*ORIGINAL ARTICLE*

A C G publications

*Rec. Nat. Prod.* X:X (2023) XX-XX

records of natural products

# Butenolide Derivatives from the Fungus *Aspergillus terreus* and Their $\alpha$-Glucosidase Inhibitory Effects

**Wei Shen*, Xiaojing Huang and Kai Wang**

*Infectious Department, The First People's Hospital of Linping District, Hangzhou 311100, China*

*(Received May 14, 2023; Revised May 30, 2023; Accepted June 04, 2023)*

**Abstract:** The strain was isolated from the sea sediment of Hangzhou Bay and was cultured on solid fermentation using rice bran. The fermented material was extracted with ethyl acetate. The chemical study of the extract led to the isolation of 8 butenolide derivatives (**1–8**). Their structures were elucidated by detailed analyses of spectroscopic techniques including 1D and 2D NMR and HRESIMS data. The absolute configuration of **1** was determined by comparing the experimental ECD curve of **1** with that of the computed ECD curves of a model molecule (**1a**). A butenolide derivative was originally misassigned to bear the same structure as that of **1**, but it was later revised. Thus, the compound **1** was reported as a new compound and was named 4-demethyl ester aspernolide N (**1**). The known compounds were identified as 3-hydroxy-5-[[4-hydroxy-3-(3-methyl-2-buten-1-yl)phenyl]methyl]-4-(4-hydroxyphenyl)-2(5H)-furanone (**2**), 4-(4-hydroxyphenyl)-5-(4-hydroxyphenylmethyl)-2-hydroxyfurane-2-one (**3**), versicolactone B (**4**), butyrolactone I (**5**), aspernolide A (**6**), butyrolactone IV (**7**), aspernolide O (**8**). Bioassay study suggested that compounds **2**–**6** had better inhibitory effects on $\alpha$-glucosidase than that of the positive control acabose with $IC_{50}$ values ranging from 95 to 148 μM.

**Keywords:** Butenolide derivatives; *Aspergillus terreus*; Inhibitory effects on *α-glucosidase*. 

## 1. Introduction

In recent years, fungal strains have been a source of chemically diverse and biologically active secondary metabolites. The *Aspergillus* strains are ubiquitous in the environment, which can be found in soil, decomposing plant matter, household dust, building materials, plants, food, and water. The genus comprises about 200 species, the common strains are *A. fumigatus*, *A. flavus*, *A. clavatus*, *A. parasiticus*, *A. oryzae*, *A. terreus*, *A. nidulans*, and *A. niger* [1]. *Aspergillus* strains could produce metabolites with complex structures or obvious biological activity, such as terpenoids [1-3], cytotoxic sterols [4], penolic C-glycosides [5], novel alkaloids [6-8], phenolic bisabolane sesquiterpenes [9], amide [10], cyclic peptides [11, 12], and indole glucoside [13].

The species *A. terreus* from marine resources was found to be prolific and, previous chemical investigations on the species led to the isolation of butyrolactones [14-16], meroterpenoids [17, 18], sesterterpenoids [19], alkaloids [20], and cyclic peptides [20]. Some of them exhibited outstanding bioactivities, particularly, the butenolide derivatives have been reported to possess noteworthy $\alpha$-glucosidase inhibitory [21] and promising antiallergic effects [22].

In our research, we found that the $^1$H NMR spectrum of the extract of a strain *Aspergillus terreus* exhibited the characteristic resonances of butyrolactones. Further purification of the extract afforded 8 butyrolactones. Compounds **1**–**8** were screened for inhibitory effects of α-glucosidase enzyme. Herein, we report the isolation, structure elucidation, and biological evaluation of the isolated compounds from the species.

