SYNTHESIS OF 6-ACYL-2, 2-DIMETHYL-2-SILATETRALINS

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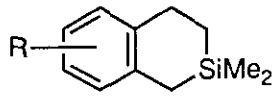
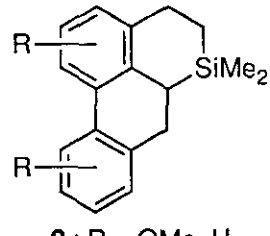
Abstract —— Friedel-Crafts reaction of 2-silatetralin (**4**) with acid anhydrides (acetic anhydride, succinic anhydride, glutaric anhydride, phthalic anhydride, *cis*-1, 2-cyclohexanedicarboxylic anhydride, and diphenic anhydride) or benzoyl chloride in the presence of $AlCl_3$ in CH_2Cl_2 at room temperature gave exclusively the corresponding 6-acyl-2-silatetralins in fair to good yield. This findings were supported by the MNDO molecular orbital calculations of 2-silatetralin (**4**).

Previously, we have reported syntheses of 2-silatetralins (**1**)[1] having oxygen functional groups, tetracyclic organosilicon compounds (**2**),[2] and 1-alkyl-2-silatetralins (**3**).[3] In our continuous investigation on synthesis and reaction of 2-silatetralin derivatives, we found that Friedel-Crafts reaction of 2-silatetralin (**4**) gave exclusively 6-acyl-2-silatetralins. This paper deals with formation of 6-acyl-2-silatetralins.



1 : R = OMe, OH



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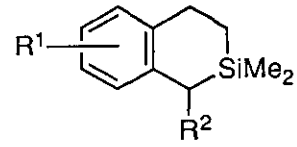
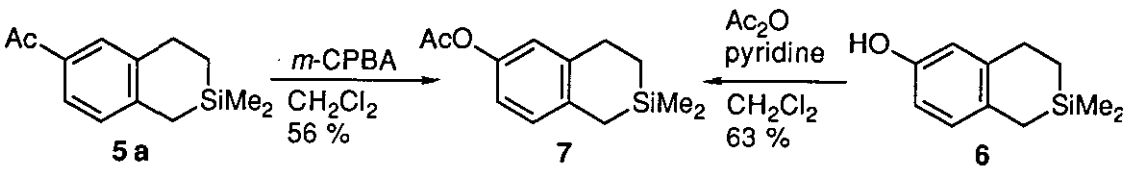
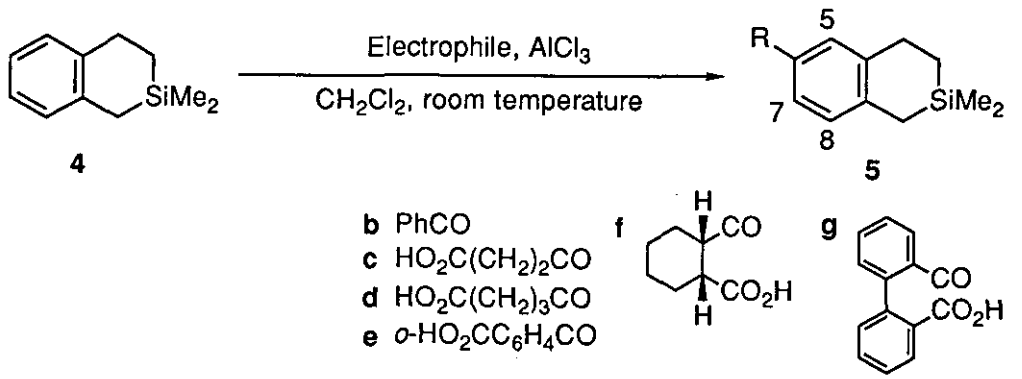


