Chem. Pharm. Bull. 37(9) 2310—2312 (1989) Vol. 37, No. 9

Three New Lignans from the Nutmeg of *Myristica cagayanesis*

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The following constituents were isolated from the nutmeg of *Myristica cagayanesis* MERR.: trimyristin (1), otobain (2a), malabaricone A (3), otobanone (2b), cagayanin (4a), and cagayanone (4b). Compounds 2b, 4a and 4b are new lignans, and their structures were determined from spectral and chemical evidence.

Keywords *Myristica cagayanesis*; nutmeg; lignan; otobanone; cagayanin; cagayanone

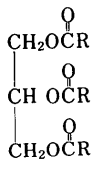
There are only three species of Myristicaceae indigenous to Taiwan: *Myristica* (*M.*) *simarum* A. DC., *M. cagayanesis* MERR., and *M. fragrans* HOUTT. In connection with our interest in lignans and in view of the use of nutmegs of *M. fragrans* and *M. cagayanesis* as native drugs,[1] chemical investigations on the nutmegs of these three species were undertaken in our laboratory.[2-5] Initially studies on the essential oil[6] and on the cyclic and acyclic bisphenylpropanoids[7] of the nutmeg of *M. fragrans* were carried out. Recently, Hattori *et al.* investigated the aril of *M. fragrans*, and more than twenty new lignans and neolignans were isolated.[8] In our studies, we have found a new 8-O-4′ ether type dilignol (**5**)[4] from the nutmeg of *M. fragrans*. From the nutmeg of *M. simarum*, two compounds, trimyristin (**1**) and a new lignan otobanone (**2b**), were isolated. In the previous communication[5] we reported the structural elucidation of a new lignan, cagayanin (**4a**), as well as the isolation of **2b** from the nutmeg of *M. cagayanesis*. In this paper we described the isolation of three new lignans, **2b**, **4a** and cagayanone (**4b**), together with three known compounds, trimyristin (**1**), otobain (**2a**), and malabaricone A (**3**), from the nutmeg of *M. cagayanesis*, and the structural determination of **2a**, **4a**, and **4b**.

Otobanone (**2b**), mp 175—176 °C, needles from acetone, has the molecular formula $C_{20}H_{18}O_5$ on the basis of elementary analysis. Its ultraviolet (UV) spectrum (λ_{max} 236 and 288 nm) and infrared (IR) spectrum (ν_{max} 3080, 1675, 1620, 1585, and 1500 cm^{-1}) suggested the presence of the benzoyl moiety. The proton nuclear magnetic resonance (^{1}H-NMR) spectrum indicated the presence of two secondary methyl groups, two methylenedioxyphenyl groups, and one benzoyl moiety (Table I). Based on the above data, otobanone (**2b**) is proposed to be a phenyltetrahydronaphthalene type lignan. Reduction of otobanone with sodium borohydride in MeOH afforded an alcohol (**6a**), the IR spectrum of which showed hydroxy stretching absorption at 3320 cm^{-1}, but no absorption of a conjugated carbonyl group. The alcohol (**6a**) was treated with *p*-toluenesulfonic acid in benzene under reflux to gave a liquid (**7**) (ν_{max} 1630 and 810 cm^{-1}; λ_{max} 241, 273.5, 281 and

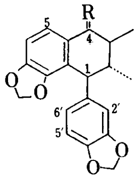
TABLE I. ^{1}H-NMR Data for Otobanone (**2b**), Cagayanin (**4a**), and Cagayanone (**4b**) ($CDCl_3$)

H	**2b**[a]	**4a**[a]	**4b**[b]
1	3.72 d (9.2)[c]	3.38 d (10.0)	3.61 d (10.8)
2	1.90 m	1.44—1.65	1.99 m
3	2.34 m	m	2.32 m
4		2.50—2.73 m[d]	
5	7.64 d (7.7)	6.68 s	7.44 s
6	6.76 d (7.7)		
8		6.15 s	6.17 s
2′	6.65 d (1.3)	6.50 s	6.51 d (1.5)
5′	6.69 d (9.0)	6.70 d (8.0)	6.76 d (6.3)
6′	6.47 dd (9.0, 1.3)	6.55 d (8.0)	6.63 dd (6.3, 1.5)
-OCH$_2$O-	5.66, 5.74 d (1.2)	5.88 s	5.91 s
-OCH$_2$O-	5.90 s	5.79 s	5.93 s
C-2 Me	1.00 d (6.1)	0.85 d (6.0)	0.90 d (6.6)
C-3 Me	1.20 d (6.1)	1.03 d (6.0)	1.26 d (6.6)

