 1:0) as the mobile phase, resulting in 16 fractions (Fr. B.3.8.1–Fr. B.3.8.16). Fr.B.3.8.7 (27.3 mg) was separated by semipreparative HPLC (MeCN–H<sub>2</sub>O, 40:60, 3 mL/min) to obtain compound **13** (5.4 mg, *t*<sub>R</sub> = 25.0 min), **20** (1.7 mg, *t*<sub>R</sub> = 32.9 min), **16** (0.6 mg, *t*<sub>R</sub> = 61.8 min). Fr.B.3.12 (551.8 mg) was separated by semipreparative HPLC (MeCN–H<sub>2</sub>O, 65:35, 3 mL/min) to obtain compound **24** (4.8 mg, *t*<sub>R</sub> = 25.1 min). Fr.B.6 and Fr.B.7 (6.25 g) were combined and purified using ODS CC with MeOH/H<sub>2</sub>O (3:7, 1:1, 7:3, 9:1, 1:0) as the mobile phase, resulting in 17 fractions (Fr. B.6.1–Fr. B.6.17). Fr.B.6.7 (153.5 mg) was separated by

semipreparative HPLC (MeCN–H<sub>2</sub>O, 25:75, 3 mL/min) to obtain compound **14** (0.5 mg,  $t_R = 25.9$  min). Fr.B.6.8 (214.7 mg) was separated by semipreparative HPLC to obtain compound **12** (3.9 mg, MeCN–H<sub>2</sub>O, 35:65,  $t_R = 11.6$  min, 3 mL/min), compound **18** (1.4 mg, MeCN–H<sub>2</sub>O, 28:72,  $t_R = 29.9$  min, 3 mL/min), compound **11** (9.0 mg, MeCN–H<sub>2</sub>O, 36:64  $t_R = 20.7$  min, 3 mL/min), compound **17** (2.6 mg, MeCN–H<sub>2</sub>O, 36:64,  $t_R = 22.2$  min, 3 mL/min). Fr.B.6.9 (173 mg) was separated by semipreparative HPLC to obtain compound **22** (2.5 mg, MeCN–H<sub>2</sub>O, 45:55,  $t_R = 25.5$  min, 3 mL/min), compound **15** (3.7 mg, MeCN–H<sub>2</sub>O, 35:65,  $t_R = 31.5$  min, 3 mL/min). Fr.B.6.11 (220 mg) was separated by semipreparative HPLC (MeCN–H<sub>2</sub>O, 30:70, 3 mL/min) to obtain compound **6** (39.4 mg,  $t_R = 22.1$  min), compound **8** (4.3 mg,  $t_R = 33.6$  min), compound **7** (8.87 mg,  $t_R = 38.3$  min), compound **9** (3.0 mg,  $t_R = 41.4$  min), compound **10** (2.1 mg,  $t_R = 44.4$  min), compound **4** (6.0 mg,  $t_R = 19.0$  min). Fr.B.6.13 (230 mg) was separated by semipreparative HPLC (MeCN–H<sub>2</sub>O, 65:35, 3 mL/min) to obtain compound **1** (2.9 mg,  $t_R = 24.0$  min). The combined Fr.B.6.15 and Fr.B.6.16 (738.8 mg) were separated by silica gel CC with P.E./EtOAc (200:1, 100:1, 50:1, 30:1, 10:1, 8:2, 6:4, 1:1, 0:1) as the mobile phase, and then prepared by semipreparative HPLC to obtain compound **2** (1.7 mg, MeCN–H<sub>2</sub>O, 64:36,  $t_R = 32.3$  min, 3 mL/min), **3** (0.3 mg, MeCN–H<sub>2</sub>O, 64:36,  $t_R = 34.1$  min, 3 mL/min), **5** (1.0 mg, MeCN–H<sub>2</sub>O, 60:40,  $t_R = 49.5$  min, 3 mL/min).

The *n*-butanol extract was chromatographed on a D-101 macroporous adsorption resin column, eluted successively with EtOH/H<sub>2</sub>O (3:7, 1:1, 7:3, 9:1, 1:0) to obtain 8 fractions (Fr.C.1–Fr.C.8). Fr.C.5 (11.97 g) was then purified using ODS CC with MeOH/H<sub>2</sub>O (3:7, 1:1, 7:3, 9:1, 1:0) as the mobile phase, resulting in 6 fractions (Fr.C.5.1–Fr. C.5.6). Fr.C.5.6 (118 mg) was separated by semipreparative HPLC (MeCN–H<sub>2</sub>O, 23:77, 3 mL/min) to obtain compound **21** (3.4 mg,  $t_R = 29.9$  min), compound **25** (5.7 mg,  $t_R = 31.5$  min).

