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Diversity of Secondary Metabolites from Two Antarctic Microbes *Rhodococcus* sp. NJ-008 and *Pseudomonas* sp. NJ-011

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Abstract

Diversity analysis on secondary metabolites of Antarctic microbes, *Rhodococcus* sp. NJ-008 and *Pseudomonas* sp. NJ-011, together with the structural elucidation of some purified compounds, has been carried out for understanding of their chemical constituents. The methanol extracts of *Rhodococcus* sp. NJ-008 and *Pseudomonas* sp. NJ-011 were subjected to HPLC-TOF MS test for diversity analysis on secondary metabolites, respectively. The chemical constituents of NJ-011 are mainly N-containing compounds including some alkaloids and short polypeptides, while those of NJ-008 are not N-containing ones. Three compounds were also isolated and identified from extract of NJ-011 by different column chromatography and preparative HPLC, and their structures were elucidated as β-carboline (1), 3-benzylhexahydropyrrolo[1,2-a]pyrazine-1,4-dione (2) and 3-isobutylhexahydropyrrolo[1,2-a]pyrazine-1,4-dione (3) by comparison of TOF MS, ^{1}H- and ^{13}C-NMR data with those reported. More microbial material of *Pseudomonas* sp. NJ-011 should be needed for exploration of the minor constituents with complicated structures.

Keywords

Antarctic Microbes, *Rhodococcus* sp. NJ-008, *Pseudomonas* sp. NJ-011, Secondary Metabolite

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1. Introduction

Marine microbes from Antarctic area were well-known as bioactive compounds producers. In the past few years, some Chinese scientists have done fine chemical investigation from Antarctic fungui and led to the isolation of many interesting secondary metabolites, including new structures of two epipolythiodioxopiperazines and five diketopiperazines [1], two novel polyketides [2], six new peptaibols [3], together with some known aromatic phenols [4], anthraquinone derivatives and steroids [5]. During our first trip to Antarctic Ocean in 2010, some marine microbes associated with the Antarctic krill *Euphausia superba* had been obtained. Among these strains, *Rhodococcus* sp. NJ-008 was the only representative of *Rhodococcus* genus, while *Pseudomonas* sp. NJ-011 showed antimicrobial activity against *Staphylococcus aureus*. In the primary chemical investigation carried out for understanding the diversity of secondary metabolites from these Antarctic microbes, we found the methanol extracts of these two strains showed abundant & interesting ion peaks in HPLC-TOF MS tests. We herein report the diversity analysis on secondary metabolites of these two microbes, and the purification and structural elucidation of three compounds from *Pseudomonas* sp.NJ-011.

2. Experimental Section

2.1. General Procedures

All common solvents used were of anal. grade (Shanghai Chemical Plant). Solvents for HPLC and HPLC-TOF MS: Methanol and acetonitrile (Tedia, USA). Thin-layer chromatography (TLC): pre-coated silica gel GF254 plates (Qingdao Haiyang Chemical Co. Ltd.). Column chromatography (CC): HP-20 macroporos resin (Mitsubishi Chemical Industries Co., Ltd.) and Sephadex LH-20 (Pharmacia Biotech, Sweden). Semi-preparative HPLC was performed on a Shimadazu LC-20AT pump equipped with a Shimadazu SPD-M20A PDA detector and a YMC-Pack ODS-AQ column (250 × 10 mm, S-5 μm, 12 nm), flow rate: 2.5 mL·min^{-1}. NMR spectra were recorded on a Bruker AM-400 spectrometer; δ in ppm rel. to Me4Si, J in Hz. HR-ESI-MS were carried out on a Agilent 1290 HPLC-6224 TOF MS instrument; in m/z (rel. %).

2.2. Bacterial Source

Rhodococcus sp. NJ-008 and *Pseudomonas* sp. NJ-011 were isolated from the Antarctic krill *Euphausia superba*, collected in Jan 2010 in FAO 48.1 area, and were identified by Dr. Yang Qiao. The voucher specimens (No. DHS-NJ-008 and DHS-NJ-011) were deposited in East China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences.