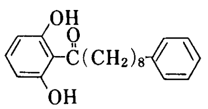
a) 60 MHz. *b*) 300 MHz. *c*) Figures in parentheses are coupling constant in Hz. *d*) 2.53 (1H, dd, *J* = 10.6, 7.2 Hz), 2.71 (1H, dd, *J* = 10.6, 4.5 Hz) (in 300 MHz).



1 : R=$(CH_2)_{12}CH_3$



2a : R=H, H
2b : R=O



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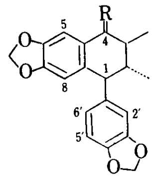
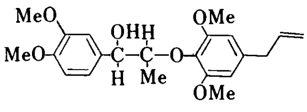


4a : R=H, H
4b : R=O



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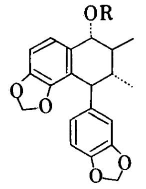
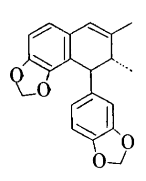


6a : R=H
6b : R=Ac



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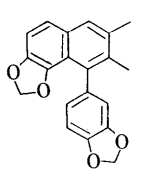

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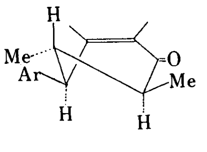

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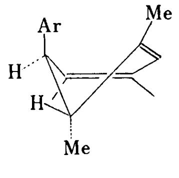

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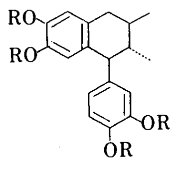
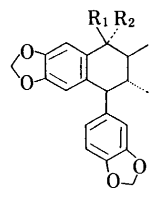
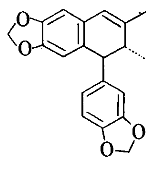


11a : R=H
11b : R=Me



12a : R$_1$=H, R$_2$=OH
12b : R$_1$=OH, R$_2$=H
12c : R$_1$=H, R$_2$=OAc



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315 nm). Dehydrogenation of **7** with dichlorodicyanobenzoquinone produced a phenyl naphthalene derivative (**8**) (mp 183—185 °C) which was identified as detetrahydrootobain.[9] Treatment of **6a** with acetic anhydride in pyridine yielded an acetate (**6b**) [mp 139.5—140.5 °C, ν_{max} 1720 cm^{-1}) which was treated with Zn in acetic acid under reflux to give **7**. Hydrogenation of **7** with 5% Pd–C in MeOH gave **2a**.[9] The structure of **2b** was thus concluded to be 1-oxootobain (**2b**) or its C-3 epimer. Since **2b** showed no reaction with 1 N methanolic NaOH overnight, the C-3 methyl group was considered to have the stable β-equatorial orientation. Further evidence to confirm the identification of **2b** as 4-oxootobain is that **2b** afforded **2a** on hydrogenolysis with 5% Pd–C.

The orientation of the 4-hydroxyl group in **6a** was assigned to be α-quasiequatorial from by the observation that H-4 of the acetate (**6b**) exhibited a signal at δ 5.88 (d, $J=8.0$ Hz) with a larger diquasi-axial coupling constant. In the ^{1}H-NMR spectra, the configuration and the conformation of ring B in **2b** were considered to be the same as those of **2a**. The signal of H-1 in **2b** shows a larger coupling constant at δ 3.72 (d, $J=9.2$ Hz), and the chemical shift of the methylenedioxy protons attached to ring A are markedly different. In **2b**, this is a proton of a typical AB system in which the coupling constant is 1.2 Hz and the difference of the chemical shift is 0.08 ppm.[3] This is to be expected from formula (**2b**) provided that the conformation of ring B is pseudo-chair form (**9**), and that in this conformation the phenyl group is quasi-equatorial. The conformation of ring B in **7** is obviously different from that of otobanone, based on its nuclear magnetic resonance (NMR)-spectrum. The signal of H-1 in **7** shows a slightly broadened singlet at δ 4.00 ($W_{1/2}=3$ Hz), and the signal of the equivalent methylenedioxy protons attached to ring A appears at δ 5.93, slightly different from that of other methylenedioxy protons attached to ring C. This is to be expected from **7** provided that the conformation of ring B is another pseudo-chair form (**10**) and that in this conformation the phenyl group is quasi-axial.

