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牡丹花化学成分研究

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摘 要:对毛茛科芍药属植物牡丹的花瓣化学成分进行研究。运用多种色谱方法进行分离纯化,运用^{1}H NMR、^{13}C NMR 和 MS 波谱学数据鉴定其结构。结果得到 7 个单萜糖苷类化合物,分别为吡啶芍药苷(**1**)、paeodanin B(**2**)、芍药新苷(**3**)、乙酰芍药苷(**4**)、芍药苷(**5**)、苯甲酰芍药苷(**6**)和氧化芍药苷(**7**),及 2 个酚酸类化合物,分别为没食子酸(**8**)和没食子酸甲酯(**9**)。化合物 **1** ~ **7** 均首次从牡丹花中分离得到。

关键词:牡丹;花瓣;单萜糖苷;芍药苷;没食子酸

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Chemical Constituents from the Flower Petals of *Paeonia suffruticosa* Andr.

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Abstract: Seven paeoniflorin-related monoterpene glycosides, namely pyridylpaeoniflorin (**1**), paeodanin B (**2**), lactiflorin (**3**), acetylpaeoniflorin (**4**), paeoniflorin (**5**), benzoyl paeoniflorin (**6**), oxypaeoniflorin (**7**) as well as two phenoic acids, namely gallic acid (**8**) and methyl gallate (**9**) were isolated from the flower petals of *Paeonia suffruticosa* Andr. by various chromatographic methods. Their structures were identified by ^{1}H NMR, ^{13}C NMR and MS spectral analysis. Compounds **1-7** were obtained from the flowers of *P. suffruticosa* for the first time.

Key words: *Paeonia suffruticosa* Andr.; flower petals; monoterpene glycosides; paeoniflorin; gallic acid

牡丹(*Paeonia suffruticosa* Andr.)属毛茛科芍药属灌木,为中国特有名贵观赏花卉和药用植物。其根皮,又称牡丹皮、丹皮,是一味应用广泛的传统中药,《神农本草经》列为中品,具有清热凉血,活血化瘀之功效,现代研究证明其在临床治疗中可起到止痛,止痉挛,抗凝和抗氧化等作用[1-3]。牡丹花作为特色的天然生物资源和新资源食品,在我国有悠久的药用和食用历史,《四川中药志》载:牡丹花性平、苦、淡,具有调经活血的功能,主治月经不调,痛经。前期研究证明,牡丹花花瓣富含黄酮类化合物[4,5],但系统的化学成分研究报道较少。为了进一步利用牡丹花资源,我们对牡丹花的化学成分进行了系统的分离,从中的到 7 个单萜糖苷类化合物,分别为吡啶芍药苷(**1**)、paeodanin B(**2**)、芍药新苷(**3**)、乙酰芍药苷(**4**)、芍药苷(**5**)、苯甲酰芍药苷(**6**)和氧化芍药苷(**7**),及 2 个酚酸类化合物,分别为没食子酸(**8**)和没食子酸甲酯(**9**)。化合物 **1** ~ **7** 均首次从牡丹花中分离得到,这是第一次从牡丹花瓣中分离得到芍药苷单萜糖苷类化合物。

1 仪器与材料

Varian INOVA-400 型核磁共振波谱仪(美国 Varian 公司,以 TMS 为内标);Agilent5973 型质谱仪(美国 Agilent 公司);岛津 1200 分析型高效液相(日本岛津公司);岛津 LC 6AD 制备型高效液相(日本岛津公司,色谱柱为 Shim-park RP-C_{18} column,200 × 20 mm)。柱色谱用 C_{18} 填料(日本 YMC 公司);Sephadex LH-20(Amersham Biosciences 公司);柱色谱用硅胶(200 ~ 300 目)以及 G_{254} 硅胶薄层板(青岛海洋化工);乙醇(分析纯,德州恒业化工有限公司);甲醇、二氯甲烷,分析纯(天津市化学试剂厂);甲醇、乙腈(色谱纯,山东禹王试剂有限公司)。

