

连翘的化学成分研究

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摘要: 目的 研究连翘 *Forsythia suspensa* 的化学成分及其体外抗肿瘤活性。方法 采用多种色谱技术进行分离纯化, 通过理化性质和波谱学手段 (NMR 和 MS) 鉴定化合物结构, 测试各化合物对 HepG-2 和 MCF-7 细胞的细胞毒性。结果 从连翘 75% 乙醇提取物中共分离鉴定出 26 个化合物, 分别为 2-(4-羟基苯基)乙基-6-O-[(4-羟基苯基)乙酰基]- β -D-吡喃葡萄糖苷 (1)、木通苯乙醇苷 B (2)、2-(4-羟基苯基)乙基-6-O-(E)-咖啡酰- β -D-吡喃葡萄糖苷 (3)、6'-O-香豆酰-1'-O-[2-(3,4-二羟基苯基)乙基]- β -D-吡喃葡萄糖苷 (4)、(+)-松脂素 (5)、8-羟基松脂素 (6)、松脂素-4-O- β -D-吡喃葡萄糖苷 (7)、(+)-表松脂素 (8)、(+)-1-羟基-2-表松脂素 (9)、连翘脂素 (10)、(+)-表松脂素-4'-O- β -D-吡喃葡萄糖苷 (11)、(+)-落叶松脂素 (12)、(-)-落叶松脂素 (13)、*rel*-(7*R*,8*R*,8*S*)-forsythialan C (14)、*rel*-(7*R*,8*R*,8*R*)-forsythialan C (15)、(7*S*,8*R*,8'*R*)-异落叶松脂素 (16)、罗汉松脂素 (17)、罗汉松脂素-4'-O- β -D-吡喃葡萄糖苷 (18)、(-)-甘密树皮素 B- β -D-吡喃葡萄糖苷 (19)、(7*R*,7'*R*,8*S*,8'*R*)-4,4'-二羟基-3,3'-二甲氧基-7,7'-环氧木脂素-4-O- β -D-吡喃葡萄糖苷 (20)、(7*R*,7'*R*,8*S*,8'*R*)-4,4'-二羟基-3,3'-二甲氧基-7,7'-环氧木脂素-4'-O- β -D-吡喃葡萄糖苷 (21)、10-O- β -D-桃金娘烯醇苷 (22)、neryl- β -D-glucopyranoside (23)、 α -松油醇-8-O- β -D-吡喃葡萄糖苷 (24)、连翘环己醇酮 (25) 和阿魏酸甲酯 (26)。结论 化合物 1、3、4 和 19~24、26 为首次从连翘属植物中分离得到。在 40 μ mol/L 浓度下化合物 5~18 对 HepG-2 和 MCF-7 细胞系具有一定的细胞毒性活性。

关键词: 连翘; 苯乙醇苷; 单萜苷; 木脂素; 抗肿瘤活性; 2-(4-羟基苯基)乙基-6-O-(E)-咖啡酰- β -D-吡喃葡萄糖苷; (+)-松脂素; 罗汉松脂素-4'-O- β -D-吡喃葡萄糖苷; α -松油醇-8-O- β -D-吡喃葡萄糖苷

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Study on chemical constituents from *Forsythia suspensa*

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Abstract: Objective To study the chemical constituents from Lianqiao [*Forsythia suspensa* (Thunb.) Vahl]. **Methods** The

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compounds were separated and purified by various chromatographic techniques, and their structures were identified by physical and chemical properties and spectroscopic methods (NMR and MS). The cytotoxicity of each compound on HepG-2 and MCF-7 cells was tested. **Results** A total of 26 compounds were isolated and identified as 2-(4-hydroxyphenyl)ethyl-6-*O*-[(4-hydroxyphenyl)acetyl]- β -*D*-glucopyranoside (**1**), calceolarioside B (**2**), 2-(4-hydroxyphenyl)ethyl-6-*O*-(*E*)-caffeoyl- β -*D*-glucopyranoside (**3**), 6'-*O*-coumaroyl-1'-*O*-[2-(3,4-dihydroxyphenyl) ethyl]- β -*D*-glucopyranoside (**4**), (+)-pinoresinol (**5**), 8-hydroxypinoresinol (**6**), pinoresinol-4-*O*- β -*D*-glucopyranoside (**7**), (+)-epipinoresinol (**8**), (+)-1-hydroxy-2-epipinoresinol (**9**), phillygenin (**10**), (+)-epipinoresinol-4'-*O*- β -*D*-glucopyranoside (**11**), (+)-lariciresinol (**12**), (-)-lariciresinol (**13**), *rel*-(7*R*,8*R*,8*S*)-forsythialan C (**14**), *rel*-(7*R*,8*R*,8*R*)-forsythialan C (**15**), (7'*S*,8*R*,8'*R*)-isolariciresinol (**16**), matairesinol (**17**), martairesinol-4'-*O*- β -*D*-glucopyranoside (**18**), (-)-nectandrin B- β -*D*-glucopyranoside (**19**), (7*R*,7'*R*,8*S*,8'*R*)-4,4'-dihydroxy-3,3'-dimethoxy-7,7'-epoxylignan-4-*O*- β -*D*-glucopyranoside (**20**), (7*R*,7'*R*,8*S*,8'*R*)-4,4'-dihydroxy-3,3'-dimethoxy-7,7'-epoxylignan-4'-*O*- β -*D*-glucopyranoside (**21**), myrtenyl-*O*- β -*D*-glucopyranoside (**22**), neryl- β -*D*-glucopyranoside (**23**), α -terpineol-8-*O*- β -*D*-glucopyranoside (**24**), renyolone (**25**) and methyl ferulate (**26**). **Conclusion** Compounds **1**, **3**, **4**, **19**—**24** and **26** are separated from the genus of *Forsythia* for the first time. All compounds are evaluated for cytotoxic activities against MCF-7 and HepG-2 cell lines by MTT assay, and the results showed that compounds **5**—**18** have potential inhibitory activity on MCF-7 and HepG-2 cell lines at 40 μ mol/L.

Key words: *Forsythia suspensa* (Thunb.) Vahl.; phenylethanol glycoside; monoterpene glycoside; lignan; antitumor activity; 2-(4-hydroxyphenyl)ethyl-6-*O*-(*E*)-caffeoyl- β -*D*-glucopyranoside; (+)-pinoresinol; martairesinol-4'-*O*- β -*D*-glucopyranoside; α -terpineol-8-*O*- β -*D*-glucopyranoside

连翘 *Forsythia suspensa* (Thunb.) Vahl. 为木犀科 (Oleaceae) 连翘属 *Forsythia* Vahl. 植物, 气微香, 味苦, 微寒。归小肠、心、肺经。古人称其为“疮家圣药”, 主要用于清热解毒, 消肿散结, 主治痈疽瘰疬, 乳痈丹毒等症^[1-2]。目前国内外学者从连翘中发现多种化学成分 (苯乙醇苷类、木脂素类、萜类黄酮类成分和其他类成分等) 和多种药理活性 (抗肿瘤、抗炎、抗病毒和抗氧化等)^[3]。研究表明, 连翘属植物具有较好的抗肿瘤活性, 但研究对象主要局限于其提取物^[4-8], 无法全面反映连翘属植物中各类化学成分的活性特点, 导致活性成分不够明确, 药效物质难以阐明。为进一步阐明中药连翘抗肿瘤的药效物质, 深入挖掘连翘中抗肿瘤活性成分, 本实验对连翘进行了系统的化学成分研究, 利用液液萃取方法和多种色谱手段 (硅胶柱色谱、开放 ODS 柱色谱和高效液相色谱等) 对连翘 75% 乙醇提取物进行分离, 基于理化性质和波谱学手段进行化学结构的鉴定。从连翘 75% 乙醇提取物中分离鉴定出 26 个化合物, 分别为 2-(4-羟基苯基)乙基-6-*O*-[(4-羟基苯基)乙酰基]- β -*D*-吡喃葡萄糖苷 (2-(4-hydroxyphenyl)ethyl-6-*O*-[(4-hydroxyphenyl) acetyl]- β -*D*-glucopyranoside, **1**)、木通苯乙醇苷 B (calceolarioside B, **2**)、2-(4-羟基苯基)乙基-6-*O*-(*E*)-咖啡酰- β -*D*-吡喃葡萄糖苷 [2-(4-hydroxyphenyl)ethyl-6-*O*-(*E*)-caffeoyl- β -*D*-glucopyranoside, **3**]、6'-*O*-香豆酰-1'-*O*-[2-(3,4-二羟基苯基)乙基]- β -*D*-吡喃葡

