SUPPLEMENTARY MATERIAL

Chemical constituents from Agrimonia pilosa Ledeb. and their chemotaxonomic significance

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Abstract

Phytochemical investigation of the ethanol extract from the whole plant of Agrimonia pilosa led to the isolation of thirty one compounds, including sixteen flavonoids (1-16), five triterpenes (17-21), one isocoumarin (22), five phenolic acids (23-27), one ceramide (28), two agrimols (29-30) and one fatty acid (31). Their structures were determined by various spectroscopic analysis. Compounds 5, 7 and 20 were firstly isolated from the genus Agrimonia, and compounds 6, 10-11, 15, 26, 28 and 31 were isolated from the family Rosaceae for the first time. Moreover, the chemotaxonomic significance of these compounds was summarized.

Key words: Agrimonia pilosa Ledeb., Flavonoids, Triterpenoids, Phenolic derivatives, Chemotaxonomy
1. Experimental

1.1 General

IR spectra were recorded on a Bruker Tensor 27 spectrometer with KBr-disks (Bruker, Karlsruhe, Germany). Mass spectra were obtained on a MS Agilent 1100 Series LC/MSD Trap mass spectrometer (ESI-MS). NMR spectra were measured on a Bruker AV-300 NMR and a Bruker AV-500 NMR spectrometers with TMS as an internal standard. HR-ESI-MS spectra was conducted on a Mariner API-TOF mass spectrometer. Column chromatography was done with silica gel (Qingdao marine Chemical Co., Ltd., P.R.China), ODS (40-63 μm, Fuji, Japan) and Sephede x LH-20 (Uppsala, Sweden). TLC analysis was carried out on precoated silica gel GF254 plates(Qingdao marine Chemical Co., Ltd., P.R.China) and RP_18(200μm, Merck, Darmstadt, Germany). All chemical solvents used in this study were of analytical grade.

1.2 Plant material

The Agrimonia pilosa sample was collected from Jiangsu Province, China and identified by Prof. She-Ban Pu (China Pharmaceutical University, Nanjing 210009, China). A voucher specimen (20130512) was deposited at Department of Natural Medicinal Chemistry, China Pharmaceutical University, Nanjing 210009, China.

1.3 Extraction and isolation

The whole plants of Agrimonia pilosa (9 kg) were extracted with 80% EtOH four times. The extract solutions were combined and concentrated by rotary evaporator at 60 °C. The residue (1500 g) was suspended in H_2O and extracted with petroleum ether (PE), EtOAc and n-butanol. The EtOAc fraction (86 g) was subjected to column chromatography (CC) over silica gel (200-300 mesh) using a CH_2Cl_2-MeOH gradient (50:1, 30:1, 20:1, 10:1, 5:1, 3:1, v/v) to afford six fractions (fraction A-F). Fraction B was subjected to a macroporous resin D101 column eluted by water-MeOH (70:30, 50:50, 30:70, v/v) to yield three fractions (subfraction B1-B3). Subfraction B2 (1 g) was chromatographed on an ODS column eluted by water-MeOH (100:0, 70:30, 60:40, 50:50, 40:60, 30:70, 0:100, v/v), and then isolated by silica gel CC (200-300 mesh, eluted by CH_2Cl_2/Methanol), after purified by Sephadex LH-20 with MeOH, compounds 2 (50 mg), 3 (17 mg), 4 (25 mg) and 23 (10 mg) were afforded. Subfraction B1 (2 g) was repeatedly isolated by silica gel CC with CH_2Cl_2/Methanol as elution solvent and further purified by Sephadex LH-20 with CH_2Cl_2/Methanol (1:1, v/v) to afford compounds 15 (10 mg), 24 (50 mg), 25 (7 mg), 26 (20 mg) and 27 (30 mg). Subfraction B3 (2 g) was subjected to silica gel CC eluted by CH_2Cl_2/EtOAc, then chromatographed on an ODS column eluted by water-MeOH to afford compound 17 (5 mg). Fraction A was subjected to silica gel CC eluted by PE/EtOAc and further isolated by ODS coloumn, finally purified by recrystal to yield compounds 18 (10 mg), 19 (340 mg), 20 (300 mg), and 21 (20 mg). Fraction C (9 g) was isolated by silica gel CC, futher seperated by ODS column eluted by water-MeOH (40:60, 30:70, 20:80, v/v), and then purified by Sephadex LH-20 with MeOH to afford compounds 5 (4 mg), 6 (5 mg), 7 (3 mg), 8 (5 mg), 9 (20 mg), 10 (5 mg), 11 (11 mg), 13 (4 mg), 16 (10 mg), and 22 (70 mg). Fraction D (18 g) was repeatedly seperated by silica gel CC eluted by CH_2Cl_2/Methanol to afford compounds 1 (400 mg), 12 (170 mg), 28 (10 mg), and 31 (8 mg). Fraction E was chromatographed on an ODS column, eluted by water-MeOH (40:60,
30:70, 20:80, v/v) and then purified by sephadex LH-20 with MeOH to afford compound 14 (10 mg).