牡丹花采自山东菏泽,经鉴定为毛茛科芍药属植物牡丹(*Paeonia suffruticosa* Andr.)的花。

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2 提取与分离

取干燥后的牡丹花瓣 3.0 kg,粉碎后于 70% 乙醇中 60 ℃温浸三次,每次 4 h,合并提取液,减压浓缩至无醇味。浸膏分散于水中(1 L)成悬浊液,用乙酸乙酯萃取三次(3 × 1 L),得乙酸乙酯萃取物 20 g。乙酸乙酯部分采用硅胶常压柱,以二氯甲烷-甲醇(50∶1 ~2∶1)梯度洗脱,分段收集,其中二氯甲烷-甲醇(20∶1 ~10∶1)段经 TLC 检测后分为 A-C 三个组分。组分 A(二氯甲烷-甲醇 20∶1 段)经常压反相 C-18 柱甲醇-水梯度洗脱(5% 到 70% 甲醇)得 5 个组分(Fr. A1-A5)。Fr. A1(10% 甲醇洗脱部位)经过制备液相得到化合物 **9**(5.0 mg),Fr. A3(50% 甲醇洗脱部位)经过制备液相得到化合物 **3**(7.0 mg)和 **4**(6.0 mg),Fr. A5(70% 甲醇洗脱部位)经过制备液相得到化合物 **6**(32.0 mg)。组分 B(二氯甲烷∶甲醇 15∶1 段)经常压反相 C-18 柱甲醇-水梯度洗脱(5% 到 70% 甲醇)分为 5 个组分(Fr. B1-B5)。Fr. B2(30% 甲醇洗脱部位)经过 Sephadex LH-20(甲醇)得化合物 **5**(60.0 mg),Fr. B3(50% 甲醇洗脱部位)经过制备液相得化合物 **2**(8.0 mg)。组分 C(二氯甲烷∶甲醇 10∶1 段)经常压反相 C-18 柱甲醇-水梯度洗脱(5% 到 70% 甲醇)得到 3 个组分(Fr. C1-C3)。Fr. C1(10% 甲醇洗脱部位)经过 Sephadex LH-20(甲醇)得化合物 **8**(21.0 mg),Fr. C2 经过 Sephadex LH-20(甲醇),后经制备液相得化合物 **1**(4.0 mg)和化合物 **7**(14.0 mg)。

3 结构鉴定

化合物 1 白色粉末(甲醇),ESI-MS *m/z*:482 [M + H]$^+$;^{1}H NMR (DMSO,400MHz):δ_H 2.05 (1H,d,*J* =12.0 Hz,H-3a),1.65 (1H,d,*J* =12.0 Hz,H-3b),2.47 (1H,d,*J* = 6.4 Hz,H-5),2.37 (1H,dd,*J* =10.6,6.8 Hz,H-7a),1.82 (1H,d,*J* = 10.6 Hz,H-7b),4.66 (2H,d,*J* = 15.6 Hz,H-8),5.35 (1H,s,H-9),1.24 (3H,s,H-10),4.37 (1H,d,*J* = 7.7 Hz,H-1′),2.97 (1H,m,H-2′),2.98 (1H,m,H-4′),3.07 (2H,m,H-3′,5′),3.65 (1H,m,H-6′a),3.35 (1H,m,H-6′b),9.12 (1H,d,*J* = 1.5 Hz,H-2″),8.31 (1H,dt,*J* =7.9,1.8 Hz,H-4″),7.60 (1H,dd,*J* = 7.9,4.8 Hz,H-5″),8.84 (1H,dd,*J* =4.8,1.5 Hz,H-6″);^{13}C NMR (DMSO,100MHz):δ_C 88.0 (C-1),85.4 (C-2),44.0 (C-3),105.2 (C-4),42.7 (C-5),70.7 (C-6),22.4 (C-7),61.4 (C-8),100.4 (C-9),19.6 (C-10),99.1 (C-1′),73.9 (C-2′),77.4 (C-3′),70.3 (C-4′),77.4 (C-5′),61.7 (C-6′),154.2 (C-2″),126.1 (C-3″),137.4 (C-4″),124.4 (C-5″),150.6 (C-6″),165.1 (C-7″)。以上数据与文献[6]报道对照基本一致,故鉴定化合物为吡啶芍药苷。

