

## · 基础研究 ·

连翘中具有抗菌活性的苯乙醇苷类化学成分研究<sup>△</sup>

姜醒, 鲁丽敏, 张春蕾, 王兴焱, 孙琦, 王佳天, 苑光军\*

(黑龙江中医药大学 佳木斯学院, 黑龙江 佳木斯 154007)

**[摘要]** **目的:** 研究连翘中具有抗菌活性的苯乙醇苷类化合物, 探讨连翘抗菌药效物质基础。**方法:** 采用有机溶剂提取药材, 不同极性有机溶剂萃取提取液, 抗菌活性跟踪结合各种色谱法, 获得活性化合物。与文献报道谱学数据对比确定化合物的结构。**结果:** 从该药材中分离获得9个化合物, 分别鉴定为6'-O-(顺式-1, 4-二羟基环己乙酰基)-类叶升麻苷(1), 4-O-鼠李糖基-7S, 8R-7', 8'-赤式-蒜芥茄脂素(2), 毛花球花苷 A (3), 黄花马缨丹苷 B (4), 石蚕苷 B (5), 紫茎女贞苷 J (6), 厚朴苷 F (7), 松果菊苷(8), 异厚叶车前苷(9)。化合物1、6、8对金黄色葡萄球菌(ATCC 33591)生长具有中等强度抑制作用, MIC值分别为8.0、16.0、4.0  $\mu\text{g} \cdot \text{mL}^{-1}$ 。**结论:** 8个苯乙醇苷类化合物(1, 3~9)和1个木脂素类化合物(2)系首次从该植物中获得。

**[关键词]** 连翘; 苯乙醇苷类化合物; 抗菌活性

Antibacterial Phenylethanoid Glycosides from Fruits of *Forsythia suspensa*

JIANG Xing, LU Limin, ZHANG Chunlei, WANG Xingyan, SUN Qi, WANG Jiatian, YUAN Guangjun\*

(Jiamusi College, Heilongjiang University of Chinese Medicine, Jiamusi 154007, China)

**[Abstract]** **Objective:** To Study on the antibacterial phenylethanoids from the fruits of *Forsythia suspensa*. **Methods:** The plant materials were extracted with organic solvent. The extract was extracted by different polarity organic solvents again. Compounds were obtained by comprehensive chromatography. The structures were identified by NMR. **Results:** Nine compounds were isolated and identified from the fruits of *F. suspensa*, including 6'-O-(cis-1, 4-dihydroxycyclohexanacetyl)-acteoside (1), 4-O-rhamnosyl-7S, 8R-7', 8'-erythro-sisymbriofolin (2), trichosantheside A (3), fucatoside B (4), poliumoside B (5), ligupurpurosides J (6), magnoside F (7), echinacoside (8), and isocrassifolioside (9). Compounds 1, 6, 8 showed antibacterial activity against *Staphylococcus aureus* with MICs of 8.0, 16.0 and 4.0  $\mu\text{g} \cdot \text{mL}^{-1}$ , respectively. **Conclusion:** Eight phenylethanoid glycosides (1, 3-9) and a neolignan (2) were obtained from the plant firstly.

**[Keywords]** *Forsythia suspensa*; phenylethanoid glycosides; antibacterial activity

doi:10.13313/j.issn.1673-4890.2017.5.010

连翘为木犀科(Oleaceae)植物连翘 *Forsythia suspensa*(Thunb.) Vahl 的干燥成熟果实, 又名落翘, 《中华人民共和国药典》2015版收载<sup>[1]</sup>。连翘在全国范围内均有种植, 野生多生于河边, 商品药材以野生为主, 有“老翘”、“青翘”之分。连翘主要分布于秦岭、太行山一带, 主产于陕、晋、川等地。其味苦, 性微寒, 归肺、心、小肠经, 具有清热解毒、消肿散结、疏散风热等功效, 可以与金银花、牡丹皮、栀子、大黄等多种中药配伍, 如复方银翘散、凉隔散等, 多数用于疮、痈、瘰疬、热毒的治疗, 为“疮家之圣药”。连翘中主要的成分为苯乙

烯及其苷类、黄酮类、香豆素类、酚酸类等多种成分, 具有很强的抗菌、抗炎、抗病毒等作用<sup>[2]</sup>。以往研究表明苯乙醇苷类是连翘主要的抗菌活性成分<sup>[3-4]</sup>, 已经作为先导化合物应用于寻找新药<sup>[5]</sup>。本文继续寻找连翘中具有抗菌活性的苯乙醇苷类化合物, 结果从该植物中首次分离得到9个苯乙醇苷类化合物并进行了抗菌活性研究。

## 1 仪器与材料

BRUKER AV500型核磁共振仪(德国布鲁克公司), 溶剂峰为内标; 岛津 LC-6AD(日本岛津公

<sup>△</sup> [基金项目] 黑龙江省自然基金项目(H201464)

\* [通信作者] 苑光军, 副教授, 研究方向: 中草药药效物质; Tel: (0554)6103868, E-mail: yuanguangjun@sina.com

司); 岛津 Shim-pack PREP-ODS 制备色谱柱(250 mm × 25 mm, 日本岛津公司); 所用试剂为色谱纯或分析纯。

金黄色葡萄球菌 ATCC 33591、ATCC 33591, 大肠埃希菌(ATCC 25922), 粪肠球菌(ATCC 29212), 购于中国医学科学院生物技术研究所。