2.3. Cultivation and Extraction

Rhodococcus sp. NJ-008 in 2.0 L R2A liquid medium was shared with three 2000 mL Erlenmeyer flasks, and the flasks were incubated on a rotary shaker at 150 rpm for 7 d (28˚C). *Pseudomonas* sp. NJ-011 in 2.0 L GAUZE's Medium NO.1 also in three 2000 mL flasks was incubated on the same rotary shaker as one batch culture.

Pseudomonas sp. NJ-011 in 8.0 L GAUZE's Medium NO.1 in twelve 2000 mL flasks was incubated on the same rotary shaker at 150 rpm for 7 d (28˚C) as another batch culture.

The culture broth (2 L) of *Rhodococcus* sp. NJ-008 (or *Pseudomonas* sp. NJ-011) was centrifuged at 4000 rpm. The bacterial cells were frozen at −78˚C for 3 h, and then were extracted with 100 mL acetone and 100 mL methanol, successively. The organic solutions were concentrated under reduced pressure to afford a residue. The supernatant was evaporated to a salty dryness in vacuum. And these two parts were combined in 100 mL methanol, taking 1.0 mL supernatant for HPLC-TOF MS tests.

The culture broth (8 L) of *Pseudomonas* sp. NJ-011was extracted with ethyl acetate (1500 mL) for three times, and the mixture was treated with ultrasonic cleaner for 30 min each time. The organic solutions were combined and concentrated under reduced pressure to afford a residue (1.4 g).

2.4. HPLC-TOF MS test

HPLC column: YMC ODS-AA12S03-L546WT (4.6 × 75 mm, S-5 μm, 12 nm); injection volume: 10 μL; flow rate: 0.5 mL·min^{-1}; mobile phase (CH_3CN in H_2O containing 0.1% HCOOH): 0 - 1.2 min 5%, 14 min 95%, 17 min 95%, 17.5 min 5%, 20 min 5%; TOF MS: positive ion mode ESI; gas temperature 340˚C, N_2 8.0 L·min^{-1},

nebulizer 40 psi. After test, the data of ion peaks with volume > 100,000 were extracted in TIC scan. Possible formula for each peak and the calculated exact mass for $[M + H]^+$ were given by DNP database and ChemBio Draw Ultra version 12.0, respectively.

2.5. Isolation

Total extract (1.3 g) from 8 L culture broth of *Pseudomonas* sp. NJ-011 was absorbed by HP-20 macroporos resin (600 mL), and eluted with H_2O (1500 mL) and methanol/H_2O (10:90, 1500 mL) to remove some salts, sugars, amino acids and proteins, and then eluted with methanol/H_2O (50:50 → 80:20 → 100:0, 2500 mL each)to afford three sections NJ-011-A (0.5 g), NJ-011-B (0.1 g) and NJ-011-C (0.4 g), successively. The section NJ-011-A was passed through a Sephadex LH-20 column, eluted with ethanol/H_2O (70:30), to yield three fractions A1 to A3. Finally, A1 were purified by repeated semi-preparative HPLC with mobile phase of CH_3CN/H_2O-0.1%TFA (25:75 → 70:30, 2.5 mL/min), and three compounds **1** (7.6 mg), **3** (2.3 mg), and **2** (3.5 mg) were obtained.

***β*-carboline (1):** positive ion mode ESI *m/z*: 169.0758 $[M + H]^+$; ^{1}H-NMR (CD_3OD, 400 MHz) *δ*: 8.80 (1H, *br s*), 8.28 (1H, *br s*), 8.20 (1H, *dt*, *J* = 1.0, 8.0 Hz), 8.10 (1H, *br d*, *J* = 5.5 Hz), 7.57 (1H, *m*), 7.56 (1H, *m*), 7.27 (1H, *ddd*, *J* = 3.1, 5.1, 8.0 Hz); ^{13}C-NMR (CD_3OD, 100 MHz) *δ*: 143.5, 138.8, 134.6, 130.9, 130.3, 123.3 (C × 2), 122.7, 121.4, 116.7, 113.3.