*Corresponding author: E-Mail: swmjsyx3@163.com

The article was published by ACG Publications
http://www.acgpubs.org/journal/records-of-natural-products Month-Month 202x EISSN:1307-6167
DOI: http://doi.org/10.25135/rnp.398.2305.2786
Available online: June 17, 2023

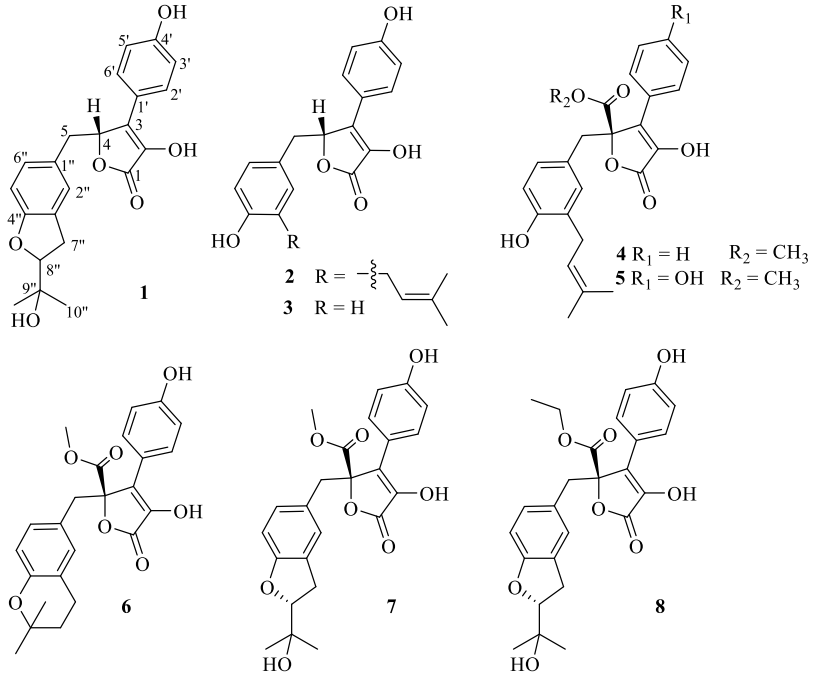


**Figure 1**. Isolated compounds **(1**–**8)** from the marine-derived fungus *Aspergillus terreus* LPFH-SW1

## 2. Materials and Methods

### *2.1. General Experimental Procedures*

UV spectrum was recorded on a Cary 300 spectrometer. The $^{1}H$ and $^{13}C$ NMR spectra were measured on a Bruker Avance-400FT NMR spectrometer. HRESIMS spectrum was achieved on a Waters Xevo G2 Q-TOF spectrometer equipped with an ESI source. Semi-preparative high-performance liquid chromatography (HPLC) was performed on a Shimadzu LC-6AD pump with a UV detector, and a YMC-Pack ODS-A column was used for separation. Ethyl acetate (EtOAC, ACS grade), Methanol (MeOH, ACS Grade), Acetonitrile (ACN, ACS grade) and Ultrapure water used during the extraction process.

### *2.2. Microorganism Material*

The fungal strain LPFH-SW1 was obtained from the sea sediments of Hangzhou Bay. It was identified to be *Aspergillus terreus* based on morphological features and by comparison of the ITS sequence region with that of a similar record in GenBank (MG575480.1). The strain was kept in store in the First People's Hospital of Linping District of Hangzhou.

### *2.3. Fermentation and Isolation*

The fermentation was carried out in 40 Fernbach flasks (500 mL), each containing 90 g of rice. Distilled water (100 mL) was added to each flask, and the contents were soaked for 3 h and then were autoclaved at 15 psi for 30 min. Each flask was inoculated with 3.0 mL of the spore inoculum and incubated at room temperature for about a month. The fermented materials were extracted with ethyl acetate (EtOAc) (3 × 6000 mL) in an ultrasonic bath for 20 min. After evaporation under vacuum, the EtOAc extract (12.0 g) was subjected to an Octadecylsilyl (ODS) silica gel column chromatography eluted with MeOH/$H_2O$ (20:80→100:0) to afford 10 fractions (F1–F10). F7 was separated into seven subsequent fractions (F7a–F7g) via C-18 silica gel column chromatography

