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地稔中酚酸类化学成分研究

程　淼,霍揽明,李先盛,刘百联,周光雄*

暨南大学药学院中药及天然药物研究所,广州 510632

摘　要:采用硅胶、Sephadex LH-20、ODS 柱层析等色谱技术,从地稔 95% 乙醇提取物的乙酸乙酯萃取部位分离得到 16 个化合物。通过波谱分析并与文献数据对照方法,将其分别鉴定为反式阿魏酰二十烷醇酯(**1**)、邻羟基苯甲酸(**2**)、香草酸(**3**)、对香豆酸(**4**)、没食子酸甲酯(**5**)、没食子酸乙酯(**6**)、原儿茶酸(**7**)、没食子酸(**8**)、3-甲氧基鞣花酸(**9**)、3,3′-*O*-二甲基鞣花酸-4-*O*-α-*L*-鼠李糖苷(**10**)、4-*O*-(6″-*O*-对-香豆酰基-β-*D*-吡喃葡萄糖)-对-香豆酸(**11**)、2-*O*-(*E*)-咖啡酰基-1-*O*-对-(*E*)-香豆酰基-β-*D*-吡喃葡萄糖(**12**)、1,5-二咖啡酰奎尼酸(**13**)、对羟基苯乙酮(**14**)、aviculin(**15**)、苍耳烯吡喃(**16**)。其中除化合物 **8** 外,其他 15 个化合物均为首次从地稔中分离得到。

关键词:地稔;化学成分;酚酸类

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Chemical Constituents of Phenolic Acids in *Melastoma dodecandrum*

CHENG Miao, HUO Lan-ming, LI Xian-sheng, LIU Bai-lian, ZHOU Guang-xiong*

Institute of Traditional Chinese Medicine and Natural Products, College of Pharmacy, Jinan University, Guangzhou 510632, China

Abstract: Sixteen compounds were isolated and purified from EtOAc fraction derived from 95% ethanol extract of *Melastoma dodecandrum* Lour by silica gel, Sephadex LH-20 and ODS column chromatography. On the basis of their physicochemical properties and spectroscopic data, these compounds were identified as eicosyl-(*E*)-ferulate (**1**), oxybenzoic acid (**2**), vanillic acid (**3**), *p*-coumaric acid (**4**), methyl gallate (**5**), ethyl gallate (**6**), protocatechuic acid (**7**), gallic acid (**8**), 3-*O*-methylellagic acid (**9**), 3,3′-*O*-dimethyl ellagic acid 4-*O*-α-L-rhamnopyranoside (**10**), 4-*O*-(6″-*O*-*p*-coumaroyl-β-D-glucopyranosyl)-*p*-coumaric acid (**11**), 2-*O*-(*E*)-caffeoyl-1-*O*-*p*-(*E*)-coumaroyl-β-D-glucopyrannose (**12**), 1,5-di-*O*-caffeoylquinicacid (**13**), *p*-hydroxyacetophenone (**14**), aviculin (**15**), xanthienopyran (**16**). All of these compounds except compound **8** were obtained from *Melastoma dodecandrum* Lour for the first time.