样品于2013年6月购于河北省安国中药材集散中心, 经黑龙江中医药大学赵喜副教授鉴定为木犀科植物连翘 *Forsythia suspensa* (Thunb.) Vahl 的干燥成熟果实。

## 2 提取、分离

甲醇作为提取溶剂进行回流提取药材(8 kg), 提取物减压回收后分散于水中, 先后采用石油醚、乙酸乙酯和正丁醇进行萃取, 分别得到石油醚部分(300 g)、乙酸乙酯部分(500 g)、正丁醇部分(350 g)。其中, 乙酸乙酯部分在质量浓度为 100  $\mu\text{g} \cdot \text{mL}^{-1}$  时显示出抗菌活性; 因此, 选择硅胶柱色谱法对乙酸乙酯部分进行下一步分离, 洗脱剂采用三氯甲烷-甲醇溶剂系统(100:1 ~ 1:1), 极性由低到高进行梯度洗脱。在薄层色谱法的跟踪检测下, 共收集到了10个流分(Fr. 1 ~ Fr. 10)。Fr. 3部分(17.2 g), 先后采用硅胶柱色谱法和高效液相色谱法(反相柱: 流动相为乙腈-水溶剂系统)进行分离纯化, 分别得到化合物 **1** (10 mg) 和 **2** (5 mg)。Fr. 6部分(15 g)先后采用硅胶和高效液相色谱法进行分离纯化, 分别得到化合物 **3** (12 mg)、**4** (8 mg)、**5** (3 mg)。Fr. 7部分(20 g)先后采用硅胶和高效液相色谱法进行分离纯化, 分别得到化合物 **6** (353 mg)、**7** (206 mg) 和 **8** (62 mg)。Fr. 9部分(10 g)采用中压制备色谱和高效液相色谱法进行分离纯化, 得到化合物 **9** (8 mg)。

## 3 结构鉴定

化合物 **1**: 白色粉末。ESI-MS:  $m/z$  779  $[\text{M}-1]^-$ ;  $^1\text{H-NMR}$  ( $\text{CD}_3\text{OD}$ , 500 MHz)  $\delta$ : acetylcyclohexyl: 1.80 (2H, m, H-2, 6), 1.54 (2H, m, H-2, 6), 1.68 (4H, m, H-3, 5), 3.53 (1H, m, H-4), 2.49 (2H, s, H-7); glycosyl: 4.43 (1H, d,  $J=8.3$  Hz, H-1'), 3.44 (1H, m, H-2'), 3.86 (1H, t,  $J=9.0$  Hz, H-3'), 5.03 (1H, t,  $J=9.5$  Hz, H-4'), 3.77 (1H, m, H-5'), 4.24 (1H, dd,  $J=11.7, 2.7$  Hz, H-6'a), 4.15 (1H, dd,  $J=11.7,$

5.1 Hz, H-6' b); aglycone: 6.71 (1H, d,  $J=2.4$  Hz, H-2''), 6.70 (1H, d,  $J=8.3$  Hz, H-5''), 6.60 (1H, dd,  $J=8.3, 2.0$  Hz, H-6''), 3.99 (1H, m, H- $\alpha$ ), 3.74 (1H, m, H- $\alpha$ b), 2.83 (2H, m, H- $\beta$ ); caffeoyl: 7.09 (1H, d,  $J=1.9$  Hz, H-2'''), 6.81 (1H, d,  $J=8.3$  Hz, H-5'''), 6.99 (1H, dd,  $J=8.3, 1.9$  Hz, H-6'''), 6.31 (1H, d,  $J=16.1$  Hz, H- $\alpha$ ), 7.63 (1H, d,  $J=15.6$  Hz, H- $\beta$ ); rhamnosyl: 5.21 (1H, d,  $J=1.5$  Hz, H-1'''), 3.94 (1H, m, H-2'''), 3.59 (1H, m, H-3'''), 3.32 (1H, m, H-4'''), 3.61 (1H, d,  $J=2.9$  Hz, H-5'''), 1.13 (3H, d,  $J=6.4$  Hz, H-6''');  $^{13}\text{C-NMR}$  ( $\text{CD}_3\text{OD}$ , 125 MHz)  $\delta$ : acetylcyclohexyl: 70.6 (C-1), 36.1 (C-2, 6), 31.6 (C-3, 5), 70.7 (C-4), 48.5 (C-7), 172.7 (C-8); glycosyl: 104.4 (C-1'), 76.3 (C-2'), 81.5 (C-3'), 73.2 (C-4'), 73.9 (C-5'), 63.9 (C-6'); aglycone: 131.8 (C-1''), 117.4 (C-2''), 146.4 (C-3''), 145.1 (C-4''), 116.6 (C-5''), 121.5 (C-6''), 37.0 (C-7''), 72.8 (C-8''); caffeoyl: 127.9 (C-1'''), 115.6 (C-2'''), 147.2 (C-3'''), 150.3 (C-4'''), 116.8 (C-5'''), 123.5 (C-6'''), 148.4 (C-7'''), 114.9 (C-8'''), 168.3 (CO), 103.4 (C-1'''), 72.6 (C-2'''), 70.8 (C-3'''), 74.1 (C-4'''), 72.3 (C-5'''), 18.8 (C-6''')。以上核磁数据与文献报道的一致<sup>[6]</sup>, 所以化合物 **1** 鉴定为 6'-O-(*cis*-1, 4-dihydroxycyclohexanacetyl)-acteoside, 为首次从该植物中分离得到。