化合物 2 白色粉末(甲醇),ESI-MS *m/z*:495 [M + H]$^+$;^{1}H NMR (DMSO,400 MHz):δ_H 2.89 (1H,d,*J* =18.0 Hz,H-3a),2.34 (1H,d,*J* =18.0 Hz,H-3b),3.04 (1H,m,H-5),3.00 (1H,m,H-7a),2.10 (1H,d,*J* =10.6 Hz,H-7b),4.68 (2H,m,H-8),5.02 (1H,s,H-9),1.33 (3H,s,H-10),4.45 (1H,d,*J* =8.0 Hz,H-1′),3.66 (1H,d,*J* = 11.0 Hz,H-6′a),3.08-3.46 (5H,m,H-2′-6′b),7.96 (2H,d,*J* =7.5 Hz,H-2″,6″),7.55 (2H,t,*J* =7.5 Hz,H-3″,5″),7.68 (1H,t,*J* =7.0 Hz,H-4″),3.20 (3H,s,9-OMe);^{13}C NMR (DMSO,100 MHz):δ_C 87.2 (C-1),86.3 (C-2),48.9 (C-3),205.7 (C-4),47.0 (C-5),63.2 (C-6),26.3 (C-7),63.2 (C-8),106.3 (C-9),20.6 (C-10),98.9 (C-1′),73.9 (C-2′),77.5 (C-3′),70.7 (C-4′),77.3 (C-5′),61.7 (C-6′),130.1 (C-1″),129.7 (C-2″,6″),129.3 (C-3″,C-5″),133.9 (C-4″),166.2 (C-7″)。以上波谱数据与文献[7]对照基本一致,故鉴定为 paeodanin B。

化合物 3 白色粉末(甲醇),ESI-MS *m/z*:463 [M + H]$^+$;^{1}H NMR (DMSO,400MHz):δ_H 2.77 (1H,m,H-3a),2.45 (1H,d,*J* =18.0 Hz,H-3b),2.78 (1H,m,H-5),2.38 (1H,t,*J* =13.0 Hz,H-7a),2.08 (1H,d,*J* =13.0,4.0 Hz,H-7b),4.71 (2H,s,H-8),4.84 (1H,s,H-9),1.40 (3H,s,H-10),4.49 (1H,d,*J* =7.6 Hz,H-1′),3.14 (3H,s,H-3′,4′,5′),3.63 (1H,d,*J* =10.2 Hz,H-6′a),3.43 (1H,d,*J* =10.2 Hz,H-6′b),7.99 (2H,d,*J* =8.0 Hz,H-2″,6″),7.56 (2H,t,*J* =7.2 Hz,H-3″,5″),7.68 (1H,t,*J* =7.2 Hz,H-4″);^{13}C NMR (DMSO,100 MHz):δ_C 85.2 (C-1),102.8 (C-2),44.6 (C-3),217.1 (C-4),37.4 (C-5),55.4 (C-6),30.6 (C-7),62.7 (C-8),80.0 (C-9),16.5 (C-10),95.2 (C-1′),75.4 (C-2′),79.5 (C-3′),70.6 (C-4′),73.2 (C-5′),61.2 (C-6′),129.7 (C-1″),129.7 (C-2″,6″),129.4 (C-3″,C-5″),134.1 (C-