The dried PE residue was subjected to silica gel CC eluted by PE/EtOAc (50:1, 30:1, 10:1, 5:1, 3:1, v/v) to afford five fractions (Fraction A-E). Fraction B was repeatedly isolated by silica gel CC eluted by PE/EtOAc to afford two agrimols, compounds 29 (50 mg), and 30 (20 mg).

1.4 Spectral and experimental data of the isolated compounds

**Compound 1:** Yellow powder (MeOH); mp:135–140°C; ESI-MS m/z:595.13 [M+H]+; 1H-NMR (500 MHz, DMSO-d6) δH 12.59 (1H, s, 5-OH), 10.82 (1H, s, 7-OH), 10.13 (1H, s, 4'-OH), 9.99 (1H, s, 4''-OH), 6.18 (1H, s, 6-H), 6.41 (1H, s, 8-H), 8.02 (2H, brs, 2', 6'-H), 6.89 (2H, brs, 3', 5'-H), 7.38 (2H, brs), 6.82 (2H, brs), 6.14 (1H, d, J = 15.0 Hz), 7.37 (1H, d, J = 15.0 Hz), 5.47 (1H, brs, 1''-H), 4.31 (1H, d, J = 10.6 Hz, 6''-H), 4.07 (1H, brs, 6'-H), 3.2–3.4 (4H, m, Glc-H); 13C-NMR (125 MHz, DMSO-d6) δC 156.4 (C-2'), 133.1 (C-3'), 177.4 (C-4'), 161.1 (C-5'), 98.9 (C-6), 164.1 (C-7), 93.8 (C-8), 156.3 (C-9), 103.9 (C-10), 124.9 (C-1'), 130.1 (C-2',6'), 115.7 (C-3', 5'), 159.8 (C-4'), 101.0 (C-1'''), 74.2 (C-2''), 76.2 (C-3''), 70.0 (C-4''), 74.1 (C-5''), 63.0 (C-6''), 113.6 (C-α), 144.6 (C-β), 124.9 (C-1'''), 130.1 (C-2''', 6''), 115.7 (C-3''', 5''), 159.8 (C-4'').

**Compound 2:** Yellow powder (MeOH); mp:313–314°C; ESI-MS m/z:300.96 [M-H]-; 1H-NMR (500 MHz, DMSO-d6) δH 12.47 (1H, s, 5-OH), 10.72 (1H, s, 3-OH), 9.52 (1H, s, -OH), 9.28 (1H, s, -OH), 7.68 (1H, d, J = 1.9 Hz, 2'-H), 7.54 (1H, dd, J = 8.4, 1.9 Hz, 6'-H), 6.89 (1H, d, J = 8.4 Hz, 5'-H), 6.40 (1H, d, J = 1.8 Hz, 8-H), 6.19 (1H, d, J = 1.8 Hz, 6-H).

**Compound 3:** Yellow powder (MeOH); mp:328–330°C; ESI-MS m/z:287.06 [M+H]+; 1H-NMR (500 MHz, DMSO-d6) δH 12.96 (1H, s, 5-OH), 10.77 (1H, s, 7-OH), 9.85 (1H, s, 4'-OH), 9.34 (1H, s, 3'-OH), 7.42 (1H, brs, 6'-H), 7.40 (1H, s, 2'-H), 6.89 (1H, d, J = 8.15 Hz, 5'-H), 6.65 (1H, s, 3-H), 6.44 (1H, s, 8-H), 6.20 (1H, s, 6-H).