萄糖苷 (6'-*O*-coumaroyl-1'-*O*-[2-(3,4-dihydroxyphenyl)ethyl]- β -*D*-glucopyranoside, **4**)、(+)-松脂素 [(+)-pinoresinol, **5**]、8-羟基松脂素 (8-hydroxypinoresinol, **6**)、松脂素-4-*O*- β -*D*-吡喃葡萄糖苷 (pinoresinol-4-*O*- β -*D*-glucopyranoside, **7**)、(+)-表松脂素 [(+)-epipinoresinol, **8**]、(+)-1-羟基-2-表松脂素 [(+)-1-hydroxy-2-epipinoresinol, **9**]、连翘脂素 (phillygenin, **10**)、(+)-表松脂素-4'-*O*- β -*D*-吡喃葡萄糖苷 [(+)-epipinoresinol-4'-*O*- β -*D*-glucopyranoside, **11**]、(+)-落叶松脂素 [(+)-lariciresinol, **12**]、(-)-落叶松脂素 [(-)-lariciresinol, **13**]、*rel*-(7*R*,8*R*,8*S*)-forsythialan C (**14**)、*rel*-(7*R*,8*R*,8*R*)-forsythialan C (**15**)、(7'*S*,8*R*,8'*R*)-异落叶松脂素 [(7'*S*,8*R*,8'*R*)-isolariciresinol, **16**]、罗汉松脂素 (matairesinol, **17**)、罗汉松脂素-4'-*O*- β -*D*-吡喃葡萄糖苷 (martairesinol-4'-*O*- β -*D*-glucopyranoside, **18**)、(-)-甘密树皮素 B- β -*D*-吡喃葡萄糖苷 [(-)-nectandrin B- β -*D*-glucopyranoside, **19**]、(7*R*,7'*R*,8*S*,8'*R*)-4,4'-二羟基-3,3'-二甲氧基-7,7'-环氧木脂素-4-*O*- β -*D*-吡喃葡萄糖苷 [(7*R*,7'*R*,8*S*,8'*R*)-4,4'-dihydroxy-3,3'-di-methoxy-7,7'-epoxylignan-4-*O*- β -*D*-glucopyranoside, **20**]、(7*R*,7'*R*,8*S*,8'*R*)-4,4'-二羟基-3,3'-二甲氧基-7,7'-环氧木脂素-4'-*O*- β -*D*-吡喃葡萄糖苷 [(7*R*,7'*R*,8*S*,8'*R*)-4,4'-dihydroxy-3,3'-dimethoxy-7,7'-epoxylignan-4'-*O*- β -*D*-glucopyranoside, **21**]、10-*O*- β -*D*-桃金娘烯醇苷 (myrtenyl-*O*- β -*D*-

glucopyranoside, **22**)、neryl- β -D-glucopyranoside (**23**)、 α -松油醇-8-O- β -D-吡喃葡萄糖苷(α -terpineol-8-O- β -D-glucopyranoside, **24**)、连翘环己醇酮(rengyolone, **25**)和阿魏酸甲酯(methyl ferulate, **26**)。其中化合物**1**、**3**、**4**和**19**~**24**、**26**为首次从连翘属植物中分离得到。对分离得到的化合物进行了体外抗肿瘤活性测试,结果显示在40 μ mol/L浓度下化合物**5**~**18**对HepG-2和MCF-7细胞系具有一定的细胞毒性活性。

1 仪器与材料

Waters 2487 紫外检测器和 Waters 515 高效液相色谱仪(美国 Waters 公司), UPLC-Waters SYNG2SIHD TOF 超高效液相-高分辨飞行时间质谱(美国 Waters 公司), Bruker avance III600 核磁共振波谱仪(德国 Bruker 公司)和 P850 型旋光仪(中国济南海能仪器股份有限公司)。

柱色谱硅胶(100~200、200~300目)和薄层硅胶 GF₂₅₄(青岛海洋化工有限公司),聚酰胺(60~90目,江苏长丰化工有限公司),MCI GEL CHP20P 填料(日本三菱化学),开放柱 ODS 填料(日本三菱公司)和 YMC-Pack ODS-A 反相色谱柱(日本三菱公司)。

连翘药材采购于哈尔滨三棵树药材市场,经沈阳药科大学中药学院吕重宁副教授鉴定为木犀科连翘属植物连翘 *F. suspensa* (Thunb.) Vahl 的干燥果实。样品(FS-201909)保存于西南民族大学敬文园 B 栋 221 实验室。

2 提取与分离

75%乙醇水溶液超声提取连翘果实(11.8 kg),减压浓缩后,用水复溶,依次用氯仿、醋酸乙酯和正丁醇试剂按照1:1的比例进行萃取,得到氯仿层(650.9 g)、醋酸乙酯层(213.2 g)和正丁醇层(700.3 g)。对醋酸乙酯萃取层采用 HP20 色谱柱进行分离,流动相为体积分数10%、30%、50%、70%、90%甲醇水以及纯甲醇梯度洗脱,得到7个流分(E-1~E-7)。E-2 首先经硅胶柱色谱进行初步分离,二氯甲烷-甲醇(40:1、20:1、10:1、8:1、4:1、0:1)梯度洗脱,得到7个流分(E-2-1~E-2-7)。E-2-2 经凝胶柱色谱分离,纯甲醇等度洗脱,得到8个流分(E-2-2-1~E-2-2-8),对E-2-2-7采用 pHPLC 进行等度洗脱,流动相为55%甲醇水,得到化合物**22**(E-2-2-7-2-1, $t_R=60$ min, 10.5 mg)、**23**($t_R=62$ min, 7.2 mg)和**24**($t_R=62$ min, 5.9 mg); E-2-3 经凝胶

柱色谱分离,流动相依次为纯甲醇,洗脱7个保留体积,合并浓缩后得到5个流分(E-2-3-1~E-2-3-5),对E-2-3-4采用 pHPLC 进行等度洗脱,流动相为40%甲醇水,得到化合物**1**($t_R=30$ min, 15.8 mg)。E-2-4 经聚酰胺柱色谱分离,流动相二氯甲烷-甲醇(30:1、25:1、15:1、10:1、5:1、0:1)梯度洗脱,得到10个流分(E-2-4-1~E-2-4-10)。E-2-4-4 经硅胶柱色谱分离,二氯甲烷-甲醇-水(15:1:0.05、8:2:0.2、7:3:0.5)进行洗脱,得到3个流分(E-2-4-4-1~E-2-4-4-3)。对E-2-4-4-2采用 pHPLC 进行等度洗脱,流动相为38%甲醇水,得到化合物**7**($t_R=40$ min, 12.5 mg)、**11**($t_R=45$ min, 25.1 mg)、**18**($t_R=50$ min, 6.1 mg)。E-2-4-9, 经硅胶柱色谱分离,流动相为二氯甲烷:甲醇:水=15:1:0.05、8:2:0.2和7:3:0.5进行洗脱,得到4个流分(E-2-4-9-1~E-2-4-9-4),对E-2-4-9-3采用 pHPLC 进行等度洗脱,流动相为36%甲醇水,得到化合物**3**($t_R=51$ min, 15.1 mg)、**4**($t_R=52$ min, 10.2 mg); E-2-5 经聚酰胺柱色谱分离,流动相为二氯甲烷-甲醇(30:1、25:1、15:1、10:1、5:1、0:1)梯度洗脱,得到4个流分(E-2-5-1~E-2-5-4)。E-2-5-3 经硅胶柱色谱分离,流动相二氯甲烷-甲醇-水(15:1:0.05、8:2:0.2、7:3:0.5)洗脱,得到6个流分(E-2-5-3-1~E-2-5-3-6)。对E-2-5-3-4采用 pHPLC 进行等度洗脱,流动相为29%甲醇水,得到化合物**2**($t_R=37$ min, 13.4 mg)。E-7 首先经硅胶柱色谱进行初步的分离,开放柱流动相依次为二氯甲烷-甲醇(40:1、20:1、10:1、8:1、4:1、0:1)梯度洗脱,得到5个流分(E-7-1~E-7-5)。E-7-4 经聚酰胺柱色谱分离,流动相二氯甲烷-甲醇(30:1、25:1、15:1、10:1、5:1、0:1)梯度洗脱,得到6个流分(E-7-4-1~E-7-4-6)。E-7-4-5-6 通过 ODS 开放柱色谱,以甲醇-水(40%~100%)为流动相梯度洗脱,得到6个流分(E-7-4-5-6-1~E-7-4-5-6-5)。E-7-4-5-6-4 在经 pHPLC 进行等度洗脱,流动相为32%甲醇水,得到化合物**19**($t_R=19$ min, 7.2 mg)、**20**($t_R=23$ min, 15 mg)、**21**($t_R=26$ min, 20 mg)。

对氯仿萃取层采用 HP20 色谱柱进行分离,流动相依次为体积分数为30%~90%甲醇水以及纯甲醇,进行梯度洗脱,得到7个流分(D-1~D-7)。D-3 经硅胶柱色谱,流动相二氯甲烷-醋酸乙酯(40:1、30:1、20:1、15:1、10:1、2:1)梯

度洗脱, 得9个流分(D-3-1~D-3-9)。D-3-3通过Sephadex LH-20柱色谱分离, 流动相为纯甲醇, 得到5个流分(D-3-3-1~D-3-3-5), D-3-3-3通过pHPLC等度洗脱, 流动相为45%甲醇水, 得到化合物**5**($t_R=17$ min, 15.4 mg)、**17**($t_R=19$ min, 10.2 mg)、**8**($t_R=22$ min, 9.1 mg)、**12**($t_R=24$ min, 4.4 mg)和**10**($t_R=36$ min, 11.6 mg)。D-3-5通过pHPLC等度洗脱, 流动相为30%甲醇水, 得到化合物**9**($t_R=19$ min, 9 mg)、**6**($t_R=26$ min, 16.9 mg)和**13**($t_R=31$ min, 10 mg)。D-3-7通过ODS开放柱色谱, 以甲醇-水(40%~100%)为流动相梯度洗脱, 得到6个流分(D-3-7-1~D-3-7-6), D-3-7-2经pHPLC进行等度洗脱, 流动相为35%甲醇水, 得到化合物**14**($t_R=17$ min, 6.2 mg)、**15**($t_R=32$ min, 22.5 mg)和**16**($t_R=38$ min, 5.6 mg)。D-6经硅胶柱色谱进行初步的分离, 流动相二氯甲烷-醋酸乙酯(40:1、30:1、20:1、15:1、10:1、2:1)梯度洗脱, 得到7个流分(D-6-1~D-6-7)。D-6-2通过ODS开放柱色谱, 以甲醇-水(40%~100%)为流动相梯度洗脱, 得到5个流分(D-6-2-1~D-6-2-5), D-6-2-3在经pHPLC进行等度洗脱, 流动相为35%甲醇水, 得到化合物**26**($t_R=38$ min, 5.9 mg)。D-6-4经聚酰胺柱色谱分离, 流动相二氯甲烷-甲醇(40:1、25:1、15:1、10:1、4:1)梯度洗脱, 得到6个流分(D-6-4-1~D-6-4-6), D-6-4-4通过ODS开放柱色谱, 以甲醇-水(40%~100%)为流动相梯度洗脱, 得到6个流分(D-6-4-4-1~D-6-4-4-6)。D-6-6经聚酰胺柱色谱, 以二氯甲烷-甲醇(40:1、30:1、20:1、15:1、10:1、4:1)为流动相, 梯度洗脱得到5个流分(D-6-6-1~D-6-6-5), D-6-6-2通过ODS开放柱色谱以甲醇-水(40%~100%)为流动相梯度洗脱, 得到6个流分(D-6-6-2-1~D-6-6-2-6), D-6-6-2-4在经pHPLC进行等度洗脱, 流动相为37%甲醇水, 得到化合物**25**($t_R=35$ min, 4.1 mg)。