4″),166.0 (C-7″)。以上数据与文献[8]报道对照基本一致,故鉴定化合物为芍药新苷。

化合物 4 白色粉末(甲醇),ESI-MS *m/z*:523 [M + H]$^+$;^{1}H NMR (DMSO,400MHz):δ_H 1.95 (1H,d,*J* =12.5 Hz,H-3a),1.67 (1H,d,*J* =12.5 Hz,H-3b),2.44 (1H,d,*J* =6.0 Hz,H-5),2.41 (1H,m,H-7a),1.70 (1H,d,*J* =10.6 Hz,H-7b),4.63 (2H,d,*J* =12.0 Hz,H-8),5.34 (1H,s,H-9),1.20 (3H,s,H-10),4.42 (1H,d,*J* =7.4 Hz,H-1′),4.28 (1H,d,*J* =10.5 Hz,H-6′a),4.02 (1H,dd,*J* =10.5,7.5 Hz,H-6′b),2.95-3.18 (5H,m,H-2′-5′),7.99 (2H,d,*J* =7.5 Hz,H-2″,6″),7.56 (2H,t,*J* =7.0 Hz,H-3″,5″),7.68 (1H,t,*J* =7.5 Hz,H-4″),2.01 (3H,s,H-COCH$_3$);^{13}C NMR (DMSO,100MHz):δ_C 88.1 (C-1),85.2 (C-2),44.1 (C-3),105.1 (C-4),42.7 (C-5),70.7 (C-6),22.3 (C-7),60.8 (C-8),100.5 (C-9),19.4 (C-10),99.0 (C-1′),74.0 (C-2′),77.0 (C-3′),70.3 (C-4′),73.8 (C-5′),64.0 (C-6′),130.1 (C-1″),129.7 (C-2″,6″),129.2 (C-3″,C-5″),133.9 (C-4″),166.2 (C-7″),170.6 (COCH$_3$),21.1 (COCH$_3$)。以上数据与文献[9]报道对照基本一致,故鉴定化合物为乙酰芍药苷。

化合物 5 白色粉末(甲醇),ESI-MS *m/z*:481 [M + H]$^+$;^{1}H NMR (DMSO,400MHz):δ_H 2.05 (1H,d,*J* =12.0 Hz,H-3a),1.66 (1H,d,*J* =12.0 Hz,H-3b),2.45 (1H,d,*J* =6.0 Hz,H-5),2.38 (1H,dd,*J* =10.6,6.5 Hz,H-7a),1.82 (1H,d,*J* =10.6 Hz,H-7b),4.65 (2H,d,*J* =12.4 Hz,H-8),5.33 (1H,s,H-9),1.25 (3H,s,H-10),4.39 (1H,d,*J* =6.4 Hz,H-1′),3.66 (1H,m,H-6′a),3.18-3.45 (5H,m,H-2′-6′b),7.99 (2H,d,*J* =8.0 Hz,H-2″,6″),7.55 (2H,t,*J* =7.2 Hz,H-3″,5″),7.67 (1H,t,*J* =6.8 Hz,H-4″);^{13}C NMR (DMSO,100 MHz):δ_C 87.5 (C-1),85.0 (C-2),43.6 (C-3),104.8 (C-4),42.3 (C-5),70.3 (C-6),22.0 (C-7),60.5 (C-8),100.1 (C-9),19.1 (C-10),98.6 (C-1′),74.5 (C-2′),76.9 (C-3′),70.0 (C-4′),76.9 (C-5′),61.2 (C-6′),129.7 (C-1″),129.3 (C-2″,6″),128.8 (C-3″,C-5″),133.5 (C-4″),165.8 (C-7″)。以上数据与文献[10]报道对照基本一致,故鉴定化合物为芍药苷。

化合物 6 白色粉末(甲醇),ESI-MS *m/z*:585 [M + H]$^+$;^{1}H NMR (DMSO,400 MHz):δ_H 1.70 (1H,d,*J* =12.5 Hz,H-3a),1.56 (1H,m,H-3b),2.39 (1H,m,H-5),2.39 (1H,m,H-7a),1.56 (1H,m,H-7b),4.62 (2H,d,*J* =9.0 Hz,H-8),5.31 (1H,s,H-9),1.14 (3H,s,H-10),4.47 (1H,d,*J* =7.5 Hz,H-1′),3.50 (1H,t,*J* =8.0 Hz,H-6′a),3.00-3.25 (6H,m,H-2′-6′b),7.98 (4H,d,*J* =7.2 Hz,H-2″,6″,2‴,6‴),7.56 (2H,d,*J* =8.0 Hz,H-3″,5″),7.51 (2H,d,*J* =8.0 Hz,H-3‴,5‴),7.66 (2H,m,H-4″,4‴);^{13}C NMR (DMSO,100 MHz):δ_C 88.1 (C-1),85.2 (C-2),43.9 (C-3),105.0 (C-4),42.6 (C-5),70.2 (C-6),22.0 (C-7),60.8 (C-8),100.4 (C-9),19.4 (C-10),99.0 (C-1′),74.0 (C-2′),77.0 (C-3′),70.2 (C-4′),73.8 (C-5′),64.7 (C-6′),130.2 (C-1″),129.7 (C-2″,6″),129.2 (C-3″,C-5″),133.9 (C-4″),166.2 (C-7″),130.1 (C-1‴),129.5 (C-2‴,6‴),129.2 (C-3‴,C-5‴),133.9 (C-4‴),165.9 (C-7‴)。以上数据与文献[11]报道对照基本一致,故鉴定化合物为苯甲酰芍药苷。

