

Volatile Constituents of *Semnostachya menglaensis* Tsui

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Semnostachya menglaensis Tsui (Acanthaceae) is a rare plant indigenous to Mengla in the tropical rainforest of the Xishuangbanna prefecture in the south of Yunnan province, People's Republic of China. When the leaves are crushed, a characteristic smell of basmati rice or pandan leaves develops. Their hexane extract, prepared from a specimen growing in a greenhouse of the botanical garden of the Kunming Institute of Botany, contains 1-(3,4,5,6-tetrahydro-2-pyridyl)-1-propanone (41.2%) and 1-(1,4,5,6-tetrahydro-2-pyridyl)-1-propanone (37.5%) which constitute the main part of the volatile compounds. Minor components are 1-(3,4,5,6-tetrahydro-2-pyridyl)-1-ethanone (4.9%), 1-(1,4,5,6-tetrahydro-2-pyridyl)-1-ethanone (4.8%), 1-(2-piperidyl)-1-propanone (5.2%), 1-octen-3-ol (3.2%), 1-octen-3-one (1.9%), and 3-octanol and 1-(2-pyridyl)-1-propanone in trace amounts.

KEYWORDS: *Semnostachya menglaensis*; Acanthaceae; tetrahydropyridines; synthesis

INTRODUCTION

Semnostachya menglaensis Tsui (Acanthaceae) is a rare plant indigenous to Mengla situated in the tropical rainforest of the Xishuangbanna prefecture in the south of Yunnan province, People's Republic of China. When the long, lanceolate leaves are crushed, a strong odor reminiscent of basmati rice or pandan leaves is liberated.

To the best of our knowledge, only nonvolatile phenolic glycosides have been previously identified from this plant (1). The characteristic odor principle has not yet been investigated.

EXPERIMENTAL PROCEDURES

Preparation of the Natural Extract. Crushed leaves (10 g), picked from a specimen of *Semnostachya menglaensis* grown in a greenhouse of the botanical garden of the Kunming Institute of Botany were immersed in hexane (100 mL). The plant material was then filtered off, and the extract was concentrated at atmospheric pressure using a Vigreux column (yield 20 mg).

GC/MS Analysis. The concentrated extract was analyzed by GC/MS on a GC 6890 coupled to an MSD 5973 inert (Agilent, Palo Alto, CA) equipped with an apolar column (SPB-1, 30 m × 0.25 mm fused silica capillary column, film thickness 1 μm). After 5 min at 60 °C, the oven temperature was raised by 5°/min to 250 °C, at an ion source temperature of 156 °C and a helium flow of 1 mL/min. The mass spectra in the electron impact mode (EI) were measured at 70 eV in a scan range from 35 to 300.

NMR Analysis. NMR spectra were measured in CDCl₃ with a Bruker DPX 400 instrument with tetramethylsilane as the internal standard, δ = 0.00 ppm.

Model Reaction (2). L-Proline (10 mmol, 1.15 g) and glucose (10 mmol, 1.80 g) were added to a phosphate buffer 0.1 M, pH 7.00 (200 mL, 2.4 g of NaHPO₄ in 200 mL of H₂O) in a Likens–Nickerson apparatus and heated for 6 h, the volatiles formed being simultaneously extracted with pentane (150 mL). The solvent was dried over MgSO₄ and evaporated using a Vigreux column.

Syntheses. Preparation of 1-(3,4,5,6-Tetrahydro-2-pyridyl)-1-propanone (3) and 1-(1,4,5,6-Tetrahydro-2-pyridyl)-1-propanone (4) (3). 1-(2-Pyridyl)-1-propanone (6, 8.4 g, 62.2 mmol, MP Biomedical cat. no. 220569) in ethanol (75 mL) was hydrogenated at room temperature using rhodium on alumina (5%, 1.5 g) as catalyst. An amount of 1.2 L of hydrogen was consumed after 6 h and 5.6 L after 2 days. The crude mixture was filtered on Celite, concentrated, and distilled using a Vigreux column. Bp (0.11 mbar): 53 °C. The solid was recrystallized from hexane to give 5.27 g of pure 1-(2-piperidyl)-1-propanol (7), mp = 89–90 °C, yield 60%.