3 结构鉴定

化合物**1**: 白色无定形粉末(氯仿-甲醇)。ESI-MS m/z 457.146 8 $[M+Na]^+$ (Calcd. 457.146 8, $C_{22}H_{26}O_9Na$), 分子式为 $C_{22}H_{26}O_9$ 。 1H -NMR (600 MHz, DMSO- d_6) δ : 9.31 (1H, s, OH), 9.18 (1H, s, OH), 7.02 (2H, dd, $J=9.0, 2.0$ Hz, H-2), 6.67 (2H, dd, $J=9.0, 2.0$ Hz, H-3), 2.73 (2H, t, $J=6.7$ Hz, H-7), 3.78 (1H, td, $J=9.8, 8.1, 6.7$ Hz, H-8a), 3.58~3.56

(1H, m, H-8b), 4.19 (1H, d, $J=7.8$ Hz, H-1'), 2.97 (1H, t, $J=7.8$ Hz, H-2'), 3.18~3.13 (1H, m, H-3'), 3.06 (1H, t, $J=9.4$ Hz, H-4'), 3.33 (1H, dd, $J=11.8, 6.9, 2.0$ Hz, H-5'), 4.31 (1H, dd, $J=11.8, 2.0$ Hz, H-6'a), 4.05 (1H, dd, $J=11.8, 6.9$ Hz, H-6'b), 7.04 (2H, dd, $J=9.0, 2.0$ Hz, H-2''), 6.65 (2H, dd, $J=9.0, 2.0$ Hz, H-3''), 3.52 (2H, d, $J=2.5$ Hz, H-7''); ^{13}C -NMR (150 MHz, DMSO- d_6) δ : 129.1 (C-1), 130.2 (C-2), 115.6 (C-3), 156.1 (C-4), 115.6 (C-5), 130.2 (C-6), 35.3 (C-7), 70.5 (C-8), 103.3 (C-1'), 74.1 (C-2'), 76.9 (C-3'), 70.6 (C-4'), 73.8 (C-5'), 64.4 (C-6'), 124.8 (C-1''), 130.7 (C-2''), 115.5 (C-3''), 156.7 (C-4''), 115.5 (C-5''), 130.7 (C-6''), 40.0 (C-7''), 172.0 (C-8'')。以上数据与文献对照^[9], 鉴定化合物**1**为2-(4-hydroxyphenyl)ethyl-6-*O*-[(4-hydroxyphenyl)acetyl]- β -*D*-glucopyranoside。

化合物**2**: 棕色无定形粉末(氯仿-甲醇)。ESI-MS m/z 501.136 4 $[M+Na]^+$ (Calcd. 501.137 3, $C_{22}H_{26}O_{11}Na$), 分子式为 $C_{22}H_{26}O_{11}$ 。 1H -NMR (600 MHz, CD_3OD) δ : 6.67 (1H, d, $J=2.0$ Hz, H-2), 6.63 (1H, d, $J=8.0$ Hz, H-5), 6.53 (1H, dd, $J=8.0, 2.0$ Hz, H-6), 2.79~2.77 (2H, m, H-7), 3.97~3.95 (1H, m, H-8a), 3.71~3.69 (1H, m, H-8b), 4.32 (1H, d, $J=7.8, H-1'$), 3.22 (1H, t, $J=7.8$ Hz, H-2'), 3.38~3.36 (1H, m, H-3'), 3.37~3.35 (1H, m, H-4'), 3.52~3.50 (1H, m, H-5'), 4.50 (1H, dd, $J=11.9, 2.2$ Hz, H-6'a), 4.32 (1H, dd, $J=11.9, 6.0$ Hz, H-6'b), 7.03 (1H, d, $J=2.1$ Hz, H-2''), 6.77 (1H, d, $J=8.2$ Hz, H-5''), 6.88 (1H, dd, $J=8.2, 2.1$ Hz, H-6''), 7.56 (1H, d, $J=15.9$ Hz, H-7''), 6.28 (1H, d, $J=15.9$ Hz, H-8''); ^{13}C -NMR (150 MHz, CD_3OD) δ : 130.0 (C-1), 115.7 (C-2), 144.7 (C-3), 143.3 (C-4), 115.0 (C-5), 119.9 (C-6), 35.3 (C-7), 71.0 (C-8), 103.2 (C-1'), 73.7 (C-2'), 76.5 (C-3'), 70.3 (C-4'), 74.1 (C-5'), 63.2 (C-6'), 126.3 (C-1''), 113.6 (C-2''), 145.8 (C-3''), 148.3 (C-4''), 115.1 (C-5''), 121.8 (C-6''), 145.4 (C-7''), 113.4 (C-8''), 167.8 (C-9'')。以上数据与文献对照^[10], 鉴定化合物**2**为calceolarioside B。

化合物**3**: 淡黄色粉状物(氯仿-甲醇)。 1H -NMR (600 MHz, CD_3OD) δ : 4.33 (1H, d, $J=7.2$ Hz, H-1), 3.24 (1H, t, $J=8.2$ Hz, H-2), 3.39~3.38 (1H, m, H-3), 3.37~3.36 (1H, m, H-4), 3.54 (1H, ddd, $J=8.6, 6.1, 2.0$ Hz, H-5), 4.50 (1H, dd, $J=8.1, 2.0$ Hz, H-6a),

4.34~4.32 (1H, m, H-6b), 7.04 (1H, d, $J = 2.0$ Hz, H-2'), 6.78 (1H, d, $J = 8.4$ Hz, H-5'), 6.90 (1H, dd, $J = 8.4, 2.0$ Hz, H-6'), 7.57 (1H, d, $J = 15.9$ Hz, H-7'), 6.30 (1H, d, $J = 15.9$ Hz, H-8'), 7.03 (2H, d, $J = 8.0$ Hz, H-2'', 6''), 6.66 (2H, d, $J = 8.0$ Hz, H-3'', 5''), 2.84~2.82 (2H, m, H-7''), 3.95~3.94 (1H, m, H-8''a), 3.75~3.72 (1H, m, H-8''b); $^{13}\text{C-NMR}$ (150 MHz, CD_3OD) δ : 103.2 (C-1), 74.1 (C-2), 76.6 (C-3), 71.1 (C-4), 73.8 (C-5), 63.4 (C-6), 126.4 (C-1'), 115.2 (C-2'), 145.5 (C-3'), 148.4 (C-4'), 113.6 (C-5'), 121.9 (C-6'), 146.0 (C-7'), 113.8 (C-8'), 167.9 (C-9'), 129.3 (C-1''), 114.9 (C-2''), 129.5 (C-3''), 155.5 (C-4''), 129.6 (C-5''), 114.9 (C-6''), 35.2 (C-7''), 70.5 (C-8'')。以上数据与文献对照^[11], 鉴定化合物 **3** 为 2-(4-hydroxyphenyl)ethyl-6-*O*-(*E*)-caffeoyl- β -*D*-glucopyranoside。

化合物 **4**: 淡黄色粉状 (氯仿-甲醇)。 $^1\text{H-NMR}$ (600 MHz, CD_3OD) δ : 6.59 (1H, d, $J = 2.0$ Hz, H-2), 6.55 (1H, d, $J = 8.0$ Hz, H-5), 6.45 (1H, dd, $J = 8.0, 2.0$ Hz, H-6), 2.70 (2H, t, $J = 7.6$ Hz, H-7), 3.86 (1H, dt, $J = 9.9, 7.6$ Hz, H-8a), 3.63~3.62 (1H, m, H-8b), 4.25 (1H, d, $J = 7.7$ Hz, H-1'), 3.13 (1H, t, $J = 8.3$ Hz, H-2'), 3.32~3.31 (1H, m, H-3'), 3.27~3.26 (1H, m, H-4'), 3.43~3.42 (1H, m, H-5'), 4.42 (1H, dd, $J = 11.8, 2.2$ Hz, H-6'a), 4.23~4.22 (1H, m, H-6'b), 7.31 (2H, d, $J = 8.5$ Hz, H-2'', 6''), 6.71 (2H, d, $J = 8.5$ Hz, H-3'', 5''), 7.53 (1H, d, $J = 15.9$ Hz, H-7''), 6.25 (1H, d, $J = 15.9$ Hz, H-8''); $^{13}\text{C-NMR}$ (150 MHz, CD_3OD) δ : 130.1 (C-1), 115.8 (C-2), 143.4 (C-3), 145.6 (C-4), 113.6 (C-5), 119.9 (C-6), 35.4 (C-7), 71.2 (C-8), 103.3 (C-1'), 73.8 (C-2'), 76.6 (C-3'), 70.5 (C-4'), 74.1 (C-5'), 63.4 (C-6'), 125.8 (C-1''), 115.6 (C-2''), 129.9 (C-3''), 159.9 (C-4''), 129.9 (C-5''), 115.6 (C-6''), 144.8 (C-7''), 115.1 (C-8''), 167.9 (C-9'')。以上数据与文献对照^[12], 鉴定化合物 **4** 为 6'-*O*-coumaroyl-1'-*O*-[2-(3,4-dihydroxyphenyl)ethyl]- β -*D*-glucopyranoside。