3-benzylhexahydropyrrolo[1,2-a]pyrazine-1,4-dione (2): positive ion mode ESI *m/z*: 245.1283 $[M + H]^+$; ^{1}H-NMR (CD_3OD, 400 MHz) *δ*: 7.28 (5H, *m*), 4.47 (1H, *s*), 4.08 (1H, *m*), 3.55 (1H, *m*), 3.39 (1H, *m*), 3.20 (2H, *m*), 2.11 (1H, *m*), 1.82 (2H, *m*), 1.34 (1H, *m*); ^{13}C-NMR (CD_3OD, 100 MHz) *δ*: 169.9, 166.0, 135.3, 129.9 (2C), 128.3 (2C), 127.1, 58.4, 57.7, 44.8, 39.6, 28.4, 21.1.

3-isobutylhexahydropyrrolo[1,2-a]pyrazine-1,4-dione (3): positive ion mode ESI *m/z*: 211.1438 $[M + H]^+$; ^{1}H-NMR (CD_3OD, 400 MHz) *δ*: 4.27 (1H, *m*), 4.14 (1H, *m*), 3.54 (2H, *m*), 2.63 (2H, *m*), 2.32 (1H, *m*), 2.02 (1H, *m*), 1.92 (1H, *m*), 1.67 (1H, *m*), 1.54 (1H, *m*), 0.99 (3H, *d*, *J* = 6.4 Hz), 0.98 (3H, *d*, *J* = 6.3 Hz); ^{13}C-NMR (CD_3OD, 100 MHz) *δ*: 171.4, 167.5, 58.8, 53.2, 45.0, 37.9, 27.7, 24.3, 22.2, 21.9, 20.8.

3. Results and Discussions

3.1. Diversity Analysis on Secondary Metabolites

By high-resolution HPLC-TOF MS spectra (**Table 1**) of methanol extract solution from *Rhodococcus* sp. NJ-008, 7 peaks were not given possible formula by DNP database, which may indicate the constituents with new structures. The possible formulae of 25 sample peaks were obtained among the total 32 observed peaks. Except for a plasticizer (Cpd**19**), the possible formulae indicated 13 - 15 compounds without nitrogen in their structures, and the other 9 - 11 were N-containing compounds. There were also 2S-containing metabolites, but no halogen-containing sample peaks were found by typical MS spectra. The relative contents (Vol%) of 14 sample peaks were higher than 2.0%, including 9 compounds not bearing N-atoms, 4 N-containing compounds, and another one without possible formula. So the chemical constituents of *Rhodococcus* sp. NJ-008 are mainly non-N-containing compounds, and the N-containing compounds showed a minor relative content.

The methanol extract solution of *Pseudomonas* sp. NJ-011 was also subjected to HPLC-TOF MS test. Among the total 53 observed peaks (**Table 2**), 10 peaks were not given possible formula by DNP database, which may indicate the constituents with new structures. The possible formulae of 43 sample peaks were obtained by high-resolution HPLC-TOF MS spectra, including 29 N-containing compounds, and the other 14 compounds without nitrogen in their structures. There were also 1 metabolite which was both S- and N-containing compound, and another compound might bear P-atom, but no halogen-containing sample peaks were found by typical MS spectra. Most sample peaks showed very low relative contents with their Vol% much less than 1.0%. Besides a plasticizer (Cpd**36**), there were only 10 sample peaks with Vol% higher than 2.0%, including 9 N-containing compounds and another one without possible formula. So the chemical constituents of *Pseudomonas* sp. NJ-011 are mainly N-containing compounds, including some alkaloids and short polypeptides.

3.2. Structural Elucidation

Three compounds were obtained from the high polarity extract section of *Pseudomonas* sp. NJ-011, by different column chromatography and repeated preparative HPLC, and their structures were elucidated by comparison of

Table 1. LC-TOF MS data of the NJ-008 methanol extract.