**Berpolydiquinone A (1).** Yellow amorphous powder;  $[\alpha]_D^{20} +33.3$  (*c* 0.02, MeOH); UV (MeOH)  $\lambda_{\max}$  (log  $\epsilon$ ): 225 (4.54), 250 (4.41), 290 (4.30) nm; ECD ( $3.66 \times 10^{-4}$  M, MeOH)  $\lambda$  ( $\theta$ )207 (−2.76), 228 (+9.08), 249 (−2.04) 286 (+5.64), 307 (−11.10) nm; <sup>1</sup>H NMR (600 MHz, CD<sub>3</sub>OD) and <sup>13</sup>C NMR (151 MHz, CD<sub>3</sub>OD) see Table 1; HRESIMS *m/z* 547.16008 [M + H]<sup>+</sup> (calcd for C<sub>30</sub>H<sub>27</sub>O<sub>10</sub>, 547.15987).

**Berpolydiquinone B (2).** Yellow amorphous powder;  $[\alpha]_D^{20} +127.8$  (*c* 0.01, MeOH); UV (MeOH)  $\lambda_{\max}$  (log  $\epsilon$ ): 225 (4.27), 260 (4.11), 290 (3.91) nm; ECD ( $3.91 \times 10^{-4}$  M, MeOH)  $\lambda$  ( $\theta$ )215 (−11.51), 231 (+15.06), 272 (−3.95) 300 (+3.81) nm; <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) and <sup>13</sup>C NMR (126 MHz, CDCl<sub>3</sub>) see Table 1; HRESIMS *m/z* 513.11841 [M + H]<sup>+</sup> (calcd for C<sub>29</sub>H<sub>21</sub>O<sub>9</sub>, 513.11801).

**Berpolydiquinone C (3).** Yellow amorphous powder;  $[\alpha]_D^{20} -51.1$  (*c* 0.01, MeOH); UV (MeOH)  $\lambda_{\max}$  (log  $\epsilon$ ): 225 (4.43), 250 (4.25), 295 (4.12) nm; ECD ( $2.0 \times 10^{-4}$  M, MeOH)  $\lambda$  ( $\theta$ )212 (−2.23), 256 (+3.65), 290 (−1.46) nm; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) and <sup>13</sup>C NMR (151 MHz, CDCl<sub>3</sub>) see Table 1; HRESIMS *m/z* 501.11768 [M + H]<sup>+</sup> (calcd for C<sub>28</sub>H<sub>21</sub>O<sub>9</sub>, 501.11801).

**Berpolydinaphthalene A (4).** Brown amorphous powder;  $[\alpha]_D^{20} +276.4$  (*c* 0.05, MeOH); UV (MeOH)  $\lambda_{\max}$  (log  $\epsilon$ ): 235 (4.55), 320 (4.25) nm; ECD ( $9.15 \times 10^{-4}$  M, MeOH)  $\lambda$  ( $\theta$ )209 (+124.71), 218 (+69.59), 226 (+116.46), 244 (−283.2) nm; <sup>1</sup>H NMR (500 MHz, CD<sub>3</sub>OD) and <sup>13</sup>C NMR

(126 MHz, CD<sub>3</sub>OD) see Table 2; HRESIMS *m/z* 569.21399 [M + H]<sup>+</sup> (calcd for C<sub>32</sub>H<sub>34</sub>O<sub>8</sub>Na, 569.21459).

**NMR Calculation.** Computational NMR data were obtained from the IEFPCM model at the mPW1PW91/6-311+G (2d, p) level in methanol using the GIAO (gauge-independent atomic orbital) method. Detailed NMR calculations are provided in the Supporting Information.

## ■ ASSOCIATED CONTENT

### Supporting Information

The Supporting Information is available free of charge at <https://pubs.acs.org/doi/10.1021/acsomega.3c08357>.

