Germacrane-Type Sesquiterpenes from *Curcuma wenyujin*

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Two new germacrane-type sesquiterpene lactones, curdionolides A and B (**1** and **2**, resp.), and a novel germacrane-type sesquiterpene lactam, curdionolide C (**3**), were isolated from *Curcuma wenyujin*. Y. H. CHEN ET C. LING together with five known germacrane-type sesquiterpenes, **4**–**8**. The structures of the new compounds were elucidated by spectroscopic methods. The inhibitory effects of compounds **1**–**8** on nitric oxide (NO) production in lipopolysaccharide-activated macrophages were evaluated.

Introduction. – There are many reports on the pharmacological effects of the genus *Curcuma* such as their antitumor [1], anti-inflammatory [2], and immunological activities [3]. In traditional Chinese and Japanese medicine, *Curcuma* plants are generally used to treat the *Oketsu* syndromes (various syndromes caused by the obstruction of blood circulation such as arthralgia, psychataxia, and dysmenorrhea) [4]. The essential oil of *Curcuma wenyujin* is currently embodied in the Pharmacopoeia of the P. R. China (2005), as an anticancer and antivirus remedy [5]. Previous chemical investigations on the genus *Curcuma* have led to the isolation of sesquiterpenoids [6] and diarylheptanoids [7], some of these compounds possess significant vasorelaxant [6c] [8] and hepatoprotective activities [9]. Investigation of bioactive constituents from the dried rhizomes of *Curcuma wenyujin*, has resulted in the isolation of three new germacrane-type sesquiterpenes **1**–**3**, together with five known compounds **4**–**8**. This article mainly describes the isolation and characterization of these compounds and their inhibitory effects on nitric oxide (NO) production in lipopolysaccharide-(LPS) activated macrophages.

Results and Discussion. – The dried rhizomes of *Curcuma wenyujin* (cultivated in Zhejiang Province, P. R. China) were extracted successively with cyclohexane and 50% EtOH. The 50% EtOH extract was partitioned successively with cyclohexane, AcOEt, and BuOH. These fractions were purified by repeated column chromatography, including silica gel, *Sephadex LH-20* column, *ODS* column, HPLC, and preparative TLC to afford three new and five known compounds.

Compound **1**, obtained as a colorless oil, possesses the molecular formula $C_{15}H_{20}O_4$ as determined on the basis of HR-ESI-MS data, which was compatible with the NMR

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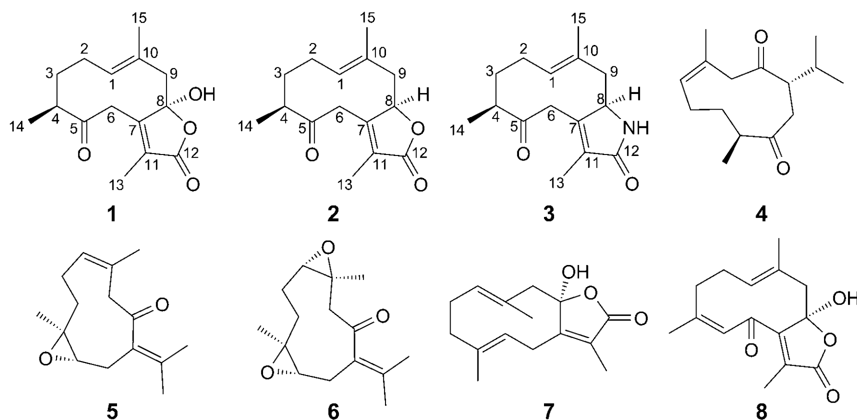