1-(2-Piperidyl)-1-propanol (7, 5 g, 35.2 mmol) in benzene (250 mL) in the presence of silver carbonate on Celite (57 g) (4) was heated under reflux for 11 h. The mixture was filtered, concentrated, and bulb-to-bulb distilled under 1 mbar at 100–120 °C to give 2.1 g of a yellow oil which was purified by flash-chromatography on SiO₂ (30 g, pentane/Et₂O 3:2) and again bulb-to-bulb distilled to remove traces of solvent. Compounds 3 (56% GC) and 4 (40% GC) were obtained (1.23 g, yield 25%).

Preparation of 1-(2-Piperidyl)-1-propanone (5). 1-(2-Pyridyl)-1-propanone (6, 6 g, 44.4 mmol, MP Biomedical cat. no. 220569) in toluene (60 mL), ethylene glycol (5.5 g, 88.7 mmol), and *p*-toluenesulfonic acid (9.3 g, 48.8 mmol) were heated at reflux under N₂. The water was removed by using a Dean Stark apparatus during 2 h. The crude mixture was cooled, water was added (50 mL), and then Na₂CO₃ was added portionwise (pH 12). The organic phase was separated, and the water phase was extracted twice with Et₂O. The organic phase was dried over MgSO₄ and concentrated in vacuo to give crude 2-ethyl-2-(2-pyridyl)-1,3-dioxolane (8, 7.75 g, yield 97%). MS: 179 (M⁺, 0), 150 (73), 136 (8), 134 (8), 106 (25), 101 (100), 78 (53), 57 (27). ¹H

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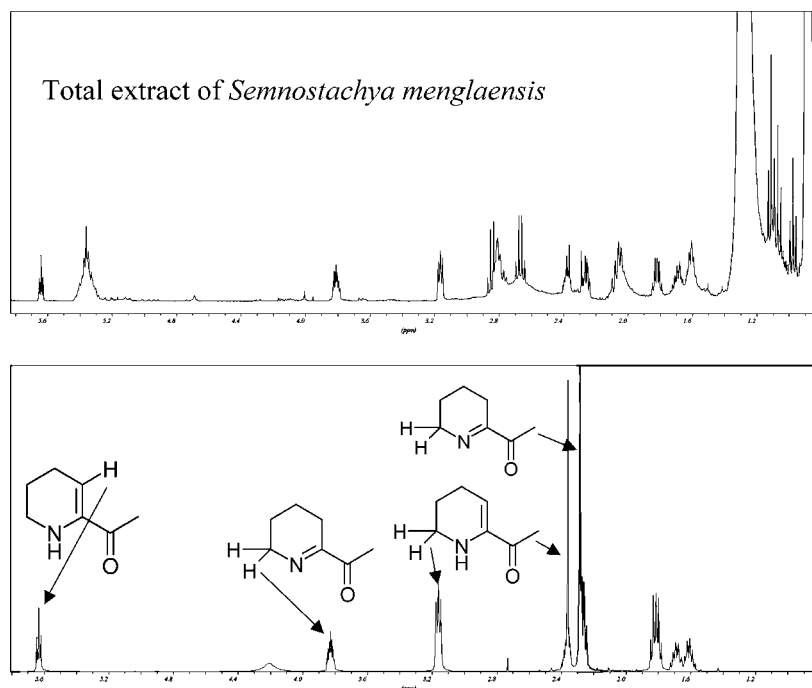
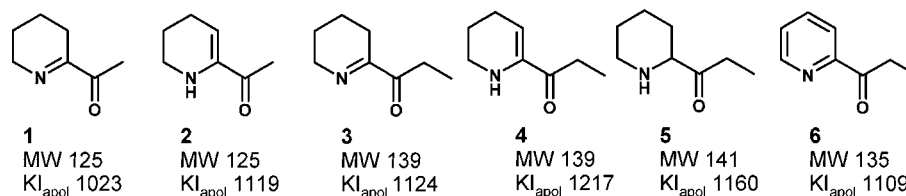


Figure 1. ^1H NMR spectra of the total extract of *Semnostachya menglaensis* and of a reference sample of a mixture of compounds **1** and **2**.