HRESIMS, UV, CD, and 1D and 2D NMR spectra of compounds **1–4**; NMR calculations of compounds **1** and **4** (PDF)

## ■ AUTHOR INFORMATION

### Corresponding Authors

Hong-Li Teng – Guangxi International Zhuang Medicine Hospital, Nanning 530201, P. R. China;  
Email: 564988177@qq.com

Guang-Zhong Yang – Ethnopharmacology Level 3 Laboratory, School of Pharmaceutical Sciences, South-Central Minzu University, Wuhan 430074, P. R. China;  
orcid.org/0000-0001-9853-5078; Email: yanggz888@126.com

### Authors

Wen-Li Xie – Ethnopharmacology Level 3 Laboratory, School of Pharmaceutical Sciences, South-Central Minzu University, Wuhan 430074, P. R. China

Zheng-Yang Lu – College of Chemistry and Material Sciences, South-Central Minzu University, Wuhan 430074, P. R. China

Jing Xu – Ethnopharmacology Level 3 Laboratory, School of Pharmaceutical Sciences, South-Central Minzu University, Wuhan 430074, P. R. China

Yu Chen – College of Chemistry and Material Sciences, South-Central Minzu University, Wuhan 430074, P. R. China

Complete contact information is available at:

<https://pubs.acs.org/doi/10.1021/acsomega.3c08357>

### Author Contributions

<sup>¶</sup>W.-L.X. and Z.-Y.L. contributed equally to this work.

### Notes

The authors declare no competing financial interest.

## ■ ACKNOWLEDGMENTS

This work was supported by the National Natural Science Foundation of China (no. 81960762) and the National Key Research and Development Program (no. 2022YFC3502200).

## ■ REFERENCES

- Chen, L.; Dong, J. X. Advances in studies on chemical constituents from plants of *Berchemia* Neck and their bioactivities. *Chin. Tradit. Herb. Drugs* **2006**, *37*, 627–630.
- Jing, Y. S.; Xie, G. Y.; Gu, W. W.; S, L.; Qin, M. J. Research advances in chemical constituents and pharmacological activities of Tiebaojin medicine. *Chin. Wild Plant Resour.* **2017**, *36*, 49–53.
- Zhang, G. L.; Teng, H. L.; Chen, K. L. Advances in study on chemical constituents and pharmacological effects of *Berchemia* Ramulus of the Traditional Zhuang Medicine. *China Med. Her.* **2011**, *8*, 5–13.