化合物 **5**: 白色粉末 (氯仿-甲醇), $[\alpha]_{\text{D}}^{20} + 164.3$ (c 0.05, MeOH), ESI-MS m/z 357.134 6 $[\text{M}-\text{H}]^-$ (Calcd. 357.133 8, $\text{C}_{20}\text{H}_{21}\text{O}_6$), 分子式为 $\text{C}_{20}\text{H}_{22}\text{O}_6$ 。 $^1\text{H-NMR}$ (600 MHz, $\text{DMSO}-d_6$) δ : 6.90 (2H, d, $J = 8.4$ Hz, H-2, 2'), 6.74 (2H, d, $J = 1.8$ Hz, H-5, 5'), 6.76 (2H, dd, $J = 8.4, 1.8$ Hz, H-6, 6'), 4.62 (2H, d, $J = 4.3$ Hz, H-7, 7'), 3.06~3.01 (2H, m, H-8, 8'), 3.73 (2H,

dd, $J = 3.7, 3.2$ Hz, H-9, 9'), 3.77 (12H, s, $4 \times \text{OCH}_3$); $^{13}\text{C-NMR}$ (150 MHz, $\text{DMSO}-d_6$) δ : 132.8 (C-1, 2'), 111.0 (C-2, 2'), 148.1 (C-3, 3'), 146.5 (C-4, 4'), 115.7 (C-5, 5'), 119.2 (C-6, 6'), 85.7 (C-7, 7'), 56.2 (C-8, 8'), 71.5 (C-9, 9'), 54.2 ($2 \times \text{OCH}_3$)。以上数据与文献对照^[13], 鉴定化合物 **5** 为 (+)-pinoresinol。

化合物 **6**: 黄色油状物 (氯仿-甲醇), ESI-MS m/z 373.129 6 $[\text{M}-\text{H}]^-$ (Calcd. 373.128 7, $\text{C}_{20}\text{H}_{21}\text{O}_7$), 分子式为 $\text{C}_{20}\text{H}_{22}\text{O}_7$ 。 $^1\text{H-NMR}$ (600 MHz, CD_3OD) δ : 7.05 (1H, d, $J = 8.0$ Hz, H-2), 6.85 (1H, d, $J = 1.9$ Hz, H-5), 6.86 (1H, dd, $J = 8.0, 1.9$ Hz, H-6), 4.68 (1H, brs, H-7), 3.87 (1H, m, H-9a), 3.76 (2H, dd, $J = 9.1, 6.2$ Hz, H-9b), 6.88 (1H, d, $J = 2.0$ Hz, H-2'), 6.73 (1H, d, $J = 8.1$ Hz, H-5'), 6.79 (1H, dd, $J = 8.1, 2.0$ Hz, H-6'), 4.87 (1H, d, $J = 5.2$ Hz, H-7'), 4.04 (1H, d, $J = 9.3$ Hz, H-9'a), 4.46 (1H, dd, $J = 9.3, 8.2$ Hz, H-9'b), 3.02~3.05 (1H, m, H-8'), 3.87 (3H, s, $-\text{OCH}_3$), 3.86 (3H, s, $-\text{OCH}_3$); $^{13}\text{C-NMR}$ (150 MHz, $\text{DMSO}-d_6$) δ : 132.3 (C-1), 111.4 (C-2), 147.5 (C-3), 146.2 (C-4), 115.0 (C-5), 120.3 (C-6), 88.0 (C-7), 91.5 (C-8), 74.8 (C-9), 127.9 (C-1'), 110.0 (C-2'), 147.4 (C-3'), 146.1 (C-4'), 114.7 (C-5'), 119.2 (C-6'), 86.5 (C-7'), 61.1 (C-8'), 70.7 (C-9'), 55.1 ($-\text{OCH}_3$), 55.0 ($-\text{OCH}_3$)。以上数据与文献对照^[14], 鉴定化合物 **6** 为 8-hydroxypinoresinol。

化合物 **7**: 黄色胶体 (氯仿-甲醇), ESI-MS m/z 543.183 4 $[\text{M}+\text{Na}]^+$ (Calcd. 543.184 2, $\text{C}_{26}\text{H}_{32}\text{O}_{11}\text{Na}$), 分子式为 $\text{C}_{26}\text{H}_{32}\text{O}_{11}$ 。 $^1\text{H-NMR}$ (600 MHz, CD_3OD) δ : 6.94 (1H, d, $J = 1.9$ Hz, H-2), 6.76 (1H, d, $J = 8.1$ Hz, H-5), 6.80 (1H, dd, $J = 8.1, 1.9$ Hz, H-6), 4.70 (1H, d, $J = 4.2$ Hz, H-7), 3.14~3.12 (1H, m, H-8), 4.24~4.22 (1H, m, H-9a), 3.86~3.85 (1H, m, H-9b), 7.02 (1H, d, $J = 2.1$ Hz, H-2'), 7.14 (1H, d, $J = 8.3$ Hz, H-5'), 6.91 (1H, dd, $J = 8.3, 2.1$ Hz, H-6'), 4.75 (1H, d, $J = 4.0$ Hz, H-7'), 3.15~3.13 (1H, m, H-8'), 4.23~4.21 (1H, m, H-9'a), 3.85~3.84 (1H, m, H-9'b), 4.88 (1H, d, $J = 8.0$ Hz, H-1''), 3.40~3.38 (1H, m, H-2''), 3.47~4.45 (1H, m, H-3''), 3.39~3.37 (1H, m, H-4''), 3.52~3.47 (1H, m, H-5''), 3.34 (1H, m, H-6''b), 3.68 (1H, dd, $J = 11.9, 3.6$ Hz, H-6''a), 3.86 (3H, s, $-\text{OCH}_3$), 3.85 (3H, s, $-\text{OCH}_3$); $^{13}\text{C-NMR}$ (150 MHz, CD_3OD) δ : 136.1 (C-1), 110.2 (C-2), 149.6 (C-3), 146.1 (C-4), 116.6 (C-5), 118.4 (C-6), 85.7 (C-7), 54.1

(C-8), 71.3 (C-9), 132.4 (C-1'), 109.6 (C-2'), 147.7 (C-3'), 145.9 (C-4'), 114.7 (C-5'), 118.7 (C-6'), 86.1 (C-7'), 54.0 (C-8'), 71.3 (C-9'), 101.4 (C-1''), 73.5 (C-2''), 76.4 (C-3''), 69.9 (C-4''), 76.8 (C-5''), 61.1 (C-6''), 55.3 (-OCH₃), 55.0 (-OCH₃)。以上数据与文献对照^[15], 鉴定化合物 **7** 为 pinoresinol-4-*O*-β-*D*-glucopyranoside。

化合物 **8**: 白色粉末 (氯仿-甲醇)。[α]_D²⁰ +32 (c 0.05, MeOH); ¹H-NMR (600 MHz, CD₃OD) δ: 6.83 (1H, d, *J* = 1.7 Hz, H-2), 6.81 (1H, d, *J* = 7.2 Hz, H-5), 6.96 (1H, dd, *J* = 7.2, 1.7 Hz, H-6), 4.42 (1H, d, *J* = 6.9 Hz, 1H, H-7), 4.10 (1H, dd, *J* = 8.4, 1.3 Hz, H-9), 6.77 (1H, d, *J* = 1.8 Hz, H-2'), 6.79 (1H, d, *J* = 7.2 Hz, H-5'), 6.80 (1H, dd, *J* = 7.2, 1.8 Hz, H-6'), 4.86 (1H, d, *J* = 6.1 Hz, H-7'), 2.93~2.92 (1H, m, H-8'), 3.78~3.76 (1H, m, H-9a'), 3.36~3.34 (1H, m, H-9b'), 3.86 (3H, s, -OCH₃), 3.86 (3H, s, -OCH₃); ¹³C-NMR (150 MHz, CD₃OD) δ: 132.5 (C-1), 109.6 (C-2), 147.9 (C-3), 145.4 (C-4), 114.8 (C-5), 118.9 (C-6), 88.2 (C-7), 54.3 (C-8), 70.7 (C-9), 130.0 (C-1'), 109.2 (C-2'), 147.6 (C-3'), 146.3 (C-4'), 114.8 (C-5'), 118.1 (C-6'), 82.2 (C-7'), 50.0 (C-8'), 70.7 (C-9'), 55.1 (-OCH₃), 55.0 (-OCH₃)。以上数据与文献对照^[16], 鉴定化合物 **8** 为 (+)-epipinoresinol。

