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## CHAENOMELOIDIN: A PHENOLIC GLUCOSIDE FROM LEAVES OF *SALIX CHAENOMELOIDES*

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**ABSTRACT.**—A new phenolic glucoside, chaenomeloidin, was isolated from the leaves of *Salix chaenomeloides* together with salicin, tremuloidin, tremulacin, salicyloyltremuloidin, hyperin, quercitrin, rutin, isorhamnetin-3-*O*-glucoside, and isorhamnetin-3-*O*-rutinoside. The structure of chaenomeloidin was established to be salicyl alcohol-1-*O*- $\beta$ -D-(3'-benzoyl)glucopyranoside [**1**] by spectral analysis.

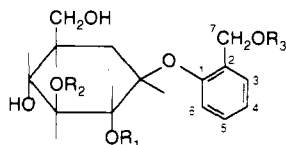
In continuation of our chemotaxonomic studies on Salicaceous plants, we have reported the occurrence of a number of flavonoids in *Salix* species (1-3) and revealed the presence of an intraspecies chemical variation in *Salix sachalinensis* (4,5). In this paper, the structural elucidation of a new phenolic glucoside isolated from the leaves of *Salix chaenomeloides* Kimura is described.

From an MeOH extract of *S. chaenomeloides*, compound **1** was obtained together with nine known compounds: tremuloidin [**2**] (6), salicin [**3**], tremulacin [**4**] (7), salicyloyltremuloidin [**5**] (8), quercetin-3-*O*-glucoside (hyperin), quercetin-3-*O*-rhamnoside (quercitrin), quercetin-3-*O*-rutinoside (rutin), isorhamnetin-3-*O*-glucoside, and isorhamnetin-3-*O*-rutinoside.

The structure of tremuloidin [**2**] was confirmed by the  $^1\text{H}$ - and  $^{13}\text{C}$ -nmr spectral data. The signal assignments of

all protons and carbons in their spectra were thoroughly supported by  $^1\text{H}$ - $^1\text{H}$ ,  $^1\text{H}$ - $^{13}\text{C}$  COSY,  $^1\text{H}$ - $^1\text{H}$  relay COSY, and  $^1\text{H}$ - $^1\text{H}$  and  $^1\text{H}$ - $^{13}\text{C}$  long range COSY.

Compound **1** was regarded as a derivative of salicin [**3**]. In the  $^1\text{H}$ -nmr spectrum, taken in DMSO- $d_6$ , the presence of an ortho-substituted phenolic residue [exhibited by the following signals:  $\delta$  7.02 (br t,  $J = 7.3$  Hz, H-4), 7.13 (br d,  $J = 7.3$  Hz, H-6), 7.22 (br t,  $J = 7.3$  Hz, H-5) and 7.38 (br d,  $J = 7.3$  Hz, H-3)] and a benzoyl residue, observed as five-proton signals at  $\delta$  7.54-8.03, were observed and suggested a structure similar to that of **2**. This suggestion was confirmed by the assignment of all carbons in the  $^{13}\text{C}$ -nmr spectrum. However, the carbon signals due to a glucose moiety were different from those of **2**. A downfield shift at C-3' (+1.4 ppm), and upfield shifts at C-2' (-1.9 ppm) and C-4' (-2.1 ppm) were observed by comparison with similar signals of **3**, which indicated that the benzoyl residue was attached to C-3' of the glucosyl moiety (Table 1). In the  $^1\text{H}$ -nmr spectrum of **1** measured in  $\text{Me}_2\text{CO}-d_6$ , a doublet at  $\delta$  5.06 was assignable to an anomeric proton of the glucose. In the  $^1\text{H}$ - $^1\text{H}$  COSY spectrum of **1**, a broad triplet signal at  $\delta$  3.85 assigned to H-2' caused a cross peak with the anomeric proton and further caused a cross peak with a broad triplet at  $\delta$  5.36. Therefore, the triplet was assigned to a proton at C-3', the chemical shift of which was at a lower field than the usual one, indicating that the position was