Cpd	Possible formula	Cacld. for $[M + H]^+$ (*m/z*)	Base peak (*m/z*)	RT (min)	Vol%
1	-[a]		132.04055	1.677	1.25
2	$C_4H_6O_2S_3$	182.9603	182.96213	1.679	1.81
3	-		223.98907	1.681	1.55
4	$C_8H_6O_3$	151.0390	151.03505	1.684	1.9
5	-		265.0155	1.686	1.01
6	$C_{26}H_{42}N_4O_4$	475.3279	475.32547	5.984	0.46
7	$C_{20}H_{36}O_4$	341.2686	341.26267	6.665	9.83
8	$C_{26}H_{47}NO_5$	454.3527	454.34701	7.044	4.62
9	$C_{29}H_{44}N_2O_2$	453.3476	453.3437	7.279	4.47
10	$C_{30}H_{55}N_5O_5$	566.4276	566.42768	7.298	1.01
11	$C_9H_{18}N_2O$	171.1492	171.14896	9.521	4.47
12	$C_{26}H_{43}NO_6$	466.3163	466.31663	10.182	0.28
13	-		199.18021	11.461	3.18
14	$C_{13}H_{24}N_2O$	225.1961	225.19591	12.309	0.99
15	$C_{19}H_{22}O$	267.1743	267.17183	15.316	0.45
16	$C_{19}H_{26}O_6$ or $C_{15}H_{30}N_2O_3S_2$	351.1802 351.1771	351.17785	15.513	0.18
17	$C_{20}H_{34}N_2O_6$ or $C_{25}H_{34}O_4$	399.2490 399.2530	399.25088	15.84	0.45
18	$C_{18}H_{35}NO$	282.2791	282.27894	15.985	0.79
19	plasticizer[b]		301.14378	16.339	0.67
20	$C_{23}H_{38}O_4$	379.2843	379.28203	16.381	3
21	$C_{18}H_{37}NO$	284.2948	284.29486	16.554	8.57
22	-		344.27943	16.716	1.03
23	$C_{21}H_{32}O_4$	349.2373	349.23495	16.735	0.83
24	$C_{24}H_{38}O_4$	391.2843	391.2845	17.96	4.64
25	-		280.26352	18.319	0.48
26	$C_{24}H_{40}O_4$	393.2999	393.29749	18.433	11.2
27	$C_6H_{10}O_4$	147.0652	147.06501	18.459	3.48
28	$C_{22}H_{42}O_4$	371.3156	371.31557	18.461	9.28
29	$C_6H_8O_3$	129.0546	129.05452	18.462	6.66
30	$C_{14}H_{26}O_4$	259.1904	259.19034	18.472	4.25
31	-		402.35806	18.479	1.03
32	$C_{46}H_{82}O_8$	763.6082	763.6059	18.521	6.2

[a]No possible formula given; [b]Ion peak of plasticizer dibutyl phthalate $[M + Na]^+$.

Table 2. LC-TOF MS data of the NJ-011 methanol extract.