化合物 **2**: 白色粉末。ESI-MS:  $m/z$  537  $[\text{M}-1]^-$ ;  $^1\text{H-NMR}$  ( $\text{CD}_3\text{OD}$ , 500 MHz)  $\delta$ : 7.05 (1H, d,  $J=2.0$  Hz, H-2), 7.09 (1H, d,  $J=8.3$  Hz, H-5), 6.93 (1H, dd,  $J=8.3, 2.0$ , H-6), 5.62 (1H, d,  $J=5.9$  Hz, H-7), 3.49 (1H, m, H-8), 3.87 (1H, m, H-9a), 3.79 (1H, m, H-9b), 3.81 (3H, s, 3-OMe), 6.97 (1H, br s, H-2'), 6.91 (1H, br s, H-6'), 4.59 (1H, d,  $J=5.9$  Hz, H-7'), 3.69 (1H, m, H-8'), 3.55 (1H, dd,  $J=11.5, 4.2$  Hz, H-9'a), 3.40 (1H, dd,  $J=11.2, 6.4$  Hz, H-9'b), 3.91 (3H, s, 3'-OMe), 5.36 (1H, d,  $J=1.5$  Hz, H-1''), 4.08 (1H, dd,  $J=3.2, 1.7$  Hz, H-2''), 3.87 (1H, m, H-3''), 3.49 (1H, m, H-4''), 3.78 (1H, m, H-5''), 1.24 (3H, d,  $J=6.4$  Hz, H-6'');  $^{13}\text{C-NMR}$  ( $\text{CD}_3\text{OD}$ , 125 MHz)  $\delta$ : 138.9 (C-1), 111.6 (C-2), 152.4 (C-

3), 146.7 (C-4), 119.9 (C-5), 119.3 (C-6), 89.1 (C-7), 55.8 (C-8), 65.3 (C-7), 56.8 (3-OMe), 137.4 (C-1'), 112.9 (C-2'), 145.6 (C-3'), 149.3 (C-4'), 129.8 (C-5'), 116.9 (C-6'), 75.8 (C-7'), 77.7 (C-8'), 64.5 (C-9'), 57.1 (3'-OMe), 101.7 (C-1''), 72.3 (C-2''), 72.5 (C-3''), 74.1 (C-4''), 71.1 (C-5''), 18.3 (C-6'')。以上核磁数据与文献报道的一致<sup>[6]</sup>, 所以化合物**2**鉴定为4-*O*-rhamnosyl-7*S*, 8*R*-7', 8'-*erythro*-sisymbriofolin, 为首次从该植物中分离得到。

化合物**3**: 白色粉末。ESI-MS:  $m/z$  257 [M + 1]<sup>+</sup>; <sup>1</sup>H-NMR (CD<sub>3</sub>OD, 500 MHz)  $\delta$ : aglycon: 6.72 (1H, d,  $J=2.0$  Hz, H-2), 6.71 (1H, d,  $J=8.0$  Hz, H-5), 6.59 (1H, dd,  $J=8.0, 2.0$  Hz, H-6), 4.07 (1H, m, H- $\alpha$ a), 3.74 (1H, m, H- $\alpha$ b), 2.82 (1H, m, H- $\beta$ ); glucosyl: 4.41 (1H, d,  $J=7.9$  Hz, H-1'), 3.43 (1H, dd,  $J=7.9, 9.1$  Hz, H-2'), 3.87 (1H, t,  $J=9.1$  Hz, H-3'), 4.95 (1H, t,  $J=9.5$  Hz, H-4'), 3.55 (1H, m, H-5'), 3.70 (1H, H-6'a), 3.63 (1H, H-6'b); rhamnosyl: 5.27 (1H, d,  $J=1.7$  Hz, H-1''), 3.96 (1H, dd,  $J=1.7, 3.2$  Hz, H-2''), 3.79 (1H, dd,  $J=3.2, 9.5$  Hz, H-3''), 3.48 (1H, t,  $J=9.5$  Hz, H-4''), 3.66 (1H, H-5''), 1.18 (3H, d,  $J=6.2$  Hz, H-6''); xylopentaose: 4.41 (1H, d,  $J=7.7$  Hz, H-1'''), 3.04 (1H, dd,  $J=7.7, 9.0$  Hz, H-2'''), 3.26 (1H, t,  $J=9.0$  Hz, H-3'''), 3.39 (1H, m, H-4'''), 3.75 (1H, H-5'''a), 3.10 (1H, dd,  $J=11.2, 10.4$  Hz, H-5'''b); caffeoyl: 7.09 (1H, d,  $J=2.0$  Hz, H-2'''), 6.82 (1H, d,  $J=8.3$  Hz, H-5'''), 6.98 (1H, dd,  $J=8.3, 2.0$  Hz, H-6'''), 6.28 (1H, d,  $J=15.9$  Hz, H- $\alpha'$ ), 7.60 (1H, d,  $J=15.9$  Hz, H- $\beta'$ ); <sup>13</sup>C-NMR (CD<sub>3</sub>OD, 125 MHz)  $\delta$ : aglycon: 131.42 (C-1), 117.09 (C-2), 146.10 (C-3), 144.64 (C-4), 116.29 (C-5), 121.25 (C-5), 72.20 (C- $\alpha$ ), 36.54 (C- $\beta$ ); glucosyl: 104.15 (C-1'), 76.31 (C-2'), 80.64 (C-3'), 70.43 (C-4'), 75.92 (C-5'), 62.28 (C-6'); rhamnosyl: 102.35 (C-1''), 72.10 (C-2''), 72.27 (C-3''), 83.64 (C-4''), 68.70 (C-5''), 18.41 (C-6''); xylopentaose: 106.52 (C-1'''), 75.71 (C-2'''), 78.03 (C-3'''), 70.96 (C-4'''), 67.05 (C-5'''); caffeoyl: 127.65 (C-1'''), 115.36 (C-2'''), 146.75 (C-3'''),

