Sesquiterpene Lactones from the Pericarps of *Illicium majus*; 2-Oxy Derivatives of Neomajucin and 3,4-Dehydroxyneomajucin

Isao KOUNO,*[,a] Naosuke BABA,[a] Miwa HASHIMOTO,[a] Nobusuke KAWANO,[a] Masakatsu TAKAHASHI,[a] Hiroshi KANETO,[a] and Chun-Shu YANG[b]

Faculty of Pharmaceutical Sciences, Nagasaki University,[a] Bunkyo-machi 1–14, Nagasaki 852, Japan and Beijing College of Traditional Medicine,[b] Beijing, People's Republic of China. *Received July 7, 1989*

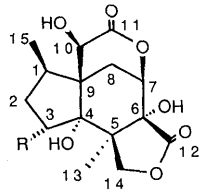
Six more anisatin-like sesquiterpene lactones were isolated from the pericarps of *Illicium majus*. The structures of these compounds (4—9) were characterized as majucins having a 2-oxy group. It is noteworthy that one of the six compounds has a (10*S)-hydroxyl group, whereas usual anisatin- and majucin-type compounds have a (10*R**)-hydroxyl group. All these structures were determined on the basis of spectral data, compared with those of majucin and neomajucin. These compounds did not exhibit convulsive toxicity to mice, although the (10*S**)-hydroxy compound was not examined.**

Keywords *Illicium majus*; Illiciaceae; sesquiterpene lactone; 2-oxyneomajucin; 2D COSY NMR; Chinese *Illicium* plant; 3,4-dehydroxyneomajucin; 2-oxymajucin; majucin

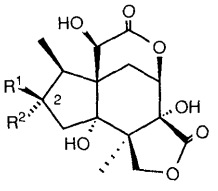
During a search for anisatin-like sesquiterpene lactones from Japanese and Chinese *Illicium* plants, we have reported the isolation of anisatin and anisatin-like sesquiterpene lactones (majucin (**1**), neomajucin (**2**), and 2,3-dehydroneomajucin (**3**)) from the pericarps of *Illicium majus* HOOK. f. & THOMS. (Illiciaceae),[1,2] which is one of the Chinese *Illicium* plants, and is regarded as toxic. The structure of neomajucin (**2**) was determined by an X-ray crystallographic analysis, and the other structures were clarified by analysis of the spectral data in comparison with those of neomajucin (**2**). These compounds possess a γ-lactone moiety instead of the characteristic β-lactone in the structure of anisatin, which is a well-known toxic sesquiterpene from the seeds and pericarps of *Illicium anisatum* (Japanese star anise).[3,4] Although its convulsive toxicity is only one-tenth of that of anisatin, neomajucin is still toxic.[2] In the present paper, we report the isolation and structure elucidation of six more majucin-type sesquiterpene lactones from the pericarps of *I. majus*. They have a 2-oxo or 2-hydroxyl group in the five-membered ring of neomajucin or 3,4-dehydroxyneomajucin.

The MeOH extraction from dried pericarps (1.5 kg) of *Illicium majus* was performed according to the previously reported procedure,[2] and extraction from the MeOH extracts with AcOEt afforded the AcOEt-soluble part, which was separated by counter-current distribution to give five fractions (I—V). Of these fractions, fraction II was chromatographed on silica gel, and purified by chromatography on a prepacked column or by recrystallization to yield compounds **4** (50 mg) and **5** (132 mg), in addition to pseudomajucin, previously reported from the same plant.[5] Fraction III yielded compounds **6** (100 mg), **7** (247 mg), **8** (104 mg), and **9** (9 mg), together with 2,3-dehydroneomajucin[2] on separation by silica gel column chromatography, followed by purification with a Kusano Si-5 column. Chromatographic purification on a Kusano Si-5 column was carried out with the solvent system of *n*-hexane–AcOEt (1 : 3) for **6**, and $CHCl_3$–AcOEt–acetone (20 : 20 : 3) for **7**, **8**, and **9**.