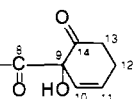


**1** R<sub>1</sub>=R<sub>3</sub>=H, R<sub>2</sub>=benzoyl

**2** R<sub>1</sub>=benzoyl, R<sub>2</sub>=R<sub>3</sub>=H

**3** R<sub>1</sub>=R<sub>2</sub>=R<sub>3</sub>=H

**4** R<sub>1</sub>=benzoyl, R<sub>2</sub>=H, R<sub>3</sub>=



**5** R<sub>1</sub>=benzoyl, R<sub>2</sub>=H, R<sub>3</sub>=

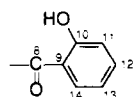


TABLE I.  $^{13}\text{C}$ -nmr Spectra of Compounds 1-3.<sup>a</sup>

| Carbon                | Compound |       |       |
|-----------------------|----------|-------|-------|
|                       | 1        | 2     | 3     |
| C-1 . . . . .         | 154.3    | 158.5 | 154.6 |
| C-2 . . . . .         | 131.5    | 131.2 | 131.4 |
| C-3 . . . . .         | 127.7    | 126.5 | 127.6 |
| C-4 . . . . .         | 121.9    | 122.0 | 121.6 |
| C-5 . . . . .         | 127.1    | 127.5 | 127.1 |
| C-6 . . . . .         | 114.6    | 114.1 | 114.7 |
| C-7 . . . . .         | 58.1     | 57.4  | 58.2  |
| C-1' . . . . .        | 100.7    | 98.4  | 101.4 |
| C-2' . . . . .        | 71.4     | 74.3  | 73.3  |
| C-3' . . . . .        | 78.4     | 73.9  | 77.0  |
| C-4' . . . . .        | 67.5     | 70.0  | 69.6  |
| C-5' . . . . .        | 76.7     | 77.3  | 76.4  |
| C-6' . . . . .        | 60.3     | 60.7  | 60.7  |
| C-1'' . . . . .       | 130.4    | 129.9 |       |
| C-2'', -6'' . . . . . | 129.4    | 129.4 |       |
| C-3'', -5'' . . . . . | 128.6    | 128.8 |       |
| C-4'' . . . . .       | 133.1    | 133.4 |       |
| C-7'' . . . . .       | 165.3    | 165.1 |       |

<sup>a</sup>The spectra were measured in  $\text{Me}_2\text{CO}-d_6$  (for 1) and  $\text{DMSO}-d_6$  (for 2 and 3) at 67.5 MHz. Chemical shifts are shown in  $\delta$  values.

acylated with a benzoyl residue. Consequently, 1 was determined to be salicyl alcohol 1-*O*- $\beta$ -D-(3'-benzoyl)glucopyranoside, i.e., 3'-benzoylsalicin, and named chaenomeloidin. In the Salicaceous plants, many kinds of acylated salicin derivatives, which are usually esterified at C-2' or C-6' in the glucose moiety, have been reported (6-14). To the best of our knowledge, chaenomeloidin is the first example of a 3'-benzoyl ester of salicin. Migration of an acyl residue on a sugar is sometimes observed in mild conditions (15). A benzoyl residue will be likely to migrate on a glucose in the case of chaenomeloidin, tremuloidin, and populin (9); however, the solution to this problem is not resolved at the present.

Dommissé *et al.* (16) and Lindroth *et al.* (17) have ambiguously reported the spectral properties of salicin, tremuloidin, tremulacin, and salicyloyl-tremuloidin. Complete assignments of their nmr spectral data, supported by 2D nmr, are presented in this paper.

## EXPERIMENTAL

PLANT MATERIAL.—Leaves of *S. chaenomeloides* were collected at Mitahorahigashi, Gifu, Japan on July 31, 1987 and identified by Dr. Arika Kimura (Tohoku University, Japan). Voucher specimens are deposited in the herbarium of Gifu Pharmaceutical University and Biological Institute of Tohoku University (TUS).

ISOLATION OF PHENOLICS.—The dried leaves (700 g) were extracted twice with MeOH under reflux for 30 h. The combined extract was concentrated in vacuo. The residue was suspended in  $\text{H}_2\text{O}$  and fractionated with EtOAc and *n*-BuOH. The EtOAc- and the *n*-BuOH-soluble fractions were chromatographed on Si gel. The fractions containing phenolic glucosides and flavonoids monitored by tlc [ $\text{CHCl}_3$ -MeOH- $\text{H}_2\text{O}$  (65:35:10), lower phase on Si gel] were rechromatographed on Si gel and Sephadex LH-20 to afford 1 (30 mg), 2 (2 g), 3 (50 mg), 4 (200 mg), 5 (10 mg), hyperin (10 mg), quercitrin (20 mg), rutin (40 mg), isorhamnetin-3-*O*-glucoside (60 mg), and isorhamnetin-3-*O*-rutinoside (150 mg).

SPECTRAL ANALYSES.—The mp's were obtained on a Büchi mps apparatus and are uncorrected.  $^1\text{H}$ - and  $^{13}\text{C}$ -nmr spectra were taken on a JEOL GX-270 spectrometer using TMS as internal standard. All signals were assigned by comparison with those of 2 and 5, the assignments of which were thoroughly made by 2D nmr. Ms were measured on a JEOL JMS-D270 instrument.

