

CHEMICAL CONSTITUENTS FROM *Rhododendron spinuliferum*

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Rhododendron spinuliferum Fr. is a member of the Ericaceae family, which is distributed mainly in southwestern China. *R. spinuliferum* is an evergreen shrub or tree. The dried stems, leaves, and flowers of this plant have been used as Chinese folk medicine for eliminating phlegm, relieving cough, and as an anti-asthmatic [1]. Up to now, no phytochemical investigation has been reported on this plant. In our studies of the chemical constituents of *R. spinuliferum*, 23 compounds were isolated and identified. All compounds were obtained from this plant for the first time.

Stems and barks of *R. spinuliferum* were collected in Yunnan Province in China in July, 2006. The plant material was identified by Prof. Huang Baokang and Zheng Hanchen, Department of Phytochemistry, Second Military Medical University. The air-dried and powdered aerial parts of *R. spinuliferum* (15 kg) were extracted with 95% EtOH (50 L) three times at room temperature. The extract was evaporated under *vacuo* to afford a residue extract (1.89 kg), which was partitioned with petroleum ether, CHCl₃, EtOAc, and *n*-BuOH successfully, yielding 190.2, 283.5, 40.5, and 470.2 g of extracts, respectively. These fractions were subjected to a series of chromatographic techniques, such as silica gel column (mesh 200–300), Sephadex LH-20, PTLC, and prep-HPLC, yielding compounds **1–23**.

The compounds were identified using UV, IR, mass, and NMR spectral data, and determined as ursolic acid (**1**), oleanolic acid (**2**), quercetin (**5**), catechin (**9**), epicatechin (**10**), and compounds **3**, **4**, **6–8**, **11–23** [2–16].

Umbelliferone (3), C₉H₆O₃, white powder, mp 225–227°C; ESI-MS: *m/z* 162 [M]⁺; ¹H NMR (500 MHz, DMSO-*d*₆, δ, ppm, J/Hz): 6.21 (1H, d, J = 9.0, H-3), 6.73 (1H, d, J = 2.0, H-8), 6.80 (1H, dd, J = 8.0, 2.0, H-6), 7.53 (1H, d, J = 8.0, H-5), 7.94 (1H, d, J = 9.0, H-4).

Scopoletin (4), C₁₀H₈O₄, colorless crystal, mp 206–207°C; ESI-MS: *m/z* 193 [M+H]⁺; ¹H NMR (500 MHz, CDCl₃, δ, ppm, J/Hz): 3.91 (3H, s, 6-OCH₃), 6.18 (1H, d, J = 9.0, H-3), 6.80 (1H, s, H-5), 7.19 (1H, s, H-8).

Taxifolin (6), C₉H₈O₃, yellow powder, mp 223–225°C; ESI-MS: *m/z* 321 [M+H]⁺; ¹H NMR (500 MHz, CD₃OD, δ, ppm, J/Hz): 4.54 (1H, d, J = 12.0, H-3), 4.93 (1H, d, J = 12.0, H-2), 5.96 (1H, d, J = 2.0, H-6), 5.99 (1H, d, J = 2.0, H-8), 6.80–6.97 (3H, m, H-2', 5', 6'); ¹³C NMR (125 MHz, CD₃OD, δ, ppm): 73.7 (C-3), 85.1 (C-2), 96.3 (C-8), 97.3 (C-6), 101.8 (C-10), 115.9 (C-5'), 116.7 (C-2'), 120.9 (C-6'), 129.8 (C-1'), 146.3 (C-3'), 147.1 (C-4'), 164.5 (C-9), 165.3 (C-5), 168.7 (C-7), 198.4 (C-4) [5].