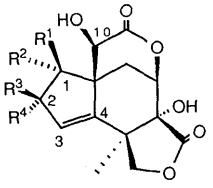
Compound **4**, colorless needles, mp 215—218 °C, $[\alpha]_D$ −61.4°, gave the molecular formula, $C_{15}H_{20}O_8$, the same as that of majucin (**1**), from the mass spectrum (MS) (*m/z*; 328 (M^+)) and the elemental analysis. In the infrared (IR) spectrum, it showed absorptions due to hydroxyl groups at 3470, 3430 and 3250, γ-lactone at 1764, and γ-lactone at 1724 cm^{-1}. The features of the proton nuclear magnetic resonance (^{1}H-NMR) spectrum (Table I), along with the carbon-13 nuclear magnetic resonance (^{13}C-NMR) spectrum (Table II), assigned by carbon-13–proton two dimensional correlation spectroscopy (^{13}C–^{1}H 2D COSY) and ^{13}C–^{1}H long-range 2D COSY, were very similar to those of majucin (**1**). The partial connectivities of carbon bonds also supported the majucin skeleton for **4**, as shown in Table III. The proton connectivities of H_3-15–H_1-1–H_1-2–H_2-3 were clarified by proton–proton (^{1}H–^{1}H) 2D COSY, and the signal due to H-2 on methine carbon appeared at δ 4.81, indicating that **4** is the 2-hydroxy derivative of neomajucin. The relative stereochemistry at C-1 in the structure of **4** can be deduced from a consideration of the results of nuclear Overhauser effect (NOE) difference experiments as 1β-methyl; *i.e.*, irradiation of H-15 produced an NOE enhancement at H-10 (5%). On the other hand, irradiation of



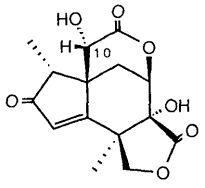
1: R = OH majucin
2: R = H neomajucin



4: R^1 = H, R^2 = OH
5: R^1, R^2 = O



6: R^1 = CH_3, R^2, R^4 = H, R^3 = OH
7: R^1 = CH_3, R^2 = H, R^3, R^4 = O
8: R^1 = H, R^2 = CH_3, R^3, R^4 = O



9

Fig. 1

TABLE I. ^{1}H-NMR Data for Majucin (**1**), Neomajucin (**2**), and Compounds **4**—**9** (400 MHz, δ from TMS in Pyridine-d_5; J (Hz) in Parentheses)