3 : R^1 = *OMe, t-BuMe*$_2$*SiO*
R^2 = Me, CH_2Ph

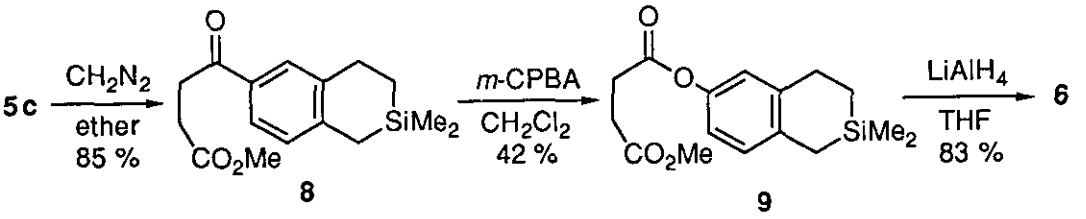
At first, Friedel-Crafts reaction of 2-silatetralin (**4**) with acetic anhydride in the presence of $AlCl_3$ (3.5 eq.) in CH_2Cl_2 at room temperature gave acetyl-2-silatetralin in 84 % yield. The ^{1}H-nmr spectrum showed one proton due to aromatic proton at the 8-position at δ 7.14 (d, J = 8.6 Hz) and two protons due to aromatic protons at the 5 and 7-positions at δ 7.59-7.79 (m). Ir spectrum indicated an absorption due to α, β-unsaturated carbonyl group at 1685 cm^{-1}, and in the ms a molecular peak (M^+) was measured at *m/z* 218. From these spectral data, the structure of acetylated product was presumed to be 6-acetyl-2-silatetralin (**5a**). Moreover, the position of acetyl group was determined as follows. Baeyer-Villiger reaction of the 6-acetyl-2-silatetralin (**5a**) with *m*-chloroperbenzoic acid (*m*-CPBA) in CH_2Cl_2 at room temperature gave 6-acetoxy-2-silatetralin in 56 % yield, which was identical with 6-acetoxy-2-silatetralin (**7**) derived from 6-hydroxy-2-silatetralin (**6**).[1] From this results, the position of acetyl group introduced was confirmed to be the 6-position.



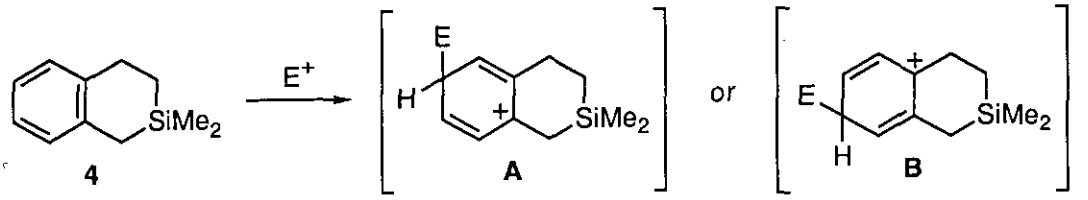
Based on the above results, Friedel-Crafts reaction of **4** with benzoyl chloride, succinic anhydride, glutaric anhydride, phthalic anhydride, *cis*-1,2-cyclohexanedicarboxylic anhydride, and diphenic anhydride was performed under reaction conditions similar to those noted for **5a** to give 6-acyl-2-silatetralins (**5b-g**) in fair to good yield.



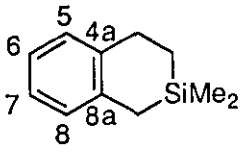
In order to prove again the position of acyl group introduced among the products, 6-(3'-carboxypropanoyl)-2-silatetralin (**5c**) was converted to **6** in unequivocal reaction sequences (esterification, Baeyer-Villiger oxidation, and reduction).



In the present reaction, formation of 6-acyl-2-silatetralins (**5**) would be explained by considering that the reaction intermediate (**A**) is preferable to intermediate (**B**) by ß-effect[4] of a silicon atom.



This assumption was also supported by the molecular orbital calculation of **4** using the MNDO method,[5, 6] showing the maximum value of π HOMO coefficient at the 6-position.



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Calculated by the MNDO method
Δ H_f = -33.860 kcal / mol (heat of formation)
Total energy -1722.678 eV

Position	π HOMO Coefficients
4a	-0.426
5	0.101
6	**0.511**
7	0.367
8	-0.175
8a	-0.540

In conclusion, Friedel-Crafts reaction of 2-silatetralin (**4**) afforded exclusively 6-acyl-2-silatetralins (**5**).