- (4) Wei, F. L.; Zhou, T. T.; Liang, J. L.; Wei, Z. X.; Ye, X.; Chen, Y. Research progress on the Traditional Zhuang Medicine Tiebaojin. *Chin. J. Ethnomed. Ethnopharm.* **2015**, *24*, 30–31.
- (5) Li, Y. T.; Chen, Y.; Xie, W. L.; Li, X. N.; Mei, G.; Xu, J.; Zhao, X. P.; Teng, H. L.; Yang, G. Z. Phenolic compounds from the stems and leaves of *Berchemia lineata* (L.) DC. *Front. Chem.* **2022**, *10*, No. 889441.
- (6) Tang, Y. J.; Shang, Y. S.; Zhou, S. X.; Yu, B.; Yang, H. Research progress on *Berchemia polyphylla* var. *leioclada*. *Heilongjiang Anim. Sci. Vet. Med.* **2018**, *6*, 164–167.
- (7) (a) Wei, X.; Jiang, J. S.; Feng, Z. M.; Zhang, P. C. Anthraquinone-benzisochromanquinone dimers from the roots of *Berchemia floribunda*. *Chem. Pharm. Bull.* **2008**, *56*, 1248–1252. (b) Xie, W.-L.; Lu, Z.; Xu, J.; Chen, Y.; Teng, H.; Yang, G. Anthraquinone-benzisochromanquinone dimers from the stems and leaves of *Berchemia polyphylla*. *Nat. Prod. Res.* **2023** DOI: 10.1080/14786419.2023.2293150.
- (8) Blouin, M.; Béland, M. C.; Brassard, P. Regiospecific and Highly Stereoselective Formation of Benzisochroman-6,9-quinones. Synthesis of (±)-Ventilagone and (±)-Ventiloquinone. *H. J. Org. Chem.* **1990**, *55*, 1466–1471.
- (9) Khalil, A. A. K.; Park, W. S.; Kim, H. J.; Akter, K. M.; Ahn, M. J. Anti-helicobacter pylori compounds from *Polygonum cuspidatum*. *Nat. Prod. Sci.* **2016**, *22*, 220–224.
- (10) Rauwald, H. W.; Miething, H. 2-Methoxystypandrone, a new naphthoquinone from *Rhamnus fallax* B. Z. *Naturforsch.* **1983**, *38*, 17–20, DOI: 10.1515/znc-1983-1-205.
- (11) Harada, N. The enduring legacy of Koji Nakanishi's research on natural products and bioorganic chemistry. Part 2. Inception and establishment of the ECD exciton chirality method in 1960s to 1970s: A marvel of Nakanishi's Japanese team. *Chirality* **2020**, *32*, 535–546.
- (12) Pescitelli, G. ECD exciton chirality method today: a modern tool for determining absolute configurations. *Chirality* **2022**, *34*, 333–363.
- (13) Costa, F. L. P.; de Albuquerque, A. C. F.; Fiorot, R. G.; Lião, L. M.; Martorano, L. H.; Mota, G. V. S.; Valverde, A. L.; Carneiro, J. W. M.; dos Santos, F. M., Jr Structural Characterisation of Natural Products by Means of Quantum Chemical Calculations of NMR Parameters: New Insights. *Org. Chem. Front.* **2021**, *8*, 2019–2058, DOI: 10.1039/D1QO00034A.
- (14) Marcarino, M. O.; Cicetti, S.; Zanardi, M. M.; Sarotti, A. M. A Critical Review on the Use of DP4+ in the Structural Elucidation of Natural Products: the Good, the Bad and the Ugly. A Practical Guide. *Nat. Prod. Rep.* **2022**, *39*, 58–76.
- (15) Choi, S. Z.; Lee, S. O.; Jang, K. U.; Chung, S. H.; Park, S. H.; Kang, H. C.; Yang, E. Y.; Cho, H. J.; Lee, K. R. Antidiabetic stilbene and anthraquinone derivatives from *Rheum undulatum*. *Arch. Pharm. Res.* **2005**, *28*, 1027–1030.
- (16) Wei, X.; Jiang, J. S.; Feng, Z. M.; Zhang, P. C. New anthraquinone derivatives from the roots of *Berchemia floribunda*. *Chin. Chem. Lett.* **2007**, *18*, 412–414.
- (17) Buchanan, M. S.; Gill, M.; Millar, P.; Phonh-Axa, S.; Raudies, E.; Yu, J. Pigments of fungi. Part 51. Structure and stereochemistry of coupled pre-anthraquinones of the pseudophlegmacin type from Australian toadstools belonging to the genus *Dermocybe*. *J. Chem. Soc., Perkin Trans. 1.* **1999**, *28*, 795–801.
- (18) Budzianowski, J. Naphthoquinones of *Drosera spatulata* from *in vitro* cultures. *Phytochemistry* **1995**, *40*, 1145–1148.
- (19) Guo, S. Y.; Feng, B.; Zhu, R. N.; Ma, J. K.; Wang, W. Preparative isolation of three Anthraquinones from *Rumex japonicus* by high-speed counter-current chromatography. *Molecules* **2011**, *16*, 1201–1210.