data. The IR spectrum of **1** indicated the presence of an α,β-unsaturated γ-lactone ring (1741 cm^{-1}) and a ketone (1715 cm^{-1}). The UV spectrum showed an absorption maximum at 224 nm. The ^{13}C-NMR spectrum (recorded in CD_3OD; *Table 1*) displayed 15 C-atom resonances comprising three Me, four CH_2, and two CH groups (thereof one olefinic CH), as well as six quaternary C-atoms (one O-bearing, three olefinic C-atoms, one ketone CO, and one ester CO group). These functionalities accounted for four degrees of unsaturation. Considering the degrees of unsaturation and molecular formula, compound **1** must be bicyclic. The aforementioned spectroscopic features implied that compound **1** might be a germacrane-type sesquiterpene [10]. This assumption was corroborated by an HMBC experiment. The HMBC correlations of Me(14) to C(3), C(4), and C(5); Me(15) to C(2), C(3), C(9), C(10), C(1), and C(8); and CH_2(6) to C(5), C(7), and C(8) supported a germacrane skeleton for **1**. The HMBC correlations of Me(13) to C(7), C(11), C(12), C(8), C(5), and C(6) confirmed that an α,β-unsaturated γ-lactone ring (δ(C) 156.7, 108.3, 130.5, and 173.7) was located at C(7), C(8), C(11), and C(12) with a Me group (δ(H) 1.83; δ(C) 9.4) attached to C(11). The location of the OH group at C(8) was confirmed by the ketol C-atom signal (δ(C) 108.3, C(8)). Thus, the constitutional formula of **1** was established. The C(1)=C(10) bond was assigned an (*E*)-configuration owing to the chemical shift of C(15) (δ(C) 16.8), which appears at δ(C) *ca.* 15 [11]. The NOE correlation between Me(14) and Me(15) indicated they had a same orientation in the molecule, while correlations between H–C(4)/H_α–C(9), and H_α–C(9)/HO–C(8) (measured in C_5D_5N) suggested them to be on the same orientation of the ring but opposite to that of Me(14). The ten-membered ring is conformationally flexible [12], while the H-atom signals in the ^{1}H-NMR of **1** (*Table 2*) are not broadened, which indicated the positioning of the ketone CO at C(5) and the OH group on C(8) in **1** favor formation of an O–H···O intramolecular H-bond [13]. This hypothesis was confirmed by IR ((CCl_4): 3365 cm^{-1}) and molecular modeling of **1**. Accordingly, the structure of **1** was determined, and it was named as curdionolide A.

Compound **2**, obtained as a colorless oil, had the molecular formula $C_{15}H_{20}O_3$ as determined by means of HR-ESI-MS. The IR spectrum exhibited CO absorptions at

Table 1. *^{13}C-NMR Data for Compounds* **1**–**3**. δ in ppm.

	1[a])[b])	**1**[b])[c])	**2**[a])[b])	**3**[a])[d])	**3**[d])[e])
H−C(1)	134.8	133.9	134.4	133.7	132.9
CH_2(2)	28.2	27.8	28.2	28.3	27.3
CH_2(3)	37.4	36.7	37.1	37.3	36.1
H−C(4)	48.8	48.1	49.4	48.2	47.8
C(5)	211.9	209.8	211.6	209.7	210.0
CH_2(6)	41.3	41.0	42.4[f])	42.9[f])	42.6[f])
C(7)	156.7	156.1	159.3	151.9	151.5
C(8) or H−C(8)	108.3	107.8	81.7	58.6	58.6
CH_2(9)	50.9	51.0	47.4	47.3	46.4
C(10)	132.1	129.8	131.0	132.1	130.2
C(11)	130.5	131.9	129.0	133.6	132.8
C(12)	173.7	172.2	176.1	175.9	174.1
Me(13)	9.4	9.8	9.2	8.9	8.9
Me(14)	18.8	18.5	18.8	18.9	18.6
Me(15)	16.8	17.1	16.0	15.8	15.7

[a]) In CD_3OD. [b]) Recorded at 75 MHz. [c]) In C_5D_5N. [d]) Recorded at 150 MHz. [e]) In $CDCl_3$. [f]) Low and broad.