化合物 **9**: 黄色油状物 (氯仿-甲醇), [α]_D²⁰ +68.7 (c 0.05, CD₃OD), ESI-MS *m/z* 373.129 8 [M-H]⁻ (Calcd. 373.128 7, C₂₀H₂₁O₇), 分子式为 C₂₀H₂₂O₇。 ¹H-NMR (600 MHz, CD₃OD) δ: 4.39 (1H, brs, H-2), 5.17 (1H, d, *J* = 5.2 Hz, H-3), 3.06~3.10 (1H, m, H-4), 3.89 (1H, t, *J* = 9.1 Hz, H-5a), 3.61 (1H, d, *J* = 9.2 Hz, H-5b), 4.13 (1H, d, *J* = 9.1 Hz, H-6a), 3.22 (1H, t, *J* = 9.2 Hz, H-6b), 7.04 (1H, d, *J* = 2.0 Hz, H-2'), 6.76~6.79 (3H, m, H-5', 6', 6''), 6.95 (1H, d, *J* = 2.0 Hz, H-2''), 6.85 (1H, dd, *J* = 8.1, 2.0 Hz, H-5''), 3.86 (3H, s, -OCH₃), 3.86 (3H, s, -OCH₃); ¹³C-NMR (150 MHz, CD₃OD) δ: 90.3 (C-1), 89.5 (C-2), 81.5 (C-3), 57.4 (C-4), 67.8 (C-5), 75.5 (C-6), 127.7 (C-1'), 109.1 (C-2'), 147.4 (C-3'), 145.4 (C-4'), 114.3 (C-5'), 117.7 (C-6'), 129.8 (C-1''), 111.5 (C-2''), 147.6 (C-3''), 146.2 (C-4''), 114.8 (C-5''), 120.3 (C-6''), 55.1 (-OCH₃), 55.0 (-OCH₃)。以上数据与文献对照^[14], 鉴定化合物 **9** 为 (+)-1-hydroxy-2-epipinoresinol。

化合物 **10**: 无色针状结晶 (氯仿-甲醇)。

¹H-NMR (600 MHz, DMSO-*d*₆) δ: 3.77, 3.76, 3.75 (9H, s, 3, 3', 4'-OCH₃), 6.72~6.93 (6H, m, H-2, 2', 5, 5', 6, 6'), 4.32 (1H, d, *J* = 7.0 Hz, H-7), 2.81~2.85 (m, 1H, H-8), 4.07 (1H, d, *J* = 9.3 Hz, H-9a), 3.73 (1H, m, 1H, H-9b), 4.80 (1H, d, *J* = 5.9 Hz, 1H, H-7'), 3.36~3.41 (1H, m, H-8', 9a'), 3.73 (1H, m, H-9b'); ¹³C-NMR (150 MHz, DMSO-*d*₆) δ: 132.9 (C-1), 110.8 (C-2), 148.1 (C-3), 148.1 (C-4), 115.7 (C-5), 119.2 (C-6), 87.6 (C-7), 54.5 (C-8), 69.4 (C-9), 131.8 (C-1'), 110.0 (C-2'), 149.0 (C-3'), 146.5 (C-4'), 112.1 (C-5'), 118.1 (C-6'), 81.8 (C-7'), 49.9 (C-8'), 70.9 (C-9'), 56.1 (-OCH₃), 56.0 (-OCH₃), 54.5 (-OCH₃)。以上数据与文献对照^[17], 鉴定化合物 **10** 为 phillygenin。

化合物 **11**: 黄色胶体 (氯仿-甲醇), [α]_D²⁰ +20.8 (c 0.4, MeOH), ESI-MS *m/z* 543.184 3 [M+Na]⁺ (Calcd. 543.184 2, C₂₆H₃₂O₁₁Na), 分子式为 C₂₆H₃₂O₁₁。 ¹H-NMR (600 MHz, DMSO-*d*₆) δ: 6.96 (1H, brs, H-2), 7.05 (1H, d, *J* = 9.0 Hz, H-5), 6.71 (1H, dd, *J* = 9.0, 1.1 Hz, H-6), 4.31 (1H, t, *J* = 5.7 Hz, H-7), 2.85~2.83 (1H, m, H-8), 4.01 (1H, d, *J* = 9.9 Hz, H-9a), 3.68~3.66 (1H, m, H-9b), 6.84 (1H, brs, H-2'), 6.66 (1H, d, *J* = 7.7 Hz, H-5'), 6.81 (1H, dd, *J* = 7.7, 2.7 Hz, H-6'), 4.79 (1H, d, *J* = 5.3 Hz, H-7'), 3.29~3.27 (1H, m, H-8'), 3.60~3.58 (1H, m, H-9'a), 3.15~3.11 (1H, m, H-9'b), 4.75 (1H, d, *J* = 7.0 Hz, H-1''), 3.21~3.19 (1H, m, H-2''), 3.22~3.20 (1H, m, H-3''), 3.21~3.19 (1H, m, H-4''), 3.22~3.20 (1H, m, H-5''), 3.40~3.37 (1H, m, H-6''a), 3.39~3.36 (1H, m, H-6''b), 3.77 (3H, s, OCH₃), 3.75 (3H, s, OCH₃); ¹³C-NMR (150 MHz, DMSO-*d*₆) δ: 132.7 (C-1), 109.1 (C-2), 147.0 (C-3), 145.3 (C-4), 113.9 (C-5), 118.0 (C-6), 87.3 (C-7), 53.5 (C-8), 69.9 (C-9), 131.6 (C-1'), 108.7 (C-2'), 148.5 (C-3'), 144.8 (C-4'), 115.6 (C-5'), 117.2 (C-6'), 81.0 (C-7'), 49.0 (C-8'), 68.4 (C-9'), 100.6 (C-1''), 72.7 (C-2''), 75.6 (C-3''), 69.1 (C-4''), 76.0 (C-5''), 60.3 (C-6''), 54.5 (-OCH₃), 54.2 (-OCH₃)。以上数据与文献对照^[18], 鉴定化合物 **11** 为 (+)-epipinoresinol-4'-*O*-β-*D*-glucopyranoside。

化合物 **12**: 白色粉末 (氯仿-甲醇) [α]_D²⁰ +48.7 (c 0.05, MeOH)。 ¹H-NMR (600 MHz, CD₃OD) δ: 6.91 (1H, d, *J* = 1.9 Hz, H-2), 6.72 (1H, d, *J* = 8.0 Hz, H-5), 6.78 (1H, dd, *J* = 8.0, 1.9 Hz, H-6), 4.75 (1H, d, *J* =

6.9 Hz, H-7), 2.73~2.72 (1H, m, H-8), 3.84 (1H, m, H-9a), 3.64 (1H, dd, $J = 11.0, 6.5$ Hz, H-9b), 6.77 (1H, d, $J = 1.9$ Hz, H-2'), 6.71 (1H, d, $J = 8.1$ Hz, H-5'), 6.65 (1H, dd, $J = 8.1, 1.9$ Hz, H-6'), 2.94 (1H, dd, $J = 13.5, 4.9$ Hz, H-7b'), 2.50 (1H, dd, $J = 13.5, 11.2$ Hz, H-7a'), 2.75~2.72 (1H, m, H-8'), 3.98 (1H, dd, $J = 8.4, 6.4$ Hz, H-9'a), 3.72 (1H, dd, $J = 8.4, 5.9$ Hz, H-9'b), 3.85 (3H, s, -OCH₃), 3.83 (3H, s, -OCH₃); ¹³C-NMR (150 MHz, CD₃OD) δ : 134.5 (C-1), 109.4 (C-2), 147.7 (C-3), 145.8 (C-4), 114.9 (C-5), 118.5 (C-6), 82.8 (C-7), 52.8 (C-8), 59.2 (C-9), 132.2 (C-1'), 112.1 (C-2'), 147.7 (C-3'), 144.5 (C-4'), 114.7 (C-5'), 120.9 (C-6'), 32.4 (C-7'), 42.6 (C-8'), 72.2 (C-9'), 55.1 (-OCH₃), 55.0 (-OCH₃)。以上数据与文献对照^[19], 鉴定化合物 **12** 为 (+)-lariciresinol。

化合物 **13**: 白色粉末 (氯仿-甲醇), $[\alpha]_D^{20} -48.1$ (c 0.05, MeOH)。¹H-NMR (600 MHz, DMSO-*d*₆) δ : 8.83 (1H, s, -OH), 8.70 (1H, s, -OH), 6.83 (1H, d, $J = 1.9$ Hz, H-2), 6.72 (1H, d, $J = 8.1$ Hz, H-5), 6.71 (1H, dd, $J = 8.1, 1.9$ Hz, H-6), 4.67 (1H, d, $J = 6.2$ Hz, H-7), 2.60~2.56 (1H, m, H-8), 3.89 (1H, dd, $J = 6.6, 6.5$ Hz, H-9a), 3.56 (1H, dd, $J = 6.6, 6.5$ Hz, H-9b), 6.75 (1H, d, $J = 8.1$ Hz, H-2'), 6.70 (1H, d, $J = 1.9$ Hz, H-5'), 6.59 (1H, dd, $J = 8.1, 1.9$ Hz, H-6'), 2.43 (1H, dd, $J = 10.9, 4.9$ Hz, H-7a'), 2.83 (1H, dd, $J = 13.2, 4.9$ Hz, H-7b'), 3.76 (6H, s, 2×OCH₃); ¹³C-NMR (150 MHz, DMSO-*d*₆) δ : 135.3 (C-1), 110.5 (C-2), 147.9 (C-3), 145.1 (C-4), 115.6 (C-5), 118.8 (C-6), 82.3 (C-7), 53.0 (C-8), 59.2 (C-9), 132.3 (C-1'), 113.3 (C-2'), 148.0 (C-3'), 146.1 (C-4'), 115.9 (C-5'), 121.2 (C-6'), 32.7 (C-7'), 42.6 (C-8'), 72.4 (C-9'), 56.1 (-OCH₃), 56.0 (-OCH₃)。以上数据与文献对照^[20], 鉴定化合物 **13** 为 (-)-lariciresinol。