(CC) that eluted with MeOH/$H_2O$ (50:50→100:0). F7d was separated by HPLC using ACN/$H_2O$ (71:29, 3 mL/min) to afford **4** (4.2 mg, $t_R$ 20 min). F6 was further chromatographed over C-18 silica gel CC eluted with MeOH/$H_2O$ (40:60→100:0) to afford 6 subfractions F6a–F6f. F6b was separated by HPLC using ACN/$H_2O$ (52:48, 3 mL/min) to obtain **1** (7.2 mg, $t_R$ 38 min). F6c was separated by HPLC using ACN/$H_2O$ (56:44, 3 mL/min) to obtain **8** (109.5 mg, $t_R$ 21 min) and **9** (34.7 mg, $t_R$ 18 min). F6d was chromatographed by HPLC using ACN/$H_2O$ (60:40, 3 mL/min) as eluent to abtain **2** (3.0 mg, $t_R$ 26 min). F6e was separated by HPLC eluted with ACN/$H_2O$ (60:40, 3 mL/min) to obtain **5** (2.3 mg, $t_R$ 22 min) and **7** (2.5 mg, $t_R$ 15 min). F5 was subjected to semi-preparative YMC-pack ODS-A column ACN/$H_2O$ (55:45) to obtain **6** and subfractions (F5a–F5f). F5c was further purified by HPLC on a semi-preparative YMC-pack ODS-A column using MeOH/$H_2O$ (65:35, 3 mL/min) to afford **3** (3.5 mg, $t_R$ 31 min).

*4-Demethyl ester aspernolide N (**1**)*: Yellowish oil; $[\alpha]^{25}_D$ −32 (*c* 0.10, MeOH); UV (MeOH) $\lambda_{max}$ (log $\varepsilon$) 203 (4.52), 295 (4.21) nm; ECD (*c* $1.0 \times 10^{-4}$ M, MeOH) $\lambda_{max}$ ($\Delta\varepsilon$) 287 (−4.15), 231 (−5.62); $^1$H and $^{13}$C NMR data, see Table 1; HRESIMS *m*/*z* 381.1327 $[M–H]^-$ (calcd. for $C_{22}H_{21}O_6^-$, 381.1344).

### *2.4 α-Glucosidase Inhibitory Assay*

The *α*-glucosidase (0.2 U) from *Saccharomyes cerevisiae* was diluted to 0.067 M phosphate buffer containing disodium hydrogen phosphate and potassium phosphate monobasic (pH 6.8). The test was performed in a 60 μL reaction system consisting of α-glucosidase solution (20 μL) and DMSO or sample (20 μL). After incubation, PNPG (20 μL, 4 mM) was added and was incubated for 15 min at 37 ◦C, and the reaction was quenched by the addition of $Na_2CO_3$ (60 μL, 0.2 M). The absorbance was determined (405 nm). All assays were performed in three replicates, acarbose was used as the reference. Inhibition was determined according to the equation: Inhibition (%) = (($A_{Control}$ − $A_{test}$)/$A_{control}$)); $IC_{50}$ values are computed via concentration vs. percent inhibition values [13].

## 3. Results and Discussion

### *3.1. Structure Elucidation*

Compound **1** had a molecular formula of $C_{22}H_{22}O_6$, as established by the HRESIMS and $^{13}$C NMR spectroscopy (Table 1), requiring 12 degrees of unsaturation. The $^1$H NMR spectrum provided signals for two methyls [$\delta_H$ 1.21 (s) and 1.19 (s)], two oxygenated proton [$\delta_H$ 4.52 (dd, *J* = 9.2, 8.7 Hz, 1H); 5.57 (dd, *J* = 3.6, 5.3 Hz, 1H)], a 1,3,4-trisubstituted benzene ring [$\delta_H$ 6.76, (d, *J* = 1.6 Hz, 1H); 6.69 (d, *J* = 8.0, 1.6 Hz, 1H); 6.54 (d, *J* = 8.0 Hz, 1H)], a 1,4-disubstituted benzene ring [$\delta_H$ 7.58 (d, *J* = 8.7 Hz, 2H); 6.89 (d, *J* = 8.7 Hz, 2H)], and another four protons ($\delta_H$ 3.24, 3.06×2, 2.87) including two geminally coupled protons [$\delta_H$ 3.24 (1H, dd, *J* = 14.6, 3.6 Hz); 2.87 (1H, d, *J* = 14.6, 5.3 Hz)]. The $^{13}$C NMR and HSQC spectra exhibited 22 carbon resonances, including 15 aromatic carbons for two benzene rings, a double bond, and one carbonyl carbon, the remaining seven carbons were attributed to two methyls ($\delta_C$ 25.2, 25.3), two methylenes ($\delta_C$ 31.5, 39.8), two oxygen-bearing methines ($\delta_C$ 90.4, 80.3), and an oxygen-bearing tertiary carbon ($\delta_C$ 72.5). These structural features suggested a butenolide derivative, structurally similar to butyrolactone IV (**8**). A comparison of their NMR data revealed that the obvious differences between **1** and **8** were attributed to the absence of the methyl ester moiety and the presence of an additional oxygenated methine in **1**, suggesting that the methyl ester moiety attached to C-1 in **8** was replaced by a hydrogen atom in **1**.