ACKNOWLEDGEMENT

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EXPERIMENTAL

General —— All melting points were measured on Büchi or Yanagimoto (hot plate) melting point apparatus and are uncorrected. Ir spectra were taken with a Hitachi model 260-10 spectrophotometer in $CHCl_3$ solution, unless otherwise noted. ^{1}H-Nmr spectra were recorded on a JEOL model FX-100 or JEOL model JUM-EX270 spectrometer in $CDCl_3$ solution using $CHCl_3$ or CH_2Cl_2 as internal standard. Ms were measured on a Hitachi M-80 or M-80A spectrometer. HRms was measured on a Hitachi M-80 spectrometer. Elemental analysis was measured on a Heraeus CHN-O-PAPID. Ball-to-ball distillation was carried out by use of a Sibata glass tube oven model GTO-250RS. Preparative tlc was performed with Kieselgel 60 F_{254} Art. 5744 (Merck) or Kieselgel 60 GF_{254} Art. 7730 (Merck). For column chromatography, silica gel [Wako gel C-200 or Silica Gel 60 (Cica-Merck)] was used. CH_2Cl_2 was distilled from CaH_2 prior to use, after treatment in a usual manner.

General Procedure for Preparation of 6-Acyl-2, 2-dimethyl-2-silatetralins (5). A mixture of **4**, $AlCl_3$, and acid anhydrides or benzoyl chloride in CH_2Cl_2 was stirred at room temperature for 45 min. The reaction was quenched with addition of water. The organic layer was separated and the aqueous layer was extracted with CH_2Cl_2. The combined organic layers were washed with saturated $NaHCO_3$ and brine (for **5a**, **b**) or only brine (for **5c-g**) and dried ($MgSO_4$). Removal of the solvent *in vacuo* gave a residue, which was purified by column chromatography, preparative tlc, or ball-to-ball distillation under reduced pressure.

6-Acetyl-2, 2-dimethyl-2-silatetralin (5a) : Compound (**4**) (212 mg, 1.2 mmol), $AlCl_3$ (560 mg, 4.2 mmol), acetic anhydride (184 mg, 1.8 mmol), and CH_2Cl_2 (32 ml) were used. The residue (252 mg) was purified by preparative tlc (three developments with hexane : AcOEt = 20 : 1) to afford **5a** (219 mg, 84 %) as a colorless oil, 70-100 °C / 2 Torr. ^{1}H-Nmr δ :

0.08 (6H, s, $SiMe_2$), 0.76 (2H, t, J = 7.1 Hz, C_3-H), 2.05 (2H, s, C_1-H), 2.58 (3H, s, MeCO), 2.79 (2H, t, J = 7.1 Hz, C_4-H), 7.14 (1H, d, J = 8.6 Hz, C_8-H), 7.59-7.79 (2H, m, C_5-H, C_7-H). Ir : 1685 (CO) cm^{-1}. HRms *m/z calcd for* $C_{13}H_{18}OSi$ (M^+) : 218.1126, found : 218.1122; ms *m/z* : 218 (M^+).

6-Benzoyl-2, 2-dimethyl-2-silatetralin (5b) : *Compound* (**4**) (212 mg, 1.2 mmol), $AlCl_3$ (272 mg, 2.04 mmol), benzoyl chloride (253 mg, 1.8 mmol), and CH_2Cl_2 (32 ml) were used. The residue (382 mg) was purified by preparative tlc (two developments with hexane : AcOEt = 20 : 1) to afford **5b** (249 mg, 74 %) as a colorless oil, 130-160 °C / 1 Torr. ^{1}H-Nmr δ : 0.09 (6H, s, $SiMe_2$), 0.78 (2H, t, J = 7.1 Hz, C_3-H), 2.08 (2H, s, C_1-H), 2.79 (2H, t, J = 7.1 Hz, C_4-H), 7.15 (1H, d, J = 8.6 Hz, C_8-H), 7.35-7.64 (5H, m, 5xAr-H), 7.78 (2H, dd, J = 1.4, 7.1 Hz, $Ar_{2'}$-H, $Ar_{6'}$-H). Ir : 1650 (CO) cm^{-1}. HRms *m/z calcd for* $C_{18}H_{20}OSi$ (M^+) : 280.1282, *found* : 280.1279; ms *m/z* : 280 (M^+).

