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Chemical Constituents and Anti-platelet Aggregation Activity from the Root of *Peucedanum formosanum*

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ABSTRACT

Analysis of the root extract of *Peucedanum formosanum* (Taiwan Qian-Hu) led to the isolation of 32 known compounds. The structures of these isolates were determined by spectral data. Some of them displayed strong anti-platelet aggregation activities. Analysis showed that most of the constituents found in *P. formosanum* were the same as those found in *P. praeruptorum* (Bai-Hua Qian-Hu), in that many isolates of both plants' roots belong to seselin-type dihydropyranocoumarins and psoralen-type furanocoumarins.

Key words: *Peucedanum formosanum*, Umbelliferae, root, Qian-Hu, furanocoumarin, dihydropyranocoumarin, anti-platelet aggregation

INTRODUCTION

Peucedanum formosanum Hay. (Umbelliferae) is an endemic perennial herb in Taiwan and distributed at medium to high altitudes through the island[(1)]. Its root has been used as folk medicine to treat coughs, fever, headache and excessive sputum caused by colds. In this regard it resembles the traditional Chinese medicine Qian-Hu, which is derived from the roots of *P. praeruptorum* (Bai-Hua Qian-Hu) and *Angelica decursiva* (*P. decursivum*, *Porphyroscias decursiva*; Zi-Hua Qian-Hu). Two new compounds, peuformosin and (+)-anomalin, have been isolated by means of ether extraction from the root of *P. formosanum*[(2,3)]. The methanolic extract of the root exerted anti-platelet aggregation activity in preliminary screening and subsequent investigation, which led to the isolation of 32 known compounds. In this paper, we report the isolation, the anti-platelet aggregation activities of these isolates, and the comparisons of the constituents of several *Peucedanum* species used in folk or traditional Chinese medicine.

MATERIALS AND METHODS

I. *General*

All melting points were determined on a YANACO micro-melting point apparatus and were uncorrected. ^{1}H-NMR (400 MHz) and ^{13}C-NMR (100 MHz) spectra were taken on a Varian Unity plus-400 and Varian Mercury plus-400. Chemical shifts were given in δ with TMS as an internal standard. EI-mass spectra were performed on a VG Biotech Quattro 5002 using a direct inlet system. HR-mass spectra were recorded on a JEOL JMX-HX 110 spectrometer. UV spectra were determined on a Hitachi U-2000 double beam spectrophotometer in methanol (MeOH) solution. IR spectra were recorded on a Perkin Elmer system 2000 FT-IR (KBr or neat) spectrophotometer. Optical rotation was measured on a JASCO P-1020 polarimeter. Column chromatography (CC) was carried out on silica gel (Merck, 70-230 and 230-400 mesh) or Sephadex LH-20 gel (Pharmacia, Fine Chemicals AB, Uppsala). Prep. TLC was run on silica gel plates (Merck, 60 F-254). The HPLC system is consisted of a Hitachi L-7100 pump, a Biscoff RI detector and a silica gel column (LiChroCART® 250-10, Merck).

II. *Plant*

The roots of *P. formosanum* were collected from Wutai, Pingtung County, Taiwan, in Aug. 2003 and identified by Dr. Ih-Sheng Chen, College of Pharmacy, Kaohsiung Medical University. A voucher specimen (Chen 6145) was deposited in the Herbarium of the School of Pharmacy, Kaohsiung Medical University, Kaohsiung, Taiwan, R.O.C.

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III. *Extraction and Isolation*

Dried root (3.4 kg) of *P. formosanum* was sliced and extracted four times with cold MeOH. The precipitate filtered from the concentrated MeOH solution was washed by ethyl acetate (EtOAc), then recrystallized from EtOH to obtain D-mannitol (**1**, 80 g). The filtrate was removed from the solvent in vacuum and partitioned into $CHCl_3$ soluble fraction (180 g), *n*-BuOH soluble fraction (40 g), and H_2O soluble fraction (360 g). The $CHCl_3$-soluble fraction (180 g) was chromatographed over silica gel (2.0 kg), eluted with $CHCl_3$ and gradually enriched with MeOH to give 12 fractions (frs. 1–12).

Fr. 3 (18.5 g; $CHCl_3$–MeOH, 49:1) was washed by *n*-hexane to get the crystalline mass (11.3 g) which was silica gel CC (330 g) eluted with *n*-hexane/acetone (20:1) with gradually increasing polarity to afford bergapten (**2**, 33.5 mg), isoimperatorin (**3**, 12.2 mg), (–)-deltoin (**4**, 23.5 mg), and xanthotoxin (**5**, 10.4 mg), a mixture (75.8 mg) of β-sitosterol (**6**) and stigmasterol (**7**), a mixture (23.5 mg) of (+)-praeruptorin E (**8**) and (+)-hyuganin A (**9**), and (–)-*cis*-3'-isovaleryl-4'-senecioylkhellactone (**10**, 4.5 mg). The washings (4.5 g) of fr. 3 were silica gel CC (135 g) and eluted with *n*-hexane–acetone (5:1) to produce panaxynol (**11**, 156 mg).

Fr. 4 (40.1 g; $CHCl_3$/MeOH, 97:3) was washed with *n*-hexane to obtain the crystalline mass (15.2 g). Part (1.0 g) of the crystalline mass was subjected to preparative HPLC (*n*-hexane/EtOAc, 4:1, flow rate = 3 mL/min) to produce (–)-isosamidin (**12**, 18.5 mg), (+)-peuformosin (**13**, 141 mg), (+)-anomalin (**14**, 86.2 mg), and (+)-*cis*-3'-acetoxy-4'-(2-methylbutyroyloxy)-3',4'-dihydroseselin (**15**, 7.8 mg). The washings (20 g) of fr. 4 were silica gel CC (600 g) eluted with *n*-hexane/EtOAc (10:1), with gradually increasing polarity to obtain a mixture (3.4 mg) of *cis*-3'-hydroxy-4'-isovaleryloxy-3',4'-dihydroseselin (**16**) and laserpitin (**17**), (–)-*cis*-3'-hydroxy-4'-(2-methylbutyryloxy)-3',4'-dihydroseselin (**18**, 6.8 mg), and (+)-marmesin (**19**, 8.9 mg).

Part (5.0 g) of fr. 5 (33.4 g; $CHCl_3$/MeOH, 24:1) was silica gel CC (150 g) eluted with *n*-hexane/CH_2Cl_2 (5:1), with gradually increasing polarity with CH_2Cl_2/EtOAc (10:1) to produce umbelliferone (**20**, 4.6 mg), isoscopoletin (**21**, 1.6 mg), *p*-hydroxyphenethyl ferulate (**22**, 8.9 mg), falcarindiol (**23**, 32.6 mg), and psoralen (**24**, 1.5 mg).

Fr. 7 (3.4 g; $CHCl_3$/MeOH, 96:4) was silica gel CC (150 g) eluted with $CHCl_3$/MeOH (10:1), with gradually increasing polarity to afford (+)-lomatin (**25**, 3.2 mg), isofraxidin (**26**, 1.8 mg), and (–)-*cis*-khellactone (**27**, 3.8 mg).

Fr. 8 (2.6 g; $CHCl_3$/MeOH, 9:1) was chromatographed on Sephadex LH-20 eluted with MeOH to obtain 1-*O*-hexadecanoyl glycerol (**28**, 2.5 mg), (+)-3'-hydroxymarmesin (**29**, 4.7 mg) and (+)-rutaretin (**30**, 28.3 mg).

Fr. 9 (0.8 g; $CHCl_3$/MeOH, 4:1) was chromatographed on Sephadex LH-20 eluted with MeOH to afford (+)-oxypeucedanin hydrate (**31**, 1.7 mg) and (+)-dorsteniol (**32**, 1.8 mg).

IV. *Isolates*

D-Mannitol (**1**): colorless needles, m.p. 166–168°C (EtOH), $[\alpha]_D^{24}$: +45.6° (*c* 1.55, pyridine).

Bergapten (**2**): colorless needles, m.p. 192–194°C (Et_2O), EI-MS *m/z* (%): 216 ($[M]^+$, 100), 201 (31), 173 (57), 145 (20). IR ν_{max}^{KBr} cm^{-1}: 1731(C=O). UV λ_{max}^{MeOH} nm (log ε): 222 (4.58), 249 (4.46), 259 (4.42), 267 (4.46), 310 (4.38). ^{1}H-NMR ($CDCl_3$, 200 MHz): δ 4.26 (3H, *s*, OMe-5), 6.26 (1H, *d*, *J* = 9.8 Hz, H-3), 7.01 (1H, *br d*, *J* = 2.4 Hz, H-3'), 7.12 (1H, *br s*, H-8), 7.59 (1H, *d*, *J* = 2.4 Hz, H-2'), 8.14 (1H, *d*, *J* = 9.8 Hz, H-4).