CHAENOMELOIDIN [1].—A pale yellow amorphous powder: eims  $m/z$  124, 106, 105;  $^1\text{H}$  nmr ( $\text{DMSO}-d_6$ )  $\delta$  4.48, 4.64 (each 1H, br d,  $J = 14.5$  Hz, H-7), 5.03 (1H, d,  $J = 8.1$  Hz, H-1'), 5.16 (1H, t,  $J = 8.8$  Hz, H-3'), 7.02 (1H, br t,  $J = 7.3$  Hz, H-4), 7.13 (1H, br d,  $J = 7.3$  Hz, H-6), 7.22 (1H, br t,  $J = 7.3$  Hz, H-5), 7.38 (1H, br d,  $J = 7.3$  Hz, H-3), 7.54 (2H, br t,  $J = 7.3$  Hz, H-3'', -5''), 7.66 (1H, br t,  $J = 7.3$  Hz, H-4''), 8.03 (2H, br d,  $J = 7.3$  Hz, H-2'', -6'');  $^1\text{H}$  nmr ( $\text{Me}_2\text{CO}-d_6$ )  $\delta$  3.71 (1H, ddd,  $J = 9.5, 5.1, 2.6$  Hz, H-5'), 3.81 (1H, dd,  $J = 12.0, 5.1$  Hz, H-6'), 3.85 (1H, br t,  $J = 8.1$  Hz, H-2'), 3.86 (1H, br t,  $J = 9.5$  Hz, H-4'), 3.96 (1H, dd,  $\delta$  12.0, 2.6 Hz, H-6'), 4.54, 4.79 (each 1H, d,  $J = 13.0$  Hz, H-7), 5.06 (1H, d,  $J = 8.1$  Hz, H-1'), 5.36 (1H, t,  $J = 9.1$  Hz, H-3'), 7.01-7.06 (1H, m, H-4), 7.22-7.31 (2H, m, H-5, 6), 7.36 (1H, br d,  $J = 7.3$  Hz, H-3), 7.52 (2H, td,  $J = 7.0, 1.5$  Hz, H-3'', -5''), 7.64 (1H, tt,  $J = 7.0, 1.5$  Hz, H-4''), 8.08 (2H, dt,  $J = 7.0, 1.5$  Hz, H-2'', -6'');  $^{13}\text{C}$  nmr see Table 1.

TREMULOIDIN [2].—A colorless powder: eims  $m/z$  124, 106, 105;  $^1\text{H}$  nmr ( $\text{DMSO}-d_6$ )  $\delta$  3.33-3.45 (1H, m, H-4'), 3.46-3.55 (1H, m, H-5'), 3.51-3.64 (1H, m, H-6'), 3.65-3.78

(1H, m, H-3'), 3.70–3.93 (1H, m, H-6'), 4.13, 4.40 (each 1H, dd,  $J = 15.1, 5.6$  Hz, H-7), 4.74 (1H, br t,  $J = 5.4$  Hz, 6'-OH), 4.90 (1H, br t,  $J = 5.6$  Hz, 7-OH), 5.08 (1H, dd,  $J = 9.2, 7.7$  Hz, H-2'), 5.26 (1H, d,  $J = 7.7$  Hz, H-1'), 5.35 (1H, d,  $J = 5.4$  Hz, 4'-OH), 5.51 (1H, d,  $J = 5.4$  Hz, 3'-OH), 6.97 (1H, br t,  $J = 7.3$  Hz, H-4), 7.08 (1H, br d,  $J = 7.3$  Hz, H-6), 7.16 (1H, br t,  $J = 7.3$  Hz, H-5), 7.31 (1H, br d,  $J = 7.3$  Hz, H-3), 7.49 (2H, br t,  $J = 7.7$  Hz, H-3'', -5''), 7.62 (1H, br t,  $J = 7.7$  Hz, H-4''), 7.99 (2H, br d,  $J = 7.7$  Hz, H-2'', -6'');  $^{13}\text{C}$  nmr see Table 1.

**SALICIN [3].**—Colorless rectangles: mp 191–192° (MeOH); eims  $m/z$  124, 106;  $^1\text{H}$  nmr (DMSO- $d_6$ )  $\delta$  4.45 (1H, dd,  $J = 14.3, 5.1$  Hz, H-7), 4.64 (1H, dd,  $J = 14.3, 5.9$  Hz, H-7), 4.74 (1H, d,  $J = 7.3$  Hz, H-1'), 6.99 (1H, br t,  $J = 7.3$  Hz, H-4), 7.08 (1H, br d,  $J = 7.3$  Hz, H-6), 7.19 (1H, br t,  $J = 7.3$  Hz, H-5), 7.35 (1H, br d,  $J = 7.3$  Hz, H-3);  $^{13}\text{C}$  nmr see Table 1.