Key words: *Melastoma dodecandrum* L; chemical constituents; phenolic acids

地稔为野牡丹科植物地稔(*Melastoma dodecandrum* Lour.)的全草,分布于长江以南的贵州、福建、浙江、广西、云南等省区,瑶族、苗族、畲族等少数民族使用较广泛[1]。民间常用于治痛经,产后腹痛,血崩,带下,便血,痢疾,痈肿,疔疮。现代临床研究报道,地稔制剂治疗消化道出血的止血功效显著[2]。周添浓等[3]证明地稔的止血作用与其含有的总酚类物质有关。唐迈等[4]也已从地稔中分离得到了没食子酸和阿魏酸等酚酸类物质。但是,目前对地稔中酚酸类物质的研究还不够充分。为此,本实验对地稔的化学成分进行了较系统的研究,从中得到 16 个酚酸类化合物。采用波谱学和理化方法,将这些化合物分别鉴定为反式阿魏酰二十烷醇酯(**1**)、邻羟基苯甲酸(**2**)、香草酸(**3**)、对香豆酸(**4**)、没食子酸甲酯(**5**)、没食子酸乙酯(**6**)、原儿茶酸(**7**)、没食子酸(**8**)、3-甲氧基鞣花酸(**9**)、3,3′-*O*-二甲基鞣花酸-4-*O*-α-L-鼠李糖苷(**10**)、4-*O*-(6″-*O*-对-香豆酰基-β-D-吡喃葡萄糖)-对-香豆酸(**11**)、2-*O*-(*E*)-咖啡酰基-1-*O*-对-(*E*)-香豆酰基-β-D-吡喃葡萄糖(**12**)、1,5-二咖啡酰奎尼酸(**13**)、对羟基苯乙酮(**14**)、aviculin(**15**)、苍耳烯吡喃(**16**)。

1　仪器与材料

Bruker AVANCEIII 300 型核磁共振光谱仪(瑞士 Bruker 公司);Finnigan LCQ Advantage MAX 质谱仪(美国 Thermo 公司);UltiMate 3000 高效液相色谱

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* 通讯作者　Tel:86-20-85221469;E-mail:guangxzh@sina.com

仪(法国 Gilson 公司),Agilent 1200 型液相半制备色谱仪,Welch Material Column XB-C_{18} 分析色谱柱(4.6×250 mm,5 μm,上海月旭材料科技有限公司);Ultimate® XB-C_{18} 制备色谱柱(10×250 mm,5 μm,上海月旭材料科技有限公司);Sephadex LH-20 葡聚糖凝胶(美国 Pharmacia 公司);薄层色谱硅胶预涂板(HSAF254,200×200 mm,烟台市化学工业研究所);ODS(50 mm,YMC,德国 Merck 公司)。

实验用药材于 2013 年 5 月采自广东省从化市,经暨南大学生药学教研室周光雄教授鉴定为野牡丹科植物地稔(*Melastoma dodecandrum* Lour.)的全草。

2 分离与纯化

地稔全草 30 kg 粉碎,用 95% 乙醇回流提取三次。提取液减压浓缩后得粗浸膏 1210 g,用适量水混悬,依次用石油醚、乙酸乙酯萃取,分别得到石油醚萃取物(430 g)、乙酸乙酯萃取物(148 g)。

将乙酸乙酯部位经硅胶柱色谱,以氯仿-甲醇(100∶0~0∶100)系统梯度洗脱,经 TLC 薄层分析后合并浓缩,得到 4 个组分(A1~A4)。A1 组分继续经硅胶柱色谱,以石油醚-乙酸乙酯(100∶0-1∶1)系统梯度洗脱,反复分离纯化得到化合物 **1**(173 mg)、**2**(2 mg)、**3**(10 mg)和 **4**(22 mg)。A2 组分经硅胶柱色谱,以氯仿-丙酮(100∶0~0∶100)系统梯度洗脱,重结晶得到化合物 **8**(506 mg),其他子馏分经过 Sephadex LH-20 凝胶柱色谱及半制备-HPLC,得到化合物 **5**(84 mg)、**6**(4 mg)和 **7**(360 mg)。A3 组分经反相 ODS 开放柱色谱,以甲醇-水(3∶7-10∶0)系统梯度洗脱得到三个组分(A3B~A3D),A3B 和 A3C 经 Sephadex LH-20 凝胶柱色谱,以氯仿-甲醇(1∶1)系统洗脱,分别得到化合物 **9**(17 mg)、**10**(16 mg)和 **11**(61 mg),A3D 经过 Sephadex LH-20 凝胶柱色谱及半制备-HPLC,得到化合物 **12**(12 mg)和 **13**(13 mg)。A4 组分经硅胶柱色谱,以氯仿-丙酮(100∶0~1∶1)系统梯度洗脱,子馏分经过 Sephadex LH-20 凝胶柱色谱得到化合物 **14**(10 mg)、**15**(21 mg)和 **16**(5 mg)。