149.76 (C-4'''), 116.52 (C-5'''), 123.37 (C-6'''), 114.55 (C- $\alpha'$ ), 148.20 (C- $\beta'$ ), 168.14 (C=O)。以上核磁数据与文献报道的一致<sup>[7]</sup>, 所以化合物**3**鉴定为 trichosanthoside A, 为首次从该植物中分离得到。

化合物**4**: 白色粉末。ESI-MS:  $m/z$  741 [M - 1]<sup>-</sup>; <sup>1</sup>H-NMR (CD<sub>3</sub>OD, 500 MHz)  $\delta$ : aglycon: 6.74 (1H, d,  $J=1.7$  Hz, H-2), 6.72 (1H, d,  $J=7.9$  Hz, H-5), 6.62 (1H, dd,  $J=7.9, 1.7$  Hz, H-6), 4.09 (1H, m, H- $\alpha$ a), 3.75 (1H, m, H- $\alpha$ b), 2.83 (2H, m, H- $\beta$ ); glucosyl: 4.55 (1H, d,  $J=7.6$  Hz, H-1'), 3.68 (1H, dd,  $J=7.6, 9.4$  Hz, H-2'), 3.93 (1H, t,  $J=9.4$  Hz, H-3'), 4.94 (1H, t,  $J=9.4$  Hz, H-4'), 3.60 (1H, m, H-5'), 3.61 (1H, dd,  $J=12.0, 5.0$  Hz, H-6'a), 3.75 (1H, dd,  $J=12.0, 3.8$  Hz, H-6'b); xylopentaose: 4.64 (1H, d,  $J=7.4$  Hz, H-1''), 3.26 (1H, dd,  $J=7.4, 8.9$  Hz, H-2''), 3.37 (1H, dd,  $J=8.9, 8.9$  Hz, H-3''), 3.58 (1H, m, H-4''), 3.20 (1H, dd,  $J=11.0, 2.5$  Hz, H-5''a), 3.91 (1H, dd,  $J=11.0, 5.0$  Hz, H-5''b); apiosyl: 5.34 (1H, d,  $J=3.2$  Hz, H-1'''), 3.99 (1H, d,  $J=3.2$  Hz, H-2'''), 3.77 (1H, d,  $J=9.8$  Hz, H-4''a), 4.14 (1H, d,  $J=9.8$  Hz, H-4''b), 3.53 (2H, br s, H-5'''); caffeoyl: 7.08 (1H, d,  $J=2.0$  Hz, H-2'''), 6.82 (1H, d,  $J=8.2$  Hz, H-5'''), 6.98 (1H, dd,  $J=8.2, 2.0$  Hz, H-6'''), 6.31 (1H, d,  $J=15.9$  Hz, H- $\alpha''$ ), 7.63 (1H, d,  $J=15.9$  Hz, H- $\beta''$ ); <sup>13</sup>C-NMR (CD<sub>3</sub>OD, 125 MHz)  $\delta$ : aglycon: 132.9 (C-1), 117.5 (C-2), 147.5 (C-3), 145.8 (C-4), 117.2 (C-5), 122.1 (C-6), 72.3 (C- $\alpha$ ), 36.2 (C- $\beta$ ); glucosyl: 103.5 (C-1'), 82.7 (C-2'), 83.6 (C-3'), 71.3 (C-4'), 76.0 (C-5'), 62.8 (C-6'); xylopentaose: 105.9 (C-1''), 76.2 (C-2''), 77.9 (C-3''), 71.5 (C-4''), 67.5 (C-5''); apiosyl: 112.3 (C-1'''), 78.8 (C-2'''), 81.8 (C-3'''), 75.2 (C-4'''), 65.6 (C-5'''); caffeoyl: 124.1 (C-1'''), 115.6 (C-2'''), 149.9 (C-3'''), 147.6 (C-4'''), 117.1 (C-5'''), 123.2 (C-6'''), 116.1 (C- $\alpha''$ ), 148.5 (C- $\beta''$ ), 169.2 (C=O)。以上核磁数据与文献报道的一致<sup>[8]</sup>, 所以化合物**4**鉴定为 fucatoside B, 为首次从该植物中分离得到。