6-(3'-Carboxypropanoyl)-2, 2-dimethyl-2-silatetralin (5c) : *Compound* (**4**) (212 g, 12 mmol), $AlCl_3$ (3.2 g, 24 mmol), succinic anhydride (1.08 g, 10.8 mmol), and CH_2Cl_2 (270 ml) were used. The light yellow crystals (2.44 g) were recrystallized from hexane-AcOEt to afford **5c** (1.81 g, 61 %, mp 113-115 °C) as colorless needles. Anal. Calcd for $C_{15}H_{20}O_3Si$: C, 65.18; H, 7.29. Found : C, 65.20; H, 7.29. ^{1}H-Nmr δ : 0.06 (6H, s, $SiMe_2$), 0.76 (2H, t, J = 7.1 Hz, C_3-H), 2.04 (2H, s, C_1-H), 2.79 (4H, t, J = 7.1 Hz, C_4-H, CH_2CO_2H), 3.29 (2H, t, J = 7.1 Hz, CH_2CO), 7.14 (1H, d, J = 8.6 Hz, C_8-H), 7.64-7.79 (2H, m, C_5-H, C_7-H), 7.79-8.64 (1H, br, CO_2H). Ir (KBr) : 3650-2450 (OH), 1715 (CO), 1680 (CO) cm^{-1}; ms *m/z* : 276 (M^+).

6-(4'-Carboxybutanoyl)-2, 2-dimethyl-2-silatetralin (5d) : Compound (**4**) (212 mg, 1.2 mmol), $AlCl_3$ (320 mg, 2.4 mmol), glutaric anhydride (123 mg, 1.08 mmol), and CH_2Cl_2 (32 ml) were used. The residue (532 mg) was purified by column chromatography with hexane-AcOEt (5 : 1, 3 : 1) to afford **5d** (236 mg, 75 %, mp 103-105 °C) as colorless crystals, mp 106-107 °C (hexane). Anal. Calcd for $C_{16}H_{22}O_3Si$: C, 66.17; H, 7.64. Found : C, 66.28; H, 7.52. ^{1}H-Nmr δ : 0.06 (6H, s, $SiMe_2$), 0.76 (2H, t, J = 7.1 Hz, C_3-H), 2.04 (2H, s, C_1-H), 2.08 (2H, tt, J = 7.1, 7.1 Hz, $CH_2CH_2CH_2$), 2.51 (2H, t, J = 7.1 Hz, CH_2CO_2H), 2.79 (2H, t, J = 7.1 Hz, C_4-H), 3.05 (2H, t, J = 7.1 Hz, CH_2CO), 7.12 (1H, d, J = 8.6 Hz, C_8-H), 7.59-7.76 (2H, m, C_5-H, C_7-H). Ir (KBr) : 3300-2500 (OH), 1720 (CO), 1685 (CO) cm^{-1}; ms *m/z* : 290 (M^+).

6-(2'-Carboxybenzoyl)-2, 2-dimethyl-2-silatetralin (5e) : Compound (**4**) (212 mg, 1.2 mmol), $AlCl_3$ (320 mg, 2.4 mmol), phthalic anhydride (160 mg, 1.08 mmol), and CH_2Cl_2 (32 ml) were used. The residue (623 mg) was purified three times by column chromatography [two times, $CHCl_3$ and $CHCl_3$-MeOH (100 : 1 ~ 5 : 1); third, $CHCl_3$ and $CHCl_3$-MeOH (200 : 1)] to afford **5e** (91 mg, 26 %, mp 140-144 °C) as light yellow crystals, mp 144.5-148.5 °C (hexane-AcOEt). Anal. Calcd for $C_{19}H_{20}O_3Si$: C, 70.34; H, 6.21. Found : C, 70.03; H, 6.25. ^{1}H-Nmr δ : 0.05 (6H, s, $SiMe_2$), 0.74 (2H, t, *J* = 7.1 Hz, C_3-H), 2.02 (2H, s, C_1-H), 2.75 (2H, t, *J* = 7.1 Hz, C_4-H), 4.36-4.78 (1H, br, COOH), 7.06 (1H, d, *J* = 8.6 Hz, C_8-H), 7.28-7.72 (5H, m, 5xAr-H), 7.95-8.12 (1H, m, Ar-H). Ir (KBr) : 3700-2200 (OH), 1695 (CO), 1675 (CO) cm^{-1}; ms *m/z* : 324 (M^+).