Isoimperatorin (**3**): light yellow needles, m.p. 108–110°C (Et_2O), EI-MS *m/z* (%): 270 ($[M]^+$, 0.2), 202 (100), 174 (19), 69 (70). IR ν_{max}^{KBr} cm^{-1}: 1728 (C=O). UV λ_{max}^{MeOH} nm (log ε): 222 (4.73), 250 (4.63), 259 (4.58), 267 (4.57), 308 (4.53). ^{1}H-NMR ($CDCl_3$, 200 MHz): δ 1.70 (3H, *s*, H-4"), 1.80 (3H, *s*, H-5"), 4.92 (2H, *d*, *J* = 7.4 Hz, H-1"), 5.53 (1H, *br t*, *J* = 7.4 Hz, H-2"), 6.27 (1H, *d*, *J* = 10.0 Hz, H-3), 6.95 (1H, *br d*, *J* = 2.2 Hz, H-3'), 7.15 (1H, *br s*, H-8), 7.59 (1H, *d*, *J*= 2.2 Hz, H-2'), 8.16 (1H, *d*, *J* = 10.0 Hz, H-4).

(–)-Deltoin (**4**): colorless prisms, m.p. 86–88°C (*n*-hexane), $[\alpha]_D^{25}$: –70.4° (*c* 0.08, $CHCl_3$), EI-MS *m/z* (%): 328 ($[M]^+$, 0.1), 228 (28), 214 (15), 213 (100), 187 (13), 83 (43). IR ν_{max}^{KBr} cm^{-1}: 1708 (C=O). UV λ_{max}^{MeOH} nm (log ε): 222 (4.78), 258 (4.15), 333 (4.17). ^{1}H-NMR ($CDCl_3$, 200 MHz): δ 1.60 (3H, *s*, Me-4'), 1.62 (3H, *s*, Me-4'), 1.67 (3H, *s*, H-5"), 1.88 (3H, *br d*, *J* = 6.0 Hz, H-4"), 3.26 (2H, *d*, *J* = 8.4 Hz, H-3'), 5.06 (1H, *t*, *J* = 8.4 Hz, H-2'), 5.98 (1H, *br q*, *J* = 6.0 Hz, H-3"), 6.21 (1H, *d*, *J* = 9.4 Hz, H-3), 6.73 (1H, *s*, H-8), 7.21 (1H, *br s*, H-5), 7.59 (1H, *d*, *J* = 9.4 Hz, H-4).

Xanthotoxin (**5**): colorless needles, m.p. 144–146°C (MeOH), EI-MS *m/z* (%): 216 ($[M]^+$, 100), 201 (23), 173 (46), 145 (21), 89 (26). IR ν_{max}^{KBr} cm^{-1}: 1713 (C=O). UV λ_{max}^{MeOH} nm (log ε): 218 (4.54), 248 (4.52), 300 (4.24). ^{1}H-NMR ($CDCl_3$, 200 MHz): δ 4.30 (3H, *s*, OMe-8), 6.38 (1H, *d*, *J* = 9.6 Hz, H-3), 6.82 (1H, *d*, *J* = 2.2 Hz, H-3'), 7.36 (1H, *s*, H-5), 7.69 (1H, *d*, *J* = 2.2 Hz, H-2'). 7.77 (1H, *d*, *J* = 9.6 Hz, H-4).

β-Sitosterol (**6**) & stigmasterol (**7**): colorless needles, m.p. 142–144°C (MeOH), $[\alpha]_D^{25}$: –54.3° (*c* 0.08, $CHCl_3$).

(+)-Praeruptorin E (**8**) & (+)-hyuganin A (**9**): colorless prisms, m.p. 127–130°C (*n*-hexane), $[\alpha]_D^{25}$: +36.18° (*c* 2.78, $CHCl_3$), GC-EI-MS *m/z* (%): **8**: 428 ($[M]^+$, 0.2), 328 (9), 313 (2), 244 (24), 229 (100), 85 (1.8), 83 (1.6); **9**: 428 ($[M]^+$, 0.2), 328 (10), 313 (12), 244 (12), 229 (100), 85 (3), 83 (6). IR ν_{max}^{KBr} cm^{-1}: 1735 (C=O). UV λ_{max}^{MeOH} nm (log ε): 220 (4.94), 245 (4.44), 255 sh (4.31), 300 sh (4.67), 321 (4.85). ^{1}H-NMR ($CDCl_3$, 200 MHz): **8**: δ 0.94 (3H, *d*, *J* = 6.2 Hz, H-4'''), 0.95 (3H, *d*, *J* = 6.6 Hz, H-5'''), 1.44 (3H, *s*, Me-2'), 1.47 (3H, *s*, Me-2'), 1.88 (3H, *br q*, *J* = 1.2 Hz, H-5"), 1.96 (3H, *br dq*, *J* = 7.2, 1.2 Hz, H-4"), 2.0–2.4 (3H, *m*, H-2''', 3'''), 5.37 (1H, *d*, *J* = 5.0 Hz, H-3'), 6.12 (1H, *br q*, *J* = 7.2 Hz, H-3"), 6.21 (1H, *d*, *J* = 9.4 Hz, H-3), 6.61 (1H, *d*, *J* = 5.0 Hz, H-4'), 6.80 (1H, *d*, *J* = 8.6 Hz, H-6), 7.35 (1H, *d*, *J* = 8.6 Hz, H-5), 7.60 (1H, *d*, *J* = 9.4 Hz, H-4); **9**: δ 0.89 (3H, *t*, *J* = 7.4 Hz, H-4'''), 1.17 (3H, *d*, *J* =

6.8 Hz, H-5'''), 1.44 (3H, *s*, Me-2'), 1.47 (3H, *s*, Me-2'), 1.56–1.80 (2H, *m*, H-2'''), 5.37 (1H, *d*, *J* = 5.0 Hz, H-3'), 6.21 (1H, *d*, *J* = 9.4 Hz, H-3), 6.59 (1H, *d*, *J* = 5.0 Hz, H-4'), 6.80 (1H, *d*, *J* = 8.6 Hz, H-6), 7.35 (1H, *d*, *J* = 8.6 Hz, H-5), 7.60 (1H, *d*, *J* = 9.4 Hz, H-4).

(–)-*cis*-3'-Isovaleryl-4'-senecioylkhellactone (**10**): colorless oil, $[\alpha]_D^{25}$: –13.3° (*c* 0.08, $CHCl_3$), EI-MS *m/z* (%): 428 ($[M]^+$, 0.1), 326 (5), 311 (10), 261 (5), 244 (8), 229 (39), 231(4.4), 189 (3), 83 (100). IR ν_{max}^{KBr} cm^{-1}: 1731 (C=O). UV λ_{max}^{MeOH} nm (log ε): 217 (4.82), 255 sh (4.09), 300 sh (4.32), 323 (3.50). ^{1}H-NMR ($CDCl_3$, 200 MHz): δ 0.95 (3H, *d*, *J* = 6.2 Hz, H-4"), 0.97 (3H, *d*, *J* = 6.2 Hz, H-5"), 1.41 (3H, *s*, Me-2'), 1.45 (3H, *s*, Me-2'), 1.89 (3H, *s*, H-4'''), 2.23 (3H, *s*, H-5'''), 1.90–2.20 (3H, *m*, H-2", 3"), 5.33 (1H, *d*, *J* = 4.8 Hz, H-3'), 5.63 (1H, *br s*, H-2'''), 6.21 (1H, *d*, *J* = 9.6 Hz, H-3), 6.59 (1H, *d*, *J* = 4.8 Hz, H-4'), 6.79 (1H, *d*, *J* = 8.8 Hz, H-6), 7.33 (1H, *d*, *J* = 8.8 Hz, H-5), 7.58 (1H, *d*, *J* = 9.6 Hz, H-4). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ 20.4 (C-5'''), 22.4 (C-4", 5"), 22.5 (Me-2'), 25.3 (Me-2', C-3"), 27.5(C-4'''), 43.1 (C-2"), 59.6 (C-4'), 70.2 (C-3'), 77.5 (C-2'), 107.6 (C-8), 112.5 (C-4a), 113.3 (C-3), 114.3 (C-6), 115.1 (C-2'''), 129.0 (C-5), 143.1 (C-4), 154.0 (C-8a), 156.7 (C-7), 158.2 (C-3'''), 159.9 (C-2), 165.1 (C-1"), 171.9 (C-1''').