Farrerol (7), C₁₆H₁₇O₅, yellow crystal, mp 314–315°C; ESI-MS: *m/z* 301 [M+H]⁺; ¹H NMR (500 Hz, CD₃OD, δ, ppm, J/Hz): 1.99 (3H, s, 6-CH₃), 2.01 (3H, s, 8-CH₃), 2.72 (1H, dd, J = 17.0, 3.0, H-3β), 3.07 (1H, dd, J = 17.0, 12.0, H-3α), 5.31 (1H, dd, J = 12.0, 2.0, H-2), 6.83 (2H, d, J = 8.0, H-3', 5'), 7.32 (2H, d, J = 8.0, H-2', 6'); ¹³C NMR (125 MHz, CD₃OD, δ, ppm): 7.4 (8-CH₃), 8.1 (6-CH₃), 44.1 (C-3), 80.1 (C-2), 103.3 (C-10), 104.1 (C-8), 116.3 (C-3', 5'), 128.8 (C-2', 6'), 131.6 (C-1'), 158.9 (C-4'), 159.3 (C-5), 164.1 (C-9), 158.8 (C-4'), 159.3 (C-5), 198.4 (C-4) [6].

(2s)-4',5,7-Trihydroxy-8-methylflavanone (8), C₁₆H₁₄O₅, yellow powder, mp 206–207°C; ESI-MS: *m/z* 287 [M+H]⁺; ¹H NMR (500 MHz, CD₃OD, δ, ppm, J/Hz): 1.96 (8-CH₃), 2.68 (2H, dd, J = 17.0, 3.0, H-3), 3.08 (1H, s, H-6), 5.42 (1H,

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d, J = 3.0, 12.0, H-2), 6.91 (2H, d, J = 8.0, H-3', 5'), 7.39 (2H, d, J = 8.0, H-2', 6'); ¹³C NMR (125 MHz, CD₃OD, δ, ppm): 7.7 (8-CH₃), 44.3 (C-3), 80.6 (C-2), 95.8 (C-6), 103.7 (C-10), 105.4 (C-8), 116.9 (C-3', 5'), 129.7 (C-2', 6'), 131.7 (C-1'), 159.4 (C-4'), 163.2 (C-5), 165.7 (C-7), 197.9 (C-4) [7].

Myricetin (11), C₉H₆O₃, yellow powder, mp 324–325°C; ESI-MS: *m/z* 319 [M+H]⁺; ¹H NMR (500 MHz, CD₃OD, δ, ppm, J/Hz): 6.17 (1H, d, J = 2.0, H-8), 6.37 (1H, d, J = 2.0, H-6), 7.41 (2H, s, H-2', 6').

Dihydromyricetin (12), C₉H₈O₃, yellow powder, mp 352–355°C; ESI-MS: *m/z* 321 [M+H]⁺; ¹H NMR (500 MHz, CD₃OD, δ, ppm, J/Hz): 4.54 (1H, d, J = 12.0, H-3), 4.93 (1H, d, J = 11.0, H-2), 6.58 (2H, s, H-2', 6'); ¹³C NMR (125 MHz, CD₃OD, δ, ppm): 73.6 (C-3), 85.2 (C-2), 96.3 (C-8), 97.3 (C-6), 101.8 (C-10), 107.7 (C-2'), 108.1 (C-6'), 129.1 (C-1'), 134.8 (C-4'), 146.8 (C-3', 5'), 164.4 (C-9), 165.2 (C-5), 168.6 (C-7), 198.2 (C-4) [9].

Kaempferol (13), C₁₅H₁₀O₆, yellow crystal, mp 224–227°C; ESI-MS: *m/z* 287 [M+H]⁺; ¹H NMR (500 MHz, CD₃OD, δ, ppm, J/Hz): 6.19 (1H, d, J = 2.0, H-6), 6.38 (1H, d, J = 2.0, H-8), 6.88 (1H, dd, J = 8.0, 2.0, H-3', 5'), 8.08 (1H, dd, J = 8.0, 2.0, H-2', 6').