**Compound 4:** Yellow powder (MeOH); mp:328–330°C; ESI-MS m/z:287.06 [M+H]+; 1H-NMR (500 MHz, DMSO-d6) δH 12.96 (1H, s, 5-OH), 10.77 (1H, s, 7-OH), 9.85 (1H, s, 4'-OH), 9.34 (1H, s, 3'-OH), 7.42 (1H, brs, 6'-H), 7.40 (1H, s, 2'-H), 6.89 (1H, d, J = 8.15 Hz, 5'-H), 6.65 (1H, s, 3-H), 6.44 (1H, s, 8-H), 6.20 (1H, s, 6-H).

**Compound 5:** White crystals (MeOH); mp:130–132°C; ESI-MS m/z:419.11 [M+H]+; 1H-NMR (500 MHz, DMSO-d6) δH 12.01 (1H, s, 5-OH), 5.65 (1H, dd, J = 12.6, 2.5 Hz, 2-H), 3.23 (1H, m, 3a-H), 2.86 (1H, dd, J = 17.1, 2.5 Hz, 3b-H), 7.53 (2H,d, J = 7.5 Hz, 2', 6'-H), 7.43(3H,m, 3', 4', 5'-H), 6.20 (1H, s, 8-H), 6.16 (1H, s, 6-H), 4.97 (1H, d, J = 7.4, 1''-H); 13C-NMR (125 MHz, DMSO-d6) δC 78.6 (C-2), 42.2 (C-3), 196.7 (C-4), 162.9 (C-5, 9), 96.6 (C-6), 165.3 (C-7), 95.5 (C-8), 103.3 (C-10), 138.4 (C-1'), 126.7 (C-2', 6), 128.6 (C-3', 5'), 128.5 (C-4'), 99.6 (C-1''), 73.0 (C-2''), 76.3 (C-3''), 69.5 (C-4''), 77.1 (C-5''), 60.6 (C-6'').

**Compound 6:** White granular crystal (MeOH); ESI-MS m/z:397.14 [M+H]+; 1H-NMR (500 MHz, CD3OD) δH 6.69 (1H, d, J = 1.9 Hz, 8-H), 6.48 (1H, d, J = 1.9 Hz, 6-H), δH 6.11 (1H, s, 3-H), δH 0.95 (3H, t, J = 7.4 Hz, 3'-H), 1.30 (3H, d, J = 7.0 Hz, 4'-H), δH 2.67 (1H, tq, J = 7.0, 7.0 Hz, 1'-H), δH 1.76 (1H, dq, J = 7.0, 7.0 Hz, 2'a-H), δH 1.64 (1H, dq, J = 7.0, 7.0 Hz, 2'b-H), δH 5.04 (1H, d, J = 7.1 Hz), δH 3.91 (1H, brd, J = 12.0 Hz), 3.70 (1H, dd, J = 12.0, 5.7 Hz); 13C-NMR (125 MHz, CD3OD) δC 184.3, 41.8 (C-1'), 28.6 (C-2'), 18.2 (C-4'), 11.9 (C-3'), 176.5 (C-2), 164.8
(C-7), 163.0 (C-5), 159.5 (C-9), δC 107.1 (C-10), 108.0 (C-3), 101.1 (C-6), 96.0 (C-8), δC 101.7 (C-1"'), 74.7 (C-2"'), 77.9 (C-3"'), 71.3(C-4''), 78.4 (C-5''), 62.4 (C-6'').

Compound 7: Yellow powder (MeOH); ESI-MS m/z:419.06 [M+H]⁺; ¹H-NMR (500 MHz, DMSO-d₆) δH 12.67 (1H, s, 5-OH), 10.87 (1H, s, 7-OH), 10.19 (1H, s, 4'−OH). δH 6.49 (1H, d, J = 1.9 Hz, 8-H), 6.26 (1H, d, J = 1.9 Hz, 6-H), 8.07 (2H, d, J = 8.8 Hz, 2', 6'-H), 6.95 (2H, d, J = 8.8 Hz, 3', 5'-H), 5.68 (1H, d, 1''-H), 3.3−4.2 (8H, m, Ala-H).