Protons	Majucin (**1**)	Neomajucin (**2**)	**4**	**5**	**6**	**7**	**8**	**9**
1	3.02 (qdd, 10.2, 9.5, 7.0)	2.90 m	3.15 (qd, 7.0, 7.0)	3.49 (q, 7.0)	2.08 (qd, 7.3, 5.9)	2.56 (q, 7.0)	2.94 (q, 7.7)	3.27 (q, 7.7)
2β	2.48 (dt, 12.6, 9.5)	2.39 m	4.81 (br dd, 8.8, 7.0)	—	—	—	—	—
2α	2.21 (ddd, 12.6, 10.2, 4.4)	2.29 m	—	—	4.50 (dd, 5.9, 2.9)	—	—	—
3β	5.21 (dd, 9.5, 4.4)	1.85—2.05 (2H) m	2.86 (dd, 13.6, 8.8)	3.17 (d, 17.2)	6.47 (d, 2.9)	6.76 (s)	6.66 (s)	6.58 (s)
3α	—		2.24 (br d, 13.6)	2.70 (br d, 17.2)	—	—	—	—
7	5.14 (dd, 3.3, 2.2)	5.12 (dd, 2.6, 2.5)	5.13 (dd, 3.3, 2.6)	5.17 (dd, 3.3, 2.2)	5.10 (dd, 4.0, 1.5)	5.19 (dd, 4.0, 1.5)	5.22 (dd, 4.0, 1.5)	5.27 (dd, 4.4, 1.5)
8β	2.05 (dd, 14.3, 3.3)	2.00 (dd, 14.2, 2.6)	2.02 (dd, 14.3, 3.3)	2.23 (dd, 14.3, 3.3)	2.45 (dd, 14.3, 4.0)	2.59 (dd, 14.3, 4.0)	2.45 (dd, 14.3, 4.0)	2.87 (dd, 14.3, 4.4)
8α	3.11 (dd, 14.3, 2.2)	3.01 (dd, 14.2, 2.5)	3.19 (dd, 14.3, 2.6)	3.32 (dd, 14.3, 2.2)	2.25 (dd, 14.3, 1.5)	2.67 (dd, 14.3, 1.5)	2.66 (dd, 14.3, 1.5)	2.44 (ddd, 14.3, 1.8, 1.5)
10	4.65 (br d, 4.5)	4.66 (br d, 4.8)	4.65 (s)	4.77 (s)	4.36 (s)	4.70 (s)	4.76 (s)	4.37 (d, 1.8)
10-OH	8.95 (br d, 4.5)	8.78 (br d, 4.8)	—	—	—	—	—	—
13	1.95 (br s)	1.70 (br s)	1.72 (br s)	1.71 (br s)	1.58 (br s)	1.67 (br s)	1.66 (br s)	1.64 (br s)
14a	4.30 (d, 10.8)	4.19 (d, 11.0)	4.17 (d, 11.0)	4.21 (d, 11.0)	4.09 (d, 10.3)	4.21 (d, 10.3)	4.23 (d, 10.6)	4.24 (d, 10.6)
14b	5.11 (br d, 10.8)	5.02 (br d, 11.0)	4.97 (br d, 11.0)	5.01 (br d, 11.0)	4.46 (br d, 10.3)	4.62 (br d, 10.3)	4.80 (br d, 10.6)	4.35 (br d, 10.6)
15	1.10 (d, 7.0)	1.18 (d, 7.0)	1.37 (d, 7.0)	1.33 (d, 7.0)	1.22 (d, 7.3)	1.46 (d, 7.0)	1.21 (d, 7.7)	1.30 (d, 7.7)

Assignments were aided by the ^{1}H–^{1}H 2D COSY spectra.

TABLE II. ^{13}C-NMR Data for Majucin (**1**), Neomajucin (**2**), and Compounds **4**—**9** (100 MHz, δ from TMS in Pyridine-d_5)

Carbons	**1**	**2**	**4**	**5**	**6**	**7**	**8**	**9**
1	38.0 d	39.4 d	50.0 d	49.6 d	48.8 d	53.4 d	50.7 d	49.1 d
2	42.9 t	31.4 t	79.0 d	215.2 s	74.2 d	206.1 s	208.1 s	208.6 s
3	72.7 d	31.6 t	42.8 t	45.7 t	135.4 d	134.5 d	134.1 d	133.6 d
4	82.8 s	84.1 s	83.1 s	79.0 s	146.0 s	171.9 s	172.8 s	176.2 s
5	47.5 s	47.5 s	47.2 s	46.3 s	42.8 s	43.8 s	44.6 s	44.8 s
6	79.9 s	79.6 s	79.5 s	79.4 s	78.5 s	79.4 s	80.0 s	79.4 s
7	80.6 d	80.5 d	80.5 d	79.7 d	79.8 d	78.8 d	79.1 d	79.8 s
8	27.1 t	27.5 t	27.4 t	26.5 t	30.8 t	30.0 t	27.7 t	22.7 t
9	51.5 s	51.0 s	52.6 s	50.8 s	50.2 s	49.7 s	50.4 s	51.4 s
10	70.3 d	70.7 d	70.1 d	70.0 d	68.5 d	69.6 d	72.5 d	73.6 d
11	174.7 s	174.8 s	174.9 s	174.0 s	173.3 s	173.6 s	174.3 s	170.6 s
12	177.6 s	177.2 s	177.6 s	177.5 s	177.9 s	177.2 s	177.0 s	177.0 s
13	20.9 q	21.4 q	21.6 q	21.6 q	22.7 q	22.8 q	22.7 q	23.1 q
14	72.4 t	72.6 t	72.5 t	72.2 t	74.7 t	73.8 t	73.2 t	73.7 t
15	14.1 q	14.3 q	12.3 q	8.5 q	9.2 q	8.8 q	12.3 q	13.2 q