化合物 **14**: 白色粉末 (氯仿-甲醇), ESI-MS m/z 357.134 7 [M-H]⁻ (Calcd. 357.133 8, C₂₀H₂₁O₆), 分子式为 C₂₀H₂₂O₆。¹H-NMR (600 MHz, CD₃OD) δ : 7.52 (1H, d, $J = 2.1$ Hz, H-2), 6.96 (1H, d, $J = 8.1$ Hz, H-5), 7.57 (1H, dd, $J = 8.1, 2.1$ Hz, H-6), 4.46 (1H, d, $J = 8.4$ Hz, H-8), 4.42 (1H, dd, $J = 9.0, 6.5$ Hz, H-9a), 4.28 (1H, dd, $J = 6.5, 4.1$ Hz, H-9b), 6.81 (1H, d, $J = 1.8$ Hz, H-2'), 6.80 (1H, d, $J = 8.5$ Hz, H-5'), 6.77 (1H, dd, $J = 8.5, 1.8$ Hz, H-6'), 2.55~2.48 (1H, m, H-8'), 0.79 (3H, d, $J = 7.1$ Hz, 9'-CH₃), 3.88 (3H, s, -OCH₃),

3.87 (3H, s, -OCH₃); ¹³C-NMR (150 MHz, CD₃OD) δ : 132.1 (C-1), 110.1 (C-2), 147.8 (C-3), 149.2 (C-4), 115.5 (C-5), 124.7 (C-6), 199.4 (C-7), 46.0 (C-8), 69.6 (C-9), 127.4 (C-1'), 109.7 (C-2'), 146.2 (C-3'), 145.1 (C-4'), 114.7 (C-5'), 119.2 (C-6'), 87.7 (C-7'), 48.6 (C-8'), 11.7 (C-9'), 55.1 (-OCH₃), 54.9 (-OCH₃)。以上数据与文献对照^[21], 鉴定化合物 **14** 为 *rel*-(7*R*,8'*R*,8*S*)-forsythialan C。

化合物 **15**: 白色粉末 (氯仿-甲醇), ESI-MS m/z 357.134 9 [M-H]⁻ (Calcd. 357.133 8, C₂₀H₂₁O₆), 分子式为 C₂₀H₂₂O₆。¹H-NMR (600 MHz, CD₃OD) δ : 7.58 (1H, d, $J = 2.0$ Hz, H-2), 6.96 (1H, d, $J = 8.3$ Hz, H-5), 7.61 (1H, dd, $J = 8.3, 2.0$ Hz, H-6), 3.84 (1H, dt, $J = 10.3, 9.0$ Hz, H-8), 4.09 (1H, dd, $J = 8.4, 6.9$ Hz, H-9a), 4.01 (1H, dd, $J = 9.0, 6.9$ Hz, H-9b), 6.93 (1H, d, $J = 1.8$ Hz, H-2'), 6.89 (1H, d, $J = 8.4$ Hz, H-5'), 6.81 (1H, dd, $J = 8.4, 1.8$ Hz, H-6'), 4.38 (1H, d, $J = 9.6$ Hz, H-7'), 2.44~2.43 (1H, m, H-8'), 1.02 (3H, d, $J = 6.6$ Hz, H-9'), 3.93 (3H, s, -OCH₃), 3.88 (3H, s, -OCH₃); ¹³C-NMR (150 MHz, CD₃OD) δ : 131.5 (C-1), 110.8 (C-2), 146.4 (C-3), 149.3 (C-4), 114.8 (C-5), 124.0 (C-6), 198.8 (C-7), 53.6 (C-8), 70.2 (C-9), 132.5 (C-1'), 109.7 (C-2'), 147.9 (C-3'), 146.8 (C-4'), 114.6 (C-5'), 119.8 (C-6'), 89.1 (C-7'), 46.4 (C-8'), 13.8 (C-9'), 55.2 (-OCH₃), 54.1 (-OCH₃)。以上数据与文献对照^[21], 鉴定化合物 **15** 为 *rel*-(7*R*,8'*R*,8*R*)-forsythialan C。

化合物 **16**: 黄色无定形粉末 (氯仿-甲醇), ESI-MS m/z 359.150 5 [M-H]⁻ (Calcd. 359.149 5, C₂₀H₂₃O₆), 分子式 C₂₀H₂₄O₆。¹H-NMR (600 MHz, CD₃OD) δ : 6.66 (1H, s, H-2), 6.19 (1H, s, H-5), 2.78 (2H, d, $J = 7.8$ Hz, H-7), 2.02~1.98 (m, 1H, H-8), 3.68~3.66 (1H, m, H-9a), 3.66~3.64 (1H, m, H-9b), 6.68 (1H, d, $J = 2.0$ Hz, H-2'), 6.75 (1H, d, $J = 8.0$ Hz, H-5'), 6.62 (1H, dd, $J = 8.0, 2.0$ Hz, H-6'), 3.81~3.79 (1H, m, H-7'), 1.77~1.75 (1H, m, H-8'), 3.71 (1H, dd, $J = 11.3, 4.9$ Hz, H-9'a), 3.40 (1H, dd, $J = 11.3, 4.1$ Hz, H-9'b), 3.81 (3H, s, -OCH₃), 3.78 (3H, s, -OCH₃); ¹³C-NMR (150 MHz, CD₃OD) δ : 138.8 (C-1'), 113.9 (C-2'), 149.2 (C-3'), 146.1 (C-4'), 115.9 (C-5'), 123.3 (C-6'), 48.2 (C-7'), 48.1 (C-8'), 62.3 (C-9'), 129.1 (C-1), 112.5 (C-2), 147.3 (C-3), 145.4 (C-4), 117.5 (C-5), 134.3 (C-6), 33.7 (C-7), 40.1 (C-8),

66.1 (C-9), 56.5 (-OCH₃), 56.5 (-OCH₃)。以上数据与文献对照^[22], 鉴定化合物 **16** 为 (7'S,8R,8'R)-isolariciresinol。

化合物 **17**: 淡黄色油状物(氯仿-甲醇), ESI-MS m/z 357.135 1 [M-H]⁻ (Calcd. 357.133 8, C₂₀H₂₁O₆), 分子式 C₂₀H₂₂O₆。¹H-NMR (600 MHz, CD₃OD) δ : 6.57 (1H, d, $J = 2.0$ Hz, H-2), 6.53 (1H, d, $J = 7.6$ Hz, H-5), 6.69 (1H, dd, $J = 7.6, 2.0$ Hz, H-6), 2.82 (2H, d, $J = 7.0$ Hz, H-7), 2.54~2.52 (1H, m, H-8), 4.18 (1H, d, $J = 7.4$ Hz, H-9a), 4.16 (1H, d, $J = 7.4$ Hz, H-9b), 6.70 (1H, d, $J = 2.0$ Hz, H-2'), 6.51 (1H, d, $J = 7.0$ Hz, 1H, H-5'), 6.59 (1H, dd, $J = 7.0, 2.0$ Hz, H-6'), 2.90 (2H, dd, $J = 5.4, 2.0$ Hz, H-7'), 2.68~2.66 (1H, m, H-8'), 3.80 (3H, s, -OCH₃), 3.79 (3H, s, -OCH₃); ¹³C-NMR (150 MHz, CD₃OD) δ : 129.5 (C-1), 112.6 (C-2), 147.8 (C-3), 145.1 (C-4), 114.9 (C-5), 121.8 (C-6), 37.6 (C-7), 46.5 (C-8), 71.6 (C-9), 130.2 (C-1'), 112.0 (C-2'), 147.7 (C-3'), 144.9 (C-4'), 114.8 (C-5'), 120.9 (C-6'), 34.1 (C-7'), 41.2 (C-8'), 180.4 (C-9'), 55.0 (-OCH₃), 55.0 (-OCH₃)。以上数据与文献对照^[23], 鉴定化合物 **17** 为 matairesinol。

化合物 **18**: 黄色无定型粉末(氯仿-甲醇), ESI-MS m/z 543.184 1 [M+Na]⁺ (Calcd. 543.184 2, C₂₆H₃₂O₁₁Na), 分子式 C₂₆H₃₂O₁₁。¹H-NMR (600 MHz, DMSO-*d*₆) δ : 6.62 (1H, d, $J = 2.0$ Hz, H-2), 6.99 (1H, d, $J = 8.0$ Hz, H-5), 6.49 (1H, dd, $J = 8.0, 2.0$ Hz, H-6), 2.42 (1H, d, $J = 5.4$ Hz, H-8), 4.09 (1H, m, H-9a), 3.86 (1H, t, $J = 8.5$ Hz, H-9b), 6.68 (1H, d, $J = 2.0$ Hz, H-2'), 6.65 (1H, d, $J = 8.0$ Hz, H-5'), 6.78 (1H, dd, $J = 8.0, 2.0$ Hz, H-6'), 2.43 (1H, d, $J = 9.0$ Hz, H-7'a), 2.81~2.80 (1H, m, H-7'b), 2.73 (1H, dt, $J = 8.9, 6.0$ Hz, H-8'), 4.84 (1H, d, $J = 7.2$ Hz, H-1''), 3.26~3.25 (1H, m, H-2''), 3.27~3.26 (1H, m, H-3''), 3.15~3.14 (1H, m, H-4''), 3.23~3.22 (1H, m, H-5''), 3.65 (1H, dd, $J = 11.7, 2.1$ Hz, H-6''a), 3.44 (1H, dd, $J = 11.7, 5.6$ Hz, H-6''b), 3.72 (3H, s, -OCH₃), 3.71 (3H, s, -OCH₃); ¹³C-NMR (150 MHz, DMSO-*d*₆) δ : 132.2 (C-1), 113.1 (C-2), 149.1 (C-3), 145.4 (C-4), 115.5 (C-5), 121.2 (C-6), 37.3 (C-7), 41.3 (C-8), 71.2 (C-9), 130.0 (C-1'), 114.3 (C-2'), 148.0 (C-3'), 145.7 (C-4'), 115.8 (C-5'), 121.8 (C-6'), 33.9 (C-7'), 46.0 (C-8'), 178.9 (C-9'), 100.6 (C-1''), 73.7 (C-2''), 77.4 (C-3''), 70.1 (C-4''), 77.3 (C-5''), 61.1 (C-6''), 56.1 (-OCH₃), 56.0