化合物**5**: 白色粉末。ESI-MS:  $m/z$  925 [M +

Na]<sup>+</sup>; <sup>1</sup>H-NMR (CD<sub>3</sub>OD, 500 MHz) δ: caffeoyl: 7.06 (1H, s, H-2), 6.79 (1H, d, *J*=8.1 Hz, H-5), 6.96 (1H, dd, *J*=8.1, 1.2 Hz, H-6), 7.65 (1H, d, *J*=15.7 Hz, H-7), 6.29 (1H, d, *J*=15.7 Hz, H-8); phenylethylalcohol: 6.72 (1H, s, H-2), 6.68 (1H, d, *J*=8.0 Hz, H-5), 6.58 (1H, dd, *J*=1.2, 8.0 Hz, H-6), 3.99 (1H, m, H-αa), 3.75 (1H, m, H-αb), 2.81 (2H, m, H-β); glycosyl: 4.39 (1H, d, *J*=7.9 Hz, H-1'), 3.39 (1H, H-2'), 3.77 (1H, H-3'), 5.01 (1H, t, *J*=9.9 Hz, H-4'), 3.70 (1H, m, H-5'), 3.49 (1H, dd, *J*=11.4, 5.6 Hz, H-6'a), 3.77 (1H, H-6'b); rhamnosyl I: 4.63 (1H, d, *J*=1.4 Hz, H-1''), 3.85 (1H, H-2''), 3.69 (1H, H-3''), 3.37 (1H, H-4''), 3.61 (1H, H-5''), 1.22 (3H, d, *J*=6.1 Hz, H-6''); rhamnosyl II: 5.49 (1H, d, *J*=1.4 Hz, H-1'''), 3.96 (1H, dd, *J*=1.4, 3.2 Hz, H-2'''), 3.66 (1H, H-3'''), 3.29 (1H, t, *J*=8.6 Hz, H-4'''), 3.55 (1H, H-5'''), 1.08 (3H, d, *J*=6.1 Hz, H-6'''); arabinosyl: 4.31 (1H, d, *J*=7.3 Hz, H-1'''), 3.60 (1H, H-2'''), 3.51 (1H, H-3'''), 3.79 (1H, H-4'''), 3.55 (1H, H-5'''' a), 3.87 (1H, H-5'''' b); <sup>13</sup>C-NMR (CD<sub>3</sub>OD, 125 MHz) δ: caffeoyl: 127.7 (C-1), 115.1 (C-2), 147.2 (C-3), 150.1 (C-4), 116.4 (C-5), 123.1 (C-6), 147.9 (C-7), 114.5 (C-8), 167.7 (C-9); phenylethylalcohol: 131.3 (C-1), 117.0 (C-2), 147.1 (C-3), 144.9 (C-4), 116.3 (C-5), 121.1 (C-6), 72.8 (C-α), 36.5 (C-β); glycosyl: 104.2 (C-1'), 75.9 (C-2'), 82.2 (C-3'), 70.1 (C-4'), 74.5 (C-5'), 67.4 (C-6'); rhamnosyl I: 102.0 (C-1''), 71.8 (C-2''), 71.9 (C-3''), 73.9 (C-4''), 69.9 (C-5''), 17.9 (C-6''); rhamnosyl II: 101.8 (C-1'''), 82.8 (C-2'''), 72.1 (C-3'''), 73.9 (C-4'''), 70.3 (C-5'''), 18.5 (C-6'''); arabinosyl 107.3 (C-1'''), 72.6 (C-2'''), 74.2 (C-3'''), 69.8 (C-4'''), 67.3 (C-5'''). 以上核磁数据与文献报道的一致<sup>[9]</sup>, 所以化合物**5**鉴定为 poliumoside B, 为首次从该植物中分离得到。

化合物**6**: 白色粉末。ESI-MS: *m/z* 793 [M + Na]<sup>+</sup>; <sup>1</sup>H-NMR (MeOD, 500 MHz) δ: 6.68 (1H, d, *J*=2.0 Hz, H-2), 6.63 (1H, d, *J*=8.0 Hz, H-5), 6.55 (1H, dd, *J*=8.0, 2.0 Hz, H-6),

2.79 (2H, t, *J*=7.4 Hz, H-7), 3.96 (1H, m, H-8a), 3.74 (1H, m, H-8b), 4.34 (1H, d, *J*=8.0 Hz, H-1'), 3.32 (1H, m, H-2'), 3.51 (1H, m, H-3'), 3.42 (1H, m, *J*=9.9 Hz, H-4'), 3.55 (1H, m, H-5'), 4.50 (1H, dd, *J*=11.9, 1.7 Hz, H-6'a), 4.34 (1H, *J*=11.9, 6.2 Hz, H-6'b), 5.19 (1H, s, H-1''), 3.98 (1H, m, H-2''), 3.87 (1H, m, H-3''), 3.53 (1H, m, H-4''), 4.12 (1H, dd, *J*=9.5, 6.2 Hz, H-5''), 1.25 (3H, d, *J*=6.2 Hz, H-6''), 5.19 (1H, s, H-1'''), 3.88 (1H, m, H-2'''), 3.59 (1H, m, H-3'''), 3.41 (1H, m, H-4'''), 3.72 (1H, m, H-5'''), 1.29 (3H, d, *J*=6.2 Hz, H-6'''), 7.04 (1H, d, *J*=1.9 Hz, H-2'''), 6.79 (1H, d, *J*=8.3 Hz, H-5'''), 6.89 (1H, dd, *J*=8.3, 1.9 Hz, H-6'''), 7.57 (1H, d, *J*=15.9 Hz, H-7'''), 6.29 (1H, d, *J*=15.9 Hz, H-8'''); <sup>13</sup>C-NMR (MeOD, 125 MHz) δ: 131.4 (C-1), 117.3 (C-2), 144.7 (C-3), 146.4 (C-4), 116.7 (C-5), 121.3 (C-6), 36.8 (C-7), 72.6 (C-8), 104.7 (C-1'), 75.9 (C-2'), 83.6 (C-3'), 70.6 (C-4'), 75.5 (C-5'), 64.9 (C-6'), 103.3 (C-1''), 72.6 (C-2''), 73.1 (C-3''), 81.3 (C-4''), 68.5 (C-5''), 18.8 (C-6''), 102.5 (C-1'''), 73.2 (C-2'''), 72.5 (C-3'''), 73.9 (C-4'''), 70.6 (C-5'''), 17.9 (C-6'''), 127.9 (C-1'''), 115.4 (C-2'''), 146.9 (C-3'''), 149.8 (C-4'''), 116.4 (C-5'''), 123.5 (C-6'''), 147.4 (C-7'''), 115.0 (C-8'''), 169.3 (C-9'''). 以上核磁数据与文献报道的一致<sup>[10]</sup>, 所以化合物**6**鉴定为 ligupurpuroside J, 为首次从该植物中分离得到。