Scheme 1. Compounds Identified in *Semnostachya menglaensis*



NMR: 0.88 (t, 3H), 2.07 (q, 2H), 3.83–3.87 (m, 2H), 4.07–4.01 (m, 2H), 7.18–7.23 (m, 1H), 7.52 (d, 1H), 7.67–7.80 (m, 1H), 8.63–8.66 (m, 1H). ^{13}C NMR: 160.6 (s), 149.6 (d), 136.2 (d), 122.7 (d), 120.2 (d), 110.5 (s), 65.1 (2t), 31.5 (t), 7.7 (q).

2-Ethyl-2-(2-pyridyl)-1,3-dioxolane (**8**, 7.75 g, 43 mmol) in ethanol (70 mL) was hydrogenated at room temperature using rhodium on alumina (5%, 1.6 g) as catalyst. Hydrogen (2.7 L) was consumed after 90 h. The organic phase was dried over MgSO_4 and concentrated to give 2-ethyl-2-(2-piperidyl)-1,3-dioxolane (**9**, 7.8 g, yield 98%). MS: 185 (M^+ , 2), 156 (5), 110 (5), 101 (30), 84 (100), 57 (10), 56 (10). ^1H NMR: 0.89 (t, 3H), 1.19–1.47 (m, 3H), 1.52–1.59 (m, 1H), 1.62–1.87 (m, 5H), 2.55–2.62 (m, 2H), 3.08–3.14 (m, 1H), 3.95–4.03 (m, 4H). ^{13}C NMR: 112.4 (s), 65.8 (t), 65.5 (t), 61.9 (d), 47.4 (t), 27.0 (t), 26.5 (t), 26.4 (t), 24.9 (t), 7.4 (q).

2-Ethyl-2-(2-piperidyl)-1,3-dioxolane (**9**, 4.4 g, 23.8 mmol) was heated at 70 °C during 15 h in HCl 10% (50 mL) and acetone (15 mL). The reaction mixture was cooled, and NaOH 15% and NaCl were added. The crude product was extracted with EtOAc and bulb-to-bulb distilled (0.9 mbar, 90 °C) to give 1-(2-piperidyl)-1-propanone (**5**, 3.2 g, yield 95%). MS: 141 (M^+ , 1), 84 (100), 56 (20), 55 (8), in agreement with the data published by Tressl et al. (5). ^1H NMR: 1.07 (t, 3H), 1.22–1.62 (m, 5H), 1.59 (m, 1H), 1.83–1.91 (m, 1H), 1.92–2.00 (m, 1H), 2.43–2.52 (m, 2H), 2.59–2.65 (m, 1H), 3.08–3.12 (m, 1H), 3.30–3.32 (m, 1H). ^{13}C NMR: 211.6 (s), 65.3 (d); 45.8 (t), 32.20 (t), 29.6 (t), 26.2 (t), 24.8 (t), 7.7 (q).

RESULTS AND DISCUSSION

The extract of this rare plant with its extraordinary smell of basmati rice, bread, and popcorn was preferentially analyzed by injection onto an apolar column (SPB-1), where perfect separation was observed, the polar phase (Supelcowax) producing broad and badly resolved peaks. The characteristic odor was

not caused, as first supposed, by 2-acetyl-1-pyrroline, the odor principle of cooked rice (6) and of pandan leaves (7). In fact, this compound could not be identified in the extract.

The mass spectra (MS) of the two main peaks were very similar to the fragmentation patterns of 1-(3,4,5,6-tetrahydro-2-pyridyl)-1-ethanone (**1**) and 1-(1,4,5,6-tetrahydro-2-pyridyl)-1-ethanone (**2**) (3, 8), with a molecular weight (MW) of 139 instead of 125 (see **Scheme 1**).