1741 (α,β-unsaturated γ-lactone) and 1711 cm^{-1} (ketone). The ^{1}H- and ^{13}C-NMR data of **2** were similar to those of **1** (measured in CD_3OD; *Table 2* and *1*, resp.), expect for the appearance of an O-bearing CH group (δ(C) 81.7, δ(H) 5.21), and the disappearance of the hemiketal C-atom (δ(C) 108.3). Considering the difference of the respective molecular weights, the hemiketal C-atom C(8) of **1** was replaced by a O-bearing CH group in **2**. This assumption was confirmed by HMBC correlations of CH_2(6) and Me(13) with C(8). Compound **2** is conformationally flexible, as evidenced by the broadened NMR signals (*Tables 1* and *2*). This indicated that several conformers are present at room temperature [12]. The C(1)=C(10) bond was assigned an (*E*)-configuration due to the chemical shift of C(15) (δ(C) 16.0) [11]. In the NOESY spectrum of **2**, the correlation between H−C(8)/H_α−C(9) suggested that both H−C(8) and H_α−C(9) had α-orientation. The β-orientation was assigned to the Me(14) on the basis of the correlation between H_β−C(9) and Me(14). Accordingly, the structure of **2** was determined, and the compound was named curdionolide B.

The HR-ESI-MS of compound **3** indicated its molecular formula to be $C_{15}H_{21}NO_2$ with six degrees of unsaturation. The IR spectrum exhibited absorption at 1652 cm^{-1} typical for an unsaturated lactam CO group. The ^{13}C-NMR and DEPT spectra displayed three Me, four CH_2, and three CH groups (thereof one olefinic CH group), together with signals for five quaternary C-atoms (two CO groups and three olefinic C-atoms). The NMR data (*Tables 1* and *2*) exhibited broadened lines indicative of equilibrating conformers [12]. The ^{1}H- and ^{13}C-NMR spectra were similar to those of **2**, the main difference between **3** and **2** was that **3** contains an extra NH H-atom which resonates at δ(H) 6.70 (measured in $CDCl_3$). Comparison of the ^{1}H-NMR data (measured in CD_3OD) of **3** with those of **2** revealed that the H−C(8) signal of **3** was shifted upfield to δ(H) 4.24 from δ(H) 5.21, and that the CH_2(9) signals of **3** were shifted upfield to δ(H) 1.82–1.84/2.79 compared to δ(H) 1.98–2.01/3.02 for compound

Table 2. *^{1}H-NMR Data for Compounds* **1**–**3**. δ in ppm, J in Hz.