Compound 8: Yellow powder (MeOH); mp:276−278°C; ESI-MS m/z:419.06 [M+H]⁺; ¹H-NMR (500 MHz, DMSO-d₆) δH 12.47 (1H, s, 5-OH), 10.75 (1H, s, 7-OH), 10.07 (1H, s, 4'-OH), 9.35 (1H, s, 3-OH). δH 8.04 (2H, d, J = 8.7 Hz, 2', 6'-H), 6.92 (2H, d, J = 8.7 Hz, 3', 5'-H), 6.43 (1H, d, J = 1.8 Hz, 6-H), 6.19 (1H, d, J = 1.8 Hz, 6-H).

Compound 9: White cluster crystal (MeOH); mp 175−177 °C; ESI-MS m/z:291.04 [M+H]⁺; ¹H-NMR (500 MHz, DMSO-d₆) δH 9.11 (1H, s, -OH), 8.89 (1H, s, -OH), 8.80 (1H, s, -OH), 8.75 (1H, s, -OH), 2.66 (1H, dd, J = 16.0, 5.2 Hz, 4′-H), 2.36 (1H, dd, J = 16.0, 8.0 Hz, 4′-α-H), 3.28 (1H, m, 3-H), 4.48 (1H, d, J = 7.4 Hz, 2-H), 5.69 (1H, s, 6-H), 5.89 (1H, s, 8-H), 6.59 (1H, d, J = 8.0 Hz, 6′-H), 6.69 (1H, d, J = 8.0 Hz, 5′-H), 6.72 (1H, s, 2′-H).

Compound 10: Light yellow grains (MeOH); ESI-MS m/z 491.11 [M+H]⁺; ¹H-NMR (500 MHz, DMSO-d₆) δH 12.56 (1H, s, 5-OH), 10.85 (1H, s, 7-OH), 10.15 (1H, s, 4′-OH), 6.24 (1H, brs, 6-H), 6.47 (1H, brs, 8-H), 8.02 (2H, d, J = 7.6 Hz, 2′, 6′-H), 6.90 (2H, d, J = 7.5 Hz, 3′, 5′-H), 5.15 (1H, d, J = 7.3 Hz, 1″-H), 5.37 (1H, s, Glc-H), 5.39 (1H, d, J = 3.7 Hz, Glc-OH), 5.11 (1H, d, J = 3.7 Hz, Glc-OH), 4.14 (1H, d, J = 11.5 Hz, 6″a-H), 3.98 (1H, d, J = 11.6, 5.4 Hz, 6″b-H), 3.16−3.35 (4H, m, Glc-H), 1.77 (3H, s, -CH3); ¹³C-NMR (125 MHz, DMSO-d₆) δC 170.1 (-COCH₃), 20.3 (-CH₃), 156.6 (C-2), 133.2 (C-3), 177.6 (C-4), 161.4 (C-5), 98.9 (C-6), 164.4 (C-7), 93.9 (C-8), 156.8 (C-9), 104.1 (C-10), 121.0 (C-1′), 131.0 (C-2′, 6′), 115.3 (C-3′, 5′), 160.2 (C-4′), 101.3 (C-1″), 74.1 (C-2″), 74.3 (C-3″), 70.0 (C-4″), 76.3 (C-5″), 62.9 (C-6″).