The NMR-spectrum (see **Figure 1**) of the total extract of the leaves showed an ethyl group for each isomer (2.6, 2.8 ppm for $-\text{CH}_2-$ and 1.1 ppm for $-\text{CH}_3$) replacing the methyl groups (2.29 and 2.36 ppm) of **1** and **2**, but the signals at 3.17, 3.82, and 5.65 ppm, respectively, were identical with the signals for the imine **1** and the enamine **2**.

These spectral data were in agreement with the data published for 1-(3,4,5,6-tetrahydro-2-pyridyl)-1-propanone (**3**) and 1-(1,4,5,6-tetrahydro-2-pyridyl)-1-propanone (**4**) by De Kimpe and Kepens, who synthesized and fully characterized the compounds (9) and by Hofmann and Schieberle who prepared them in Maillard-type model reactions and established the organoleptic descriptors (roasted, popcorn-like) and their thresholds (0.2 ng/L in air) (2) by AEDA analysis of a mixture. It is worth mentioning that the first to identify these types of compounds in model reactions involving proline and sugars was Tressl et al. in 1981 (10).

Compounds **3** (41.2%) and **4** (37.5%) constitute the main part of the volatile compounds; minor components are **1** (4.9%), **2** (4.8%), 1-(2-piperidyl)-1-propanone (**5**, 5.2%, MS (see ref 5)), 1-octen-3-ol (3.2%), 1-octen-3-one (1.9%), and 3-octanol and 1-(2-pyridyl)-1-propanone (**6**) in trace amounts (see **Figure 2**).

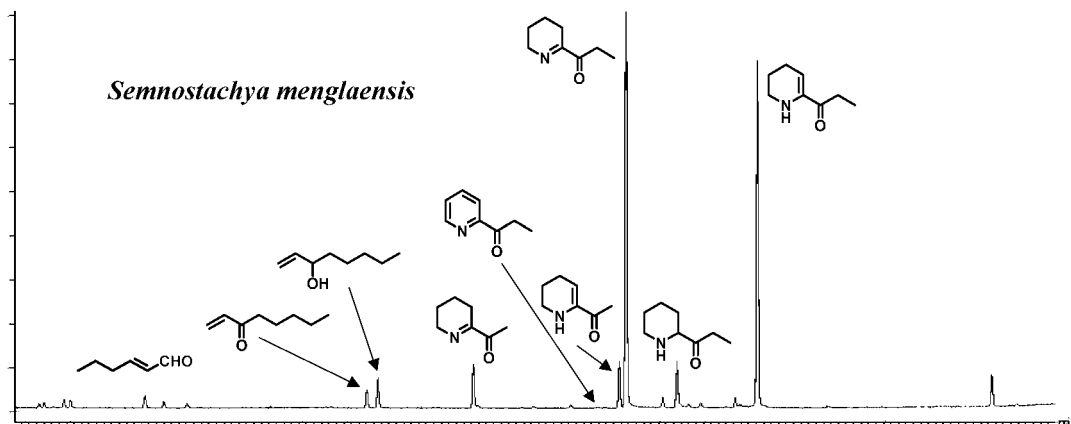
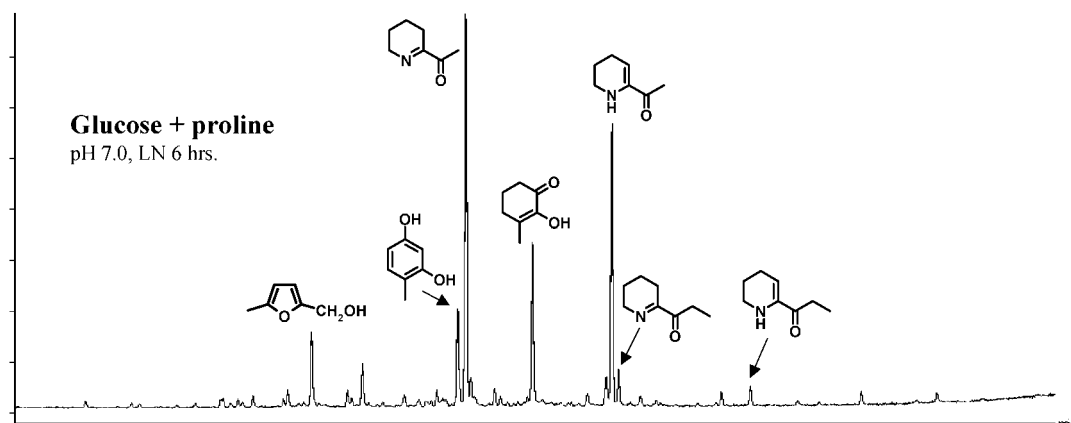
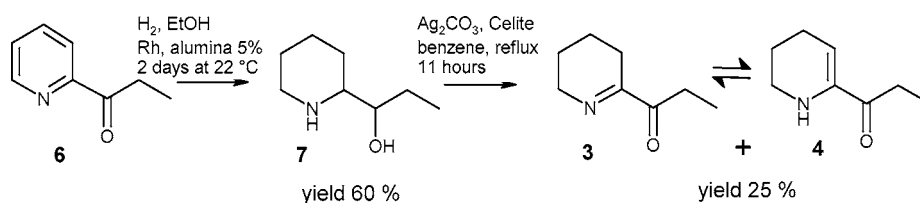
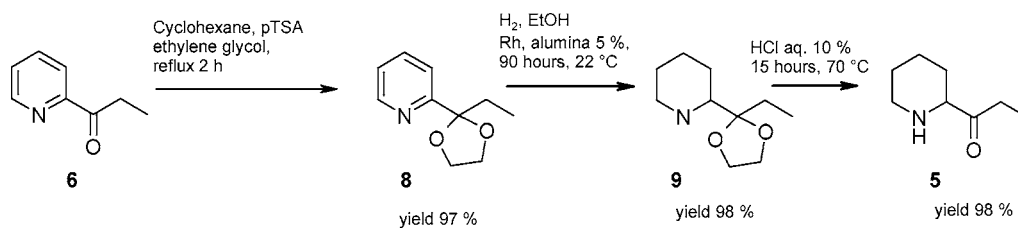
Figure 2. GC/MS profile of *Semnostachya menglaensis*.