Dihydrokaempferol (14), C₁₅H₁₂O₆, yellow crystal, mp 204–207°C; ESI-MS *m/z*: 288 [M+H]⁺; ¹H NMR (500 Hz, CD₃OD, δ, ppm, J/Hz): 4.54 (1H, d, J = 12.0, H-3), 4.98 (1H, d, J = 11.0, H-2), 5.87 (1H, d, J = 2.0, H-6), 5.93 (1H, d, J = 2.0, H-8), 6.84 (1H, d, J = 7.0, H-3', 5'), 7.36 (1H, d, J = 9.0, H-2', 6'); ¹³C NMR (125 MHz, CD₃OD, δ, ppm): 73.6 (C-3), 84.9 (C-2), 96.3 (C-8), 97.3 (C-6), 101.9 (C-10), 116.2 (C-3'), 116.1 (C-5'), 129.3 (C-1'), 130.4 (C-2'), 130.4 (C-6'), 159.2 (C-4'), 164.6 (C-9), 165.3 (C-5), 168.7 (C-7), 198.5 (C-4) [11].

Isorhamnetin (15), C₁₆H₁₂O₇, yellow crystal, mp 303–305°C; ESI-MS: *m/z* 317 [M+H]⁺; ¹H NMR (500 MHz, CD₃OD, δ, ppm, J/Hz): 3.94 (3H, s, 5'-OCH₃), 6.28 (1H, d, J = 2.0, H-6), 6.56 (1H, d, J = 2.0, H-8), 7.02 (1H, d, J = 8.0, H-2'), 7.83 (1H, d, J = 8.0, H-6').

Hirsutrin (16), C₂₁H₂₀O₁₂, yellow powder, mp 223–226°C; ESI-MS: *m/z* 465 [M+H]⁺; ¹H NMR (500 MHz, CD₃OD, δ, ppm, J/Hz): 3.04–3.48 (6H, m, Glc-H), 5.16 (1H, d, J = 8.0, Glc-1), 6.21 (1H, d, J = 2.0, H-6), 6.64 (1H, d, J = 2.0, H-8), 6.82 (1H, d, J = 9.0, H-5'), 7.54 (1H, dd, J = 8.0, 2.0, H-2'), 7.48 (1H, d, J = 2.0, H-6'); ¹³C NMR (125 MHz, CD₃OD, δ, ppm): 61.9 (C-6''), 70.1 (C-4''), 73.2 (C-2''), 75.1 (C-3''), 77.2 (C-5''), 94.7 (C-8), 99.9 (C-6), 104.4 (C-1''), 105.6 (C-10), 116.1 (C-5'), 117.8 (C-2'), 122.9 (C-6'), 122.8 (C-1'), 135.7 (C-3), 145.8 (C-4'), 149.9 (C-3'), 158.5 (C-9), 158.8 (C-2), 163.0 (C-5), 166.2 (C-7), 179.5 (C-4) [13].

Hyperin (17), C₂₁H₂₀O₁₂, yellow powder, mp 229–231°C; ESI-MS: *m/z* 465 [M+H]⁺; ¹H NMR (500 MHz CD₃OD, δ, ppm, J/Hz): 3.36–3.60 (6H, m, Gal-H), 5.38 (1H, d, J = 5.0, Gal-1), 6.22 (1H, d, J = 2.0, H-6), 6.40 (1H, d, J = 2.0, H-8), 6.80 (1H, d, J = 8.0, H-5'), 7.56 (1H, d, J = 2.0, H-2'), 7.46 (1H, dd, J = 8.0, 2.0, H-6'); ¹³C NMR (125 MHz, CD₃OD, δ): 59.8 (C-6''), 68.9 (C-4''), 72.3 (C-3''), 75.4 (C-5''), 93.6 (C-8), 99.6 (C-6), 105.4 (C-1''), 106.2 (C-10), 116.2 (C-5'), 117.8 (C-2'), 122.6 (C-6'), 121.9 (C-1'), 134.9 (C-3), 147.3 (C-4'), 150.2 (C-3'), 158.5 (C-9), 159.4 (C-2), 162.8 (C-5), 165.1 (C-7), 178.6 (C-4) [13].

