Studies on the Constituents of Artemisia annua
Part II

Tu You-you, Ni Mu-yun, Zhong Yu-rong, Li Lan-na, Cui Shu-lian, Zhang Mu-qun, Wang Xiu-zhen, Ji Zheng**
and Liang Xiaotian**

* Institute of Chinese Materia Medica, Academy of Traditional Chinese Medicine, Beijing, China

Key Word Index:
Artemisia annua L.; Compositae; Qinghaosu; Qinghaosu I—V; Qinghao acid; Flavones; Alkanol; Scopoletin; Essential oil.

Abstract

The present paper is a continuation of our study on the Chinese traditional herb Artemisia annua L. [1—5], describing several additional constituents: qinghaosu IV and V (V, VII), qinghao acid (VIII) [6], chrysosplenol (VIa) [7] and a paraffinic alcohol; V, VII and VIII are compounds with unreported structures.

Introduction

A number of our earlier papers have been devoted to studies of chemical constituents isolated from Artemisia annua L. (Compositae), the most notable constituent being the antimalerial qinghaosu (I) [1—4], a peroxidic lactone with unique structure. Other constituents include qinghaosu-I-III (II-IV), a flavonol (VI), scopoletin and a few terpenes from the essential oil [5].

This paper deals with the isolation and characterization of V, VIa, VII, VIII and a paraffinic alcohol.

It is pertinent here to point out the close stereochemical kinship among the previously established structures I—IV. They all belong to the amorphane series (IX) [9], which has a cis decalin skeleton with the isopropyl group trans to the hydrogen on the ring juncture. Compounds I and IV are further distinguished by the presence of a modified seven-membered A-ring as the result of insertion of an extra ether oxygen.

1 For Part I, see ref. 5.
Results and Discussion

Qinghaosu-IV (V) is a colourless crystalline compound with m.p. 172-173°. MS molecular weight 282 (M+) agreed with C<sub>15</sub>H<sub>22</sub>O<sub>3</sub>. Hydroxy and lactonic carbonyl groups can be inferred from its IR spectrum (3450, 1728 cm<sup>-1</sup>). The <sup>1</sup>HNMR spectrum displayed the following features: δ 0.95 (d, J = 6 Hz, 10-CH<sub>3</sub>), 1.20 (d, J = 6, 11-CH<sub>3</sub>), 1.65 (s, 4-CH<sub>3</sub>), 3.20 (m, H-C-11), 3.60 (br, H-C-3), 5.60 (s, H-C-5) and an exchanged OH group at 1.88. Except for the two signals at δ 1.88 and 3.60, the NMR spectra of IV and V are almost superposable, thus leading to the conclusion that the extra oxygen of V is in the form of a hydroxy group with only four possible places (C-2, 3, 8 and 9) for its accommodation. Eu(fod), was used for its allocation. Addition of successive aliquots of the shift reagent gave rise to linear changes of chemical shifts. In the case of qinghaosu III (IV), we have for 10-CH<sub>3</sub>, δ 0.95 → 0.96 → 1.16 → 1.16; for 11-CH<sub>3</sub>, 1.20 → 1.42 → 2.20 → 2.40; for 4-CH<sub>3</sub>, 1.54 → 1.55 → 1.74 → 1.75; and for H-C-5, 5.55 → 5.75 → 6.20 → 6.40. Qinghaosu IV (V) gave the corresponding shifts: 10-CH<sub>3</sub>, δ 1.04 → 1.46 → 1.77 → 2.15; 11-CH<sub>3</sub>, 1.27 → 1.99 → 2.60 → 3.42; 4-CH<sub>3</sub>, 1.65 → 3.93 → 5.74 → 7.25; H-C-5, 5.70 → 6.91 → 8.06 → 9.18. The marked shifts for 4-CH<sub>3</sub> and H-C-5 in compound V is compatible only with an OH group at position-3, and the W<sub>1/2</sub> 6 Hz) of the H-C-3 multiplet (hence equatorial) indicates an α-orientation for the OH group (axial). The structure of IV has been firmly established by its preparation from qinghaosu (I) by catalytic hydrogenation [5].