3 结构鉴定

化合物 1 白色粉末 分子式为 $C_{30}H_{50}O_4$,ESI-MS *m/z*:473 [M-H]$^-$。^{1}H NMR (300 MHz, $CDCl_3$) δ:7.59 (1H, d, J = 15.9 Hz, H-8), 7.04 (1H, dd, J = 8.2, 1.8 Hz, H-6), 7.00 (1H, d, J = 1.8 Hz, H-2), 6.89 (1H, d, J = 8.1 Hz, H-5), 6.27 (1H, d, J = 15.9 Hz, H-7), 4.16 (2H, t, J = 6.6 Hz, H-1′), 3.89 (3H, s, OCH_3), 1.62~1.72 (2H, m, H-2′), 1.19 (34H, br s, H-3′~19′), 0.84 (3H, t, J = 6.0 Hz, H-20′);^{13}C NMR (75 MHz, $CDCl_3$) δ:167.6 (C-9), 148.1 (C-3), 146.9 (C-4), 144.8 (C-7), 127.1 (C-1), 123.1 (C-6), 115.7 (C-5), 114.9 (C-8), 109.4 (C-2), 64.8 (C-1′), 56.0 (-OCH_3), 32.1 (C-2′), 29.8~22.8 (C-3′~C-19′), 14.2 (C-20′)。以上数据与文献报道一致[5],故化合物 **1** 鉴定为反式阿魏酰二十烷醇酯。

化合物 2 白色粉末 分子式为 $C_7H_6O_3$,ESI-MS *m/z*:137 [M-H]$^-$。^{1}H NMR (300 MHz, $CDCl_3$) δ:7.90 (1H, dd, J = 8.0, 1.7 Hz, H-6), 7.50 (2H, dt, J = 8.3, 1.4 Hz, H-5), 6.98 (1H, d, J = 8.4 Hz, H-3), 6.91 (2H, t, J = 8.4 Hz, H-4);^{13}C NMR (75 MHz, $CDCl_3$) δ:174.2 (-COOH), 162.4 (C-2), 137.0 (C-6), 131.1 (C-4), 119.7 (C-10), 117.9 (C-5), 111.6 (C-3)。以上数据与文献报道一致[6],故化合物 **2** 鉴定为邻羟基苯甲酸。

化合物 3 白色粉末 分子式为 $C_8H_8O_4$,ESI-MS *m/z*:167 [M-H]$^-$。^{1}H NMR (300 MHz, CD_3OD) δ:7.56 (1H, dd, J=8.7, 1.9 Hz, H-6), 7.54 (1H, d, J=1.8 Hz, H-2), 6.88 (1H, d, J=8.7 Hz, H-5), 3.89 (3H, s, H-8);^{13}C NMR (75 MHz, CD_3OD) δ:170.2 (C=O), 152.8 (C-3), 148.8 (C-4), 125.4 (C-6), 123.3 (C-1), 116.0 (C-5), 113.9 (C-2), 56.5 (-O CH_3)。以上数据与文献报道一致[7],故化合物 **3** 鉴定为香草酸。

化合物 4 白色粉末 分子式为 $C_9H_8O_3$,ESI-MS *m/z*:163 [M-H]$^-$。^{1}H NMR (300 MHz, CD_3OD) δ:7.60 (1H, d, J=15.9 Hz, H-3), 7.42 (2H, d, J=8.6 Hz, H-6,8), 6.80 (2H, d, J=8.6 Hz, H-5,9), 6.27 (1H, d, J=15.9 Hz, H-2);^{13}C NMR (75 MHz, CD_3OD) δ:171.3 (C-1), 161.2 (C-7), 146.8 (C-3), 131.2 (C-5,9), 127.4 (C-4), 116.9 (C-6,8), 115.7 (C-2)。以上数据与文献报道一致[8],故化合物 **4** 鉴定为对香豆酸。