Panaxynol (**11**): colorless oil, $[\alpha]_D^{25}$: –20.8° (*c* 0.23, $CHCl_3$), EI-MS *m/z* (%): 244 ($[M]^+$, 3), 243 (9), 202 (13), 159 (47), 145 (35), 141 (42), 131 (53), 129 (65), 128 (50), 117 (68), 115 (94), 91 (100). IR ν_{max}^{neat} cm^{-1}: 3421 (OH), 2233 (C≡C).

(–)-Isosamidin (**12**): colorless needles, m.p. 120–122°C (*n*-hexane), $[\alpha]_D^{25}$: –71.6° (*c* 0.08, $CHCl_3$), EI-MS *m/z* (%): 386 ($[M]^+$, 0.3), 355 (7), 326 (4), 311 (10), 244 (7), 229 (38), 83 (100). IR ν_{max}^{KBr} cm^{-1}: 1741 (C=O). UV λ_{max}^{MeOH} nm (log ε): 222 (4.93), 255 (4.36), 300 sh (4.63), 323 (4.81). ^{1}H-NMR ($CDCl_3$, 400 MHz): δ 1.42 (3H, *s*, Me-2'), 1.46 (3H, *s*, Me-2'), 1.89 (3H, *d*, *J* = 1.2 Hz, H-4'''), 2.09 (3H, *s*, H-2"), 2.23 (3H, *d*, *J* = 1.2 Hz, H-5'''), 5.30 (1H, *d*, *J* = 4.8 Hz, H-3'), 5.64 (1H, *q*, *J* = 1.2 Hz, H-2'''), 6.22 (1H, *d*, *J* = 9.6 Hz, H-3), 6.58 (1H, *d*, *J* = 4.8 Hz, H-4'), 6.79 (1H, *d*, *J* = 8.8 Hz, H-6), 7.34 (1H, *d*, *J* = 8.8 Hz, H-5), 7.58 (1H, *d*, *J* = 9.6 Hz, H-4).

(+)-Peuformosin (**13**): colorless needles, m.p. 155–156°C (*n*-hexane), $[\alpha]_D^{25}$: +48.1° (*c* 0.43, $CHCl_3$), EI-MS *m/z* (%): 426 ($[M]^+$, 0.1), 326 (4), 311 (7), 244 (4), 229 (22), 213 (3), 189 (1), 83(100). IR ν_{max}^{KBr} cm^{-1}: 1747 1725 (C=O). UV λ_{max}^{MeOH} nm (log ε): 218 (4.88), 255 sh (4.41), 300 sh (4.64), 323 (4.48). ^{1}H-NMR ($CDCl_3$, 400 MHz): δ 1.38 (3H, *s*, Me-2'), 1.43 (3H, *s*, Me-2'), 1.80 (3H, *br s*, H-5"), 1.81 (3H, *s*, H-4'''), 1.92 (3H, *d*, *J* = 7.0 Hz, H-4"), 2.12 (3H, *s*, H-5'''), 5.32 (1H, *d*, *J* = 5.0 Hz, H-3'), 5.56 (1H, *br s*, H-2'''), 6.05 (1H, *br q*, *J* = 7.0 Hz, H-3"), 6.13 (1H, *d*, *J* = 9.5 Hz, H-3), 6.58 (1H, *d*, *J* = 5.0 Hz, H-4'), 6.75 (1H, *d*, *J* = 8.5 Hz, H-6), 7.31 (1H, *d*, *J* = 8.5 Hz, H-5), 7.55 (1H, *d*, *J* = 9.5 Hz, H-4). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ 15.6 (C-4"), 20.2 (C-5"), 20.2 (C-5'''), 22.2 (Me-2'), 25.5 (Me-2'), 27.3 (C-4'''), 59.3 (C-4'), 70.3 (C-3'), 77.3 (C-2'), 107.4 (C-8), 112.3 (C-4a), 113.0 (C-3), 114.2 (C-6), 115.0 (C-2'''), 127.0 (C-2"), 129.1 (C-5), 139.3 (C-3"), 143.1 (C-4), 153.8 (C-8a), 156.6 (C-7), 157.7 (C-3'''), 159.7 (C-2), 164.8 (C-1'''), 166.1 (C-1").

(+)-Anomalin (**14**): colorless needles, m.p. 171–173°C (*n*-hexane), $[\alpha]_D^{25}$: +32.4° (*c* 0.2, $CHCl_3$), EI-MS *m/z* (%): 426 ($[M]^+$, 0.1), 327 (37), 311 (53), 229 (100). IR ν_{max}^{KBr} cm^{-1}: 1731 (C=O), 1604. UV λ_{max}^{MeOH} nm (log ε): 209 (4.81), 217 (4.80), 255 (4.36), 300 sh (4.45), 323 (4.47). ^{1}H-NMR ($CDCl_3$, 400 MHz): δ 1.45 (3H, *s*, Me-2'), 1.49 (3H, *s*, Me-2'), 1.82 (3H, *br s*, H-5"), 1.85 (3H, *br s*, H-5'''), 1.92–1.98 (6H, *m*, H-4", 4'''), 5.45 (1H, *d*, *J* = 5.0 Hz, H-3'), 6.01 (1H, *br q*, *J* = 7.2 Hz, H-3"), 6.02 (1H, *br q*, *J* = 7.2 Hz, H-3'''), 6.22 (1H, *d*, *J* = 9.4 Hz, H-3), 6.70 (1H, *d*, *J* = 5.0, H-4'), 6.81 (1H, *d*, *J* = 8.8 Hz, H-6), 7.34 (1H, *d*, *J* = 8.8 Hz, H-5), 7.59 (1H, *d*, *J* = 9.4 Hz, H-4).

(+)-*cis*-3'-Acetoxy-4'-(2-methylbutyroyloxy)-3',4'-dihydroseselin (**15**): colorless oil, $[\alpha]_D^{25}$: +12.6° (*c* 0.39, $CHCl_3$), EI-MS *m/z* (%): 388 ($[M]^+$, 0.2), 328 (2), 327 (7), 312 (7), 261 (7), 244 (11), 230 (15), 229 (100). IR ν_{max}^{neat} cm^{-1}: 1743 (C=O), 1608. UV λ_{max}^{MeOH} nm (log ε): 208 (4.76), 215 sh (4.65), 245 (4.12), 255 (4.05), 300 sh (4.43), 323 (4.62). ^{1}H-NMR ($CDCl_3$, 400 MHz): δ 0.94 (3H, *t*, *J* = 7.6 Hz, H-4'''), 1.21 (3H, *d*, *J* = 7.2 Hz, H-5'''), 1.42 (3H, *s*, Me-2'), 1.45 (3H, *s*, Me-2'), 1.48 (1H, *m*, H-3'''), 1.72 (1H, *m*, H-3'''), 2.10 (3H, *s*, H-2"), 2.41 (1H, *m*, H-2'''), 5.30 (1H, *d*, *J* = 5.0 Hz, H-3'), 6.22 (1H, *d*, *J* = 9.4 Hz, H-3), 6.52 (1H, *d*, *J* = 5.0 Hz, H-4'), 6.79 (1H, *d*, *J* = 8.6 Hz, H-6), 7.36 (1H, *d*, *J* = 8.6 Hz, H-5), 7.59 (1H, *d*, *J* = 9.4 Hz, H-4). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ 11.6 (C-4'''), 16.6 (C-5'''), 20.7 (C-2"), 21.9 (Me-2'), 25.5 (Me-2'), 26.6 (C-3'''), 41.3 (C-2'''), 60.3 (C-4'), 70.7 (C-3'), 77.3 (C-2'), 107.4 (C-8), 112.3 (C-4a), 113.3 (C-3), 114.3 (C-6), 129.3 (C-5), 143.2 (C-4), 154.0 (C-8a), 156.5 (C-7), 159.7 (C-2), 169.8 (C-1"), 175.6 (C-1''').