Compound 11: Pink powder (Acetone); ESI-MS m/z:435.04 [M-H]⁻; ¹H-NMR (500 MHz, DMSO-d₆) δH 9.66 (1H, s, -OH), 9.25 (1H, s, -OH), 8.85 (2H, s, -OH), 4.59 (1H, d, J = 7.4 Hz, 2-H), 3.94 (1H, m, 3-H), 2.59 (1H, d, J = 7.4 Hz, 4-H), 2.83 (1H, m, 4-H), 6.17 (1H, s, 8-H), 6.74 (1H, brs, 2′-H), 6.70 (1H, brs, 5′-H), 6.68 (1H, brs, 6′-H), 6.89 (2H, d, J = 8.2 Hz, 2′, 6′-H), 6.64 (2H, brs, 3′, 5′-H), 3.11 (1H, m, α-H), 2.78 (1H, m, α-H), 4.38 (1H, d, J = 6.3 Hz, β-H); ¹³C-NMR (75 MHz, DMSO-d₆) δC 81.3 (C-2), 65.6 (C-3), 27.3 (C-4), 150.1 (C-5), 105.4 (C-6), 154.0 (C-7), 98.3 (C-8), 153.1 (C-9), 100.1 (C-10), 130.1 (C-1′), 114.5 (C-2′), 144.9 (C-3′), 145.0 (C-4′), 115.2 (C-5′), 118.4 (C-6′), 132.2 (C-1″), 127.6 (C-2″, 6″), 115.3 (C-3″, 5″), 156.1 (C-4″), 167.8 (-COO-), 37.0 (C-α), 33.1 (C-β).

Compound 14: Yellow powder (MeOH-CHCl₃); mp:206−208°C; ESI-MS m/z:463.08 [M-H]⁻; ¹H-NMR (300 MHz, DMSO-d₆) δH 12.61 (1H, s, 5-OH), 10.80 (1H, s, 7-OH), 9.24 (2H, s, 3′, 4′-OH), 6.38 (1H, brs, 8-H), 6.18 (1H, brs, 6-H), 6.82 (1H, d, J = 8.9 Hz, 5′-H), 7.55 (2H, brs, 2′, 6′-H), Glc-H:5.44 (1H, d, J = 6.7 Hz, 1″-H), 5.24 (1H, s), 5.01 (1H, s), 4.91 (1H, s), 4.21 (1H, s), 3.56 (2H, d, J = 11.4 Hz), 3.20 (2H, brs), 3.06 (2H, brs).

Compound 15: White granular crystal (MeOH); mp:240−241°C; ESI-MS m/z:288.86 [M+H]⁺; ¹H-NMR (500 MHz, DMSO-d₆) δH 11.89 (1H, s, 5-OH), 10.78 (1H, s, 7-OH), 9.51 (1H, s, 4′-OH), 7.31 (2H, d, J = 8.4 Hz, 2′, 6′-H), 6.78 (2H, d, J = 8.4 Hz, 3′, 5′-H), 5.91 (1H, d, J = 1.6 Hz, 8-H),
5.86 (1H, d, J = 1.6 Hz, 6-H), 5.72 (1H, d, J = 6.2 Hz, 3-OH), 5.05 (1H, d, J = 11.4 Hz, 2-H), 4.57 (1H, dd, J = 11.4, 6.2 Hz, 3-H).

Compound 16: White powder (MeOH); mp: 230–233°C; ESI-MS m/z: 302.87 [M-H]+; 1H-NMR (500 MHz, DMSO-d6) δH 11.91 (1H, s, 5-OH), 10.91 (1H, s, 7-OH), 9.01 (1H, s, δH -OH), 8.96 (1H, s, -OH), 8.69 (1H, brs, 2'-H), 7.67 (2H, brs, 5', 6'-H), 5.93 (1H, d, J = 1.7 Hz, 8-H), 5.89 (1H, d, J = 1.7 Hz, 6-H), 5.75 (1H, d, J = 5.9 Hz, 3-OH), 5.01 (1H, d, J = 11.1 Hz, 2-H), 4.51 (1H, dd, J = 11.1, 6.1 Hz, 3-H).