Assignments were made with the aid of the ^{13}C–^{1}H 2D COSY, and long-range ^{13}C–^{1}H 2D COSY spectra except for compound **8**.

H-2 gave an NOE at H-15 (5%), whereas irradiation of H-15 gave the expected effect at H-2 (3%). These results indicated clearly that the configuration of the 2-hydroxyl group is (2*S**). Accordingly, the structure of **4** was determined as (2*S**)-hydroxyneomajucin.

Compound **5**, colorless needles, mp 255—257 °C, $[\alpha]_D$ +20.4°, was assigned the molecular formula $C_{15}H_{18}O_8$ on the basis of the MS (*m/z*; 326 (M^+)) and elemental analysis. In the IR spectrum of **5**, the absorptions of hydroxyl groups at 3530, 3470, and 3345, γ-lactone at 1766, and δ-lactone at 1728 (overlapped with the absorption due to cyclopentanone) cm^{-1} were observed, together with the carbonyl absorption due to cyclopentanone at 1728 cm^{-1}. The ^{1}H and ^{13}C signals are also similar in appearance to those of **1** and/or **2**, indicating that compound **5** is a derivative of neomajucin. In the ^{1}H-NMR spectrum, a doublet methyl signal at δ 1.33 (H-15) coupled only with a methine signal at δ 3.49 (H-1), and two isolated methylene signals at δ 2.70 and 3.17 (H-3α and β) were observed. These results suggested that **5** possesses a carbonyl group at position 2, and this was supported by the carbon signal at δ 215.2. Irradiation of H-15 caused an NOE at H-10 (4%), indicating that compound **5** is 2-oxoneomajucin.

Compound **6** was obtained as colorless needles, mp 271—273 °C, $[\alpha]_D$ −66.3°. Its molecular formula, $C_{15}H_{18}O_7$, was obtained from the MS (*m/z*; 310 (M^+)) and the ele-

TABLE III. ^1H and ^{13}C Correlations Shown in the ^{13}C–^1H Long-Range 2D COSY Spectra of Compounds **1**, **4**, **5**, **6**, **7** and **9**[a]

Protons	1	4	5	6	7	9
H-1	C-8	C-8,9,10	C-2	C-8	C-8,9	b)
H-2β	C-4,15	b)	—	—	—	—
H-2α	C-3,9	—	—	C-9	—	—
H-3β	C-9	b)	C-2	C-1,2,4,5,9	C-1,2,4,9	C-9,13
H-3α	—	C-4,9	C-4,9			
H-7	C-5,9,11	C-6,11	C-5,6,9,11	C-5,6,9,11	C-5,6,9,11	C-11
H-8β	C-4,6,7	C-4,6,7	C-4,6,7	C-4,6,7	C-4,7	C-4,6,7
H-8α	C-10	C-9	C-10	C-1,9,10	C-9	C-10
H-10	C-4,11	C-4,9,11	C-4,9	C-1,4,9,11	C-1,4,9,11	b)
H-13	C-4,5,6,14	C-4,5,6,14	C-4,5,6,14	C-5,6,14	C-4,5,6,14	C-4,5,6,14
H-14a	C-5,6,12,13	C-5,6,12,13	C-5,6,12,13	C-5,6,12,13	C-5,6,12,13	C-12,13
H-14b	C-4,11,13	C-13	C-13	C-13	C-14	b)
H-15	C-1,2,9	C-1,9	C-1,2	C-1,2,9	C-1,2,9	C-1,2

a) Measured in pyridine-d_5 ($J=8$ Hz). b) No correlations were seen.