	1[a])[b])	**1**[b])[c])	**2**[a])[d])	**3**[a])[d])	**3**[c])[e])
H–C(1)	4.82–4.90 (*m*)[f])	4.90–4.96 (*m*)[f])	5.00 (br. *s*)	4.84 (br. *s*)[f])	4.91 (br. *s*)
CH_2(2)	1.96–2.00 (*m*, H_α),	1.86–1.90 (*m*, H_α),	2.04–2.06 (*m*),	2.01–2.03 (*m*),	1.79–1.80 (*m*)[f]),
	2.28–2.33 (*m*, H_β)	2.11–2.16 (*m*, H_β)	2.31–2.39 (*m*)	2.28–2.37 (*m*)	2.00–2.02 (*m*)
CH_2(3)	2.01–2.04 (*m*, H_α),	2.19–2.20 (*m*, H_α),	2.02–2.04 (*m*, H_α),	1.97–2.01 (*m*, H_α),	1.93–1.96 (*m*, H_α),
	1.71–1.74 (*m*, H_β)	1.53–1.57 (*m*, H_β)	1.80–1.82 (*m*, H_β)[f])	1.78–1.80 (*m*, H_β)[f])	1.79–1.80 (*m*, H_β)[f])
H–C(4)	2.49–2.53 (*m*, H_α)	2.40–2.47 (*m*, H_α)[f])	2.65 (br. *s*, H_α)	2.57 (br. *s*, H_α)	2.39 (br. *s*, H_α)
CH_2(6)	3.59 (*d*, $J=15.8$, H_α),	3.83 (*d*, $J=15.5$, H_α),	3.56 (br. *s*),	3.49 (br. *s*),	3.85 (br. *s*),
	3.46 (*d*, $J=15.8$, H_β)	3.60 (*d*, $J=15.5$, H_β)	1.80–1.82 (*m*)[f])	1.78–1.80 (*m*)[f])	1.70–1.75 (*m*)
H–C(8)			5.21 (br. *s*, H_α)	4.24 (br. *s*, H_α)	4.10 (br. *s*, H_α)
CH_2(9)	2.85 (*d*, $J=13.1$, H_α),	3.15 (*d*, $J=13.0$, H_α),	3.02 (br. *s*, H_α),	2.79 (br. *s*, H_α),	2.6 (br. *s*, H_α),
	2.21 (*d*, $J=13.1$, H_β)	2.40–2.47 (*m*, H_β)[f])	1.98–2.01 (*m*, H_β)	1.82–1.84 (*m*, H_β)	1.82–1.84 (*m*, H_β)
Me(13)	1.83 (*s*)	1.98 (*s*)	1.87 (*s*)	1.81 (*s*)	1.80 (*s*)[f])
Me(14)	1.04 (*d*, $J=6.8$)	1.00 (*d*, $J=6.8$)	1.12 (*d*, $J=6.4$)	1.08 (*d*, $J=6.8$)	1.04 (*d*, $J=6.8$)
Me(15)	1.93 (*s*)	2.10 (*s*)	1.94 (br. *s*)	1.90 (br. *s*)	1.89 (br. *s*)
HO–C(8)		9.64 (br. *s*)			
NH					6.70 (br. *s*)

[a]) In CD_3OD. [b]) In C_5D_5N. [c]) Recorded at 300 MHz. [d]) Recorded at 600 MHz. [e]) In CD_3Cl_3. [f]) Overlapping signals.

2, respectively. Furthermore, the ^{13}C-NMR spectrum of **3** showed a strong shielding for C(8) ($\Delta\delta$(C) = − 23.1) and smaller, but significant effects on other C-atoms were also observed. This appearance could be explained if C(8) is attached to a less electronegative atom than an O-atom, for instance, a N-atom. The *quasi*-molecular ions supported the presence of one N-atom in the structure: 248 ([M + H]$^+$), 495 ([2M + H]$^+$), 270 ([M + Na]$^+$), and 517 ([2M + Na]$^+$). On the basis of the above evidence, **3** should have a lactam ring instead of the lactone ring present in **2**. According to these data, the constitutional formula of compound **3** was established.

The relative configuration of **3** was elucidated through NOESY correlations, namely, between Me(14) and H_β−C(2), suggesting both to be on the same side of the 10-membered ring. NOE Correlation between H−C(8) and H_α−C(9) indicated that H−C(8) and H_α−C(9) are cofacial. The C(1)=C(10) bond was assigned an (*E*)-configuration based on the chemical shift of C(15) (δ(C) 15.8) [11]. Compound **3** was thus identified and named as curdionolide C. To the best of our knowledge, curdionolide C, a novel N-containing germacrane-type sesquiterpene, has been isolated from natural sources for the first time.

N-Containing sesquiterpenes are quite rarely found in nature, however, **3**, the novel sesquiterpene compound, is very interesting with a view to its biosynthesis; we assume that the lactol O-atom of **1** may rather easily be replaced by a N-atom in plant tissue [14].