Figure 3. GC/MS profile of a model reaction (glucose + proline).

Scheme 2 Synthesis of Compounds 3 and 4



Scheme 3. Synthesis of Compound 5



1-(2-Piperidyl)-1-propanone (**5**), known as conhydrinone, was described first as a hemlock alkaloid (*11*) and later on in model reactions of proline with sugars by Tressl et al. (*5*). It exhibits a strong odor reminiscent of rice, cereals, and Chinese noodles.

We identified compounds **3** and **4** as minor constituents in a Maillard-type model reaction of proline with glucose (following ref 2, slightly modified), where the acetyl-derivatives **1** and **2** were the main compounds, to check the MS and retention times (see **Figure 3**).

Compounds **1** and **2** as well as **3** and **4** are tautomeric pairs, the ratios of the imino forms **1** and **3** to the enamino forms **2** and **4** approaching 1:1 in the natural extract.

The compounds were specifically synthesized starting from the commercial 1-(2-pyridyl)-1-propanone (**6**), as outlined in **Scheme 2** following the method of Büchi and Wüest (*3*). The overall yield for **3** and **4** (3:2 ratio) was 15% for a purity of 96%. The intermediate 1-(2-piperidyl)-1-propanol (**7**, β -conhydrine) was first isolated from the flowers of hemlock (*Conium maculatum*) in 1856 (*12*, *13*) and is widely documented.

Compound **5** was prepared by conversion of ketone **6** to the dioxolane **8** followed by reduction of the aromatic ring to compound **9** and deprotection (**Scheme 3**). This compound decomposed within 3 days when stocked as a pure compound at 4 °C.

All the major pyridine derivatives have a skeleton of eight carbons. Interestingly, the two most important compounds containing no nitrogen are unsaturated C8-compounds: 1-octen-3-ol and 1-octen-3-one. It is most likely that these structures are related.

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Received for review July 8, 2005. Revised manuscript received September 5, 2005. Accepted September 10, 2005.

JF051632D