Chrysosplenol (6a) has very similar UV and <sup>1</sup>HNMR spectra to eupatin (3, 5, 3'-triOH, 6, 7, 4'-triOMe) [7]. However, large discrepancies in m.p. of the acetates (155-157°; 219-221° for eupatin acetate) indicated the possible contamination by a C<sub>26</sub> alcohol. CH<sub>2</sub>N<sub>2</sub> for CD<sub>2</sub>N<sub>2</sub> showed <sup>1</sup>HNMR data, δ 0.83 (d, J = 6, 10-CH<sub>3</sub>), 1.60 (s, 4-CH<sub>3</sub>), 4.94 (br, H-C-5), 5.54, 6.46 (br, 11 = CH<sub>2</sub>) and 11.56 (br, CO<sub>2</sub>H). Irradiation of 4-CH<sub>3</sub> caused an NOE increase of H-C-5 by 40%. No NOE was found between H-C-5 and the endocyclic methylene hydrogens, presumably due to free rotation of the C<sub>7</sub>-C<sub>11</sub> bond.

Comparison with II or its LAH reduction product (IIa) showed that the olefinic signal of qinghao acid at 4.94 (W<sub>1/2</sub> = 5-6 Hz) is much sharper (for 2 and 2a, we have δ 5.60 and 5.50, respectively, with W<sub>1/2</sub> = 11 Hz, due to the coupling with two neighboring protons). Hence the endocyclic double bond of qinghao acid should be placed at C<sub>4</sub>-C<sub>5</sub> and not C<sub>3</sub>-C<sub>4</sub>. Biogenetic considerations led to the proposal of VIII as the structure of qinghao acid.

Qinghaosu V (VII) has m.p. 125-126°, and a formula of C<sub>15</sub>H<sub>22</sub>O<sub>3</sub> from MS data. IR data (3420, 1700, 1630 cm<sup>-1</sup>) showed the presence of OH and α, β-unsaturated lactone functionalities. The <sup>1</sup>HNMR spectrum showed two methyl groups at δ 0.85 (d) and 1.36 (s), and terminal methylene protons at 5.56 (s) and 16.16 (s). The carbonylic hydrogen at C-5 (δ 3.82) is a doublet with J = 3, hence should be in cis relationship with the hydrogen on the ring juncture (C-6). Further studies have been thwarted by scantly supply of material, and the structure as shown by VII is thus tentatively proposed, leaning heavily on biogenetic considerations.

We also isolated a straight chain fatty alcohol, m.p. 74-76°, characterized by its IR and <sup>1</sup>HNMR spectra. The MS peak at m/e 392 (M-18) [11] showed it to be octacosanol (C<sub>28</sub>H<sub>57</sub>OH), probably contaminated by some C<sub>30</sub> alcohol (ca. 5 %) as evidenced by a tiny peak at m/e 420. Further fragmentations of interest involved successive losses of 28 units from m/e 392, giving peaks at m/e 364 and 336. The last mentioned peak however was stronger than usual [11], indicating the possible contamination by a C<sub>26</sub> alcohol. ULeBELen et al. [12] reported the isolation of a C<sub>26</sub> alcohol from the same species, using elemental analysis as the main evidence. Since C<sub>26</sub> and C<sub>28</sub> alcohols cannot be adequately differentiated by elemental analysis, there is room for the possibility of their sample being also octacosanol.

Experimental

Melting points were not corrected. IR spectra were taken with KBr discs on an IR-S spectrometer. <sup>1</sup>HNMR spectra were taken with CDCl<sub>3</sub> solutions on WH-90, with TMS as the internal standard. MS were recorded with MM70-70H spectrometer.

**Plant Material**

*Artemisia annua* L. is a regular commodity, available in practically all warehouses for Chinese herbs. However, there might well be variations in chemical constituents with different localities, which were therefore specified below.

Silica gel columns and plates were used and eluted with the mixed solvent of petroleum ether and ethyl acetate in individually specified proportions.
Qinghaosu-IV

Plant material from Sichuan Province was extracted with petroleum ether and the solvent removed. The crude extract was chromatographed. Qinghaosu IV displayed only a single spot on TLC (1:1 mixed solvent, 2% phosphomolybdic acid spray). It was purified by recrystallization from ethanol. MS, m/e (%): 282 (M+5), 238 (1), 222 (75), 207 (3), 204 (11), 194 (9), 178 (14), 166 (18), 150 (23), 137 (14), 122 (5), 107 (11), 93 (11), 81 (9), 74 (4), 69 (7), 55 (15), 43 (100). IR (cm⁻¹): 3450 (s), 2950 (m), 1728 (s), 1465 (m), 1420 (m), 1390 (m), 1345 (w), 1260 (m), 1220 (w), 1185 (m), 1170 (w), 1140 (m), 1080 (m), 1050 (m), 1015 (m), 970 (m), 940 (w), 920 (m), 865 (91), 820 (80), 765 (w), 715 (w).