Cagayanin (**4a**), mp 122—123 °C, needles from acetone, has the formula $C_{20}H_{20}O_4$ on the basis of elemental analysis. The IR spectrum suggested the presence of phenyl (ν_{max} 1600 and 1500 cm^{-1}) and methylenedioxy (ν_{max} 1200, 1040 and 940 cm^{-1}) groups. The NMR spectral data (Table I) indicated that **4a** is a phenyltetrahydronaphthalene type lignan with two methylenedioxy groups. The NMR spectrum of **4a** differed from that of **2a** in that the singlet signal of the methylenedioxy protons in ring A of cagayanin is replaced by the AB coupling doublet signal of methylenedioxy protons in ring A of otobain. A phenyl proton at high field [δ 6.15 (s)] suggested that this proton was located at the C-8 position, which would be shielded by the by anisotropic effect of ring C. The above result indicated that one of the methylenedioxy group must be located at C-6 and C-7. In order to convert **4a** to galbulin (**11b**), **4a** was treated with PCl_5 in toluene followed by hydrolysis to give the tetraol (**11a**) (mp 225—227 °C, ν_{max} 3340 cm^{-1}). The reaction of **11a** with dimethylsulfate and potassium carbonate in acetone under reflux afforded a tetramethoxy compound (**11b**) [mp 127—129 °C; δ 3.51, 3.78, 3.79 and 3.85 (each 3H, s)] which was found to be identical with galbulin[10] from a comparison of physical and spectral data.

Cagayanone (**4b**), mp 236—238 °C, needles from acetone, has the molecular formula $C_{20}H_{18}O_5$ from the mass spectrum (MS) (M^+ m/z 338) and elementary analysis. The UV spectrum (λ_{max} 235 and 275 nm) and IR spectrum (ν_{max} 3080, 1600, 1607, 1499 and 1474 cm^{-1}) suggested the presence of a benzoyl moiety. The NMR spectrum (Table I) of cagayanone (**4b**) clearly indicated the presence of two secondary methyl groups, two methylenedioxyphenyl groups and one benzoyl moiety. Based on the above data, cagayanone (**4b**) is proposed to be a phenyltetrahydronaphthalene type lignan. Sodium borohydride reduction of **4b** gave two monools (**12a** and **12b**). The substituents at C-1, C-2, C-3 and C-4 in the major product **12a** (ν_{max} 3425 cm^{-1}) are all considered to be in quasi-equatorial orientation due to the signals of H-1 and H-4 at 3.41 (d, $J=10.3$ Hz) and 4.33 (t, $J=7.8$ Hz, coupling with H-3 and –OH), respectively, with larger coupling constant. From the small coupling constant of signal of H-4 of the minor component **12b** at δ 4.47 (d, $J=2.5$ Hz), the hydroxyl group (ν_{max} 3427 cm^{-1}) of **12b** was assigned to be located at C-4 with β-axial orientation. Acetylation of **12a** by acetic anhydride and pyridine yielded a monoacetate (**12c**) which showed an IR absorption band at ν_{max} 1727 cm^{-1} and a ^{1}H-NMR absorption signal at δ 2.19 (3H, s). The signal of H-4 was shifted to lower field at δ 5.87 (d, $J=8.7$ Hz). The dehydration product (**13**) was prepared from **12a** by refluxing in benzene with p-toluenesulfonic acid as a catalyst. The liquid dihydronaphthalene product (**13**) also prefers conformer (**10**) to conformer (**9**), since the H-1 signal of **13** (δ $CDCl_3$ 3.60) shows a small coupling constant ($J=3.1$ Hz). Cagayanone (**4b**) gave cagayanin (**4a**) by hydrogenolysis with 10% Pd–C and p-toluenesulfonic acid as catalyst. This result, unambiguously, proved the structure of cagayanone as the formula (**4b**).