cis-3'-Hydroxy-4'-isovaleryloxy-3',4'-dihydroseselin (**16**) & laserpitin (**17**): colorless oil, $[\alpha]_D^{25}$: –107.5°(*c* 0.22, $CHCl_3$), GC-EI-MS *m/z* (%): **16**: 346 ($[M]^+$, 8), 328 (8), 312 (9), 244 (50), 229 (100); **17**: 344 ($[M]^+$, 8), 326 (8), 310 (22), 244 (50), 229 (100). IR ν_{max}^{neat} cm^{-1}: 3473 (OH), 1729 (C=O), 1606. UV λ_{max}^{MeOH} nm (log ε): 205 (4.05), 215 sh (3.80), 324 (3.56). ^{1}H-NMR ($CDCl_3$, 200 MHz): **16**: δ 0.97 (3H, *d*, *J* = 6.2 Hz, H-4"), 1.01 (3H, *d*, *J* = 6.2 Hz, H-5"), 1.41 (3H, *s*, Me-2'), 1.45 (3H, *s*, Me-2'), 2.10–2.40 (3H, *m*, H-2", 3"), 2.88 (1H, *br s*, OH-3'), 4.03 (1H, *d*, *J* = 5.0 Hz, H-3'), 6.23 (1H, *d*, *J* = 9.6 Hz, H-3), 6.42 (1H, *d*, *J* = 5.0 Hz, H-4'), 6.80 (1H, *d*, *J* = 8.8 Hz, H-6), 7.35 (1H, *d*, *J* = 8.8 Hz, H-5), 7.60 (1H, *d*, *J* = 9.6 Hz, H-4); 17: δ 1.41 (3H, *s*, Me-2'), 1.45 (3H, *s*, Me-2'), 1.88 (3H, *br q*, *J* = 1.2 Hz, H-5"), 1.96 (3H, *br dq*, *J* = 7.2, 1.2 Hz, H-4"), 2.88 (1H, *br s*, OH-3'), 4.08 (1H, *d*, *J* = 5.0 Hz, H-3'), 6.12 (1H, *br q*, *J* = 7.2 Hz, H-3"), 6.23 (1H, *d*, *J* = 9.6 Hz, H-3), 6.49 (1H, *d*, *J* = 5.0 Hz, H-4'), 6.80 (1H, *d*, *J* = 8.8 Hz, H-6), 7.35 (1H, *d*, *J* = 8.8 Hz, H-5), 7.60 (1H, *d*, *J* = 9.6 Hz, H-4).

(–)-*cis*-3'-Hydroxy-4'-(2-methylbutyryloxy)-3',4'-dihydroseselin (**18**): colorless oil, $[\alpha]_D^{25}$: –80.5° (*c* 0.34, $CHCl_3$), EI-MS *m/z* (%): 346 ($[M]^+$, 4), 328 (6), 313 (7), 244 (20), 229 (100). IR ν_{max}^{neat} cm^{-1}: 3472 (OH), 1730 (C=O),

1607. UV λ_{max}^{MeOH} nm (log ε): 206 (4.48), 215 sh (4.16), 246 (3.56), 256 (3.50), 325 (4.12). ^{1}H-NMR ($CDCl_3$, 200 MHz): δ 0.94 (3H, *t*, *J* = 7.4 Hz, H-4"), 1.24 (3H, *d*, *J* = 6.8 Hz, H-5"), 1.42 (3H, *s*, Me-2'), 1.49 (3H, *s*, Me-2'), 1.50 (1H, *m*, H-3"), 1.75 (1H, *m*, H-3"), 2.49 (1H, *m*, H-2"), 2.87 (1H, *br s*, OH-3'), 4.05 (1H, *d*, *J* = 5.2 Hz, H-3'), 6.24 (1H, *d*, *J* = 9.6 Hz, H-3), 6.39 (1H, *d*, *J* = 5.2 Hz, H-4'), 6.79 (1H, *d*, *J* = 8.8 Hz, H-6), 7.36 (1H, *d*, *J* = 8.8 Hz, H-5), 7.61 (1H, *d*, *J* = 9.6 Hz, H-4).

(+)-Marmesin (**19**): colorless prisms, m.p. 187–188°C (*n*-hexane/$CHCl_3$), $[\alpha]_D^{25}$: +26.2° (*c* 1.1, $CHCl_3$), EI-MS *m/z* (%): 246 ($[M]^+$, 36), 213 (31), 188 (65), 187 (100), 160 (26), 131 (16). IR ν_{max}^{KBr} cm^{-1}: 3447 (OH), 1703 (C=O), 1625, 1566. UV λ_{max}^{MeOH} nm (log ε): 207 (4.50), 225 (4.24), 248 (3.81), 258 (3.73), 335 (4.45). ^{1}H-NMR ($CDCl_3$, 200 MHz): δ 1.23 (3H, *s*, Me-4'), 1.37 (3H, *s*, Me-4'), 1.80 (1H, *br s*, OH-4'), 3.22 (2H, *d*, *J* = 8.4 Hz, H-3'), 4.73 (1H, *t*, *J* = 8.4 Hz, H-2'), 6.20 (1H, *d*, *J* = 9.6 Hz, H-3), 6.74 (1H, *s*, H-8), 7.21 (1H, *s*, H-5), 7.59 (1H, *d*, *J* = 9.6 Hz, H-4).

Umbelliferone (**20**): yellow prisms, m.p. 224–226°C (Et_2O/acetone), EI-MS *m/z* (%): 162 ($[M]^+$, 100), 135 (55), 134 (63), 106 (13), 105 (16), 78 (29). IR ν_{max}^{KBr} cm^{-1}: 3161 (OH), 1709 (C=O). UV λ_{max}^{MeOH} nm (log ε): 207 (4.27), 325 (4.31). UV $\lambda_{max}^{MeOH+KOH}$ nm (log ε): 210 (4.39), 230 (4.09), 371 (4.40). ^{1}H-NMR (acetone-*d*6, 200 MHz): δ 6.16 (1H, *d*, *J* = 9.4 Hz, H-3), 6.74 (1H, *d*, *J* = 2.2 Hz, H-8), 6.83 (1H, *dd*, *J* = 8.8, 2.2 Hz, H-6), 7.50 (1H, *d*, *J* = 8.8 Hz, H-5), 7.85 (1H, *d*, *J* = 9.4 Hz, H-4).

Isoscopoletin (**21**): yellow prisms, m.p. 184–186°C (Et_2O/acetone), EI-MS *m/z* (%): 192 ($[M]^+$, 100), 188 (25), 177 (42), 164 (34), 149 (43), 121 (23), 79 (7), 69 (12). IR ν_{max}^{KBr} cm^{-1}: 3442 (OH), 1707 (C=O), 1609, 1567, 1293. UV λ_{max}^{MeOH} nm (log ε): 207 (4.02), 227 (3.75), 255 sh (3.23), 293 (3.30), 338 (3.56). UV $\lambda_{max}^{MeOH+KOH}$ nm (log ε): 208 (4.09), 244 (3.61), 278 (3.20), 391 (3.66). ^{1}H-NMR ($CDCl_3$, 200 MHz): δ 3.95 (3H, *s*, OMe-7), 6.14 (1H, *br s*, OH-6, D_2O exchangeable), 6.26 (1H, *d*, *J* = 9.6 Hz, H-3), 6.85 (1H, *s*, H-8), 6.92 (1H, *s*, H-5), 7.59 (1H, *d*, *J* = 9.6 Hz, H-4).

p-Hydroxyphenethyl ferulate (**22**): colorless oil, EI-MS *m/z* (%): 314 ($[M]^+$, 0.5), 194 (100), 177 (12), 145 (18), 120 (36). IR ν_{max}^{KBr} cm^{-1}: 3380 (OH), 1693 (C=O), 1595, 1515. UV λ_{max}^{MeOH} nm (log ε): 220 (4.66), 300 sh (4.51), 325 (4.67). UV $\lambda_{max}^{MeOH+KOH}$ nm (log ε): 210 (4.62), 225 (4.58), 311 (4.20), 378 (4.74). ^{1}H-NMR ($CDCl_3$, 400 MHz): δ 2.94 (2H, *t*, *J* = 7.2 Hz, H-7'), 3.93 (3H, *s*, OMe-3), 4.37 (2H, *t*, *J* = 7.2 Hz, H-8'), 4.95 (1H, *br s*, OH-4, D_2O exchangeable), 5.87 (1H, *s*, OH-4', D_2O exchangeable), 6.27 (1H, *d*, *J* = 16.0 Hz, H-8), 6.78 (2H, *d*, *J* = 8.8 Hz, H-3', 5'), 6.91 (1H, *d*, *J* = 8.0 Hz, H-6), 7.01 (1H, *d*, *J* = 2.0 Hz, H-2), 7.06 (1H, *dd*, *J* = 8.0, 2.0 Hz, H-5), 7.12 (2H, *d*, *J* = 8.8 Hz, H-2', 6'), 7.59 (1H, *d*, *J* = 16.0 Hz, H-7). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ 167.3 (C-9), 154.3 (C-4'), 147.9 (C-4), 146.7 (C-3), 144.9 (C-7), 130.0 (C-2', 6'), 129.9 (C-1'), 127.0 (C-1), 123.1 (C-6), 115.3 (C-3', 5', 8), 114.6 (C-5), 109.3 (C-2), 65.1 (C-1"), 55.9(OMe-3), 34.3 (C-2").