化合物 5 白色粉末 分子式为 $C_8H_8O_5$,ESI-MS *m/z*:183 [M-H]$^-$。^{1}H NMR (300 MHz, CD_3OD) δ:7.06 (2H, s, H-2,6), 3.78 (3H, s, -OCH_3);^{13}C NMR (75 MHz, CD_3OD) δ:169.3 (C-7), 146.3 (C-3,5), 139.7 (C-4), 121.4 (C-1), 110.2 (C-2,6), 52.6

(C-8)。以上数据与文献报道一致[9],故化合物 **5** 鉴定为没食子酸甲酯。

化合物 6 白色粉末　分子式为 $C_9H_{10}O_5$,ESI-MS *m/z*:197 [M-H]$^-$。^{1}H NMR (300 MHz, CD_3OD) *δ*:7.04 (2H, s, H-2,6), 4.27 (2H, q, *J* = 7.1 Hz, H-8), 1.34 (3H, t, *J* = 7.1 Hz, H-9);^{13}C NMR (75 MHz, CD_3OD) δ: 168.7 (C-7), 146.6 (C-3,5), 139.8 (C-4), 121.9 (C-1), 110.1 (C-2,6), 61.8 (C-8), 14.8 (C-9)。以上数据与文献报道一致[9],故化合物 **6** 鉴定为没食子酸乙酯。

化合物 7 白色粉末　分子式为 $C_7H_6O_4$,ESI-MS *m/z*:153 [M-H]$^-$。^{1}H NMR (300 MHz, CD_3OD) *δ*: 7.46 (1H, s, H-2), 7.43 (1H, d, *J* = 1.9 Hz, H-6), 6.82 (1H, d, *J* = 8.0 Hz, H-5);^{13}C NMR (75 MHz, CD_3OD) *δ*:170.3 (COOH), 151.4 (C-4), 145.9 (C-3), 123.9 (C-6), 122.9 (C-1), 117.6 (C-2), 115.7 (C-5)。以上数据与文献报道一致[10],故化合物 **7** 鉴定为原儿茶酸。

化合物 8 白色粉末　分子式为 $C_7H_6O_5$,ESI-MS *m/z*:169 [M-H]$^-$。^{1}H NMR (300 MHz, CD_3OD) *δ*: 7.11 (2H, d, *J* = 1.4 Hz, H-2,6);^{13}C NMR (75 MHz, CD_3OD) *δ*:170.7 (COOH), 146.2 (C-3,5), 139.6 (C-4), 121.9 (C-1), 110.4 (C-2,6)。以上数据与文献报道一致[10],故化合物 **8** 鉴定为没食子酸。

化合物 9 白色粉末　分子式为 $C_{15}H_8O_8$,ESI-MS *m/z*:315 [M-H]$^-$。^{1}H NMR (300 MHz, DMSO-d_6) *δ*:7.50 (1H, s, H-5), 7.42 (1H, s, H-5′), 4.02 (3H, s, -OMe);^{13}C NMR (75 MHz, DMSO-d_6) *δ*: 159.0 (C-7), 158.8 (C-7′), 152.1 (C-4), 148.4 (C-4′), 141.5 (C-3′), 140.1 (C-2), 136.1 (C-2′), 112.5 (C-1′), 112.2 (C-6), 111.9 (C-5′), 111.3 (C-1), 110.1 (C-5), 106.6 (C-6′), 60.9 (OMe)。以上数据与文献报道一致[11],故化合物 **9** 鉴定为 3-甲氧基鞣花酸。