Compound 17: White powder (MeOH-CHCl3); mp: 260–262°C; ESI-MS m/z: 506.35 [M+NH4]+, 523.42 [M+Cl]+; 1H-NMR (500 MHz, C6D6N) δH 1.05 (3H, s, 25-H), 1.10 (3H, s, 24-H), 1.13 (6H, brs, 26, 30-H), 1.29 (3H, s, 23-H), 1.46 (3H, s, 29-H), 1.73 (3H, s, 27-H), 5.59 (1H, s, 12-H), 4.11 (1H, m, 2α-H), 3.4 (1H, d, J = 9.3 Hz, 3β-H), 3.07 (1H, s, 18-H); 13C-NMR (125 MHz, C6D6N) δC 48.3 (C-1), 69.0 (C-2), 84.2 (C-3), 40.2 (C-4), 56.3 (C-5), 19.4 (C-6), 33.9 (C-7), 40.8 (C-8), 48.2 (C-9), 38.9 (C-10), 24.5 (C-11), 128.3 (C-12), 140.1 (C-13), 42.5 (C-14), 29.7 (C-15), 26.8 (C-16), 48.7 (C-17), 55.0 (C-18), 73.1 (C-19), 42.7 (C-20), 27.5 (C-21), 38.9 (C-22), 29.6 (C-23), 18.0 (C-24), 17.1 (C-25), 17.6 (C-26), 25.1 (C-27), 181.0 (C-28), 27.3 (C-29), 17.2 (C-30).

Compound 18: White powder (MeOH-CHCl3); mp: 293–295°C; ESI-MS m/z: 507.34 [M+Cl]+, 1H-NMR (300 MHz, C6D6N) δH 5.63 (1H, brs, 12-H), 3.46 (1H, m, 3-H), 3.08 (1H, s, 18-H), 1.75 (3H, s, -CH3), 1.47 (3H, s, -CH3), 1.26 (3H, s, -CH3), 1.15 (3H, s, -CH3), 1.14 (3H, brs, -CH3), 1.05 (3H, s, -CH3), 0.95 (3H, s, -CH3); 13C-NMR (75 MHz, C6D6N) δC 39.4 (C-1), 28.5 (C-2), 78.6 (C-3), 39.8 (C-4), 56.3 (C-5), 19.4 (C-6), 34.0 (C-7), 40.8 (C-8), 48.7 (C-9), 37.8 (C-10), 24.4 (C-11), 128.5 (C-12), 140.3 (C-13), 42.5 (C-14), 29.7 (C-15), 26.8 (C-16), 48.2 (C-17), 55.0 (C-18), 73.1 (C-19), 42.8 (C-20), 27.5 (C-21), 38.9 (C-22), 29.2 (C-23), 16.0 (C-24), 16.9 (C-25), 17.6 (C-26), 25.1 (C-27), 181.0 (C-28), 27.3 (C-29), 17.1 (C-30).

Compound 19: White powder (MeOH-CHCl3); ESI-MS m/z: 537.32 [M+Cl]+, 520.19 [M+NH4]+; 1H-NMR (300 MHz, C6D6N) δH 1.81 (3H, s, 27-H), 1.44 (3H, s, 29-H), 1.36 (3H, s, 23-H), 1.15 (3H, s, 26-H), 1.14 (3H, d, J = 8.4 Hz, 30-H), 0.97 (3H, s, 25-H), 0.91 (3H, s, 24-H), δH 5.72 (1H, s, δH -CH3), 4.37 (1H, s, 1-H), 4.33 (1H, s, 3-H), 3.14 (1H, m, 16-Ha), 3.08 (1H, s, 18-H); 13C-NMR (75 MHz, C6D6N) δC 212.5 (C-2), 181.0 (C-28), 129.4 (C-12), 139.3 (C-13), 85.6 (C-1), 82.2 (C-3), 73.1 (C-19), 29.7 (C-23), 17.5 (C-24), 12.8 (C-25), 17.4 (C-26), 25.0 (C-27), 27.5 (C-29), 17.1 (C-30).