Falcarindiol (**23**): colorless oil, $[\alpha]_D^{25}$: +95.2° (*c* 0.12, $CHCl_3$), EI-MS *m/z* (%): 260 ($[M]^+$, 4), 242 (6), 229 (35), 157 (27), 129 (87), 128 (100), 115 (53), 91 (57). IR ν_{max}^{neat} cm^{-1}: 3380 (OH), 2231, 2146 (C≡C). ^{1}H-NMR ($CDCl_3$, 400 MHz): δ 0.88 (3H, *t*, *J* = 6.8 Hz, H-17), 1.25–1.40 (10H, *br s*, H-12–16), 2.11 (2H, *q*, *J* = 7.2 Hz, H-11), 4.93 (1H, *br d*, *J* = 5.2 Hz, H-3), 5.20 (1H, *d*, *J* = 8.2 Hz, H-8), 5.26 (1H, *d*, *J* = 10.4 Hz, Ha-1), 5.47 (1H, *d*, *J* = 16.8 Hz, Hb-1), 5.51 (1H, *dd*, *J* = 10.0, 8.2 Hz, H-9), 5.60 (1H, *dt*, *J* = 10.0, 7.2 Hz, H-10), 5.93 (1H, *ddd*, *J* = 16.8, 10.4, 5.2 Hz, H-2). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ 14.1 (C-17), 22.6 (C-16), 27.7 (C-11), 29.0 (C-12), 29.1 (C-13), 29.2 (C-14), 31.7 (C-15), 58.6 (C-8), 63.4 (C-3), 68.6 (C-6), 70.2 (C-5), 78.2 (C-4), 79.8 (C-7), 117.3 (C-1), 127.6 (C-9), 134.7 (C-10), 135.8 (C-2).

Psoralen (**24**): yellow needles, m.p. 161–163°C (Et_2O), EI-MS *m/z* (%): 186 ($[M]^+$, 100), 158 (64), 130 (20), 102 (25). IR ν_{max}^{KBr} cm^{-1}: 1724 (C=O). UV λ_{max}^{MeOH} nm (log ε): 210 (4.18), 240 sh (4.29), 246 (4.31), 290 (3.94), 328 (3.72).

(+)-Lomatin (**25**): colorless needles, m.p. 156-158°C (*n*-hexane), $[\alpha]_D^{25}$: +45.3° (*c* 0.13, $CHCl_3$), EI-MS *m/z* (%): 246 ($[M]^+$, 38), 213 (16), 188 (11), 177 (17), 176 (100), 147 (13), 91 (8). IR ν_{max}^{KBr} cm^{-1}: 3440 (OH), 1712 (C=O), 1603. UV λ_{max}^{MeOH} nm (log ε): 209 (4.57), 215 sh (4.16), 247 (3.83), 257 (3.80), 327 (4.49). ^{1}H-NMR ($CDCl_3$, 200 MHz): δ 1.35 (3H, *s*, Me-2'), 1.42 (3H, *s*, Me-2'), 2.97 (1H, *dd*, *J* = 17.4, 5.2 Hz, H-4'), 3.16 (1H, *dd*, *J* = 17.4, 5.2 Hz, H-4'), 3.93 (1H, *t*, *J* = 5.2 Hz, H-3'), 6.24 (1H, *d*, *J* = 9.6 Hz, H-3), 6.79 (1H, *d*, *J* = 8.4 Hz, H-6), 7.26 (1H, *d*, *J* = 8.4 Hz, H-5), 7.64 (1H, *d*, *J* = 9.6 Hz, H-4).

Isofraxidin (**26**): yellow needles, m.p. 144–146°C (*n*-hexane), EI-MS *m/z* (%): 222 ($[M]^+$, 100), 207 (29), 194 (35), 179 (29), 167 (27), 161 (20), 149 (49). IR ν_{max}^{KBr} cm^{-1}: 3442 (OH), 1703 (C=O), 1264. UV λ_{max}^{MeOH} nm (log ε): 209 (4.30), 220 sh (4.08), 339 (3.75). UV $\lambda_{max}^{MeOH+KOH}$ nm (log ε): 215 (4.27), 398 (3.97). ^{1}H-NMR ($CDCl_3$, 200 MHz): δ 3.95 (3H, *s*, OMe-6), 4.10 (3H, *s*, OMe-8), 6.13 (1H, *br s*, OH-7, D_2O exchangeable), 6.29 (1H, *d*, *J* = 9.6 Hz, H-3), 6.66 (1H, *s*, H-5), 7.60 (1H, *d*, *J* = 9.6 Hz, H-4).

(–)-*cis*-Khellactone (**27**): colorless prisms, m.p. 145–147°C (Et_2O), $[\alpha]_D^{25}$: –17.4° (*c* 0.18, $CHCl_3$), EI-MS *m/z* (%): 262 ($[M]^+$, 15), 192 (13), 191 (100), 162 (16), 134 (16), 107 (14). IR ν_{max}^{KBr} cm^{-1}: 3418 (OH), 1712 (C=O), 1603. UV λ_{max}^{MeOH} nm (log ε): 219 (4.67), 245 sh (4.12), 257 (4.04), 300 sh (4.46), 326 (4.70). ^{1}H-NMR ($CDCl_3$, 400 MHz): δ 1.39 (3H, *s*, Me-2'), 1.44 (3H, *s*, Me-2'), 3.23 (1H, *br s*, OH, D_2O exchangeable), 3.84 (1H, *d*, *J* = 4.8 Hz, H-3'), 4.19 (1H, *br s*, OH, D_2O exchangeable), 5.18 (1H, *d*, *J* = 4.8 Hz, H-4'), 6.23 (1H, *d*, *J* = 9.6 Hz, H-3), 6.77 (1H, *d*, *J* = 8.6 Hz, H-6), 7.30 (1H, *d*, *J* = 8.6 Hz, H-5), 7.64 (1H, *d*, *J* = 9.6 Hz, H-4).

1-*O*-Hexadecanoyl glycerol (**28**): amorphous solid, m.p. 66–68°C ($CHCl_3$), $[\alpha]_D^{25}$: –12.4° (*c* 0.01, $CHCl_3$), FAB-MS *m/z* (%): 353 ($[M+Na]^+$, 19), 313 (12), 239 (14), IR ν_{max}^{KBr} cm^{-1}: 3415 (OH), 1730 (C=O). ^{1}H-NMR ($CDCl_3$, 200 MHz): δ 0.87 (3H, *t*, *J* = 6.6 Hz, H-16'), 1.25–1.30