The assumed structure of **1** was confirmed by detailed analyses of the 2D NMR data (Figure 2). Especially, the COSY relationship between the additional oxygenated methine proton at $\delta_H$ 5.57 (H-4) and the methylene protons $H_2$-5 ($\delta_H$ 3.24, 2.87) and the HMBC correlation from H-4 to C-1″ certified the location of the methine CH-4 ($\delta_H$ 5.57; 80.3). The HMBC correlations from H-8″ ($\delta_H$ 4.52) to C-3″ ($\delta_C$ 128.0) and C-4″ ($\delta_C$ 160.3) and H-7″ ($\delta_H$ 3.06) to C-3″ ($\delta_C$ 128.0), C-2″ ($\delta_C$ 127.4), and C-4″ ($\delta_C$ 160.3), and the COSY correlations between H-7″ and H-8″ ($\delta_H$ 4.52) indicated the

presence of a furan ring consisting of C-3″, C-4″, C-7″ ($\delta_C$ 31.5), and C-8″($\delta_C$ 90.4). The presence of the furan ring could be confirmed by comparing the chemical shifts of C-2″−10″ with those of compounds **7**–**9**.

**Table 1.** $^{1}$H and $^{13}$C NMR Data of **1** in Methanol-$d_4$. [a]

| No. | **1** | | | | |
|---|---|---|---|---|---|
| | $\delta_H$ | $\delta_C$ | | $\delta_H$ | $\delta_C$ |
| 1 | | 171.8 | 1″ | | 128.2 |
| 2 | | 137.9 | 2″ | 6.76, d (1.6) | 127.4 |
| 3 | | 123.7 | 3″ | | 128.0 |
| 4 | 5.57, dd (3.6, 5.3) | 80.3 | 4″ | | 160.3 |
| 5 | 3.24, dd (14.6, 3.6)<br>2.87, dd (14.6, 5.3) | 39.8 | 5″ | 6.54, d (8.0) | 109.2 |
| 1′ | | 131.6 | 6″ | 6.69, d (8.0, 1.6) | 130.4 |
| 2′ | 7.58, d (8.7) | 130.4 | 7″ | 3.06, m | 31.5 |
| 3′ | 6.89, d (8.7) | 116.6 | 8″ | 4.52, dd (9.2,8.7) | 90.4 |
| 4′ | 6.89, d (8.7) | 159.3 | 9″ | | 72.5 |
| 5′ | | 116.6 | 10″ | 1.19, s | 25.3 |
| 6′ | 7.58, d (8.7) | 130.4 | 11″ | 1.21, s | 25.2 |

[a] $^{1}$H NMR recorded at 400 MHz, $^{13}$C NMR recorded at 100 MHz.

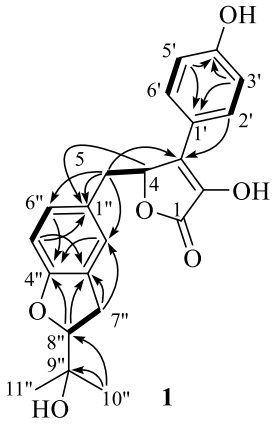


**Figure 2.** Key COSY ( ▬ ) and HMBC ( ⤻ ) correlations of **1**

In order to assign the absolute configuration of C-4 ($\delta_C$ 80.3), the ECD calculation was performed at the b3lyp/6-31+g(d,p) level in methanol using the b3lyp/6-31+g(d,p)-optimized geometries for the model molecules (*R*-**1a** and *S*-**1a**). Comparison of the experimental CD curve of **1** with the computed ECD curves (Figure 3) indicated the absolute configurations of **1** to be 4*R*. The structure of **1** was thus determined as depicted. According to the literature [16, 23], a butenolide derivative was originally misassigned the same structure as **1** and was later revised. So compound **1** was a new compound and was named 4-demethyl ester aspernolide N