化合物**7**: 白色粉末。ESI-MS: *m/z* 785 [M - 1]<sup>-</sup>; <sup>1</sup>H-NMR (CD<sub>3</sub>OD, 500 MHz) δ: 7.31 (1H, d, *J*=1.8 Hz, H-2), 7.21 (1H, overlap, H-5), 6.82 (1H, dd, *J*=7.8, 1.2 Hz, H-6), 3.06 (2H, t, *J*=7.2 Hz, H-β), 4.39 (1H, m, H-αa), 3.82 (1H, dt, *J*=9.6, 7.8 Hz, H-αb), 5.46 (1H, d, *J*=7.8 Hz, H-1'), 4.20 (1H, dd, *J*=7.8, 2.4 Hz, H-2'), 5.19 (1H, t, *J*=2.4 Hz, H-3'), 5.51 (1H, dd, *J*=9.6, 2.4 Hz, H-4'), 4.86 (1H, ddd, *J*=9.6, 5.4, 1.8 Hz, H-5'), 4.59 (1H, overlap, H-6'a), 4.12 (1H, dd, *J*=11.4, 5.4 Hz, H-6'b); glucosyl: 4.98 (1H, d, *J*=7.8 Hz, H-1''), 4.06 (1H, dd, *J*=8.4, 7.8 Hz, H-2''), 4.25 (1H, dd,

$J = 9.6, 8.4$  Hz, H-3''), 4.27 (1H, dd,  $J = 9.6, 9.0$  Hz, H-4''), 3.94 (1H, m, H-5''), 4.53 (1H, dd,  $J = 11.4, 1.8$  Hz, H-6''a), 4.38 (1H, overlap, H-6''b); rhamnosyl: 5.68 (1H, br s, H-1'''), 4.57 (1H, overlap, H-2'''), 4.69 (1H, dd,  $J = 9.6, 3.0$  Hz, H-3'''), 4.33 (1H, t,  $J = 9.6$  Hz, H-4'''), 4.78 (1H, m, H-5'''), 1.70 (3H, d,  $J = 6.0$  Hz, H-6'''), 7.54 (1H, d,  $J = 1.2$  Hz, H-2'''), 7.21 (1H, overlap, H-5'''), 7.11 (1H, dd,  $J = 8.4, 1.2$  Hz, H-6'''), 7.97 (1H, d,  $J = 15.6$  Hz, H-7'''), 6.58 (1H, d,  $J = 15.6$  Hz, H-8''');  $^{13}\text{C-NMR}$  ( $\text{CD}_3\text{OD}$ , 125 MHz)  $\delta$ : 130.9 (C-1), 117.8 (C-2), 147.8 (C-3), 145.9 (C-4), 116.8 (C-5), 120.8 (C-6), 36.6 (C- $\beta$ ), 71.8 (C- $\alpha$ ); glucosyl: 100.5 (C-1'), 74.1 (C-2'), 65.6 (C-3'), 70.9 (C-4'), 72.1 (C-5'), 69.6 (C-6'), 105.8 (C-1''), 75.4 (C-2''), 78.4 (C-3''), 71.7 (C-4''), 78.6 (C-5''), 62.9 (C-6''); rhamnosyl: 97.8 (C-1'''), 72.6 (C-2'''), 72.8 (C-3'''), 74.3 (C-4'''), 69.9 (C-5'''), 18.8 (C-6'''), 126.9 (C-1'''), 116.1 (C-2'''), 147.0 (C-3'''), 150.8 (C-4'''), 116.8 (C-5'''), 122.3 (C-6'''), 146.7 (C-7'''), 114.8 (C-8'''), 166.9 (C-9'''). 以上核磁数据与文献报道的一致<sup>[11]</sup>, 所以化合物7被鉴定为 magnoloside F, 为首次从该植物中分离得到。