Experimental

Melting points were determined on a Yanagimoto micro melting point apparatus and are uncorrected. Optical rotation was measured with a JASCO DIP-4 digital polarimeter at room temperature. IR spectra were recorded on a JASCO A-102 spectrometer. ^{1}H-NMR spectra were run on a Varian T-60 at 60 MHz and a Bruker AM 300 at 300 MHz in $CDCl_3$ solution with tetramethylsilane (TMS) as an internal standard. Chemical shifts are given in δ value and coupling constant (J) are given in hertz (Hz).

Extraction and Isolation The seed nuts (1.7 kg) of *Myristica cagayanesis* MERR. were crushed into small pieces and extracted for four times with hexane without shaking, followed by eleven times with shaking. The details of the separation of trimyristin (**1**) (50 g), otobain (**2a**) (305 mg), otobanone (**2b**) (750 mg), malabaricone A (**3**) (650 mg), cagayanin (**4a**) (40 mg) and cagayanone (**4b**) (53 mg) were presented in a previous report.[2]

Trimyristin (1) mp 55—56 °C. IR ν_{max}^{KBr} cm^{-1}: 1735, 1413, 1300, 1255, 1205, 1190, 720. ^{1}H-NMR ($CDCl_3$) δ: 0.85 (9H, t, $J=6.8$ Hz), 1.23 (about 60H, br s), 1.59 (6H, m, $-\overset{\overset{O}{\|}}{C}CH_2C\underline{H}_2-$), 2.29 (6H, m, $-\overset{\overset{O}{\|}}{C}CH_2-$), 4.12 (2H, dd, $J=12.0$, 6.0 Hz), 4.27 (2H, dd, $J=12.0$, 5.3 Hz), 5.24 (1H, m).

Otobain (2a)[9] Colorless needles, mp 134—136 °C. IR ν_{max}^{KBr} cm^{-1}: 1605, 1490, 1250, 1060, 940, 815, 800. ^{1}H-NMR ($CDCl_3$) δ: 0.98 1.02 (each 3H, d, $J=6.0$ Hz, $-CH_3$), 1.2—1.8 (2H, m, H-2, H-3), 2.66 (1H, m, H-4), 3.68 (1H, d, $J=8.5$ Hz, H-1), 5.63 and 5.69 (each 1H, d, $J=1.5$ Hz, $-OCH_2O-$), 5.91 (2H, s, $-OCH_2O-$), 6.60 (3H, br s, H-2′, H-5′, H-6′), 6.69 (2H, br s, H-5, H-6).

Otobanone (2b) Colorless needles, mp 175—176 °C. $[\alpha]_D^{15}$ $-27.1°$ ($c=0.7$ in $CHCl_3$). λ_{max}^{MeOH} nm (log ε): 236 (4.35), 288 (4.00). *Anal.* Calcd for $C_{20}H_{18}O_5$: C, 70.99; H, 5.36. Found: C, 70.76; H, 5.40. IR ν_{max}^{KBr} cm^{-1}: 3080, 1675, 1620, 1585, 1500, 1260, 1245, 1055, 950. ^{1}H-NMR: Table I.

Malabaricone A (3)[11] Light yellow needles, mp 81—82 °C. IR ν_{max}^{KBr}

cm^{-1}: 3250, 3040, 1635, 1605, 1510, 1260, 1235, 1045, 975, 790, 745, 715. ^{1}H-NMR (CDCl$_3$) δ: 1.33 (8H, br s, -COCH$_2$CH$_2$(CH$_2$)$_4$CH$_2$-), 1.4—1.9 (4H, m, -COCH$_2$CH$_2$-, PhCH$_2$CH$_2$-), 2.57 (2H, t, $J=7.2$ Hz), 3.13 (2H, t, $J=7.2$ Hz), 6.35 (2H, d, $J=8.1$ Hz), 7.15 (5H, br s), 7.18 (1H, t, $J=8.1$ Hz), 9.99 (2H, br s, disappeared on D$_2$O exchange).