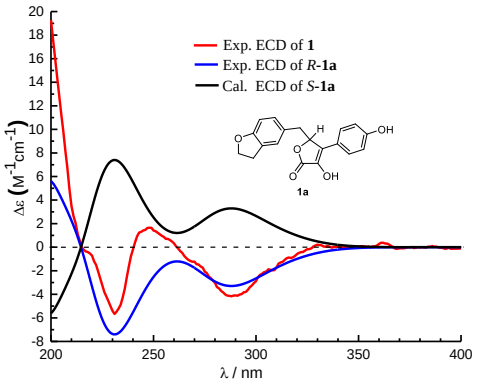


**Figure 3.** Experimental ECD spectrum of **1** in MeOH and the calculated ECD spectra of model molecules *R*-**1a** and *S*-**1a** at the b3lyp/6-31+g(d,p) level

Besides, compounds **2**–**8** were assigned to be 3-hydroxy-5-[[4-hydroxy-3-(3-methyl-2-buten-1-yl)phenyl]methyl]-4-(4-hydroxyphenyl)-2(5H)-furanone (**2**) [24], 4-(4-hydroxyphenyl)-5-(4-hydroxyphenylmethyl)-2-hydroxyfurane-2-one (**3**) [25], versicolactone B (**4**) [26], butyrolactone I (**5**) [27], aspernolide A (**6**) [27], butyrolactone IV (**7**) [28], aspernolide O (**8**) [28] by comparing the NMR data with those reported in the literature.

### *3.2. α-Glucosidase Inhibitory Effects of the Isolated Compounds*

The literature revealed that butyrolactones had *α*-glucosidase inhibitory effect. The inhibitory effect of these compounds against *α*-glucosidase were tested at an initial concentration of 200 μM following the procedures in the literature [13, 29]. Those exhibited inhibitions more than 50% were subsequently selected for further evaluation to calculate the $IC_{50}$ values. The results showed that compounds **2**–**6** showed significant inhibitory effects with $IC_{50}$ values less than 150 μM (Table 2), being more active compared to the positive control acarbose (297 μM). The structural similarity and the activity revealed some structure-activity relationship. It was found that, the isopentene group at C-3″ had no positive effect for the biological activity, since compound **3** was much more active than that of compound **2**. The hydroxyl group at C-4′ seemed to contribute to the activity, since **4** was less active than its hydroxylated derivative **5**. The furan moiety (C-3″, C-4″, C-7″, C-8″) may led to a sharp decrease on the activity, since the activity of compounds **1**, **7**, **8** was much weaker than that of **2**–**6**.

**Table 2.** Inhibitory effects of the compounds **1**–**8** on *α*-glucosidase.

| No. | Inhibition（%）[a] | $IC_{50}$ (μM) |
|---|---|---|
| **1** | 17% | nt.[b] |
| **2** | 56% | 148 |
| **3** | 92% | 95 |
| **4** | 71% | 123 |
| **5** | 79% | 115 |
| **6** | 65% | 131 |
| **7** | 23% | nt.[b] |
| **8** | 21% | nt.[b] |
| Acarbose | | 297 |

[a] at 200 *μ*M, [b] not tested

## Supporting Information

Supporting Information accompanies this paper on http://www.acgpubs.org/journal/records-of-natural-products

**ORCID**
Wei Shen: 0009-0002-2110-6229
Xiaojing Huang: 0000-0002-0332-6300
Kai Wang: 0009-0004-6916-2734

## References

[1] L. Xu, G. Liu, Y. Chen, S. Liu, W. Luo, P. Hu, C. Huang, X. Ji, S. Wang and G. Cao (2022). Cytotoxic drimane-type sesquiterpenoids from the fungus *Aspergillus flavipes* 297, *Rec. Nat. Prod.* **16**, 488-492.

[2] B. Peng, Q. Peng, J. She, B. Yang and X. Zhou (2022). Secondary metabolites from the coral-derived fungus *Aspergillus terreus* SCSIO41404 with pancreatic lipase inhibitory activities, *Rec. Nat. Prod.* **16**, 639-644.

[3] C. Sun, X. Liu, N. Sun, X. Zhang, M. Shah, G. Zhang, Q. Che, T. Zhu, J. Li and D. Li (2022). Cytotoxic nitrobenzoyl sesquiterpenoids from an Antarctica sponge-derived *Aspergillus insulicola*, *J. Nat. Prod.* **85**, 987-996.