In addition to three new sesquiterpenes **1**–**3**, five known compounds, curdione (**4**) [15], (+)-(4*S*,5*S*)-germacrone-4,5-epoxide (**5**) [16], (+)-(1*S*,4*S*,5*S*,10*S*)-germacrone-1(10)-4-diepoxide (**6**) [17], (1*E*,4*E*,8*R*)-8-hydroxygermacra-1(10),4,7(11)-trieno-12,8-lactone (**7**) [10b], and (1*E*,4*Z*)-8-hydroxy-6-oxogermacra-1(10),4,7(11)-trieno-12,8-lactone [10a] (**8**) were also isolated and identified by comparison of their spectroscopic data with those reported in the literature.

Compounds **1**–**8** were examined for their inhibitory effects on NO production induced by LPS in macrophages (see *Table 3*). Cell viability in the present experiment

Table 3. *Inhibitory Effects of Compounds* **1**–**8** *on the NO production in* RAW 264.7 *Cells*[a])

Compound	Inhibitory rate on the NO production				IC_{50}[b]) [μM]
	Concentration [μM]				
	100	30	10	3	
1	2.8 ± 1.8	− 1.5 ± 2.0	3.2 ± 1.4	2.2 ± 0.8	> 100
2	17.2 ± 3.3	10.0 ± 1.7	8.6 ± 0.9	2.8 ± 3.5	> 100
3	30.9 ± 2.1	24.3 ± 2.1	15.7 ± 4.5	13.4 ± 2.6	> 100
4	75.5 ± 2.7	35.9 ± 2.0	21.8 ± 4.9	20.4 ± 1.2	54.9
5	14.9 ± 3.1	11.3 ± 1.2	7.6 ± 0.8	2.3 ± 1.5	> 100
6	81.3 ± 1.3	46.3 ± 4.4	34.9 ± 2.1	23.6 ± 3.7	37.4
7	83.6 ± 2.6	35.2 ± 3.7	35.8 ± 2.7	23.7 ± 2.9	51.4
8	50.7 ± 3.0	30.8 ± 3.6	23.7 ± 2.5	14.0 ± 3.0	98.7
Hydrocortisone	88.7 ± 4.4	32.9 ± 2.7	25.4 ± 3.6	18.7 ± 3.7	53.8

[a]) NO concentration of control group: 2.6 ± 0.6 μM, NO concentration of LPS-treated group: 27.6 ± 1.2 μM. [b]) Values are means of three experiments.

was determined by the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl-2*H*-tetrazolium bromide (MTT) method to find out whether inhibition of NO production was due to cytotoxicity of test compounds (data not shown). As shown in *Table 3*, hydrocortisone (IC_{50} 53.8 ± 4.84 µM) was used as a positive control. Compound **6** showed strong inhibition of NO production induced by LPS. Compounds **4** and **7** exhibited moderate activities, which were close to that of hydrocortisone. Compound **8** showed very weak activity.

Since NO is the relaxation factor of vascular smooth muscle and also an inhibitor of platelet aggregation in blood vessels [4], the inhibitory activity of these compounds against NO production may be important evidence substantiating the traditional effects of this herbal medicine for the treatment of the *Oketsu* syndrome caused by blood stagnation with inflammation.

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Experimental Part

General. All reagents were purchased from *Shenyang Chemical Company* (Shenyang, P. R. China). Column chromatography (CC): silica gel (SiO_2; 200–300 mesh, *Qingdao Marine Chemical Company*, Qingdao, P. R. China); *Sephadex LH-20* (*Amersham Co.*); *RP-18* gel (10–75 µm, *Merck Chemical Ltd.*). TLC: silica gel GF_{254} (SiO_2; 200–300 mesh, *Qingdao Marine Chemical Company*, Qingdao, P. R. China). Prep. HPLC (*Waters 600*, *ODS* column (*C-18*, 250 × 20 mm, *Inertsil Pak*)). Optical rotations: *Perkin-Elmer 241* polarimeter. UV Spectra: *Shimadzu UV2201* spectrophotometer, in MeOH. IR Spectra: *Bruker IFS 55* spectrometer. NMR Experiments: *Bruker ARX-300* and *600* spectrometers. ESI-MS: *Agilent 1100-LC/MSDTrapSL* mass spectrometer. HR-ESI-MS: *Bruker APEX II* mass spectrometer.