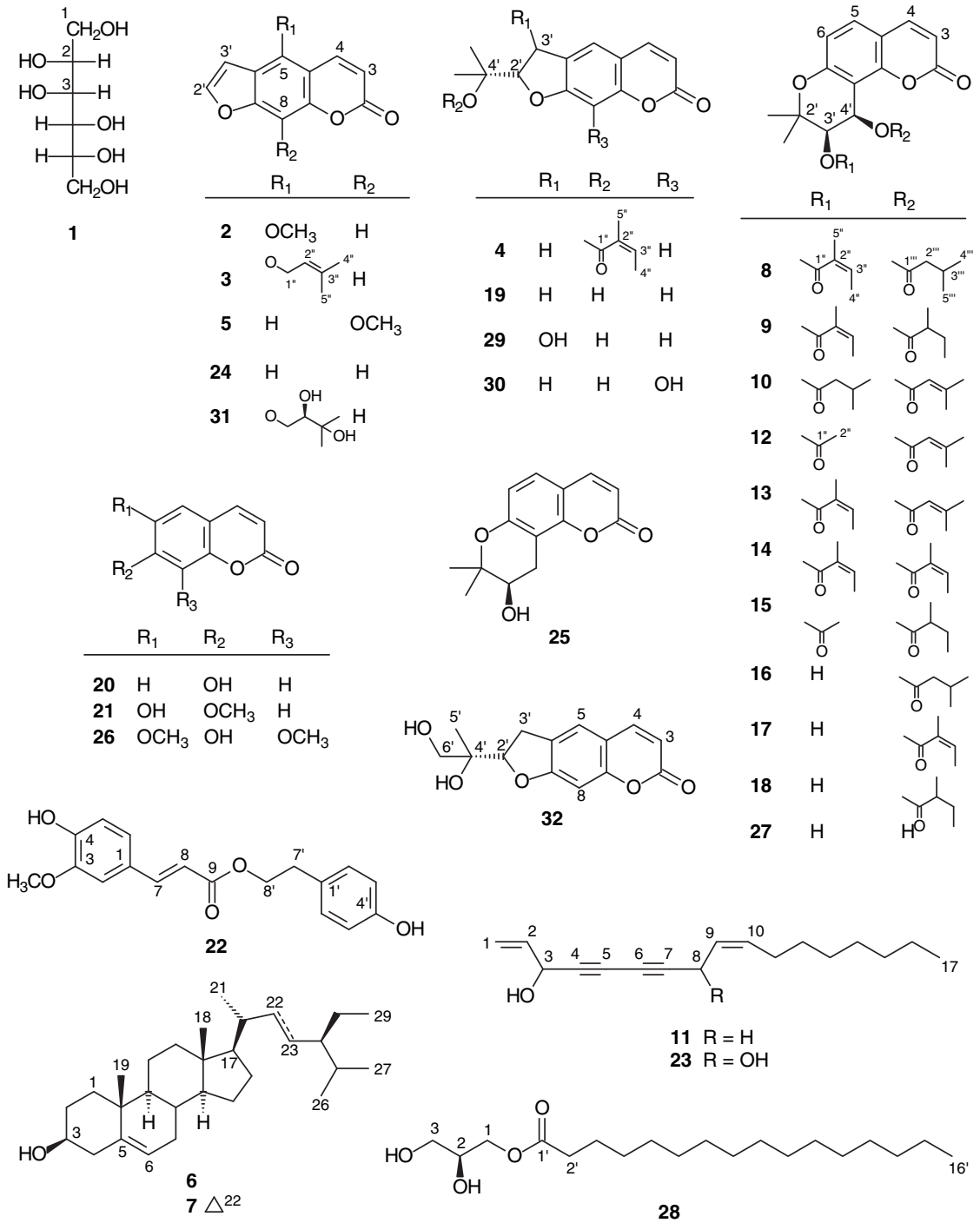

Figure 1. Structures of the root extract of *Peucedanum formosanum* (Taiwan Qian-Hu) led to the isolation of 32 known compounds.

(24H, *br s*, H-4'–15'), 1.62 (2H, *m*, H-3'), 2.35 (2H, *t*, *J* = 7.6 Hz, H-2'), 3.59 (1H, *dd*, *J* = 11.4, 5.6 Hz, H-3), 3.70 (1H, *dd*, *J* = 11.4, 4.0 Hz, H-3), 3.93 (1H, *m*, H-2), 4.13 (1H, *dd*, *J* = 11.6, 4.8 Hz, H-1), 4.22 (1H, *dd*, *J* = 11.6, 4.0 Hz, H-1).

(+)-3'-Hydroxymarmesin (**29**): colorless prisms, m.p. 120–122°C (Et_2O), $[\alpha]_D^{25}$: +36.5° (*c* 0.17, $CHCl_3$), EI-MS *m/z* (%): 262 ($[M]^+$, 18), 186 (100), 158 (36), 131 (4), 102 (6). IR ν_{max}^{KBr} cm^{-1}: 3394 (OH), 1725 (C=O), 1628. UV λ_{max}^{MeOH} nm (log ε): 205 (4.01), 222 (3.60), 257 sh (2.81), 327 (3.67). ^{1}H-NMR ($CDCl_3$, 200 MHz): δ 1.55 (3H, *s*, H-5'), 1.60 (3H, *s*, H-6'), 4.36 (1H, *d*, *J* = 6.2 Hz, H-2'), 5.37 (1H, *br d*, *J* = 6.2 Hz, H-3'), 6.25 (1H, *d*, *J* = 9.6 Hz, H-3), 6.82 (1H, *br s*, H-8), 7.51 (1H, *s*, H-5), 7.65 (1H, *d*, *J* = 9.6 Hz, H-4). ^{13}C-NMR ($CDCl_3$, 50 MHz): δ 25.3 (C-6'), 28.5 (C-5'), 71.8 (C-3'), 73.0 (C-4'), 90.5 (C-2'), 99.0 (C-8), 100.5 (C-4a), 112.9 (C-3), 124.8 (C-5), 128.1 (C-6), 143.6 (C-4), 152.2 (C-7), 156.7 (C-8a), 162.3 (C-2).

(+)-Rutaretin (**30**): yellow prisms, m.p. 179–181°C (*n*-hexane/acetone), $[\alpha]_D^{25}$: +42.2° (*c* 0.09, $CHCl_3$), EI-MS *m/z* (%): 262 ($[M]^+$, 44), 244 (5), 229 (23), 204 (62), 203 (100), 191 (26), 176 (28), 147 (16), 91 (10). IR ν_{max}^{KBr} cm^{-1}: 3420 (OH), 1700 (C=O), 1618, 1586. UV λ_{max}^{MeOH} nm (log ε): 213 (4.68), 240 sh (4.13), 266 (3.54), 332 (3.99). UV $\lambda_{max}^{MeOH+KOH}$ nm (log ε): 219 (4.65), 282 (4.29), 339 (4.23). ^{1}H-NMR (acetone-*d*6, 200 MHz): δ 1.23 (3H, *s*, H-5'), 1.29 (3H, *s*, H-6'), 3.24 (1H, *ddd*, *J* = 15.7, 9.2, 1.0 Hz, H-3'), 3.31 (1H, *ddd*, *J* = 15.7, 8.0, 1.0 Hz, H-3'), 3.84 (1H, *br s*, OH-4', D_2O exchangeable), 4.78 (1H, *dd*, *J* = 9.2, 8.0 Hz, H-2'), 6.13 (1H, *d*, *J* = 9.6 Hz, H-3), 6.97 (1H, *t*, *J* = 1.0 Hz, H-5), 7.82 (1H, *d*, *J* = 9.6 Hz, H-4), 8.60 (1H, *br s*, OH-8, D_2O exchangeable). ^{13}C-NMR (acetone-d_6, 50 MHz): δ 161.4 (C-2), 26.5 (C-5'), 31.8 (C-3'), 72,5 (C-4'), 92.8 (C-2'), 112.9 (C-3), 114.8 (C-4a), 115.6 (C-5), 127.1 (C-6), 130.1 (C-8), 145.2 (C-8a), 146.1 (C-4), 152.5 (C-7).

(+)-Oxypeucedanin hydrate (**31**): colorless needles, m.p. 132–134°C (Et_2O), $[\alpha]_D^{25}$: +26.6° (*c* 0.09, $CHCl_3$), EI-MS *m/z* (%): 304 ($[M]^+$, 23), 259 (30), 202 (91), 167 (100), 147 (29), 137 (47), 59 (45). IR ν_{max}^{KBr} cm^{-1}: 3146 (OH), 1726 (C=O). UV λ_{max}^{MeOH} nm (log ε): 220 (4.71), 249 (4.50), 265 sh (4.42), 312 (4.40). ^{1}H-NMR ($CDCl_3$, 400 MHz): δ 1.31 (3H, *s*, H-5"), 1.36 (3H, *s*, H-4"), 3.88 (1H, *d*, *J* = 8.0 Hz, H-2"), 4.45 (1H, *dd*, *J* = 10.0, 8.0 Hz, H-1"), 4.53 (1H, *dd*, *J* = 10.0, 3.2 Hz, H-1"), 6.32 (1H, *d*, *J* = 9.6 Hz, H-3), 6.99 (1H, *dd*, *J* = 2.4, 1.2 Hz, H-3') , 7.20 (1H, *d*, *J* =1.2 Hz, H-8), 7.61 (1H, *d*, *J* = 2.4 Hz, H-2'), 8.18 (1H, *dd*, *J* = 9.6 Hz, H-4).

(+)-Dorsteniol (**32**): colorless prisms, m.p. 135–137°C, $[\alpha]_D^{25}$: +36.8° (*c* 0.09, $CHCl_3$), EI-MS *m/z* (%): 262 ($[M]^+$, 39), 213(35), 188 (73), 187 (100), 160 (20), 131 (24), IR ν_{max}^{KBr} cm^{-1} 3415 (OH), 1713 (C=O), 1624. UV λ_{max}^{MeOH} nm (log ε): 210 (4.66), 225 (4.61), 250 sh (4.20), 259 (4.16), 300 sh (4.31), 333 (4.62). ^{1}H-NMR ($CDCl_3$, 400 MHz): δ 1.19 (3H, *s*, H-5'), 3.21 (1H, *dd*, *J* = 16.0, 9.6 Hz, H-3'), 3.34 (1H, *dd*, *J* = 16.0, 7.6 Hz, H-3'), 3.48 (1H, *d*, *J* =11.0 Hz, H-6'), 3.53 (1H, *d*, *J* = 11.0 Hz, H-6'), 4.97 (1H, *dd*, *J* = 9.6, 7.6 Hz, H-2'), 6.14 (1H, *d*, *J* = 9.5 Hz, H-3), 6.64 (1H, *s*, H-8), 7.43 (1H, *s*, H-5), 7.86 (1H, *d*, *J* = 9.5 Hz, H-4).