[4] V. A. Cao, J.-H. Kwon, J. S. Kang, H.-S. Lee, C.-S. Heo and H. J. Shin (2022). Aspersterols A-D, ergostane-type sterols with an unusual unsaturated side chain from the deep-sea-derived fungus *Aspergillus unguis*, *J. Nat. Prod.* **85**, 2177-2183.

[5] H. Wen, C. Chen, W. Sun, Y. Zang, Q. Li, W. Wang, F. Zeng, J. Liu, Y. Zhou, Q. Zhou, J. Wang, Z. Luo, H. Zhu and Y. Zhang (2019). Phenolic C-glycosides and aglycones from marine-derived *Aspergillus* sp. and their anti-ınflammatory activities, *J. Nat. Prod.* **82**, 1098-1106.

[6] X. Guo, Q. Meng, J. Liu, J. Wu, H. Jia, D. Liu, Y. Gu, J. Liu, J. Huang, A. Fan and W. Lin (2022). Sclerotiamides C-H, notoamides from a marine gorgonian-derived fungus with cytotoxic activities, *J. Nat. Prod.* **85**, 1067-1078.

[7] Z. B. Cheng, L. L. Lou, D. Liu, X. D. Li, P. Proksch, S. Yin and W. H. Lin (2016). Versiquinazolines A-K, fumiquinazoline-type alkaloids from the gorgonian-derived fungus *Aspergillus versicolor* LZD-14-1, *J. Nat. Prod.* **79**, 2941-2952.

[8] Y. Jiang, C. Jiang, Q. Zhou, Y. Tong and P. Wang (2022). A new alkaloid from the endophytic fungus of *Crocus sativus* L., *Aspergillus fumigatus* Y0107, *Rec. Nat. Prod.***16**, 463-470.

[9] Y. Li, J. Shi, R. Liu, Y. Liu, R. Liu, Z. Wu, W. Xu, H. Ma, H. B. Luo and Z. Cheng (2023). Structure revisions of phenolic bisabolane sesquiterpenes and a ferroptosis ınhibitor from the marine-derived fungus *Aspergillus versicolor* YPH93, *J. Nat. Prod.* **86**, 830-841.

[10] R. Yu, M. Li, Y. Wang, X. Bai, J. Chen, X. Li, H. Wang and H. Zhang (2021). Chemical investigation of a co-culture of *Aspergillus fumigatus* D and *Fusarium oxysporum* R1, *Rec. Nat. Prod.* **15**, 130-135.

[11] Y. Li, S. Sheng, J. Feng, Y. Wang, J. Guo, Y. Jiang and W. Wang (2022). New cyclic peptides from the endophytic *Aspergillus versicolor* 0312 with their antimicrobial activity, *Rec. Nat. Prod.* **16**, 585-591.

[12] M. Dong, Y. Chen, K. He, Y. Chen, Y. Ye and M. Zhou (2021). A new cyclic tetrapeptide from endophytic fungus *Aspergillus versicolor* E-2, *Rec. Nat. Prod.* **15**, 363-367.

[13] C. D. Tuan, N. Van Hung, L. T. H. Minh, H. T. H. Lien, J.-W. Chae, H.-y. Yun, Y.-H. Kim, P. Van Cuong and D. T. M. Huong (2022). A new indole glucoside and other constituents from the sea cucumber-derived *Aspergillus fumigatus* M580 and their biological activities, *Rec. Nat. Prod.* **16**, 633-638.

[14] I. S. Uras, S. S. Ebada, M. Korinek, A. Albohy, B. S. Abdulrazik, Y.-H. Wang, B.-H. Chen, J.-T. Horng, W. Lin, T.-L. Hwang and B. Konuklugil (2021). Anti-inflammatory, antiallergic, and COVID-19 main protease (Mpro) inhibitory activities of butenolides from a marine-derived fungus *Aspergillus terreus*, *Molecules* **26**, 3354.

[15] Q. Peng, W. Chen, X. Lin, J. Xiao, Y. Liu and X. Zhou (2022). Butenolides from the coral-derived fungus *Aspergillius terreus* SCSIO41404, *Mar. Drugs*, **20**, 212.