化合物 10 白色粉末　分子式为 $C_{22}H_{20}O_{12}$,ESI-MS *m/z*:475 [M-H]$^-$。^{1}H NMR (300 MHz, DMSO-d_6) δ:7.63 (1H, s, H-5), 7.33 (1H, s, H-5′), 5.52 (1H, d, *J* = 1.6 Hz, H-1″), 4.05 (3H, s, -OMe), 3.99 (1H, dd, *J* = 3.3, 9.0 Hz, H-2″), 3.71 (1H, dd, *J* = 3.0, 9.2 Hz, H-3″), 3.49 ~ 3.56 (1H, m, H-5″), 1.16 (3H, d, *J* = 6.1 Hz, H-6″);^{13}C NMR (75 MHz, DMSO-d_6) *δ*:158.1 (C-7′), 157.9 (C-7), 152.8 (C-4′), 150.3 (C-4), 141.6 (C-2′), 141.2 (C-2), 140.7 (C-3), 140.0 (C-3′), 113.5 (C-6), 112.2 (C-6′), 111.6 (C-1′), 111.5 (C-1), 111.3 (C-5), 110.5 (C-5′), 99.8 (C-1″), 71.6 (C-4″), 70.5 (C-2″), 70.3 (C-3″), 70.1 (C-5″), 61.5 (OMe), 60.9 (OMe), 18.0 (C-6″)。以上数据与文献报道一致[12],故化合物 **10** 鉴定为 3,3′-*O*-二甲基鞣花酸-4-*O*-*α*-*L*-鼠李糖苷。

化合物 11 白色粉末　分子式为 $C_{24}H_{24}O_{10}$,ESI-MS *m/z*:471 [M-H]$^-$。^{1}H NMR (300 MHz, CD_3OD) *δ*:7.62 (1H, d, *J* = 15.9 Hz, H-7), 7.52 (1H, d, *J* = 15.9 Hz, H-7′), 7.48 (1H, d, *J* = 8.7 Hz, H-2,6), 7.45 (1H, d, *J* = 8.6 Hz, H-2′,6′), 7.09 (1H, d, *J* = 8.7 Hz, H-3,5), 6.82 (1H, d, *J* = 8.6 Hz, H-3′,5′), 6.35 (1H, d, *J* = 15.9 Hz, H-8), 6.23 (1H, d, *J* = 15.9 Hz, H-8′), 4.98 (1H, d, *J* = 7.2 Hz, H-1″), 4.55 (1H, dd, *J* = 3.2, 11.9 Hz, H-6″a), 4.36 (1H, dd, *J* = 7.2, 11.9 Hz, H-6″b), 3.73 ~ 3.79 (1H, m, H-5″), 3.49 ~ 3.55 (1H, m, H-2″), 3.50 (1H, d, *J* = 2.5 Hz, H-3″), 3.38 ~ 3.44 (1H, m, H-4″);^{13}C NMR (75 MHz, CD_3OD) *δ*:170.8 (C-9), 169.0 (C-9′), 161.6 (C-4′), 160.7 (C-4), 147.0 (C-7′), 145.8 (C-7), 131.4 (C-2′,6′), 130.9 (C-2,6), 130.1 (C-1), 127.2 (C-1′), 118.2 (C-8′), 117.7 (C-3,5), 117.1 (C-3′,5′), 115.1 (C-8), 101.8 (C-1″), 78.0 (C-3″), 75.7 (C-5″), 74.9 (C-2″), 72.0 (C-4″), 64.8 (C-6″)。以上数据与文献报道一致[13],故化合物 **11** 鉴定为 4-*O*-(6″-*O*-对-香豆酰基-*β*-*D*-吡喃葡萄糖)-对-香豆酸。