Plant Material. The dried rhizomes *C. wenyujin* (9 kg) were collected from Wenzhou, P. R. China in 2004. A voucher specimen was identified by Prof. *Qi-Shi Sun* (collection No. 20040919) and deposited with the Department of Natural Products Chemistry, Shenyang Pharmaceutical University, P. R. China.

Extraction and Isolation. The dried rhizomes of *C. wenyujin* (9 kg) were extracted with cyclohexane (3 × 20 l × 2 h) and filtered. The residue was then extracted with 50% EtOH (3 × 35 l × 2 h). The filtrate was partitioned successively with cyclohexane, AcOEt, and BuOH. The combined cyclohexane extract (55.0 g) was chromatographed on CC (SiO_2, 200–300 mesh, 500 g, 10 × 100 cm), using a gradient solvent system of cyclohexane/acetone 100:1 to 0:100 to yield twelve fractions (*Frs. 1–12*). *Fr. 5* (2.0 g) was subjected to *Sephadex LH-20* with $CHCl_3$/MeOH 1:1 to give four major sub-fractions (*Frs. 5.1–5.4*). *Fr. 5.2* (740.0 mg) was separated on an *ODS* column with MeOH/H_2O 1:9 to 10:0 to yield four fractions (*Frs. 5.2.1–5.2.4*). *Fr. 5.2.3* was purified by prep. HPLC with MeOH/H_2O 45:55 to yield compounds **1** (10.0 mg), **5** (23.0 mg), and **6** (15.0 mg). *Fr. 8* (2.5 g) was applied to *Sephadex LH-20* eluted with $CHCl_3$/MeOH 1:1 to afford three fractions (*Frs. 8.1–8.3*). *Fr. 8.1* (260 mg) was purified by HPLC (MeOH/H_2O 55:45) to give compounds **3** (63.2 mg) and **4** (56.9 mg). The AcOEt fraction (78.0 g) was chromatographed on CC (SiO_2; 200–300 mesh, 550 g, 10 × 110 cm), using a gradient solvent system of $CHCl_3$/MeOH (100:1 to 0:100), which yielded 19 fractions (*Frs. 1–19*). *Fr. 3* (3.8 g) was submitted to SiO_2 using $CHCl_3$/MeOH (100:1 to 0:100) to afford ten subfractions (*Frs. 3.1–3.10*). *Fr. 3.2* (370.0 mg) was subjected to a *Sephadex LH-20* ($CHCl_3$/MeOH 1:1) to yield three fractions (*Frs. 3.2.1–3.2.3*). *Fr. 3.2.2* (180.0 mg) was separated by HPLC with MeOH/H_2O (35:65) to afford compounds **7** (12.3 mg) and **8** (10.0 mg). The BuOH fraction (25.0 g) was chromatographed on *DA-201* eluted with a gradient of EtOH/H_2O (10:90 to 0:100) to yield five fractions (*Frs. 1–5*). *Fr. 4* (3.4 g) was applied to a *Sephadex LH-20* column eluted with MeOH/H_2O (1:1) to yield compound **2** (23.0 mg).

Bioassay for NO Production. Mouse monocyte-macrophage *RAW 264.7* cells (*ATCC TIB-71*) were purchased from the *Chinese Academy of Sciences. RPMI 1640* Medium, penicillin, streptomycin, and fetal bovine serum were purchased from *Invitrogen* (New York). Lipopolysaccharide (LPS),