6-(1', 2'-cis-2'-Carboxycyclohexane-1'-carbonyl)-2, 2-dimethyl-2-silatetralin (5f) : Compound (**4**) (212 mg, 1.2 mmol), $AlCl_3$ (320 mg, 2.4 mmol), cis-1,2-cyclohexanedicarboxylic anhydride (167 mg, 1.08 mmol), and CH_2Cl_2 (32 ml) were used. The residue (415 mg) was purified by column chromatography with hexane-AcOEt (5 : 1) to afford **5f** (247 mg, 69 %, mp 50-52.5 °C) as light yellow crystals, mp 115-118 °C (hexane). Anal. Calcd for $C_{19}H_{26}O_3Si$: C, 69.05; H, 7.93. Found : C, 69.29; H, 7.92. ^{1}H-Nmr δ : 0.06 (6H, s, $SiMe_2$), 0.75 (2H, t, *J* = 7.1 Hz, C_3-H), 1.15-2.35 (8H, br, 4xCH_2), 2.02 (2H, s, C_1-H), 2.65 (1H, dt, *J* = 4.3, 4.3 Hz, C*H*CO_2H), 2.76 (2H, t, *J* = 7.1 Hz, C_4-H), 3.89 (1H, dt, *J* = 4.3, 4.3 Hz, CHCO), 7.09 (1H, d, *J* = 8.6 Hz, C_8-H), 7.51-7.68 (2H, m, C_5-H, C_7-H). Ir (KBr) : 3650-2450 (OH), 1710 (CO), 1685 (CO) cm^{-1}; ms *m/z* : 330 (M^+).

6-[2'-(2''-Carboxyphenyl)benzoyl]-2, 2-dimethyl-2-silatetralin (5g) : Compound (**4**) (106 mg, 0.6 mmol), $AlCl_3$ (160 mg, 1.2 mmol), diphenic anhydride (121 mg, 0.54 mmol), and CH_2Cl_2 (16 ml) were used. The residue (237 mg) was purified two times by column chromatography [first, $CHCl_3$ and $CHCl_3$-MeOH (300 : 1 ~ 5 : 1), second, $CHCl_3$ and $CHCl_3$-MeOH (100 : 1)] to afford **5g** (91 mg, 42 %) as a light yellow amorphous solid. ^{1}H-Nmr δ : 0.05 (6H, s, $SiMe_2$), 0.73 (2H, t, *J* = 6.9 Hz, C_3-H), 2.04 (2H, s, C_1-H), 2.73 (2H, t, *J* = 6.9 Hz, C_4-H), 7.04-7.17 (2H, m, 2xAr-H), 7.27-7.66 (8H, m, 8xAr-H), 7.76-7.82 (1H, m, Ar-H). Ir : 3500-2500 (OH), 1740 (CO), 1705 (CO) cm^{-1}. HRms *m/z* calcd for $C_{25}H_{24}O_3Si$ (M^+) : 400.1495, found : 400.1490; ms *m/z* : 400 (M^+).

Baeyer-Villiger Reaction of 6-Acetyl-2, 2-dimethyl-2-silatetralin (5a). A mixture of **5a** (102 mg, 0.47 mmol) and 80 % *m*-CPBA (609 mg, 2.82 mmol) in CH_2Cl_2 (2.5 ml) was stirred at room temperature for 3.5 h. The reaction was quenched with saturated $Na_2S_2O_3$. The organic layer was separated and the aqueous layer was extracted with CH_2Cl_2. The combined organic layers were washed with saturated $NaHCO_3$ and brine, and dried ($MgSO_4$). Removal of the solvent *in vacuo* gave a residue (130 mg), which was purified by preparative tlc (five developments with hexane : AcOEt = 40 : 1) to give **7** (62 mg, 56 %) as a colorless oil, spectral data (^{1}H-nmr, Ir, and ms) of which were in agreement with those of 6-acetoxy-2-silatetralin (**7**) obtained from **6**.