化合物 12 白色粉末　分子式为 $C_{24}H_{24}O_{11}$,ESI-MS *m/z*:487 [M-H]$^-$。^{1}H NMR (300 MHz, CD_3OD) *δ*:7.73 [1H, d, *J* = 15.8 Hz, coumaroyl (H-7$_{co}$)], 7.57 (1H, d, *J* = 15.8 Hz, H-7$_{caf}$), 7.47 (2H, d, *J* = 8.0 Hz, H-2$_{co}$,6$_{co}$), 7.06 (1H, d, *J* = 2 Hz, H-2$_{caf}$), 6.95 (1H, dd, *J* = 2,8 Hz, H-6$_{caf}$), 6.81 (2H, d, *J* = 7.9 Hz, H-3$_{co}$,5$_{co}$), 6.37 (1H, d, *J* = 8 Hz, H-5$_{caf}$), 6.29 (1H, d, *J* = 15.9 Hz, H-8$_{caf}$), 6.27 (1H, d, *J* = 15.9 Hz, H-8$_{co}$), 5.60 (1H, d, *J* = 8.0 Hz, glc H-1), 4.50 (1H, br d, glc H-2), 4.32 (1H, d, *J* = 11.4 Hz, glc H-6), 3.68 (1H, t, *J* = 9.0 Hz, glc H-3), 3.45 ~ 3.52 (2H, m, glc H-4,5);^{13}C NMR (75 MHz, CD_3OD) *δ*: caffeoyl-127.9 (C-1), 114.9 (C-2),

146.9 (C-3), 149.7 (C-4), 116.6 (C-5), 123.2 (C-6), 148.2 (C-7), 115.3 (C-8), 169.3 (C-9); coumaroyl-127.2 (C-1), 131.6 (C-2,6), 117.0 (C-3,5), 161.7 (C-4), 147.5 (C-7), 114.5 (C-8), 167.8 (C-9); glucose-95.9 (C-1), 74.1 (C-2), 76.5 (C-3), 71.5 (C-4), 78.0 (C-5), 64.5 (C-6)。以上数据与文献报道一致[14], 故化合物 **12** 鉴定为 2-*O*-(*E*)-咖啡酰基-1-*O*-对-(*E*)-香豆酰基-β-D-吡喃葡萄糖。

化合物 13 黄色粉末 分子式为 $C_{25}H_{24}O_{12}$, ESI-MS *m/z*: 515 [M-H]$^-$。^{1}H NMR (300 MHz, CD_3OD) δ: 7.59 (2H, d, *J* = 16 Hz, H-8′,8″), 7.07 (2H, br s, H-2′,2″), 6.96 (2H, dd, *J* = 2.0, 8.1 Hz, H-6′,6″), 6.78 (2H, d, *J* = 8.2 Hz, H-5′,5″), 6.29 (2H, dd, *J* = 9.4, 15.9 Hz, H-8′,8″), 5.36 ~ 5.42 (1H, m, H-5), 4.27 ~ 4.30 (1H, m, H-3), 3.78 (1H, dd, *J* = 3.3, 8.1 Hz, H-4), 2.57 (1H, dd, *J* = 3.6, 13.6 Hz, H-6), 2.43 ~ 2.46 (2H, m, H-2), 2.04 ~ 2.11 (1H, m, H-6); ^{13}C NMR (75 MHz, CD_3OD) δ: 178.0 (C-7), 168.8 (C-9″), 168.2 (C-9′), 149.8 (C-4″), 149.7 (C-4′), 147.6 (C-7″), 147.4 (C-7′), 146.9 (C-3″, 3′), 127.9 (C-1″, 1′), 123.2 (C-6″, 6′), 116.6 (C-5″, 5′), 115.4 (C-8″, 8′), 115.3 (C-2″, 2′), 81.1 (C-1), 73.0 (C-4), 71.7 (C-5), 69.6 (C-3), 37.1 (C-6), 35.8 (C-2)。以上数据与文献报道一致[15], 故化合物 **13** 鉴定为 1,5-二咖啡酰奎尼酸。

化合物 14 无色油状物 分子式为 $C_8H_8O_2$, ESI-MS *m/z*: 271 [2M-H]$^-$。^{1}H NMR (300 MHz, CD_3OD) δ: 7.83 (2H, d, *J* = 7.8 Hz, H-2′,6′), 6.77 (2H, d, *J* = 8.4 Hz, H-3′,5′), 2.48 (3H, s, H-2); ^{13}C NMR (75 MHz, CD_3OD) δ: 199.6 (C-1), 164.7 (C-4′), 132.3 (C-2′,6′), 130.0 (C-1′), 116.5 (C-3′,5′), 26.4 (C-2)。以上数据与文献报道一致[16], 故化合物 **14** 鉴定为对羟基苯乙酮。