V. *Anti-platelet Aggregation Test*

Blood was collected from the marginal vein of a rabbit, anticoagulated with EDTA (6 mM) and centrifuged for 10 min at 90 × g at room temperature to obtain platelet-rich plasma (PRP). Platelet suspension was prepared from this EDTA-anticoagulated PRP according to the washing procedures described previously[4]. Platelet numbers were counted by a Coulter counter (Model ZM) and adjusted to 3×10^8 platelets/mL. The platelet pellets were then suspended in Tyrode's solution of the following composition (mM): NaCl (136.8), KCl (2.8), $NaHCO_3$ (11.9), $MgCl_2$ (2.1), NaH_2PO_4 (0.33), $CaCl_2$ (1.0) and glucose (11.2), containing bovine serum albumin (0.35%). Platelet aggregation was measured by turbidmetric method described by O'Brien[5]. The absorbance of the platelet suspension was taken as 0% aggregation, and that of Tyrode's solution as 100% aggregation. Aggregation was measured by an aggregometer (Chrono-Log Co., Havertown, PA) with consistent stirring at 1200 rpm. All tested compounds were dissolved in dimethyl sulfoxide (DMSO). To eliminate the effect of the solvent on the aggregation, the final concentration of DMSO was fixed at 0.5%, which did not affect the measured aggregation. Aspirin was used as a positive control. Data were analyzed using Student's *t* test.

RESULTS AND DISCUSSION

All of the isolates, including D-mannitol (**1**)[6], bergapten (**2**)[7], isoimperatorin (**3**)[7], (–)-deltoin (**4**)[7], xanthotoxin (**5**)[7], β-sitosterol (**6**)[8], stigmasterol (**7**)[8], (+)-praeruptorin E (**8**)[9], (+)-hyuganin A (**9**)[10], (–)-*cis*-3'-isovaleryl-4'-senecioylkhellactone (**10**)[11], panaxynol (**11**)[12], (–)-isosamidin (**12**)[9], (+)-peuformosin (**13**)[3], (+)-anomalin (**14**)[9], (+)-*cis*-3'-acetoxy-4'-(2-methylbutyroyloxy)-3',4'-dihydroseselin (**15**)[10], *cis*-3'-hydroxy-4'-isovaleryloxy-3',4'-dihydroseselin (**16**)[9], laserpitin (**17**)[9], (–)-*cis*-3'-hydroxy-4'-(2-methylbutyryloxy)-3',4'-dihydroseselin (**18**)[9], (+)-marmesin (**19**)[7], umbelliferone (**20**)[13], isoscopoletin (**21**)[14], *p*-hydroxyphenethyl ferulate (**22**)[15], falcarindiol (**23**)[12], psoralen (**24**)[7], (+)-lomatin (**25**)[16], isofraxidin (**26**)[17], (–)-*cis*-khellactone (**27**)[13], 1-*O*-hexadecanoyl glycerol (**28**)[18], (+)-3'-hydroxymarmesin (**29**)[19], (+)-rutaretin (**30**)[20], (+)-oxypeucedanin hydrate (**31**)[7], (+)-dorsteniol (**32**)[21] were readily identified by comparison of physical and spectroscopic data (UV, IR, ^{1}H-NMR, $[\alpha]_D$, and mass spectrometry data) with values found in the literature. Among these compounds, **11**, **15**, **16**, **18**, **22**, **25**, **26**, **28**, **29**, and **32** were firstly isolated from this genus.

The constituents of three Qian-Hu, Bai-Hua Qian-Hu (*P. praeruptorum*)[13,22-34], Taiwan Qian-Hu (*P. formosanum*), and Zi-Hua Qian-Hu (*A. decursiva* = *P. decursivum*)[35-47], are compared in Table 1, showing that seselin-type dihydropyranocoumarins (**8**–**10**, **12**–**18**, **25**, **27**) and psoralen-type furanocoumarins (**2**–**5**, **19**, **24**, **28**–**32**) are two major groups of constituents in *P. formosanum*. These two types of coumarins are also the major compounds in *P. praeruptorum*. The major constituents in *Angelica decursiva* are xanthyletin-type dihydropyranocoumarins and psoralen-type furanocoumarins; the former has not been found in *P. formosanum* and few have been found in *P. praeruptorum*. *P. japonicum*[2,7,11,48-60], another species of *Peucedanum* in Taiwan[1], also has seselin-type dihydropyranocoumarins and psoralen-type furanocoumarins as its major constituents, and these may be used as a key to the chemotaxonomy of *Peucedanum* and *Angelica*.

Some of the isolates in *P. formosanum* have been reported to exert strong anti-platelet aggregation activities. These include xanthotoxin (**5**)[7], panaxynol (**11**)[61],

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Table 1. The constituents of Bai-Hua Qian-Hu (*Peucedanum praeruptorum*), Taiwan Qian-Hu (*P. formosanum*), and Zi-Hua Qian-Hu (*Angelica decursiva* = *P. decursivum*)

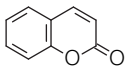
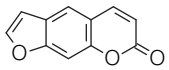
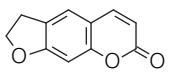
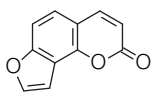
Compound	Bai-Hua Qian-Hu	Taiwan Qian-Hu	Zi-Hua Qian-Hu
			
simple coumarin			
isofraxidin (**26**)	–	+	–
isoscopoletin (**21**)	+	+	–
peucedanol	+	–	–
scopoletin	+	–	+
scopolin	+	–	–
umbelliferone (**20**)	+	+	+
furanocoumarin			
			
psoralen type			
bergapten (**2**)	–	+	+
decurside I	–	–	+
imperatorin	–	–	+
isoimperatorin (**3**)	–	+	–
5,8-dimethoxypsoralen	+	–	–
(+)-oxypeucedanin hydrate (**31**)	–	+	–
psoralen (**24**)	+	+	–
xanthotoxin (**5**)	–	+	–
			
dihydropsoralen type			
decuroside V	–	–	+
decuroside VI	–	–	+
decuroside VII	–	–	+
(–)-deltoin (**4**)	–	+	–
(+)-dorsteniol (**32**)	–	+	–
1-*O*-hexadecanoyl glycerol (**28**)	–	+	–
(+)-3'-hydroxymarmesin (**29**)	–	+	–
isorutarin	+	–	–
(+)-marmesin (**19**)	–	+	–
nodakenetin	–	–	+
nodakenin	+	–	+
praeroside	+	–	–
(+)-rutaretin (**30**)	–	+	–
rutarin	+	–	–
			
angelicin type			
angelicin	+	–	–

Table 1. continued

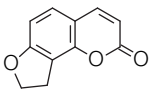
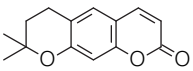
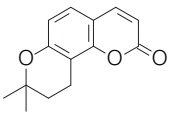
Compound	Bai-Hua Qian-Hu	Taiwan Qian-Hu	Zi-Hua Qian-Hu
			
dihydroangelicin type			
apterin	+	–	–
columbianadin	–	–	+
pyranocoumarin			
			
dihydroxanthyletin type			
3'(*S*)-acetoxy-4'(*R*)-isovaleryloxy-3',4'-dihydroxanthyletin	–	–	+
3'(*S*)-acetoxy-4'(*R*)-angeloyloxy-3',4'-dihydroxanthyletin	–	–	+
AD-I (3'(*S*)-angeloyloxy-4'(*R*,*S*)-isovaleryloxy-3',4'-dihydroxanthyletin)	–	–	+
andelin (AD-II, 3'(*S*)-angeloyloxy-4'(*R*)-senecioyloxy-3',4'-dihydroxanthyletin)	–	–	+
decursidin	–	–	+
decursin	–	–	+
decursinol	+	–	+
decursitin B	–	–	+
decursitin C	–	–	+
decursitin D	–	–	+
decursitin F	–	–	+
Pd-C-I (3'(*S*)-senecioyloxy-4'(*R*)-hydroxy-3',4'-dihydroxanthyletin)	+	–	+
Pd-C-II (3'(*S*)-hydroxy-4'(*R*)-senecioyloxy-3',4'-dihydroxanthyletin)	–	–	+
Pd-C-III (3'(*S*)-angeloyloxy-4'(*R*)-acetoxy-3',4'-dihydroxanthyletin)	–	–	+
qainhucoumarin F	+	–	–
			
dihydroseselin type			
(+)-*cis*-3'-acetoxy-4'-(2-methylbutyroyloxy)-3',4'-dihydroseselin (**15**)	–	+	–
(+)-anomalin (**14**, Pd-II)	+	+	–
cis-3',4'-disenecioyl-3',4'-dihydroseselin	+	–	–