6-Acetoxy-2, 2-dimethyl-2-silatetralin (7). A mixture of **6** (187 mg, 0.97 mmol), acetic anhydride (149 mg, 1.46 mmol), and pyridine (231 mg, 2.92 mmol) in CH_2Cl_2 (10 ml) was stirred at room temperature for 1 h. Usual work-up of the reaction mixture gave a residue, which was purified two times by preparative tlc (development with hexane : AcOEt = 3 : 1) to give **7** (143 mg, 63 %) as a colorless oil. ^{1}H-Nmr δ : 0.06 (6H, s, $SiMe_2$), 0.75 (2H, t, J = 7.1 Hz, C_3-H), 1.95 (2H, s, C_1-H), 2.29 (3H, s, MeCO), 2.72 (2H, t, J = 7.1 Hz, C_4-H), 6.68-6.88 (2H, m, C_5-H, C_7-H), 7.06 (1H, d, J = 8.6 Hz, C_8-H). Ir : 1760 (CO) cm^{-1}. HRms *m/z* calcd for $C_{13}H_{18}O_2Si$ (M^+) : 234.1074, found: 234.1072; ms *m/z* : 234 (M^+).

6-(3'-Methoxycarbonylpropanoyl)-2, 2-dimethyl-2-silatetralin (8). A solution of **5c** (387 mg, 1.40 mmol) in ether (14 ml) was treated with excess of diazomethane-ether under stirring in an ice bath. Removal of the solvent *in vacuo* gave a residue (408 mg), which was purified by column chromatography with $CHCl_3$-hexane (1 : 1) to give **8** (344 mg, 85 %) as a colorless oil. ^{1}H-Nmr δ : 0.06 (6H, s, $SiMe_2$), 0.75 (2H, t, J = 7.1 Hz, C_3-H), 2.04 (2H, s, C_1-H), 2.62-2.86 (4H, m, C_4-H, CH_2CO_2Me), 3.29 (2H, t, J = 7.1 Hz, CH_2CO), 3.69 (3H, s, OMe), 7.14 (1H, d, J = 8.6 Hz, C_8-H), 7.64-7.79 (2H, m, C_5-H, C_7-H). Ir : 1735 (COOMe), 1680 (CO) cm^{-1}. HRms *m/z* calcd for $C_{16}H_{22}O_3Si$ (M^+) : 290.1337, found : 290.1337; ms *m/z* : 290 (M^+).

6-(3'-Methoxycarbonylpropanoyloxy)-2, 2-dimethyl-2-silatetralin (9). A mixture of **8** (122 mg, 0.42 mmol) and 80 % *m*-CPBA (906 mg, 4.2 mmol) in CH_2Cl_2 (6 ml) was stirred at room temperature for 72 h. The reaction mixture was treated in a manner similar to that noted for **5b** gave light yellow crystals (144 mg), which were purified by preparative tlc (two

developments with $CHCl_3$) to give **9** (54 mg, 42 %) as a light yellow oil. ^{1}H-Nmr δ : 0.04 (6H, s, $SiMe_2$), 0.69-0.78 (2H, m, C_3-H), 1.93 (2H, s, C_1-H), 2.67-2.78 (4H, m, C_4-H, CH_2CO_2Me), 2.82-2.91 (2H, m, CH_2CO_2), 3.73 (3H, s, OMe), 6.79-6.86 (2H, m, C_5-H, C_7-H), 7.05 (1H, d, *J* = 8.6 Hz, C_8-H). Ir : 1750 (COOAr), 1740 (COOMe) cm^{-1}. HRms *m/z* calcd for $C_{16}H_{22}O_4Si$ (M^+) 306.1287, found : 306.1294; ms *m/z* : 306 (M^+).

6-Hydroxy-2, 2-dimethyl-2-silatetralin (6). A mixture of **9** (110 mg, 0.36 mmol) and $LiAlH_4$ (68 mg, 1.8 mmol) in THF (10 ml) was refluxed for 1 h under stirring. The reaction was quenched with water under ice-cooling. The reaction mixture was extracted with ether and organic layers were washed with brine, and dried ($MgSO_4$). Removal of the solvent *in vacuo* gave colorless crystals (64 mg), which were purified by preparative tlc (two developments with hexane : AcOEt = 10 : 1) to give **6** (57 mg, 83 %), mp 75.5-76 °C (petroleum ether) as colorless crystals, spectral data (^{1}H-nmr, ir, ms) of which were identical with those of authentic sample.[1]

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