Compound 20: White powder (MeOH-CHCl3); mp: 253–255°C; ESI-MS m/z: 507.36 [M+Cl]+, 490.37 [M+NH4]+; 1H-NMR (500 MHz, C6D6N) δH 1.29 (3H, s, -CH3), 1.23 (3H, s, -CH3), 1.09 (3H, s, -CH3), 1.07 (3H, s, -CH3), 1.02 (3H, d, J = 6.8 Hz, 30-H), 1.01 (3H, s, -CH3), 0.98 (3H, d, J = 6.8Hz, 29-H), 5.48 (1H, s, 12-H), 4.08 (1H, m, 2-H), 3.40 (1H, d, J = 9.3 Hz, 3-H); 13C-NMR (125MHz, C6D6N) δC 48.4 (C-1), 69.0 (C-2), 84.2 (C-3), 40.4 (C-4), 56.3 (C-5), 19.2 (C-6), 33.9 (C-7), 40.2 (C-8), 48.5 (C-9), 38.8 (C-10), 24.1 (C-11), 125.9 (C-12), 139.7 (C-13), 42.9 (C-14), 29.0 (C-15), 25.3 (C-16), 48.5 (C-17), 53.9 (C-18), 39.8 (C-19), 39.9 (C-20), 31.4 (C-21), 37.8 (C-22), 29.7 (C-23), 18.1 (C-24), 17.3 (C-25), 17.9 (C-26), 24.3 (C-27), 180.2 (C-28), 17.8 (C-29), 21.8 (C-30).

Compound 22: White powder (MeOH-CHCl3); mp: 165–167°C; ESI-MS: m/z 477.15 [M+H]+; 1H-NMR (500 MHz, DMSO-d6) δH 11.14 (1H, s, 8-OH), 7.21 (2H, d, J = 8.1 Hz, 2', 6'-H), 6.90
Compound 23: White powder (MeOH-CHCl₃); mp:235–240°C; ESI-MS m/z:168.77 [M-H]; ¹H-NMR (500 MHz, DMSO-d₆) δH 12.11 (1H, s, -COOH), 9.14 (2H, s, -OH), 8.80 (1H, s, -OH), 6.90 (2H, s, 2, 6-H).

Compound 24: Pale yellow feather crystal (MeOH-CHCl₃); mp:210–213°C; ESI-MS m/z:164.76 [M+H]+; ¹H-NMR (300 MHz, DMSO-d₆) δH 12.09 (1H, s, -COOH), 9.93 (1H, s, 4-OH), 7.51 (2H, d, J = 8.4 Hz, 2, 6-H), 6.79 (2H, d, J = 8.4 Hz, 3, 5-H), 7.50 (1H, d, J = 15.9 Hz), 6.28 (1H, d, J = 15.9 Hz).

Compound 25: White powder (MeOH-CHCl₃); mp:255–257°C; ESI-MS m/z:166.79 [M-H]; ¹H-NMR (300 MHz, DMSO-d₆) δH 12.47 (1H, s, -COOH), 9.82 (1H, s, 3-OH), 3.83 (3H, s, 4-OCH₃), 7.46 (2H, brs), 6.87 (1H, d, J = 8.7 Hz).

Compound 26: White powder (MeOH-CHCl₃); mp:214–216°C. ESI-MS m/z:136.73[M-H], ¹H-NMR (300 MHz, DMSO-d₆) δH 12.39 (1H, s, -COOH), 10.20 (1H, s, 4-OH), 7.80 (2H, d, J = 8.6 Hz, 2, 6-H), 6.84 (2H, d, J = 8.6 Hz, 3, 5-H).

Compound 27: Light yellow needle crystal (MeOH-CHCl₃); mp:197–200°C; ESI-MS m/z:152.68 [M-H]; ¹H-NMR (300 MHz, DMSO-d₆) δH 12.29 (1H, s, 1-COOH), 9.60 (1H, s, 3-OH), 9.31 (1H, s, 4-OH), 7.33 (1H, d, J = 1.9 Hz, 2-H), 7.28 (1H, dd, J = 8.2, 1.9 Hz, 6-H), 6.77 (1H, d, J = 8.2 Hz, 5-H).