Cagayanin (4a) Colorless needles, $[\alpha]_D^{20}$ $-33.5°$ ($c=1.0$ in CHCl$_3$). UV λ_{max}^{MeOH} nm (log ε): 235 (3.98), 286 (3.86). mp 122—123 °C. *Anal.* Calcd for C$_{20}$H$_{20}$O$_4$: C, 74.05; H, 6.22. Found: C, 74.21; H, 6.12. IR ν_{max}^{KBr} cm^{-1}: 1600, 1500, 1375, 1225, 1200, 1040, 940, 885, 800; ^{1}H-NMR: Table I.

Cagayanone (4b) Colorless needles, mp 236—238 °C. $[\alpha]_D^{23}$ $-27.6°$ ($c=1.0$ in CHCl$_3$). UV λ_{max}^{MeOH} nm (log ε): 235 (4.40), 275 (4.12). *Anal.* Calcd for C$_{20}$H$_{18}$O$_5$: C, 70.99; H, 5.36. Found: C, 70.86; H, 5.25. IR ν_{max}^{KBr} cm^{-1}: 3080, 1660, 1607, 1499, 1474, 1242, 1034, 933, 899, 880, 800. ^{1}H-NMR: Table I. EI-MS m/z (%): 338 (M$^+$, 90), 282 (100), 252 (20), 224 (43), 196 (42), 139 (24), 98 (22).

Sodium Borohydride Reduction of Otobanone (2b) Excess of sodium borohydride was added in small portions to a solution of otobanone (**2b**) (161 mg) in 10 ml of MeOH and the mixture was allowed to stand for 4 h. The reduction product was precipitated during the reduction. The filtrate was poured into excess water and the precipitate was collected. The combined precipitates were recrystallized from ethyl acetate to give **6a** as colorless needles (152 mg), mp 217—219 °C. IR ν_{max}^{KBr} cm^{-1}: 3320, 3030, 1600, 1502, 1485, 1360, 1245, 1050, 1030, 930, 907, 793. *Anal.* Calcd for C$_{20}$H$_{20}$O$_5$: C, 70.57; H, 5.92. Found: C, 70.40; H, 5.92.

Dehydration of 6a with Acid p-Toluenesulfonic acid (10 mg) and **6a** (30 mg) were dissolved in 10 ml of benzene. The mixture was heated under reflux for 3 h, and then poured into an excess of water. The product was purified to yield **7** (20 mg), colorless liquid. UV $\lambda_{max}^{CHCl_3}$ nm (log ε): 241 (3.91), 273 (4.00), 281 (4.16), 315 (3.75). IR ν_{max}^{neat} cm^{-1}: 3040, 1630, 1610, 1505, 1490, 1270, 1240, 1070, 1050, 940, 870, 810. ^{1}H-NMR (CDCl$_3$) δ: 1.10 (3H, d, $J=7.0$ Hz), 1.81 (3H, d, $J=1.1$ Hz), 2.38 (1H, m, H-2), 4.00 (1H, br s, $W_{1/2}=3$ Hz, H-1), 5.91 and 5.93 (each 2H, s, -OCH$_2$O-), 6.24 (1H, m, H-4), 6.5—6.9 (5H, m, phenyl protons).

Dehydrogenation of 7 with Dichlorodicyanoquinone (DDQ) DDQ (50 mg) and **7** (18 mg) were dissolved in 20 ml of benzene and the solution was heated under reflux for 2 d. The reaction mixture was subjected to chromatography on silica gel and detetrahydrootobain (**8**) (mp 183—185 °C)$^{9)}$ (8 mg) was isolated.

Acetylation of 6a with Acetic Anhydride and Pyridine Compound **6a** (51 mg) was treated with Ac$_2$O and pyridine as usual to yield the monoacetate (**6b**) (51 mg), mp 139.5—140.5 °C. IR ν_{max}^{KBr} cm^{-1}: 3050, 1720, 1600, 1500, 1250, 1130, 920, 670. ^{1}H-NMR (CDCl$_3$) δ: 1.00 (6H, d, $J=5.8$ Hz), 1.4—2.0 (1H, m, H-2, H-3), 2.20 (3H, s), 3.51 (1H, d, $J=8.7$ Hz, H-1), 5.58 and 5.67 (each 1H, d, $J=1.5$ Hz, -OCH$_2$O-), 5.84 (2H, s, -OCH$_2$O-), 5.88 (1H, d, $J=8.0$ Hz, H-4), 6.4—6.7 (5H, m, phenyl protons).