化合物 7 白色粉末(甲醇),ESI-MS *m/z*:497 [M + H]$^+$;^{1}H NMR (DMSO,400 MHz):δ_H 2.04 (1H,d,*J* =12.0 Hz,H-3a),1.64 (1H,d,*J* =12.5 Hz,H-3b),2.42 (1H,d,*J* =4.0 Hz,H-5),2.35 (1H,m,H-7a),1.80 (1H,d,*J* =10.4 Hz,H-7b),4.58 (2H,s,H-8),5.29 (1H,s,H-9),1.24 (3H,s,H-10),4.39 (1H,d,*J* =8.0 Hz,H-1′),3.66 (1H,d,*J* =11.5 Hz,H-6′a),2.95-3.17 (6H,m,H-2′-6′b),7.84 (2H,d,*J* =8.0 Hz,H-2″,6″),6.87 (2H,d,*J* =8.0 Hz,H-3″,5″);^{13}C NMR (DMSO,100 MHz):δ_C 87.9 (C-1),85.4 (C-2),44.1 (C-3),105.2 (C-4),42.8 (C-5),70.7 (C-6),22.5 (C-7),60.2 (C-8),100.6 (C-9),19.6 (C-10),99.1 (C-1′),74.0 (C-2′),77.4 (C-3′),70.5 (C-4′),77.4 (C-5′),61.7 (C-6′),120.6 (C-1″),132.0 (C-2″,6″),115.8 (C-3″,C-5″),162.7 (C-4″),166.1 (C-7″)。以上数据与文献[12]报道对照基本一致,故鉴定化合物为氧化芍药苷。

化合物 8 白色粉末(甲醇),ESI-MS *m/z*:171 [M + H]$^+$;^{1}H NMR (DMSO,400 MHz):δ_H 6.92 (2H,s,H-2,6),9.31 (3H,brs,OH);^{13}C NMR (DMSO,100 MHz):δ_C121.2 (C-1),109.2 (C-2),145.9 (C-3),138.4 (C-4),145.9 (C-5),109.2 (C-6),

168.1(C-7)。以上数据与文献[13]报道对照基本一致,故鉴定化合物为没食子酸。

化合物 9 白色粉末(甲醇),ESI-MS *m/z*:185 [M + H]$^+$. ^{1}H NMR (DMSO,400 MHz):δ_H 6.96 (2H,s,H-2,6),3.76 (3H,s,Me),9.18 (3H,brs,OH);^{13}C NMR (DMSO,100 MHz):δ_C 119.8 (C-1),109.0 (C-2),146.1 (C-3),138.9 (C-4),146.1 (C-5),109.0 (C-6),166.8 (C-7)。以上数据与文献[14]报道对照基本一致,故鉴定化合物为没食子酸甲酯。

4 结果与讨论

芍药属植物含有丰富的芍药苷类单萜化合物。在传统的牡丹产业中,大量的牡丹花被丢弃在田间地头,造成巨大的资源浪费。牡丹根皮是一味应用广泛的珍贵药材,作为丹皮中的主要成分之一,芍药苷类化合物在丹皮的药理活性中发挥很大的作用。一直以来,牡丹花的研究都集中在黄酮类化合物的提取和分离上,我们的研究证明,牡丹花中除了含有黄酮类之外,同样含有丰富的芍药苷单萜糖苷类化合物,或为解释牡丹花生物活性物质基础及牡丹花资源开发和高值化利用提供参考。

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