[16] C. Qi, W. Gao, D. Guan, J. Wang, M. Liu, C. Chen, H. Zhu, Y. Zhou, Y. Lai, Z. Hu, Q. Zhou and Y. Zhang (2018). Butenolides from a marine-derived fungus *Aspergillus terreus* with antitumor activities against pancreatic ductal adenocarcinoma cells, *Bioorg. Med. Chem.* **26**, 5903-5910.

[17] K. Sun, G. Zhu, J. Hao, Y. Wang and W. Zhu (2018). Chemical-epigenetic method to enhance the chemodiversity of the marine algicolous fungus, *Aspergillus terreus* OUCMDZ-2739, *Tetrahedron* **74**, 83-87.

[18] C.-J. Wu, X. Cui, B. Xiong, M.-S. Yang, Y.-X. Zhang and X.-M. Liu (2019). Terretonin D1, a new meroterpenoid from marine-derived *Aspergillus terreus* ML-44, *Nat. Prod. Res.* **33**, 2262-2265.

[19] Z. Liu, Y. Chen, S. Chen, Y. Liu, Y. Lu, D. Chen, Y. Lin, X. Huang and Z. She (2016). Aspterpenacids A and B, two sesterterpenoids from the mangrove endophytic fungus *Aspergillus terreus* H010, *Org. Lett.* **18**, 1406-1409.

[20] F. He, J. Bao, X. Y. Zhang, Z. C. Tu, Y. M. Shi and S. H. Qi (2013). Asperterrestide A, a Cytotoxic cyclic tetrapeptide from the marine-derived fungus *Aspergillus terreu*s SCSGAF0162, *J. Nat. Prod.* **76**, 1182-1186.

[21] Z. Cheng, Y. Li, W. Liu, L. Liu, J. Liu, W. Yuan, Z. Luo, W. Xu and Q. Li (2019). Butenolide derivatives with α-glucosidase ınhibitions from the deep-sea-derived fungus *Aspergillus terreus* YPGA10, *Mar. Drug.* **17**, 332.

[22] Q.-M. Liu, C.-L. Xie, Y.-Y. Gao, B. Liu, W.-X. Lin, H. Liu, M.-J. Cao, W.-J. Su, X.-W. Yang and G.-M. Liu (2018). Deep-sea-derived butyrolactone ı suppresses ovalbumin-ınduced anaphylaxis by regulating mast cell function in a murine model, *J. Agr. Food. Chem.* **66**, 5581-5592.

[23] J. Bao, X.-X. Li, K. Zhu, F. He, Y.-Y. Wang, J.-H. Yu, X. Zhang and H. Zhang (2021). Bioactive aromatic butenolides from a mangrove sediment originated fungal species, *Aspergillus terreus* SCAU011, *Fitoterapia* **150**, 104856.

[24] F. Guo, Z. Li, X. Xu, K. Wang, M. Shao, F. Zhao, H. Wang, H. Hua, Y. Pei and J. Bai (2016). Butenolide derivatives from the plant endophytic fungus *Aspergillus terreus*, *Fitoterapia* **113**, 44-50.

[25] M. Chen, K.-L. Wang, M. Liu, Z.-G. She and C.-Y. Wang (2015). Bioactive steroid derivatives and butyrolactone derivatives from a gorgonian-derived *Aspergillus* sp. fungus, *Chem. Biodiver.* **12**, 1398-1406.

[26] M. Zhou, G. Du, H.-Y. Yang, C.-F. Xia, J.-X. Yang, Y.-q. Ye, X.-M. Gao, X.-N. Li and Q.-F. Hu (2015). Antiviral butyrolactones from the endophytic fungus *Aspergillus versicolor*, *Planta Med.* **81**, 235-240.

[27] T. Lin, C. Lu and Y. Shen (2009). Secondary metabolites of *Aspergillus* sp. F1, a commensal fungal strain of *Trewia nudiflora*, *Nat. Prod. Res.* **23**, 77-85.

[29] Z.-Y. Jiang, J.-E. Feng, L.-K. Duan, C.-J. Liu, X.-F. Li, C.-Q. Huang, S.-L. Shi, R.-R. Wang, A.-X. Zuo and H.-P. He (2022). Tigliane diterpenoids with larvicidal, antifungal, and $\alpha$-glucosidase ınhibitory activities from *Croton damayeshu*, *J. Nat. Prod.* **85**, 405-414.