Elimination of 6b with Zinc and Acetic Acid Compound **6a** (45 mg) and an excess of zinc dust were added to 5 ml of acetic acid and the mixture was heated under reflux for 4 h. Then the reaction mixture was poured into water and extracted with ether. The extract was purified and the unexpected elimination product (**7**) (35 mg) was obtained.

Catalytic Hydrogenation of 7 with Pd–C Compound **7** (30 mg) was dissolved in 5 ml of MeOH, then 10 mg of 5% Pd–C previously suspended in 5 ml of methanol was added and the mixture was saturated with H$_2$. After one day, the catalyst was removed by filtration and washed several times with MeOH. After purification, the combined filtrate yielded otobain (**2a**) (mp 134—136 °C, 28 mg).

Conversion of 2b or 6b to Otobain (2a) Compound **2b** (20 mg) and p-toluenesulfonic acid (5 mg) were dissolved in 5 ml of MeOH, then 10 mg of 5% Pd–C previously suspended in 5 ml of methanol was added and the mixture was saturated with H$_2$. After two days, the catalyst was removed by filtration and washed several times with MeOH. After purification the combined filtrate yielded otobain (**2a**) (13 mg). Compound **6b** (23 mg) was reduced under condition similar to those used for the reduction of **2b** to give otobain (**2a**) (mp 134—136 °C, 15 mg).

Hydrolysis of 4a by Phosphorus Pentachloride Cagayanin (**4a**) (35 mg) was dissolved in dry toluene (10 ml), and fresh phosphorus pentachloride (155 mg) was added at 5—10 °C. The reaction mixture was heated under reflux for 1 h, then poured into 20 ml of H$_2$O. The binary solution was heated again under reflux for 2 h. After purification, it gave the tetraol (**11a**) (17 mg), mp 225—227 °C. IR ν_{max}^{KBr} cm^{-1}: 3340, 1600, 1510, 1285, 1250, 1220, 945, 865, 795, 760. ^{1}H-NMR (CD$_3$COCD$_3$) δ: 0.80 and 1.02 (each 3H, d, $J=6.2$ Hz), 1.35—1.45 (2H, m, H-2, H-3), 2.40—2.70 (2H, m, H-4), 3.25 (1H, d, $J=8.5$ Hz, H-1), 6.05 and 6.50 (each 1H, s, H-8, H-5, respectively), 6.48 (1H, d, $J=1.8$ Hz, H-2′), 6.45 (1H, dd, $J=7.1$, 1.8 Hz, H-6′), 6.75 (1H, d, $J=7.1$ Hz, H-5′), 7.5 (4H, br s, 4×-OH).

Conversion of the Tetraol (11a) to Galbulin (11b) The tetraol (**11a**) (15 mg) and 80 mg of dimethyl sulfate were dissolved in dry acetone (10 mg) to which excess of anhydrous potassium carbonate was added. The reaction mixture was refluxed for one day. Excess water was poured into the reaction mixture and the whole was extracted with ether. After purification, the ether extract gave galbulin (**11b**)$^{10)}$ (mp 127—129 °C, 10 mg).

Sodium Borohydride Reduction of Cagayanone (4b) An excess of sodium borohydride was added in small portions to a solution of cagayanone (**4b**) (25 mg) in 10 ml of MeOH and the mixture was left to stand for 4 h. The reaction product precipitated during reduction. Excess of water was added, and the reaction mixture was extracted with ethyl acetate (30 mg) four times. The ethyl acetate extract was subjected to chromatography on silica gel and two crystalline products, **12a** (20 mg) and **12b** (3 mg), were isolated.