Cpd	Possible formula	Cacld. for $[M + H]^+$ (*m/z*)	Base peak (*m/z*)	RT (min)	Vol%
1	$C_{10}H_{16}N_2O_2$	197.1285	197.1282	6.377	0.88
2	$C_{23}H_{33}NO$	340.2635	340.25938	6.596	16.15
3	$C_{28}H_{45}NO_7$	508.3269	508.32833	6.613	0.33
4	$C_{11}H_8N_2$	169.0760	169.07582	6.615	3.12
5	-		453.54518	7.025	0.36
6	$C_{29}H_{44}N_2O_2$	453.3476	453.34386	7.025	7.45
7	$C_{29}H_{44}N_2O_2$	453.3476	453.34377	7.261	6.12
8	$C_{30}H_{55}N_5O_5$	566.4276	566.42761	7.287	1.96
9	$C_{11}H_{18}N_2O_2$	211.1441	211.14378	7.465	0.63
10	$C_{14}H_{16}N_2O_2$	245.1285	245.12826	7.747	0.77
11	$C_9H_{18}N_2O$	171.1492	171.14889	9.449	7.17
12	$C_{31}H_{49}NO_4$	500.3734	500.37952	10.786	0.49
13	$C_{11}H_{19}NO$	182.1539	182.15379	11.277	0.91
14	-		199.1802	11.427	4.48
15	$C_{13}H_{24}N_2O$	225.1961	225.19595	12.289	1.75
16	$C_9H_{19}NO$	158.1539	158.15366	12.398	0.87
17	-		337.28505	12.648	1.13
18	$C_{12}H_{25}NO$	200.2009	200.20057	14.672	1.57
19	$C_{18}H_{33}NO$	280.2635	280.26367	14.954	0.77
20	$C_{39}H_{69}N_5O_9$	752.5168	752.51521	15.252	0.17
21	$C_{19}H_{22}O$	267.1743	267.17211	15.314	1.35
22	$C_{43}H_{65}NO_7$	708.4834	708.48923	15.355	0.37
23	-		664.46319	15.453	0.59
24	$C_{17}H_{28}O_6$	329.1959	329.19595	15.5	0.34
25	$C_{16}H_{24}O_5$	297.1697	297.16966	15.505	0.47
26	$C_{16}H_{33}NO$	256.2635	256.26346	15.527	3.05
27	-		620.43719	15.555	0.73
28	$C_{18}H_{33}NO_2$	296.2584	296.25842	15.591	3.05
29	-		576.41077	15.653	0.8
30	-		532.38476	15.748	0.77
31	-		488.35824	15.835	0.59
32	$C_{20}H_{34}N_2O_6$	399.2490	399.25077	15.835	0.87
33	-		444.33208	15.895	0.38
34	$C_{18}H_{35}NO$	282.2791	282.27922	16.023	9.17
35	$C_{18}H_{32}O_7$	361.2221	361.22235	16.158	0.15

Continued

36	plasticizer[a]		579.29763	16.374	6.77
37	$C_{30}H_{47}NO_3$	470.3629	470.3638	16.912	0.59
38	$C_{15}H_{32}N_4O_4$	333.2496	333.24722	17.503	0.3
39	$C_{11}H_{10}N_2O_3S$	251.0485	251.04837	17.614	1.87
40	$C_{18}H_{30}N_4O_8$	431.2136	431.21082	17.615	1.01
41	-		385.15449	17.616	0.64
42	$C_{25}H_{34}O_8$	463.2326	463.23608	17.617	0.35
43	$C_{23}H_{32}O_7$	421.2221	421.22551	17.618	0.55
44	$C_{24}H_{30}N_4O$	391.2492	391.25225	17.845	0.56
45	$C_{30}H_{40}O_3$	449.3050	449.30534	17.846	0.48
46	$C_{31}H_{38}O_3$ or $C_{24}H_{43}O_6P$	459.2894 459.2870	459.28978	17.848	0.37
47	$C_{24}H_{40}O_5$	409.2949	409.29372	17.926	0.6
48	$C_{24}H_{38}O_5$	407.2792	407.2777	18.149	0.67
49	$C_{31}H_{36}$	409.2890	409.29303	18.183	0.49
50	$C_{18}H_{36}N_6O_3$	385.2922	385.29356	18.301	0.41
51	$C_{18}H_{33}NO$	280.2635	280.26444	18.349	3.75
52	$C_{20}H_{36}O_4$	341.2686	341.26662	18.355	0.21
53	$C_{24}H_{38}O_5$	407.2792	407.27805	18.4	0.59

[a]Ion peak of plasticizer dibutyl phthalate $[2M + Na]^+$.