Avicularin (18), C₂₀H₁₈O₁₁, yellow powder, mp 206–208°C; ESI-MS: *m/z* 435 [M+H]⁺; ¹H NMR (500 MHz, CD₃OD, δ, ppm, J/Hz): 3.21–3.62 (5H, m, Ara-H), 5.28 (1H, d, J = 5.0, Ara-1), 6.19 (1H, d, J = 2.0, H-6), 6.39 (1H, d, J = 2.0, H-8), 6.82 (1H, d, J = 8.0, H-5'), 7.51 (1H, d, J = 2.0, H-2'), 7.63 (1 H, dd, J = 8.0, 2.0, H-6'); ¹³C NMR (125 MHz, CD₃OD, δ, ppm): 66.9 (C-5''), 69.1 (C-4''), 72.9 (C-3''), 74.1 (C-2''), 94.7 (C-8), 99.9 (C-6), 104.5 (C-1''), 105.6 (C-10), 116.2 (C-5'), 117.5 (C-2'), 122.9 (C-1'), 123.1 (C-6'), 135.7 (C-3), 145.9 (C-3'), 149.9 (C-4'), 158.4 (C-2), 158.7 (C-9), 163.1 (C-5), 166.1 (C-7), 179.5 (C-4) [13].

Quercetin-3-O-α-D-arabinofuranoside (19), C₂₀H₁₈O₁₁, yellow powder, mp 248–250°C; ESI-MS: *m/z* 465 [M+H]⁺; ¹H NMR (500 MHz, CD₃OD, δ, ppm, J/Hz): 3.25–4.34 (5H, m, Ara-H), 5.46 (1H, s, Ara-1), 6.19 (1H, d, J = 2.0, H-6), 6.38 (1H, d, J = 2.0, H-8), 6.82 (2H, d, J = 8.0, H-3', 5'), 7.51 (1H, d, J = 9.0, H-2'), 7.63 (1H, d, J = 9.0, H-6'); ¹³C NMR (125 MHz, CD₃OD, δ, ppm): 62.6 (C-5''), 78.8 (C-3''), 83.3 (C-2''), 88.1 (C-4''), 94.9 (C-8), 100.0 (C-6), 105.6 (C-1''), 109.6 (C-10), 116.5 (C-5'), 116.9 (C-2'), 122.9 (C-1'), 123.1 (C-6'), 134.9 (C-3), 146.3 (C-3'), 149.9 (C-4'), 158.6 (C-2), 159.3 (C-9), 163.6 (C-5), 166.3 (C-7), 179.9 (C-4) [13].

Kaempferol-3-O-α-D-arabinopyranoside (20), C₂₀H₁₈O₁₀, yellow powder, mp 204–209°C; ESI-MS: *m/z* 419 [M+H]⁺; ¹H NMR (500 MHz, CD₃OD, δ, ppm, J/Hz): 3.11–3.78 (5H, m, Ara-H), 5.03 (1H, d, J = 8.0, Ara-1), 6.10 (1H, d, J = 2.0, H-6), 6.29 (1H, d, J = 2.0, H-8), 6.79 (1H, d, J = 8.0, H-3', 5'), 7.92 (1H, d, J = 8.0, H-2', 6'); ¹³C NMR (125 MHz, CD₃OD, δ, ppm): 67.0 (C-5''), 69.2 (C-4''), 73.0 (C-3''), 74.2 (C-2''), 95.2 (C-8), 100.4 (C-6), 104.7 (C-1''), 105.8 (C-10), 116.6 (C-3', 5'), 121.5 (C-1'), 122.9 (C-2', 6'), 132.7 (C-3), 158.4 (C-2), 159.2 (C-9), 161.1 (C-5), 165.8 (C-7), 179.5 (C-4) [14].