- (20) Bringmann, G.; Irmer, A.; Büttner, T.; Schaumlöffel, A.; Zhang, G.; Seupel, R.; Feineis, D.; Fester, K. Axially Chiral Dimeric Naphthalene and Naphthoquinone Metabolites, from Root Cultures of the West African Liana *Triphyophyllum peltatum*. *J. Nat. Prod.* **2016**, *79*, 2094–2103.
- (21) Zhang, X. Y.; Li, B. G.; Zhou, M.; Yuan, X. H.; Zhang, G. L. Chemical constituents of *Buddleja brachystachya* Diels. *Chin. J. Appl. Environ. Biol.* **2006**, *12*, 338–341.
- (22) Dong, L.; Chen, M.; Li, M.; Liao, Z. H.; Sun, M. A new cyanosides from *Rhodiola bupleuroides*. *Acta Pharm. Sin.* **2009**, *44*, 1383–1386.
- (23) Watanabe, M. Antioxidative phenolic compounds from Japanese Barnyard Millet (*Echinochloa utilis*) Grains. *J. Agric. Food Chem.* **1999**, *47*, 4500–4505.
- (24) Lee, H. J.; Lee, H. J.; Lee, E. O.; Ko, S. G.; Bae, H. S.; Kim, C. H.; Ahn, K. S.; Lu, J.; Kim, S. H. Mitochondria-cytochrome C-caspase-9 cascade mediates isorhamnetin-induced apoptosis. *Cancer Lett.* **2008**, *270*, 342–353.
- (25) Wang, L. X.; Wu, H. G.; Zhang, H.; Lou, H. Y.; Liang, G. Y.; Jiang, W. W.; Yang, Z. C.; Pan, W. D. Studies on flavonoids from *Derris eriocarpa*. *China J. Chin. Mater. Med.* **2015**, *40*, 3009–3012.
- (26) Gao, S.; Fu, G. M.; Fan, L. H.; Yu, S. S.; Yu, D. Q. Flavonoids from *Lysidice rhodostegia* Hance. *J. Integr. Plant Biol.* **2005**, *47*, 759–763.
- (27) Gu, C. Z.; Liu, F. F.; Yao, Y. C.; Liu, L.; Cao, J. X. Study on Chemical Components From Leaves of *Mangifera indica* L. *Nat. Prod. Res. Dev.* **2013**, *25*, 36–39.
- (28) Phaopongthai, J.; Wiyakrutta, S.; Meksuriyen, D.; Sriubolmas, N.; Suwanborirux, K. Azole-synergistic anti-candidal activity of Altenusin, a biphenyl metabolite of the Endophytic Fungus *Alternaria alternata* isolated from *Terminalia chebula* Retz. *J. Microbiol.* **2013**, *51*, 821–828.
- (29) Suga, T.; Hirata, T. Biosynthesis of Aloenin in *Aloe arborescens* var. *natalensis*. *Bull. Chem. Soc. Jpn.* **1978**, *51*, 872–877.
- (30) Wu, P. L.; Hsu, Y. L.; Zao, C. W.; Damu, A. G.; Wu, T. S. Constituents of *Vittaria anguste-elongata* and their biological activities. *J. Nat. Prod.* **2005**, *68*, 1180–1184.
- (31) Reyes-Ramírez, A.; Leyte-Lugo, M.; Figueroa, M.; Serrano-Alba, T.; González-Andrade, M.; Mata, R. Synthesis, biological evaluation, and docking studies of gigantol analogs as calmodulin inhibitors. *Eur. J. Med. Chem.* **2011**, *46*, 2699–2708.
- (32) Bai, M.; Zheng, C. J.; Chen, G. Y. Study on bioactive secondary metabolites from a mangrove-derived fungus *Penicillium* sp. JY246. *Chin. J. Mar. Drugs.* **2020**, *39*, 11–18.
- (33) Cui, H.; Liu, Y. Y.; Nie, Y.; Liu, Z. M.; Chen, S. H.; Zhang, Z. R.; Lu, Y. J.; He, L.; Huang, X. S.; She, Z. G. Polyketides from the Mangrove-Derived Endophytic Fungus *Nectria* sp. HN001 and Their  $\alpha$ -Glucosidase Inhibitory Activity. *Mar. Drugs* **2016**, *14*, No. 86, DOI: 10.3390/md14050086.
- (34) Arung, E. T.; Kusuma, I. W.; Kim, Y. U.; Shimizu, K.; Kondo, R. Antioxidative compounds from leaves of Tahongai (*Klienhowia hospita*). *J. Wood Sci.* **2012**, *58*, 77–80.
- (35) Shen, J. W.; Jiang, J. S.; Zhang, X. F.; Zheng, C. F.; Zhang, P. C. Two new benzochromone glycosides from the stem of *Berchemia racemosa*. *J. Asian Nat. Prod. Res.* **2007**, *9*, 499–503.
- (36) Choi, S. Z.; Lee, S. O.; Jang, K. U.; Chung, S. H.; Park, S. H.; Kang, H. C.; Yang, E. Y.; Cho, H. J.; Lee, K. R. Antidiabetic Stilbene and Anthraquinone Derivatives from *Rheum undulatum*. *Arch. Pharm. Res.* **2005**, *28*, 1027–1030.
- (37) Li, S. D.; Wei, M. Y.; Li, Z. H.; She, Z. G.; Lin, Y. C. Isolation and Structure Elucidation of Secondary Metabolites from Mangrove Endophytic Fungus *Penicillium* sp. (ZZF29#). *Chin. J. Appl. Chem.* **2012**, *29*, 727–729.
- (38) Bezabih, M.; Abegaz, B. M. Glucoferangulin A diacetate from the fruits of *Rhamnus prinoides*. *Bull. Chem. Soc. Ethiop.* **1998**, *12*, 45–48.