化合物 15 黄色粉末 分子式为 $C_{26}H_{34}O_{10}$, ESI-MS *m/z*: 505 [M-H]$^-$。^{1}H NMR (300 MHz, CD_3OD) δ: 6.76 (1H, d, *J* = 8.0 Hz, H-5′), 6.70 (1H, s, H-5), 6.67 (1H, s, H-8), 6.64 (1H, s, *J* = 1.7 Hz, H-2′), 6.59 (1H, dd, *J* = 8.0, 1.8 Hz, H-6′), 3.84 (1H, br s, H-1), 3.81 (3H, s, -OMe), 3.77 (3H, s, -OMe), 2.83 (2H, d, *J* = 7.6 Hz, H-4), 2.02 ~ 2.06 (3H, m, H-3), 1.86 (1H, br t, *J* = 10.1 Hz, H-2), 4.52 (1H, d, *J* = 1.4 Hz, H-1″), 3.88 (1H, dd, *J* = 3.2, 1.6 Hz, H-2″), 3.65 (1H, dd, *J* = 9.5, 3.4 Hz, H-3″), 3.49 ~ 3.54 (1H, m, H-5″), 3.35 ~ 3.38 (1H, m, H-4″), 1.19 (1H, d, *J* = 6.2 Hz, H-6″); ^{13}C NMR (75 MHz, CD_3OD) δ: 149.3 (C-6), 147.4 (C-3′), 146.2 (C-7), 145.4 (C-4′), 138.2 (C-9), 134.1 (C-1′), 129.0 (C-10), 123.3 (C-6′), 117.3 (C-8), 116.2 (C-5′), 113.6 (C-2′), 112.6 (C-5), 102.4 (C-1″), 74.0 (C-4″), 72.7 (C-3″), 72.5 (C-2″), 70.3 (C-5″), 68.1 (C-2α), 65.5 (C-3α), 56.5 (6-OMe), 48.5 (C-1), 45.6 (C-2), 40.2 (C-3), 33.7 (C-4), 18.1 (C-6″)。以上数据与文献报道一致[17], 故化合物 **15** 鉴定为 aviculin。

化合物 16 黄色粉末 分子式为 $C_{17}H_{16}O_4S$, ESI-MS *m/z*: 315 [M-H]$^-$。^{1}H NMR (300 MHz, DMSO-d_6) δ: 7.36 (1H, s, H-4), 7.05 (1H, d, *J* = 1.5 Hz, H-3), 6.50 (1H, dd, *J* = 15.0, 10.5 Hz, H-10), 6.17 (1H, dd, *J* = 15.0, 10.5 Hz, H-11), 6.07 (1H, d, *J* = 6.8 Hz, H-8), 5.90 (1H, dt, *J* = 15.0, 7.2 Hz, H-12), 5.69 (1H, dd, *J* = 15.0, 7.2 Hz, H-9), 3.60 (2H, t, *J* = 6.6 Hz, H-14), 2.61 (3H, d, *J* = 1.5 Hz, H-15), 2.30 ~ 2.33 (2H, m, H-3); ^{13}C NMR (75 MHz, DMSO-d_6) δ: 170.5 (C-6), 151.6 (C-5), 145.7 (C-3a), 145.3 (C-2), 136.0 (C-10), 135.8 (C-8a), 134.7 (C-12), 132.4 (C-11), 127.7 (C-8b), 126.2 (C-9), 121.9 (C-3), 121.3 (C-4a), 114.7 (C-4), 81.9 (C-8), 62.5 (C-14), 37.2 (C-13), 16.2 (C-15)。以上数据与文献报道一致[18], 故化合物 **16** 鉴定为苍耳烯吡喃。

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