Compound 28: White powder (MeOH-CHCl₃); mp:180–182°C; ESI-MS m/z:878.80[M+Cl], 844.58 [M+H]+; ¹H-NMR (300 MHz, CD₃DN) δH 0.89 (6H, t, J = 6.7 Hz, -CH₂×2), 4.96 (1H, d, J = 7.6 Hz, H-1"), 4.36 (1H, m, Ha-6"), 4.48 (1H, brs, Hb-6"), 4.55 (1H, m, 1-Ha), 4.71 (1H, dd, J = 10.5, 6.7 Hz, 1-Hb), 5.29 (1H, m, 2-H), 4.31 (1H, m, 3-H), 4.21 (1H, m, 4-H), 4.56 (1H, m, 2'-H), 8.55 (1H, d, J = 9.0 Hz, N-H), 5.46 (1H, m, 9-H), 5.56 (1H, m, 8-H); ¹³C-NMR (75 MHz, CD₂DN) δc 70.8 (C-1), 52.1 (C-2), 76.3 (C-3), 72.8 (C-4), 28.0 (C-7), 130.8 (C-8Z), 130.6 (C-9Z), 28.3 (C-10), 105.9 (C-1"), 75.5 (C-2"), 78.8 (C-3"), 71.9 (C-4"), 78.9 (C-5"), 63.0 (C-6"), 176.0 (C-1'), 72.9 (C-2'), 35.9 (C-3'). δC 34.4, 32.5, 30.5, 30.4, 30.3, 30.2, 30.0, 27.2, 26.2, 23.3 (CH₂), 14.6 (CH₃).

Compound 29: Light yellow needle crystal (Petroleum ether-Ethyl acetate); mp:173–175°C; ESI-MS m/z:683.20 [M+H]+; ¹H-NMR (500 MHz, CDCl₃) δH 16.16 (1H, s, -OH), 15.97 (1H, s, -OH), 15.62 (1H, s, -OH), 10.72 (1H, s, -OH), 10.69 (1H, s, -OH), 9.69 (1H, s, -OH), 9.26 (1H, s, -OH), 3.82 (4H, s, Ar-CH₂×2), 3.86(1H, m), 3.72 (6H, s, Ar-OCH₃x2), 2.11 (6H, s, Ar-CH₃×2), δH 0.99 (6H, t, J = 7.3 Hz), 1.75 (4H, m), 3.09 (4H, m) 2×COCH₂CH₂CH₃, δH 0.91 (3H, t, J = 7.4Hz), 1.16 (3H, d, J = 6.4 Hz), 1.84 (1H, m), 1.14 (1H, m), 3.86 (1H, m) -COCH(CH₃)CH₂CH₃.

Compound 30: Light yellow needle crystal (Petroleum ether-Ethyl acetate); mp 147–149 °C;
ESI-MS m/z: 655.10 [M+H]+; 1H-NMR (500 MHz, CDCl3) δH 16.16 (1H, s, -OH), 15.95 (1H, s, -OH), 15.61 (1H, s, -OH), 10.69 (1H, s, -OH), 9.64 (2H, s, -OH), 9.27 (1H, s, -OH), 3.83 (4H, s, Ar-CH2-Ar×2), 3.73 (6H, s, Ar-OCH3×2), 2.12 (6H, s, Ar-CH3×2). δH 3.10 (1H, m), 1.26 (3H, brs), 1.00 (3H, d, J = 7.3 Hz) -COCH(CH3)-CH3, δH 3.10 (1H, m), 1.75 (2H, m), 0.92 (3H, t, J = 7.4Hz), 1.17 (3H, d, J = 7.2 Hz) -COCH(CH3)2CH2-CH3, δH 2.73 (3H, s) -COCH3.

Compound 31: White powder (Acetone); mp: 102~103 °C ; ESI-MS m/z: 348.29 [M+NH4]+, 329.25[M-H]; 1H-NMR (500 MHz, C5D5N) δH 6.38 (1H, dd, J = 5.7, 15.9 Hz, 10-H), 6.33 (1H, dd, J = 5.4, 15.3 Hz, 9-H), 4.50 (2H, m, 8, 11-H), 3.94 (1H, m, 7), 2.50 (2H, m, 2-H), 0.85 (3H, m, 18-H); 13C-NMR (125 MHz, C5D5N) δC 177.4 (C-1), 137.0 (C-10), 131.3 (C-9), 76.6 (C-11), 75.6 (C-8), 72.3 (C-12), 14.6(C-18), 23.4~38.9 (-CH2-).

2. Structures of the isolated compounds
Fig. S1. Structures of compounds 1-31