**TREMULACIN [4].**—A pale yellow amorphous powder: eims  $m/z$  124, 106, 105;  $^1\text{H}$  nmr (DMSO- $d_6$ )  $\delta$  2.40–2.76 (4H, m, H-12, -13), 3.28–3.40 (1H, m, H-4'), 3.47–3.60 (2H, m, H-5', 6'), 3.65–3.73 (1H, m, H-3'), 3.73–3.80 (1H, m, H-6'), 4.70 (1H, t,  $J = 5.9$  Hz, 6'-OH), 4.80, 4.96 (each 1H, d,  $J = 13.2$  Hz, H-7), 5.06 (1H, t,  $J = 8.1$  Hz, H-2'), 5.28 (1H, d,  $J = 8.1$  Hz, H-1'), 5.35 (1H, d,  $J = 5.1$  Hz, 4'-OH), 5.51 (1H, d,  $J = 5.9$  Hz, 3'-OH), 5.66 (1H, d,  $J = 9.5$  Hz, H-10), 6.08 (1H, dt,  $J = 9.5, 4.0$  Hz, H-11), 6.40 (1H, s, 9-OH), 7.00 (1H, br t,  $J = 7.7$  Hz, H-4), 7.14 (1H, br d,  $J = 7.7$  Hz, H-6), 7.17 (1H, br d,  $J = 7.7$  Hz, H-3), 7.25 (1H, br t,  $J = 7.7$  Hz, H-5), 7.51 (2H, br t,  $J = 7.3$  Hz, H-3'', -5''), 7.65 (1H, br t,  $J = 7.3$  Hz, H-4''), 7.98 (2H, dd,  $J = 7.3, 1.1$  Hz, H-2'', -6'');  $^{13}\text{C}$  nmr (DMSO- $d_6$ )  $\delta$  26.1 (C-12), 35.8 (C-13), 60.8 (C-6'), 61.8 (C-7), 70.2 (C-4'), 74.1 (C-3'), 74.5 (C-2'), 77.5 (C-9, -5'), 98.7 (C-1'), 115.3 (C-6), 122.5 (C-4), 124.5 (C-2), 128.3 (C-5), 128.8 (C-11, -3'', -5''), 129.6 (C-2'', -6''), 129.7 (C-3), 129.9 (C-1''), 131.8 (C-10), 133.5 (C-4''), 154.4 (C-1), 165.4 (C-7''), 170.1 (C-8), 206.1 (C-14).

**SALICYLOYLTREMULOIDIN [5].**—A colorless powder: eims  $m/z$  124, 106, 105;  $^1\text{H}$  nmr (DMSO- $d_6$ )  $\delta$  3.33–3.40 (1H, m, H-4'), 3.50–3.55 (1H, m, H-5'), 3.55–3.58 (1H, m, H-6'), 3.66–3.75 (1H, m, H-3'), 3.73–3.80 (1H, m, H-6'), 4.74 (1H, br s, 6'-OH), 5.08 (1H, t,  $J = 8.1$  Hz, H-2'), 5.12 (2H, s, H-7), 5.35 (1H, d,  $J = 8.1$  Hz, H-1'), 5.37 (1H, br s, 4'-OH), 5.52 (1H, br d,  $J = 5.5$  Hz, 3'-OH), 6.80 (1H, br t,  $J = 7.7$  Hz, H-13), 6.95 (1H, br d,  $J = 8.3$  Hz, H-11), 7.03 (1H, br t,  $J = 7.3$  Hz, H-4), 7.24 (1H, br d,  $J = 8.8$  Hz, H-6), 7.32–7.37 (2H, m, H-3, -5), 7.40 (2H, br t,  $J = 7.7$  Hz, H-

3'', -5''), 7.44–7.49 (1H, m, H-12), 7.49–7.53 (1H, m, H-4''), 7.50–7.56 (1H, m, H-14), 7.92 (2H, br d,  $J = 7.7$  Hz, H-2'', -6'');  $^{13}\text{C}$  nmr (DMSO- $d_6$ )  $\delta$  60.5 (C-6'), 61.5 (C-7), 69.9 (C-4'), 73.8 (C-3'), 74.2 (C-2'), 77.3 (C-5'), 98.3 (C-1'), 112.7 (C-9), 115.1 (C-6), 117.2 (C-13), 119.3 (C-11), 122.3 (C-4), 124.0 (C-2), 128.4 (C-3'', -5''), 129.2 (C-2'', -6''), 129.5 (C-1''), 129.6 (C-14), 129.9 (C-3, -5), 133.1 (C-4''), 135.6 (C-12), 154.8 (C-1), 160.1 (C-10), 165.0 (C-7''), 168.4 (C-8).

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