12a: mp 154—155 °C. IR ν_{max}^{KBr} cm^{-1}: 3425, 1608, 1499, 1480, 1250, 1241, 1040, 934, 818, 801. ^{1}H-NMR (CDCl$_3$) δ: 0.85 and 1.17 (each 3H, d, $J=6.4$ Hz), 1.39—1.52 and 1.57—1.70 (each 1H, m, H-2, H-3), 3.41 (1H, d, $J=10.3$, H-1), 4.33 (1H, d, $J=7.8$ Hz, H-4), 5.83 and 5.92 (each 2H, s, -OCH$_2$O-), 6.12 (1H, s, H-8), 6.46 (1H, d, $J=1.3$ Hz, H-2′), 6.57 (1H, dd, $J=7.8$, 1.3 Hz, H-6′), 6.72 (1H, d, $J=7.8$ Hz, H-5′), 7.06 (1H, s, H-5).

12c (Monoacetate from **12a** by Reaction with Ac$_2$O and Pyridine): Amorphous powder. IR ν_{max}^{KBr} cm^{-1}: 3075, 1727, 1606, 1498, 1480, 1240, 1039, 936, 867, 807. ^{1}H-NMR (CDCl$_3$) δ: 0.86 and 0.95 (each 3H, d, $J=6.5$ Hz), 1.60—1.90 (2H, m, H-2, H-3), 2.19 (3H, s), 3.44 (1H, d, $J=9.6$ Hz, H-1), 5.82 and 5.93 (each 2H, s, -OCH$_2$O-), 5.87 (1H, d, $J=8.7$ Hz, H-4), 6.12 (1H, s, H-8), 6.47 (1H, d, $J=1.5$ Hz, H-2′), 6.58 (1H, dd, $J=7.8$, 1.5 Hz), 6.70 (1H, s, H-5), 6.73 (1H, d, $J=7.8$ Hz, H-5′).

12b: Amorphous powder. IR ν_{max}^{KBr} cm^{-1}: 3427, 1606, 1498, 1480, 1237, 936, 876, 814. ^{1}H-NMR (CDCl$_3$) δ: 0.85 and 1.14 (each 3H, d, $J=6.5$ Hz), 1.55—1.70 and 1.80—2.08 (each 1H, m, H-2, H-3), 3.28 (1H, d, $J=10.5$ Hz, H-1), 4.47 (1H, d, $J=2.5$ Hz, H-4), 5.82 and 5.84 (each 1H, d, $J=1.2$ Hz, -OCH$_2$O-), 5.90 (2H, s, -OCH$_2$O-), 6.19 (1H, s, H-8), 6.54 (1H, d, $J=1.4$ Hz, H-2′), 6.62 (1H, dd, $J=7.9$, 1.4 Hz, H-6′), 6.72 (1H, s, H-5), 6.73 (1H, d, $J=7.8$ Hz, H-5′).

Dehydration of 12a by Acid p-Toluenesulfonic acid (5 mg) and **12a** (10 mg) were added to 5 ml of benzene, and the mixture was heated under reflux for 2 h. On usual treatment the reaction mixture gave **13** (7 mg). IR ν_{max}^{neat} cm^{-1}: 3040, 1635, 1605, 1498, 1479, 1360, 1230, 1123, 1039, 937, 870, 793. ^{1}H-NMR (CDCl$_3$) δ: 1.04 (3H, d, $J=7.0$ Hz), 1.77 (3H, d, $J=1.1$ Hz), 2.33 (1H, m, H-2), 3.60 (1H, d, $J=3.1$ Hz, H-1), 5.85 and 5.87 (each 2H, s, -OCH$_2$O-), 6.06 (1H, br s, H-4), 6.48 and 6.53 (each 1H, s, H-5, H-8), 6.25 (1H, dd, $J=7.7$, 1.1 Hz, H-6′), 6.54 (1H, d, $J=1.1$ Hz, H-2′), 6.64 (1H, d, $J=7.7$ Hz, H-5′).

Conversion of 4b to Cagayanin (4a) Cagayanone (**4b**) (20 mg) was converted to cagayanin (**4a**) (mp 122—123 °C, 16 mg) by hydrogenolysis under the condition similar to those used for the conversion of otobanone to otobain.

Acknowledgement This research was supported by the National Science Council of the ROC.

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