Compounds VIa, VIII and the fatty alcohol were isolated from the plant material of the Beijing area. The ethereal extracts were shaken with 2% aqueous sodium hydroxide, which upon acidification gave the crude acid fraction. From the chromatographic fractions with 95:5, 85:15 and 65:35 solvent compositions, were obtained qinghao acid (VIII), a fatty alcohol and chrysosplenol (VIa) respectively.

The non-acidic fraction from ether as mentioned above was concentrated, mixed with polyamide powder and percolated with ethyl alcohol. The residue was extracted again with ether and the crude extract was chromatographed on a column. Qinghaosu V came down from the 6:4 portion, showing one spot on TLC (1:1 mixed solvent, violet spot when sprayed with 2% vanillin).

Qinghao acid

The crude acid displayed a single spot on TLC (9:1 mixed solvent, 2% vanillin-H₂SO₄ spray). It was purified by recrystallization from petroleum ether as transparent prisms, soluble in sodium bicarbonate. MS, m/e (%): 234 (M+5), 219 (5), 216 (6), 206 (6), 201 (3), 189 (13), 178 (6), 173 (6), 161 (8), 147 (6), 136 (28), 121 (100), 105 (17), 93 (38), 87 (6), 71 (25), 67 (9), 55 (16), 41 (22). IR (cm⁻¹): 3480–2590 (s, br), 2550 (w), 1900 (w), 1690 (s), 1625 (m), 1445 (m), 1400 (w), 1380 (w), 1274 (m), 1210 (w), 1180 (w), 1155 (m), 1110 (w), 1080 (w), 1030 (w), 990 (w), 940 (m), 920 (w), 880 (w), 820 (w), 795 (w), 715 (w).

Diel from reduction of qinghaosu-I by LAH. The diol (Ia) so obtained was an oil. HNMR: 0.85 (d, J = 6, 10-CH₃), 1.25 (s, 4-CH₃), 5.50 (br, H-C-5). 3.80 (d, J = 3.7-CH₂OH), 4.19 (br, H-C-5).

The fatty alcohol Crude product as one spot on TLC (9:1 mixed solvent, 5% ethanolic phosphomolybdic acid spray). White powder from petroleum ether-chloroform. MS, m/e (%): 392 (9), 378 (2), 364 (22), 350 (2), 336 (14), 322 (2), 308 (4), 294 (3), 280 (3), 266 (3), 252 (4), 238 (4), 224 (4), 210 (5), 196 (6), 182 (6), 167 (11), 153 (14), 137 (21), 125 (37), 111 (58), 97 (97), 83 (100), 69 (75), 57 (92), 43 (75).

Chrysosplenol (Vla) Crude product as one spot on paper chromatography (Xinhua filter paper, 30% acetic acid as eluant, 1% AlCl₃ spray). Light yellow crystals from ethanol (twice), m.p. 221–223° (lit. 235–6° [7]). MS, m/e (%): 360 (M+100), 359 (44), 346 (11), 345 (50), 343 (5), 342 (6), 341 (21), 332 (5), 317 (8). The triacetate had m.p. 155–157° (lit. 159–160° [7]). When fully methylated, m.p. 141–142°.

Qinghaosu V

The crude material was twice recrystallized from ethyl alcohol. MS, m/e (%): 250 (M+24), 235 (7), 233 (6), 232 (15), 217 (7), 208 (18), 192 (18), 180 (15), 177 (10), 174 (8), 161 (11), 147 (15), 135 (16), 134 (12), 133 (13), 121 (15), 119 (15), 107 (26), 105 (19), 95 (27), 93 (27), 91 (31), 84 (13), 82 (23), 81 (28), 79 (28), 77 (20), 71 (35), 67 (25), 65 (10), 55 (32), 53 (30), 43 (100).

Acknowledgements

We thank Prof. T. J. MABRY of the University of Texas at Austin for a sample of eupatin. Liu Hongming of the Sichuan Institute of Chinese Materia Medica for the sample of 3,4-diethoxybenzoic acid obtained on alkali fusion of chrysosplenol (identical H.R with our sample) and our analytical colleagues for the recorded spectra.

References

12. Address: Prof. Liang Xiaotian, Institute of Materia Medica, Nan-wei Road, Beijing 100050, China.