mental analysis. In the IR spectrum, absorptions due to γ-lactone (1766 cm^{-1}) and δ-lactone (1745 cm^{-1}) as well as hydroxyl groups (3440, 3350, and 3250 cm^{-1}) were observed. Signals in the ^{13}C-NMR spectrum of **6** were closely similar to those of the other majucin-type compounds, except for two olefinic carbon signals, one of which appeared at δ 135.4 (methine carbon), and the other at δ 146.0 (quaternary). On the other hand, the connectivities of H_3-15–H_1-1–H_1-2–H_1-3 (olefinic proton) were revealed by analyzing the ^1H–^1H 2D COSY spectrum of **6**, and in these signals, H-2 appeared at δ 4.50. Therefore, **6** should have a 2-hydroxyl group and a 3,4-double bond in the five-membered ring, and this result was supported by the carbon-13–proton correlations (Table III). The resonance for H-10 has a 7% NOE on irradiation of H-15, and thus the configuration at C-1 was deduced as 1β-methyl. The combination of NOE's from H-2 to H-1 (7%) and to H-3 (6%) and the zero observation from H-2 to H-15 are best accommodated by a (2*R**)-hydroxyl group. Thus, compound **6** was determined to be (2*R**)-hydroxy-3,4-dehydroxyneomajucin.

Compound **7**, colorless needles, mp 139—142 °C, $[\alpha]_D$ −92.4°, gave the molecular formula $C_{15}H_{16}O_7$, suggesting that **7** is a dehydroxy compound of **5**, or a dehydro compound of **6**. The ^1H and ^{13}C signals due to the six-membered ring resembled to those of the above compounds (**4**—**6**). Its IR spectrum showed absorptions due to cyclopentenone (1676 cm^{-1}), hydroxyl groups (3500, 3310 cm^{-1}), γ-lactone (1764 cm^{-1}), and δ-lactone (1756 cm^{-1}). There were two olefinic carbon signals at δ 134.5 and 171.9 in the ^{13}C-NMR spectrum, as in the case of **6**, together with the carbonyl carbon signal at δ 206.1. Thus, **7** was considered to be the 2-oxo-3,4-dehydroxy derivative of neomajucin. This result was consistent with the correlations in the ^{13}C–^1H long-range 2D COSY (Table III). Irradiation of H-15 gave the expected NOE at H-10 (4%) with a much smaller effect at H-8β (1%), indicating that the configuration at C-1 is 1β-methyl. Compound **7** was therefore concluded to be 2-oxo-3,4-dehydroxyneomajucin.

Compound **8** was isolated as colorless needles, mp 136—138 °C, $[\alpha]_D$ −38.9°. Its molecular formula, $C_{15}H_{16}O_7$, is the same as that of compound **7**. The absorption (1700 cm^{-1}) in the IR spectrum indicated the presence of α,β-unsaturated carbonyl group. Its ^{13}C- and ^1H-NMR spectra have close similarities to those of **7**. These results suggested that **8** is a stereoisomer of **7**. Irradiation of H-15 caused NOE only at H-8α (2%), and not at H-10. Thus, it was concluded that compound **8** is (1*R**)-2-oxo-3,4-dehydroxyneomajucin.

Compounds **7** and **8** were obtained as a mixture at first in a ratio of 1 : 1, but the final yields of these compounds indicated that the amount of **8** was decreased during the course of purification, suggesting the 1α-methyl group of **8** accounts for the instability.