Table 1. continued

Compound	Bai-Hua Qian-Hu	Taiwan Qian-Hu	Zi-Hua Qian-Hu
cis-3'-hydroxy-4'-isovaleryloxy-3',4'-dihydroseselin (**16**)	–	+	–
(–)-*cis*-3'-hydroxy-4'-(2-methyl-butyryloxy)-3',4'-dihydrosese-lin (**18**)	–	+	–
(+)-hyuganin A (**9**)	–	+	–
(–)-isosamidin (**12**)	–	+	–
(–)-*cis*-3'-isovaleryl-4'-senecioyl-khellactone (10)	–	+	–
(–)-*cis*-khellactone (**27**)	–	+	–
trans-khellactone	+	–	–
laserpitin (**17**)	–	+	–
(+)-lomatin (**25**)	–	+	–
Pd-Ib	+	–	+
peucedanocoumarin I	+	–	–
peucedanocoumarin II	+	–	–
peucedanocoumarin III	+	–	–
(+)-peuformosin (**13**)	–	+	–
praeroside II	+	–	–
praeroside III	+	–	–
praeroside IV	+	–	–
praeroside V	+	–	–
praeruptorin A	+	–	–
(+)-praeruptorin E (**8**)	+	+	–
qainhucoumarin A	+	–	–
qainhucoumarin B	+	–	–
qainhucoumarin C	+	–	–
qainhucoumarin D	+	–	–
qainhucoumarin E	+	–	–
qainhucoumarin H	+	–	–
samidin	+	–	–
chromone			
skimmin	+	–	–
steroid			
stigmasterol (**7**)	+	+	–
β-sitosterol (**6**)	+	+	+
β-sitosterol-β-D-glucoside	+	–	+
saccharide			
galactitol	+	–	–
D-mannitol (**1**)	+	+	–
polyacetylene			
falcarindiol (**23**)	–	+	–
panaxynol (**11**)	–	+	–
benzenoid			
decursidate	–	–	+
p-hydroxyphenethyl ferulate (**22**)	–	+	–

(+)-anomalin (**14**)[62], psoralen (**24**)[7] and (–)-*cis*-khellactone (**27**)[62]. The anti-platelet aggregation effects of the other isolates are shown in Table 2. *p*-Hydroxyphenethyl ferulate (**22**) at 5 μg/mL showed nearly complete inhibition of platelet aggregation induced by arachidonic acid (AA). (–)-Isosamidin (**12**), (+)-peuformosin (**13**), (+)-*cis*-3'-acetoxy-4'-(2-methylbutyroyloxy)-3',4'-dihydroseselin (**15**), *p*-hydroxy-phenethyl ferulate (**22**) at 100 μg/mL showed complete or near complete inhibition of platelet aggregation induced by collagen. (–)-*cis*-3'-Isovaleryl-4'-senecioylkhellactone (**10**), (+)-*cis*-3'-acetoxy-4'-(2-methylbutyroyloxy)-3',4'-dihydroseselin (**15**) and *p*-hydroxyphenethyl ferulate (**22**) at 100 μg/mL abolished platelet-activating factor (PAF)-induced platelet aggregation. Of these compounds, *p*-hydroxyphenethyl ferulate (**22**) showed the strongest antiplatelet aggregation activities, with IC_{50} values of 5.1, 10.5 and 99.4 μM for platelet aggregation induced by AA, collagen and PAF, respectively.

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Table 2. Inhibitory effects[a] of compounds on the aggregation of washed rabbit platelets induced by thrombin (Thr), arachidonic acid (AA), collagen (Col) and platelet-activating factor (PAF)

Compound	Conc. (μg/mL)	Aggregation (%)			
		AA (100 μM)	Col (10 μg/mL)	Thr (0.1 U/mL)	PAF (2 ng/mL)
control		84.2 ± 1.0 (3)	84.8 ± 2.3 (3)	89.3 ± 1.6 (3)	87.8 ± 0.5 (3)
(–)-*cis*-3'-isovaleryl-4'-senecioylkhel-lactone (**10**)	100	91.4 ± 3.2 (3)	32.8 ± 15.0 (3)[d]	86.3 ± 1.9 (3)	0.0 ± 0.0 (3)[e]
	50		49.0 ± 8.1 (3)[e]		27.0 ± 14.9 (3)[d]
	20		81.8 ± 5.0 (3)		58.5 ± 1.9 (3)[e]
(–)-isosamidin (**12**)	100	38.0 ± 17.1 (3)[c]	5.4 ± 2.8 (3)[e]	87.8 ± 1.1 (3)	50.3 ± 15.9 (3)[c]
	50	45.8 ± 19.3 (3)	30.7 ± 15.1 (3)[d]		
	20	69.3 ± 6.6 (3)	68.9 ± 9.6 (3)		
	10	76.9 ± 5.4 (3)	77.4 ± 5.5 (3)		
	5	79.9 ± 4.3 (3)	83.4 ± 3.4 (3)		
(+)-peuformosin (**13**)	100	56.8 ± 7.7 (3)[c]	14.0 ± 9.7 (3)[e]	82.1 ± 2.4 (3)[c]	32.9 ± 13.3 (3)[c]
(+)-*cis*-3'-acetoxy-4'-(2-methylbutyroy-loxy)-3',4'-dihydroseselin (**15**)	100	53.4 ± 10.5 (3)[d]	0.0 ± 0.0 (3)[e]	74.4 ± 2.8 (3)[e]	0.0 ± 0.0 (3)[e]
	50	76.1 ± 2.0 (3)[e]	45.4 ± 9.3 (3)[e]		22.7 ± 9.3 (3)[e]
	20		83.4 ± 1.1 (3)[e]		70.4 ± 4.9 (3)[d]
(–)-*cis*-3'-hydroxy-4'-(2-methylbutyry-loxy)-3',4'-dihydroseselin (**18**)	100	73.9 ± 7.0 (3)	66.4 ± 3.9 (3)[e]	81.0 ± 3.7 (3)	19.5 ± 9.0 (3)[e]
	50				66.1 ± 4.9 (3)[e]
p-hydroxyphenethyl ferulate (**22**)	100	0.0 ± 0.0 (3)[e]	0.0 ± 0.0 (3)[e]	43.8 ± 8.7 (3)[e]	0.0 ± 0.0 (3)[e]
	50	0.0 ± 0.0 (3)[e]	0.0 ± 0.0 (3)[e]	80.6 ± 6.7 (3)	9.5 ± 7.7 (3)[e]
	20	0.0 ± 0.0 (3)[e]	0.0 ± 0.0 (3)[e]		74.1 ± 5.1 (3)[c]
	10	0.0 ± 0.0 (3)[e]	0.0 ± 0.0 (3)[e]		
	5	3.1 ± 2.5 (3)[e]	25.1 ± 8.9 (3)[e]		
	2	34.5 ± 17.4 (3)[c]	69.5 ± 8.7 (3)[c]		
	1	74.7 ± 3.1 (3)[d]	85.8 ± 2.8 (3)		
(+)-lomatin (**25**)	100	81.0 ± 1.4 (3)	84.7 ± 0.5 (3)e	81.4 ± 7.6 (3)	73.6 ± 5.7 (3)[c]
(+)-3'-hydroxymarmesin (**29**)	100	83.6 ± 3.1 (3)	90.8 ± 1.6 (3)	83.4 ± 3.0 (3)	83.3 ± 2.6 (3)[c]
(+)-rutaretin (**30**)	100	64.4 ± 7.5 (3)[d]	66.6 ± 3.0 (3)[e]	73.0 ± 8.3 (3)	86.0 ± 1.5 (3)
aspirin[b]	100		0.0 ± 0.0 (3)[e]	81.3 ± 0.5 (3)	
	50		11.7 ± 10.1 (4)[e]		
	20		84.3 ± 0.6 (4)[e]		

[a]Platelets were preincubated with each compound or DMSO (0.5 %, control) at 37°C for 3 min, then the inducer arachidonic acid (AA), collagen, thrombin or PAF was added. Values are presented as mean ± s.e.m. (n).
[b]Positive control.
[c]$P < 0.05$; [d]$P < 0.01$; [e]$P < 0.001$ as compared with the respective control.

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