化合物8: 白色粉末。ESI-MS:  $m/z$  785 [ $\text{M}-1$ ] $^-$ ;  $^1\text{H-NMR}$  ( $\text{CD}_3\text{OD}$ , 500 MHz)  $\delta$ : aglycone: 6.73 (1H, d,  $J = 2.1$  Hz, H-2), 6.69 (1H, d,  $J = 8.0$  Hz, H-5), 6.58 (1H, dd,  $J = 8.0, 2.0$  Hz, H-6), 2.81 (2H, t,  $J = 7.4$  Hz, H-7), 4.04 (1H, m, H-8a), 3.75 (1H, m, H-8b); glucosyl (glc): 4.40 (1H, d,  $J = 7.9$  Hz, H-1'), 3.41 (1H, dd,  $J = 7.9, 9.2$  Hz, H-2'), 3.83 (1H, t,  $J = 9.2$  Hz, H-3'), 5.01 (1H, dd,  $J = 9.9, 9.3$  Hz, H-4'), 3.78 (1H, m, H-5'), 3.92 (1H, dd,  $J = 11.5, 2.5$  Hz, H-6'a), 3.66 (1H, m, H-6'b); rhamnosyl: 5.19 (1H, d,  $J = 1.8$  Hz, H-1''), 3.93 (1H, dd,  $J = 3.3, 1.8$  Hz, H-2''), 3.57 (1H, dd,  $J = 9.6, 3.3$  Hz, H-3''), 3.30 (1H, m, H-4''), 3.57 (1H, m, H-5''), 1.09 (3H, d,  $J = 6.2$  Hz, H-6''); caffeoyl: 6.28 (1H, d,  $J = 15.9$  Hz, H- $\alpha$ '''), 7.61 (1H, d,  $J = 15.9$  Hz, H- $\beta$ '''), 7.07 (1H, d,  $J = 2.1$  Hz, H-2'''), 6.79 (1H, d,  $J = 8.2$  Hz, H-

5'''), 6.98 (1H, dd,  $J = 8.3, 2.1$  Hz, H-6'''); 6'-O-glc: 4.34 (1H, d,  $J = 7.7$  Hz, H-1'''), 3.26 (1H, dd,  $J = 9.0, 7.8$  Hz, H-2'''), 3.48 (1H, m, H-3'''), 3.55 (1H, m, H-4'''), 3.34 (1H, m, H-5'''), 3.84 (2H, m, H-6''');  $4^{\text{Glc}}\text{-O-6'-O-glc}$ : 4.37 (1H, d,  $J = 7.9$  Hz, H-1'''), 3.23 (1H, dd,  $J = 8.9, 7.9$  Hz, H-2'''), 3.38 (1H, m, H-3'''), 3.35 (1H, m, H-4'''), 3.34 (1H, m, H-5'''), 3.86 (1H, m, H-6''')a), 3.68 (1H, m, H-6''')b);  $^{13}\text{C-NMR}$  ( $\text{CD}_3\text{OD}$ , 125 MHz)  $\delta$ : aglycone: 131.8 (C-1), 117.5 (C-2), 146.4 (C-3), 144.9 (C-4), 116.7 (C-5), 121.6 (C-6), 36.9 (C-7), 72.7 (C-8); glucosyl: 104.5 (C-1'), 76.4 (C-2'), 81.9 (C-3'), 71.1 (C-4'), 75.0 (C-5'), 69.8 (C-6'); rhamnosyl: 103.3 (C-1''), 72.6 (C-2''), 72.3 (C-3''), 74.1 (C-4''), 70.7 (C-5''), 18.6 (C-6''); caffeoyl: 114.9 (C- $\alpha$ '''), 148.5 (C- $\beta$ '''), 168.8 (C=O), 127.9 (C-1'''), 115.7 (C-2'''), 147.1 (C-3'''), 150.2 (C-4'''), 116.9 (C-5'''), 123.5 (C-6'''); 6'-O-Glc: 104.6 (C-1'''), 75.2 (C-2'''), 76.4 (C-3'''), 80.7 (C-4'''), 76.8 (C-5'''), 62.1 (C-6''');  $4^{\text{Glc}}\text{-O-6'-O-Glc}$ : 104.8 (C-1'''), 75.1 (C-2'''), 78.1 (C-3'''), 71.5 (C-4'''), 78.4 (C-5'''), 62.6 (C-6'''). 以上核磁数据与文献报道的一致<sup>[12]</sup>, 所以化合物8被鉴定为 echinacoside, 为首次从该植物中分离得到。

化合物9: 白色粉末。ESI-MS:  $m/z$  769 [ $\text{M}-1$ ] $^-$ ;  $^1\text{H-NMR}$  ( $\text{CD}_3\text{OD}$ , 500 MHz)  $\delta$ : aglycone: 6.69 (1H, d,  $J = 1.9$ , H-2), 6.64 (1H, d,  $J = 8.1$  Hz, H-5), 6.55 (1H, dd,  $J = 8.1, 1.9$  Hz, H-6), 2.81 (2H, m, H-7), 3.96 (1H, m, H-8a), 3.73 (1H, m, H-8b); caffeoyl: 7.04 (1H, d,  $J = 1.9$  Hz, H-2'), 6.79 (1H, d,  $J = 8.2$  Hz, H-5'), 6.88 (1H, dd,  $J = 8.2, 1.9$  Hz, H-6'), 7.58 (1H, d,  $J = 15.9$  Hz, H-7'), 6.29 (1H, d,  $J = 15.9$  Hz, H-8'); glucosyl: 4.46 (1H, d,  $J = 7.7$  Hz, H-1''), 3.47 (1H, dd,  $J = 8.9, 7.7$  Hz, H-2''), 3.62 (1H, dd,  $J = 8.9, 8.9$  Hz, H-3''), 3.46 (1H, H-4''), 3.54 (1H, H-5''), 4.52 (1H, dd,  $J = 11.7, 1.7$  Hz, H-6''a), 4.36 (1H, dd,  $J = 11.7, 5.9$  Hz, H-6''b); rhamnosyl-I: 4.95 (1H, brs, H-1'''), 3.91 (1H, H-2'''), 3.73 (1H, H-3'''), 3.43 (1H, H-4'''), 3.99 (1H, H-5'''), 1.21