dimethylsulfoxide (DMSO), 3-(4,5-dimethyl-2-thiazolyl)-2,5-diphenyl-2*H*-tetrazolium hydrobromide (MTT), and hydrocortisone were obtained from *Sigma Co. RAW 264.7* Cells were suspended in *RPMI 1640* medium supplemented with penicillin (100 U/ml), streptomycin (100 μg/ml), and 10% heat-inactivated fetal bovine serum. The cells were harvested with trypsin and diluted to a suspension in fresh medium. The cells were seeded in 96-well plates with 1×105 cells/well and allowed to adhere for 2 h at 37° in 5% CO_2 in air. Then, the cells were treated with 1 μg/ml of LPS for 24 h with or without various concentrations of test compounds. DMSO was used as a solvent for the test compounds, which were applied at a final concentration of 0.2% (*v*/*v*) in cell culture supernatants. NO Production was determined by measuring the accumulation of nitrite in the culture supernatant using the *Griess* reagent [18]. Briefly, 100 μl of the supernatant from the incubates was mixed with an equal volume of *Griess* reagent (0.1% *N*-(naphthalene-1-yl)ethane-1,2-diamine and 1% 4-aminobenzenesulfonamide in 5% H_3PO_4). Cytotoxicity was determined by the MTT colorimetric assay, after 24 h incubation with test compounds. The concentration of NO_2^- was calculated by a working line from 0, 3, 30, and 100 μM $NaNO_2$ solns., and the inhibitory rate on NO production induced by LPS was calculated by the NO_2^- levels as follows:

$$\text{Inhibitory rate [\%]} = 100 \times \frac{[NO_2^-]_{LPS} - [NO_2^-]_{LPS+sample}}{[NO_2^-]_{LPS} - [NO_2^-]_{untreated}}$$

Experiments were performed in triplicate, and data are expressed as the mean ±SD of three independent experiments.

Curdionolide A (=*(6*S*,9*E*,11a*R*)-7,8,11,11a-Tetrahydro-11a-hydroxy-3,6,10-trimethylcyclodeca[*b*]-furan-2,5(4*H*,6*H*)-dione*; **1**). Colorless oil (MeOH). $[\alpha]_D^{25} = +76.0$ ($c = 0.25$, MeOH). UV (MeOH): 224 (4.01). IR (CCl_4): 3365 (OH), 1741 (C=O), 1715 (C=O), 1672, 1105 (α,β-unsaturated γ-lactone). ^1H- and ^{13}C-NMR: *Tables 2* and *1*, resp. HR-ESI-MS: 265.1431 ($[M+H]^+$, $C_{15}H_{21}O_4^+$; calc. 265.1440).

Curdionolide B (=*(6*S*,9*E*,11a*R*)-7,8,11,11a-Tetrahydro-3,6,10-trimethylcyclodeca[*b*]furan-2,5(4*H*,6*H*)-dione*; **2**). Colorless oil (MeOH). $[\alpha]_D^{25} = +15.0$ ($c = 0.3$, MeOH). UV (MeOH): 224 (3.87). IR (KBr): 1741, 1675, 1105 (α,β-unsaturated γ-lactone), 1711 (C=O). ^1H- and ^{13}C-NMR: *Tables 2* and *1*, resp. HR-ESI-MS: 271.1303 ($[M+Na]^+$, $C_{15}H_{20}NaO_3^+$; calc. 271.1310).

Curdionolide C (=*(6*S*,9*E*,11a*R*)-7,8,11,11a-Tetrahydro-3,6,10-trimethyl-1*H*-cyclodeca[*b*]pyrrole-2,5(4*H*,6*H*)-dione*; **3**). Colorless oil (MeOH). $[\alpha]_D^{25} = -52.0$ ($c = 0.05$, MeOH). UV (MeOH): 224 (3.95). IR (KBr): 3162 (NH), 1732 (C=O), 1652 (C=O), 1452 (C−H). ^1H- and ^{13}C-NMR: *Tables 2* and *1*, resp. HR-ESI-MS: 270.1472 ($[M+Na]^+$, $C_{15}H_{21}NNaO_2^+$; calc. 270.1470).

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