(-OCH₃)。以上数据与文献对照^[24], 鉴定化合物 **18** 为 martairesinol-4'-*O*- β -*D*-glucopyranoside。

化合物 **19**: 淡黄色油状(氯仿-甲醇), [α]_D²⁰-98.4 (*c* 0.05, MeOH)。¹H-NMR (600 MHz, CD₃OD) δ : 7.07 (1H, d, $J = 2.0$ Hz, H-2), 6.96 (1H, dd, $J = 8.4, 2.0$ Hz, H-5), 7.17 (1H, d, $J = 8.4$ Hz, H-6), 4.67 (2H, dd, $J = 12.0, 2.0$ Hz, H-7), 1.82~1.81 (1H, m, H-8, 8'), 1.03 (6H, dd, $J = 11.6, 6.0$ Hz, H-9, 9'), 6.99 (1H, d, $J = 1.9$ Hz, H-2'), 6.79 (1H, d, $J = 8.4$ Hz, H-5'), 6.85 (1H, dd, $J = 8.4, 1.9$ Hz, H-6'), 4.66 (2H, dd, $J = 16.0, 2.0$ Hz, H-7'), 4.90 (1H, d, $J = 7.4$ Hz, H-1''), 3.51 (2H, dd, $J = 9.1, 7.4$ Hz, H-2''), 3.48~3.47 (1H, m, H-3''), 3.41~3.40 (1H, m, H-4''), 3.40~3.39 (1H, m, H-5''), 3.86~3.84 (1H, m, H-6''a), 3.70~3.69 (1H, m, H-6''b), 3.90 (3H, s, -OCH₃), 3.88 (3H, s, -OCH₃); ¹³C-NMR (150 MHz, CD₃OD) δ : 136.9 (C-1), 110.5 (C-2), 149.6 (C-3), 146.1 (C-4), 114.7 (C-5), 119.1 (C-6), 88.9 (C-7), 50.7 (C-8), 12.5 (C-9), 133.3 (C-1'), 109.8 (C-2'), 147.8 (C-3'), 146.3 (C-4'), 116.6 (C-5'), 119.3 (C-6'), 88.4 (C-7'), 50.9 (C-8'), 12.6 (C-9'), 101.6 (C-1''), 73.6 (C-2''), 76.6 (C-3''), 70.0 (C-4''), 76.9 (C-5''), 61.2 (C-6''), 55.1 (-OCH₃), 55.5 (-OCH₃)。以上数据与文献对照^[25], 鉴定化合物 **19** 为 (-)-nectandrin B- β -*D*-glucopyranoside。

化合物 **20**: 淡黄色油状物(氯仿-甲醇)。¹H-NMR (600 MHz, CD₃OD) δ : 7.17 (1H, d, $J = 2.0$ Hz, H-2), 6.96 (1H, dd, $J = 8.1, 2.0$ Hz, H-5), 7.22 (1H, d, $J = 8.1$ Hz, H-6), 5.14 (2H, dd, $J = 12.1, 8.9$ Hz, H-7), 1.83~1.81 (1H, m, H-8, 8'), 1.04 (6H, dd, $J = 8.3, 6.5$ Hz, H-9, 9'), 7.07 (1H, d, $J = 2.0$ Hz, H-2'), 6.83 (1H, d, $J = 8.0$ Hz, H-5'), 6.92 (1H, dd, $J = 8.0, 2.0$ Hz, H-6'), 4.40 (2H, dd, $J = 12.4, 9.5$ Hz, H-7'), 4.93 (1H, d, $J = 7.4$ Hz, H-1''), 3.71 (1H, dd, $J = 5.2, 2.2$ Hz, H-2''), 3.48~3.47 (1H, m, H-3''), 3.43~3.42 (1H, m, H-4''), 3.41~3.40 (1H, m, H-5''), 3.72~3.70 (1H, m, H-6''a), 3.70~3.69 (1H, m, H-6''b), 3.90 (3H, s, -OCH₃), 3.89 (3H, s, OCH₃); ¹³C-NMR (150 MHz, CD₃OD) δ : 132.5 (C-1), 112.4 (C-2), 149.6 (C-3), 146.0 (C-4), 116.7 (C-5), 119.4 (C-6), 87.8 (C-7), 45.3 (C-8), 14.0 (C-9), 136.0 (C-1'), 110.7 (C-2'), 147.8 (C-3'), 146.4 (C-4'), 114.9 (C-5'), 119.7 (C-6'), 87.3 (C-7'), 48.3 (C-8'), 13.9 (C-9'), 55.5 (OCH₃), 55.4 (-OCH₃), 101.5 (C-1''), 73.6 (C-2''),

76.6 (C-3''), 70.1 (C-4''), 76.9 (C-5''), 61.2 (C-6'')。以上数据与文献对照^[25], 鉴定化合物 **20** 为 (7*R*,7'*R*,8*S*,8'*R*)-4,4'-dihydroxy-3,3'-dimethoxy-7,7'-epoxylignan-4-*O*-β-*D*-glucopyranoside。

化合物 **21**: 淡黄色油状物 (氯仿-甲醇)。¹H-NMR (600 MHz, CD₃OD) δ: 6.81 (1H, d, *J* = 1.8 Hz, H-2), 6.94 (1H, dd, *J* = 8.1, 1.8 Hz, H-5), 6.80 (1H, d, *J* = 8.1 Hz, H-6), 5.14 (2H, dd, *J* = 12.1, 8.9 Hz, H-7), 1.77~1.75 (1H, m, H-8, 8'), 1.04 (6H, dd, *J* = 8.3, 6.5 Hz, H-9, 9'), 7.02 (1H, d, *J* = 2.0 Hz, H-2'), 7.18 (1H, d, *J* = 8.0 Hz, H-5'), 7.09 (1H, dd, *J* = 8.0, 2.0 Hz, H-6'), 4.91 (2H, d, *J* = 7.5 Hz, H-7'), 4.91 (1H, d, *J* = 7.5 Hz, H-1''), 3.41~3.40 (1H, m, H-2''), 3.49~3.48 (1H, m, H-3''), 3.43~3.42 (1H, m, H-4''), 3.71 (1H, dd, *J* = 5.2, 2.2 Hz, H-5''), 3.72~3.71 (1H, m, H-6'a), 3.48~3.47 (1H, m, H-6'b), 3.86 (3H, s, -OCH₃), 3.85 (3H, s, -OCH₃); ¹³C-NMR (150 MHz, CD₃OD) δ: 131.6 (C-1), 110.4 (C-2), 147.4 (C-3), 145.6 (C-4), 114.5 (C-5), 119.1 (C-6), 83.0 (C-7), 45.7 (C-8), 13.6 (C-9), 135.4 (C-1'), 111.0 (C-2'), 149.1 (C-3'), 146.3 (C-4'), 116.1 (C-5'), 119.6 (C-6'), 83.5 (C-7'), 48.1 (C-8'), 13.6 (C-9'), 55.2 (-OCH₃), 55.1 (-OCH₃), 101.5 (C-1''), 73.6 (C-2''), 76.6 (C-3''), 70.1 (C-4''), 76.6 (C-5''), 61.2 (C-6'')。以上数据与文献对照^[25], 鉴定化合物 **21** 为 (7*R*,7'*R*,8*S*,8'*R*)-4,4'-dihydroxy-3,3'-dimethoxy-7,7'-epoxylignan-4'-*O*-β-*D*-glucopyranoside。

化合物 **22**: 白色针状结晶 (氯仿-甲醇), ESI-MS *m/z* 337.161 9 [M + Na]⁺ (Calcd. 337.162 7, C₁₆H₂₆O₆Na), 分子式 C₁₆H₂₆O₆。¹H-NMR (600 MHz, CD₃OD) δ: 2.23 (1H, td, *J* = 5.6, 1.4 Hz, H-1), 5.58~5.54 (1H, m, H-3), 2.29 (2H, dt, *J* = 11.7, 2.5 Hz, H-4), 2.11~2.06 (1H, m, H-5), 2.42 (1H, m, H-6a), 1.19 (1H, d, *J* = 8.6 Hz, H-6b), 1.30 (3H, s, H-8), 0.87 (3H, s, H-9), 4.23~4.21 (1H, m, H-10a), 4.02~4.00 (1H, m, H-10b), 4.27 (1H, d, *J* = 7.8 Hz, H-1'), 3.33 (1H, d, *J* = 8.9 Hz, H-2'), 3.28 (1H, dd, *J* = 9.1, 8.9 Hz, H-3'), 3.22~3.20 (1H, m, H-4'), 3.19~3.17 (1H, m, H-5'), 3.85 (1H, dd, *J* = 11.9, 2.3 Hz, H-6'a), 3.66 (1H, dd, *J* = 11.9, 5.7 Hz, H-6'b); ¹³C-NMR (150 MHz, CD₃OD) δ: 102.0 (C-1'), 73.7 (C-2'), 76.6 (C-3'), 71.2 (C-4'), 76.8 (C-5'), 61.4 (C-6'), 43.1 (C-1), 144.9 (C-2), 119.4 (C-3), 31.1 (C-4), 40.8 (C-5), 30.9