HPLC-TOF MS, ^{1}H- and ^{13}C-NMR data with those reported. Their structures were identified as *β*-carboline (**1**) [6], 3-benzylhexahydropyrrolo[1,2-a]pyrazine-1,4-dione (**2**, cyclo-(Pro-Phe)) [7], and 3-isobutylhexahydropyrrolo[1,2-a]pyrazine-1,4-dione (**3**, cyclo-(Pro-Leu)) [7]. These purified compounds were alkaloids or cyclic dipeptides of simple structures, and more microbial material of *Pseudomonas* sp. NJ-011 should be provided for exploration of the minor constituents with complicated structures.

4. Conclusion

Diversity analysis on secondary metabolites by HPLC-TOF MS tests exhibited that the chemical constituents of *Pseudomonas* sp. NJ-011 were mainly N-containing compounds including some alkaloids and short polypeptides, while those of *Rhodococcus* sp. NJ-008 were not N-containing ones. One alkaloid and two cyclic dipeptides were also isolated and identified from extract of *Pseudomonas* sp. NJ-011, which confirmed the chemical diversity analysis. There have been more than 200 compounds reported from the *Pseudomonas* genus, but only a small part of them were from marine derived *Pseudomonas* spp. Some known cyclic dipeptides [8] and two new *α*-pyrones [9] were reported recently, and more attention should be paid for chemical investigation on marine derived *Pseudomonas* spp.

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References

[1] Li, L.Y., Li, D.H., Luan, Y.P., Gu, Q.Q. and Zhu, T.J. (2012) Cytotoxic Metabolites from the Antarctic Psychrophilic Fungus *Oidiodendron truncatum*. *Journal of Natural Products*, **75**, 920-927. http://dx.doi.org/10.1021/np3000443

[2] Wu, G.W., Ma, H.Y., Zhu, T.J., Li, J., Gu, Q.Q. and Li, D.H. (2012) Penilactones A and B, Two Novel Polyketides from Antarctic Deep-Sea Derived Fungus *Penicillium crustosum* PRB-2. *Tetrahedron*, **68**, 9745-9749. http://dx.doi.org/10.1016/j.tet.2012.09.038

[3] Ren, J.W., Xue, C.M., Tian, L., Xu, M.J., Chen, J., Deng, Z.W., Proksch, P. and Lin, W.H. (2009) Asperelines A-F, Peptaibols from the Marine-Derived Fungus *Trichoderma asperellum*. *Journal of Natural Products*, **72**, 1036-1044.

[4] Ma, H.Y., Li, D.H., Gu, Q.Q. and Zhu, T.J. (2011) Bioactive Secondary Metabolites Produced by an Antarctic Marine-Derived Fungus *Penicillium chrysogenum* PR4-1-3. *Chinese Journal of Marine Drugs*, **30**, 18-24. http://dx.doi.org/10.1021/np900190w

[5] Ren, H., Cao, X.L. and Gu, Q.Q. (2010) Antitumor Metabolites from Marine-Derived Fungus *Gliocladium Catenulatum* T31. *Chinese Pharmaceutical Journal*, **45**, 1720-1723.

[6] Kearns, P.S. and Rideout, J.A. (2008) Nonsymmetrical β-Carbolinedimers from an Ascidian, *Didemnum* sp. *Journal of Natural Products*, **71**, 1280-1282. http://dx.doi.org/10.1021/np800077e

[7] Li, D.H., Gu, Q.Q., Zhu W.M., Liu, H.B., Fang, Y.C. and Zhu, T.J. (2005) Antitumor Components from Marine Actinomycete 11014 I: Cyclic Dipeptides. *Chinese Journal of Antibiotics*, **30**, 449-452.

[8] Qi, S.H., Qian, P.Y. and Zhang, S. (2009) Antibacterial Metabolites from Marine Bacterium *Pseudomonas* sp. *Natural Product Research and Development*, **21**, 420-423.

[9] Kong F.M., Singh, M.P. and Carter, G.T. (2005) Pseudopyronines A and B, α-Pyrones Produced by a Marine *Pseudomonas* sp. F92S91, and Evidence for the Conversion of 4-Hydroxy-α-pyrone to 3-Furanone. *Journal of Natural Products*, **68**, 920-923. http://dx.doi.org/10.1021/np050038v

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