(2R,3R)-Taxifolin-3-O- α -D-arabinoside (21), C₂₀H₂₀O₁₁, yellow powder, mp 184–186°C; ESI-MS: *m/z* 437 [M+H]⁺; ¹H NMR (500 MHz, CD₃OD, δ , ppm, J/Hz): 3.36–3.92 (5H, m, Ara-H), 4.55 (1H, d, J = 6.0, Ara-1), 4.71 (1H, d, J = 11.0, H-2), 5.13 (1H, d, J = 11.0, H-3), 5.91 (1H, d, J = 2.0, H-8), 5.93 (1H, d, J = 2.0, H-6), 6.73 (1H, d, J = 8.0, H-5'), 6.85 (1H, dd, J = 12.0, 7.0, H-6'), 7.05 (1H, s, H-2'); ¹³C NMR (125 MHz, CD₃OD, δ , ppm): 63.5 (C-5''), 66.8 (C-4''), 71.1 (C-2''), 73.0 (C-3''), 76.2 (C-3), 82.9 (C-2), 96.4 (C-8), 97.2 (C-6), 101.8 (C-1''), 102.2 (C-10), 115.6 (C-2'), 116.2 (C-5'), 120.7 (C-6'), 128.9 (C-1'), 146.3 (C-3'), 146.4 (C-4'), 165.3 (C-9), 165.2 (C-5), 168.8 (C-7), 195.9 (C-4) [15].

(2S,3R)-Taxifolin-3-O- α -D-arabinoside (22), C₂₀H₂₀O₁₁, yellow powder, mp 180–182°C; ESI-MS: *m/z* 437 [M+H]⁺; ¹H NMR (500 MHz, CD₃OD, δ , ppm, J/Hz): 3.36–3.76 (5H, m, Ara-H), 4.15 (1H, d, J = 6.0, Ara-1), 5.87 (1H, s, H-6), 4.58 (1H, d, J = 3.0, H-3), 5.46 (1H, d, J = 3.0, H-2), 5.90 (1H, s, H-8), 6.74 (1H, d, J = 8.0, H-5'), 6.85 (1H, dd, J = 12.0, 7.0, H-6'), 6.99 (1H, s, H-2'); ¹³C NMR (125 MHz, CD₃OD, δ , ppm): 65.5 (C-5''), 68.4 (C-4''), 71.8 (C-2''), 73.6 (C-3''), 78.0 (C-3), 81.7 (C-2), 96.3 (C-8), 97.2 (C-6), 102.4 (C-1''), 103.9 (C-10), 115.8 (C-2'), 116.1 (C-5'), 120.2 (C-6'), 128.3 (C-1'), 146.2 (C-3'), 146.7 (C-4'), 164.1 (C-9), 165.7 (C-5), 168.7 (C-7), 194.6 (C-4) [16].

(2R,3S)-Taxifolin-3-O- α -D-arabinoside (23), C₂₀H₂₀O₁₁, yellow powder, mp 166–169°C; ESI-MS: *m/z* 437 [M+H]⁺; ¹H NMR (500 MHz, CD₃OD, δ , ppm, J/Hz): 3.38–3.76 (5H, m, Ara-H), 4.55 (1H, d, J = 6.0, Ara-1), 4.41 (1H, s, H-3), 5.36 (1H, s, H-2), 5.90 (1H, s, H-6), 5.93 (1H, s, H-8), 6.73 (1H, d, J = 8.0, H-5'), 6.85 (1H, dd, J = 12.0, 7.0, H-6'), 7.05 (1H, s, H-2'); ¹³C NMR (125 MHz, CD₃OD, δ , ppm): 65.9 (C-5''), 68.6 (C-4''), 71.9 (C-2''), 73.6 (C-3''), 76.6 (C-3), 81.9 (C-2), 96.3 (C-8), 97.2 (C-6), 102.8 (C-1''), 102.1 (C-10), 115.9 (C-2'), 116.2 (C-5'), 120.8 (C-6'), 128.3 (C-1'), 145.9 (C-3'), 146.5 (C-4'), 165.8 (C-9), 165.8 (C-5), 168.7 (C-7), 194.4 (C-4) [16].

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