(3H, d,  $J = 6.0$  Hz, H-6'''); rhamnosyl-II: 4.99 (1H, brs, H-1'''), 3.91 (1H, H-2'''), 3.74 (1H, H-3'''), 3.44 (1H, H-4'''), 3.99 (1H, H-5'''), 1.24 (3H, d,  $J = 6.0$  Hz, H-6''');  $^{13}\text{C-NMR}$  ( $\text{CD}_3\text{OD}$ , 125 MHz)  $\delta$ : aglycone: 131.3 (C-1), 117.3 (C-2), 146.2 (C-3), 144.9 (C-4), 116.8 (C-5), 121.5 (C-6), 36.8 (C-7), 72.6 (C-8); caffeoyl: 127.8 (C-1'), 115.4 (C-2'), 146.9 (C-3'), 149.7 (C-4'), 116.8 (C-5'), 123.4 (C-6'), 147.5 (C-7'), 115.1 (C-8'), 169.3 (C-9'); glucosyl: 102.9 (C-1''), 80.3 (C-2''), 87.4 (C-3''), 70.8 (C-4''), 75.4 (C-5''), 64.7 (C-6''); rhamnosyl-I: 103.9 (C-1'''), 72.6 (C-2'''), 72.5 (C-3'''), 74.1 (C-4'''), 70.9 (C-5'''), 18.0 (C-6'''); rhamnosyl-II: 103.1 (C-1'''), 72.6 (C-2'''), 72.4 (C-3'''), 73.7 (C-4'''), 70.3 (C-5'''), 18.2 (C-6'''). 以上核磁数据与文献报道的一致<sup>[13]</sup>, 所以化合物 **9** 被鉴定为 isocrassifolioside, 为首次从该植物分离得到。

#### 4 活性测定

采用二倍稀释法(将待测样品分别设定为 64、32、16.0、4.0、2.0  $\mu\text{g} \cdot \text{mL}^{-1}$ )对分离到的化合物分别进行金黄色葡萄球菌 ATCC 33591、ATCC 33591, 大肠埃希菌(ATCC 25922), 粪肠球菌(ATCC 29212)抑菌活性测试。结果表明化合物 **1**、**6**、**8** 对金黄色葡萄球菌(ATCC 33591)生长具有中等强度抑制作用, MIC 值分别为 8.0、16.0、4.0  $\mu\text{g} \cdot \text{mL}^{-1}$ 。

#### 5 讨论

本文报道从连翘干燥果实中分离鉴定了 9 个化合物, 均为首次从该植物中分离得到, 并发现其中的 3 个化合物具有抑制金黄色葡萄球菌(ATCC 33591)生长的作用。连翘具有清热解毒的功效, 已经制成包括双黄连在内的多种制剂。本文的研究成果进一步明确了连翘清热解毒的药效物质, 为该药的进一步开发奠定了理论基础。

#### 参考文献

- [1] 国家药典委员会. 中华人民共和国药典:一部[S]. 北京:中国医药科技出版社,2015:170-171.
- [2] 胡静,马琳,张坚,等. 连翘的研究进展[J]. 中南药学, 2012,10(10):760-764.
- [3] Ming D S, Yu D Q, Yu S S. Two new caffeoyl glycosides from *Forsythia suspensa*[J]. J Asian Nat Prod Res,1999,1(4):327-335.
- [4] Nishibe S, Okabe K, Tsukamoto H, et al. The structure of forsythiaside isolated from *Forsythia suspensa* [J]. Chem Pharm Bull,1982,30(3):1048-1050.
- [5] 吴培培,闫明,霍仕霞. 苯乙醇苷类化合物的研究进展[J]. 医药导报,2011,30(10):1316-1319.
- [6] Martin F, Hay A E, Cressend D, et al. Antioxidant phenylethanoid glycosides and a neolignan from *Jacaranda caucana*[J]. J Nat Prod,2009,72(5):852-856.
- [7] Ihsan Çalis, Hasan Kirmizibekmez, Heinz Rüeegger A, et al. Phenylethanoid glycosides from *Globularia trichosanthes*[J]. J Nat Prod,1999,62(8):1165-1168.
- [8] Julião L D S, Piccinelli A L, Marzocco S, et al. Phenylethanoid glycosides from *Lantana fucata* Lindl. with *in vitro* antiinflammatory activity [J]. J Nat Prod, 2009, 72 (8): 1424-1428.
- [9] Marino S D, Festa C, Zollo F, et al. Antioxidant activity of phenolic and phenylethanoid glycosides from *Teucrium polium* L. [J]. Food Chem,2012,133(1):21-28.
- [10] Fan L, Liao C H, Li S G, et al. Phenylethanoid and secoiridoid glycosides from the leaves of *Ligustrum purpurascens*[J]. Phytochem Lett,2015,13:177-181.
- [11] Xue Z, Yan R, Yang B. Phenylethanoid glycosides and phenolic glycosides from stem bark of *Magnolia officinalis*[J]. Phytochemistry,2016,127:50-62.
- [12] Porter E A, Kite G C, Veitch N C, et al. Phenylethanoid glycosides in tepals of *Magnolia salicifolia*, and their occurrence in flowers of Magnoliaceae[J]. Phytochemistry,2015, 117:185-193.
- [13] Phakeovilay C, Disadee W, Sahakitpichan P, et al. Phenylethanoid and flavone glycosides from *Ruellia tuberosa* L. [J]. J Nat Med,2013,67(1):228-233.

(收稿日期 2016-08-01)