A small quantity of compound **9** was isolated as colorless prisms, mp 248—251 °C, $[\alpha]_D$ −150.9°. Its molecular formula, $C_{15}H_{16}O_7$, was obtained from the MS (*m/z*; 308 (M^+)) and proton and carbon counts in the ^1H- and ^{13}C-NMR spectra, and is the same as those of compounds **7** and **8**. In the IR spectrum, absorptions due to hydroxyl group, γ-lactone, δ-lactone and cyclopentenone were observed at 3430, 1779, 1730, and 1697 cm^{-1}, respectively. The ^1H- and ^{13}C-NMR spectral data suggested that the structure of **9** is similar to those of **7** and **8**. However, H-10 at δ 4.37 appeared as doublet ($J=1.8$ Hz), whereas the H-10 signal of the above compounds were singlets. This coupling was revealed as the coupling between H-8α and H-10 by ^1H–^1H 2D COSY, indicating that the configuration of the 10-hydroxyl group of **9** is reversed from that in the usual anisatin-like compounds, which have a (10*R**)-hydroxyl group; *i.e.* the protons H-8α and H-10 of **9** form a long-range coupled system. Thus, it was concluded that **9** was a (10*S**)-hydroxy derivative of compound **7** or **8**. In order to clarify the configuration at C-1, an NOE experiment was performed. Irradiation of H-15 produced small NOEs at H-1 (4%) and H-8α (1%), indicating that the configuration at C-1 is 1α-methyl. As a result, the structure of **9** was determined as (1*R**,10*S**)-2-oxo-3,4-dehydroxyneomajucin.

The toxic effects of compounds **4**, **5**, **6**, **7**, and **8** were examined using ddY-strain mice weighing 25—30 g, with 2—5 animals for each group and each dose. These compounds, however, did not produce any toxic reaction or behavioral change at the doses of 20 and 40 mg/kg within 72 h after intraperitoneal injection (data not shown). The amount of compound **9** was insufficient for testing of the pharmacological effects.

Experimental

All melting points were determined on a Yanagimoto micro melting

point apparatus and are uncorrected. ^{1}H- and ^{13}C-NMR spectra were taken at 400 and 100 MHz, respectively, with a JEOL GX-400 spectrometer. NOE and 2D COSY experiments were performed on the same apparatus. Chemical shifts are expressed in δ (ppm) values with tetramethylsilane as an internal standard. Abbreviations are as follows: s, singlet; d, doublet; t, triplet; q, quartet; br, broad; m, multiplet. Electron impact mass spectra (EI-MS) were recorded on a JEOL JMS-DX-303 spectrometer. IR spectra were recorded on a JASCO IR-180 using KBr disks. Optical rotations were measured with a JASCO DIP-181 digital polarimeter. Thin layer chromatography (TLC) was performed on Merck precoated plates. Merck Silica gel 60 (particle size 0.063—0.200 and 0.040—0.063 nm) were used for column chromatography. Medium-pressure liquid chromatography (MPLC) was carried out on a JASCO 880-PU pump using a Lobar prepacked column (Si60, size B) and a Kusano Si-5 column.

Isolation The pericarps (1.5 kg) of *Illicium majus*, collected at Guangxi, China, were extracted with MeOH three times. The AcOEt-soluble part, obtained by the aforementioned method,[2] was subjected to counter-current distribution using the solvent system of H_2O and AcOEt to give five fractions (I—V). Fraction II was chromatographed on silica gel (solvent, $CHCl_3$–MeOH–H_2O (9 : 1 : 0 : 1)) to give eight fractions. Of these fractions, fraction 8 was crystallized from AcOEt to afford compound **4** (50 mg), and fraction 7 was applied to a Lobar prepacked column with the solvent of $CHCl_3$–MeOH (87 : 13) to give compound **5** (132 mg). Fraction 9 was applied to a Kusano Si-5 column (solvent, $CHCl_3$–AcOEt–acetone (20 : 20 : 3)) to give compound **6** (100 mg). The separation and purification of fraction 10 were done on a Kusano Si-5 column (solvent, *n*-hexane–AcOEt (1 : 3)) to give compounds **7** (247 mg), **8** (104 mg), and **9** (9 mg).