(C-6), 37.5 (C-7), 25.2 (C-8), 20.2 (C-9), 70.3 (C-10)。以上数据与文献对照^[26-28], 鉴定化合物 **22** 为 myrtenyl-*O*-β-*D*-glucopyranoside。

化合物 **23**: 白色粉状物 (氯仿-甲醇), ¹H-NMR (600 MHz, CD₃OD) δ: 4.31~4.30 (1H, m, H-1), 5.40 (1H, m, H-2), 1.77~1.75 (3H, m, H-4), 2.15~2.12 (1H, m, H-5), 2.10 (1H, m, H-6), 5.12 (1H, m, H-7), 1.68 (3H, s, H-9), 1.62 (3H, s, H-10), 4.28 (1H, d, *J* = 7.8 Hz, H-1'), 3.86 (1H, dd, *J* = 8.1, 2.3 Hz, H-2'), 3.29 (1H, d, *J* = 8.1 Hz, H-3'), 3.68 (1H, dd, *J* = 11.9, 5.6 Hz, H-6'a), 3.34 (1H, m, H-6'b); ¹³C-NMR (150 MHz, CD₃OD) δ: 64.9 (C-1), 121.3 (C-2), 140.5 (C-3), 16.5 (C-4), 31.8 (C-5), 26.4 (C-6), 123.7 (C-7), 131.5 (C-8), 22.4 (C-9), 24.6 (C-10), 101.6 (C-1'), 73.8 (C-2'), 76.6 (C-3'), 70.3 (C-4'), 76.8 (C-5'), 61.4 (C-6')。以上数据与文献对照^[29], 鉴定化合物 **23** 为 neryl-β-*D*-glucopyranoside。

化合物 **24**: 淡黄色无定形粉末 (氯仿-甲醇)。¹H-NMR (600 MHz, CD₃OD) δ: 1.70~1.69 (1H, m, H-1), 1.30 (1H, ddd, *J* = 12.0, 9.5, 4.4 Hz, H-2), 2.01~1.99 (1H, m, H-3), 5.37 (1H, d, *J* = 2.3 Hz, H-5), 2.17~2.16 (1H, m, H-6), 1.21~1.20 (3H, m, H-7), 0.90 (3H, s, H-9), 0.88 (3H, d, *J* = 1.7 Hz, H-10), 4.25 (1H, d, *J* = 7.8 Hz, H-1'), 3.35~3.34 (1H, m, H-2'), 3.28 (1H, t, *J* = 9.1 Hz, H-3'), 3.22 (1H, m, H-4'), 3.16 (1H, dd, *J* = 9.1, 7.7 Hz, H-5'), 3.84 (1H, dd, *J* = 11.8, 2.4 Hz, H-6'a), 3.67 (1H, td, *J* = 11.8, 5.5 Hz, H-6'b); ¹³C-NMR (150 MHz, CD₃OD) δ: 43.9 (C-1), 22.3 (C-2), 30.8 (C-3), 133.5 (C-4), 120.6 (C-5), 26.4 (C-6), 21.7 (C-7), 83.1 (C-8), 23.8 (C-9), 23.8 (C-10), 101.8 (C-1'), 74.0 (C-2'), 76.2 (C-3'), 70.4 (C-4'), 77.1 (C-5'), 61.6 (C-6')。以上数据与文献对照^[30], 鉴定化合物 **24** 为 α-terpineol-8-*O*-β-*D*-glucopyranoside。

化合物 **25**: 淡黄色无定形粉末 (氯仿-甲醇)。¹H-NMR (600 MHz, DMSO-*d*₆) δ: 4.46 (1H, dd, *J* = 16.2, 8.4 Hz, H-2), 2.78 (1H, dd, *J* = 16.2, 4.2 Hz, H-3a), 2.60 (1H, ddd, *J* = 12.7, 3.0, 1.8 Hz, H-3b), 5.89 (1H, d, *J* = 10.1 Hz, H-5), 6.77 (1H, dd, *J* = 10.1, 1.7 Hz, H-6), 2.44 (1H, ddd, *J* = 10.5, 4.7, 4.6 Hz, H-7a), 2.15 (1H, ddd, *J* = 10.5, 2.2, 1.7 Hz, H-7b), 4.03 (1H, td, *J* = 4.7, 1.7 Hz, H-8a), 3.86 (1H, ddd, *J* = 4.7, 2.6, 1.7 Hz, H-8b); ¹³C-NMR (150 MHz,

DMSO- d_6) δ : 74.5 (C-1), 81.1 (C-2), 42.5 (C-3), 197.4 (C-4), 127.5 (C-5), 150.6 (C-6), 38.2 (C-7), 66.0 (C-8)。以上数据与文献对照^[31], 鉴定化合物 **25** 为 renyolone。

化合物 **26**: 黄色无定形粉末 (氯仿-甲醇), ESI-MS m/z 207.067 3 $[M-H]^-$ (Calcd. 207.065 7, $C_{11}H_{11}O_4$), 分子式 $C_{11}H_{11}O_4$ 。 1H -NMR (600 MHz, CD_3OD) δ : 7.18 (1H, d, $J = 2.0$ Hz, H-2), 6.80 (1H, d, $J = 8.2$ Hz, H-3), 7.06 (1H, dd, $J = 8.2, 2.0$ Hz, H-6), 7.61 (1H, d, $J = 15.9$ Hz, H-7), 6.36 (1H, d, $J = 15.9$ Hz, H-8), 3.89 (3H, s, H-10), 3.76 (3H, s, H-11); ^{13}C -NMR (150 MHz, CD_3OD) δ : 126.2 (C-1), 122.7 (C-2), 115.1 (C-3), 149.4 (C-4), 148.0 (C-5), 110.3 (C-6), 145.5 (C-7), 113.7 (C-8), 168.3 (C-9), 55.0 (C-10), 50.6 (C-11)。以上数据与文献对照^[32], 鉴定化合物 **26** 为 methyl ferulate。

4 体外抗肿瘤活性评价

取生长状态良好的细胞, 加胰酶细胞消化液使贴壁细胞消化脱落, 形成细胞混悬液, 对细胞进行计数, 并将细胞稀释到 1×10^4 个/mL。在 96 孔板上, 每孔接种 190 μ L 细胞悬液, 置 37 $^{\circ}C$ 、5% CO_2 的恒温箱中培养, 培养 12 h 使细胞贴壁。倒掉培养液, 每孔加入 100 μ L (含待测化合物浓度为 40 μ mol/L) DMEM 高糖培养液, 在恒温箱中培养 48 h。吸去 100 μ L 上清液, 加入 100 μ L 新鲜 DMEM 高糖培养液, 再加入配制好的 10 μ L MTT 溶液 (5 mg/mL、0.5% MTT), 继续在恒温箱中培养 4 h。吸去 100 μ L 上清液, 每孔加入 100 μ L 的甲臜溶解液, 置摇床上低速振荡 10 min, 在恒温箱中放置 4 h 左右。在酶联免疫检测仪 570 nm 处测量各个孔的吸光度 (A) 值, 按照公式计算抑制率。每组设定 4 个复孔, 同时设置空白组 (含有培养基和 MTT)、对照组 (含有细胞、培养液和 MTT) 和阳性对照组 (含有细胞、培养液、5-氟尿嘧啶和 MTT)。结果见表 1。

$$\text{抑制率} = [(A_{\text{对照}} - A_{\text{空白}}) - (A_{\text{给药}} - A_{\text{空白}})] / (A_{\text{对照}} - A_{\text{空白}})$$

5 讨论

本研究利用多种色谱分离手段对中药连翘进行了化学成分研究, 分离鉴定了共 26 个化合物, 其中 10 个属内首次分离的化合物, 化合物 **1~4** 为苯乙醇苷类, **5~21** 为木脂素及其苷类, **22~24** 为单萜苷类, **25** 为环己酮类, **26** 为简单苯丙素类化合物。活性测定结果表明, 在 40 μ mol/L 下化合物 **5~18** 对 HepG-2 和 MCF-7 细胞具有一定的细胞毒活性。

表 1 化合物的抑制率

Table 1 Inhibition rate of compounds

化合物	抑制率/%	
	HepG-2	MCF-7
5	57.3 \pm 4.8	49.5 \pm 5.4
6	54.7 \pm 8.9	41.6 \pm 5.5
7	53.2 \pm 9.4	43.8 \pm 1.7
8	51.0 \pm 5.8	38.1 \pm 2.4
9	54.6 \pm 5.3	44.1 \pm 5.4
10	55.3 \pm 9.3	41.7 \pm 2.2
11	51.2 \pm 0.7	47.4 \pm 4.8
12	56.2 \pm 3.5	44.1 \pm 3.5
13	49.6 \pm 7.2	40.2 \pm 3.5
14	47.4 \pm 7.8	42.5 \pm 5.1
15	49.9 \pm 3.6	43.4 \pm 3.5
16	47.9 \pm 4.3	39.1 \pm 4.9
17	52.8 \pm 1.8	39.6 \pm 4.8
18	51.1 \pm 4.4	51.7 \pm 3.4
阳性对照	73.8 \pm 4.5	71.3 \pm 3.2

本研究丰富了连翘的化学成分, 为连翘抗肿瘤作用的活性成分发现提供科学依据。

利益冲突 所有作者均声明不存在利益冲突

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