Compound **4**: Colorless needles (from AcOEt), mp 215—218 °C. $[\alpha]_D^{24}$ −61.4° (c=0.22, dioxane). EI-MS m/z: 328 (M^+). IR ν_{max}^{KBr} cm^{-1}: 3470, 3430, 3250 (–OH), 1764 (γ-lactone), 1724 (δ-lactone). *Anal.* Calcd for $C_{15}H_{20}O_8 \cdot 1/2H_2O$: C, 53.09; H, 6.83. Found: C, 53.14; H, 6.62.

Compound **5**: Colorless needles from $CHCl_3$–MeOH–H_2O (9 : 1 : 0.1), mp 255—257 °C. $[\alpha]_D^{24}$ +20.4° (c=0.25, dioxane). EI-MS m/z: 326 (M^+). IR ν_{max}^{KBr} cm^{-1}: 3530, 3470, 3345 (–OH), 1766 (γ-lactone), 1728 (δ-lactone and cyclopentanone). *Anal.* Calcd for $C_{15}H_{18}O_8$: C, 55.21; H, 5.56. Found: C, 54.82; H, 5.52.

Compound **6**: Colorless needles from AcOEt, mp 271—273 °C. $[\alpha]_D^{23}$ −66.3° (c=0.27, dioxane). EI-MS m/z: 310 (M^+). IR ν_{max}^{KBr} cm^{-1}: 3440, 3350, 3250 (–OH), 1766 (γ-lactone), 1745 (δ-lactone). *Anal.* Calcd for $C_{15}H_{18}O_7$: C, 58.06; H, 5.85. Found: C, 57.75; H, 5.74.

Compound **7**: Colorless needles from AcOEt, mp 139—142 °C. $[\alpha]_D^{26}$ −92.4° (c=0.25, dioxane). EI-MS m/z: 308 (M^+). IR ν_{max}^{KBr} cm^{-1}: 3500, 3310 (–OH), 1764 (γ-lactone), 1756 (δ-lactone), 1676 (cyclopentenone). UV λ_{max}^{EtOH} nm (log ε): 228 (4.72). *Anal.* Calcd for $C_{15}H_{16}O_7 \cdot H_2O$: C, 55.21; H, 5.56. Found: C, 54.89; H, 5.49.

Compound **8**: Colorless needles from AcOEt, mp 136—138 °C. $[\alpha]_D^{15}$ −38.9° (c=0.27, dioxane). EI-MS m/z: 308 (M^+). IR ν_{max}^{KBr} cm^{-1}: 3385, 3250 (–OH), 1776 (γ-lactone), 1740 (δ-lactone), 1700 (cyclopentenone). *Anal.* Calcd for $C_{15}H_{16}O_7$: C, 58.44; H, 5.23. Found: C, 58.12; H, 5.19.

Compound **9**: Colorless prisms from AcOEt, mp 248—251 °C. $[\alpha]_D^{20}$ −150.9° (c=0.33, dioxane). EI-MS m/z: 308 (M^+). IR ν_{max}^{KBr} cm^{-1}: 3430 (–OH), 1779 (γ-lactone), 1730 (δ-lactone), 1697 (cyclopentenone).

Acknowledgment We are grateful to Mr. Y. Ohama for valuable assistance in measuring the NMR spectra.

References

1) C.-S. Yang, I. Kouno, N. Kawano, and S. Sato, *Tetrahedron Lett.*, **29**, 1165 (1988).
2) I. Kouno, N. Baba, M. Hashimoto, N. Kawano, M. Takahashi, H. Kaneto, C.-S. Yang, and S. Sato, *Chem. Pharm. Bull.*, **37**, 2448 (1989); and references cited therein.
3) J. F. Lane, W. T. Koch, N. S. Leeds, and G. Gorin, *J. Am. Chem. Soc.*, **74**, 3211 (1952).
4) K. Yamada, S. Takada, S. Nakamura, and Y. Hirata, *Tetrahedron*, **24**, 199 (1968).
5) I. Kouno, N. Baba, M. Hashimoto, N. Kawano, C.-S. Yang, and S. Sato, *Chem. Pharm. Bull.*, **37**, 2427 (1989).