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Furoquinoline alkaloids from *Teclea nobilis*

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Abstract

Five new furoquinoline alkaloids, namely tecleabine (**1**), tecleoxine (**2**), isotecleoxine (**3**), methylnkolbisine (**4**) and chlorodesnkolbisine (**5**) were isolated from the aerial parts of *Teclea nobilis*, together with seven known furoquinoline derivatives; one acridone alkaloid, and one known flavanone. The structures of the alkaloids **1**–**5** were established by 1D and 2D NMR spectral data, including COSY, HMQC and HMBC experiments, as well as HRMS.

Keywords: *Teclea nobilis*; Rutaceae; Alkaloids; Furoquinoline; Tecleabine; Tecleoxine; Isotecleoxine; Methylnkolbisine; Chlorodesnkolbisine

1. Introduction

In a previous communication (Al-Rehaily et al., 2002), we described the structures of two new isomeric axane and oppositane sesquiterpene derivatives, namely teclenone A and teclenone B. They were isolated from the aerial parts of *Teclea nobilis* Delile (Rutaceae), locally known as Al-dhureim, which is used in African traditional medicine to treat gonorrhea and also as an analgesic and antipyretic (Watt and Breyer-Brandwijk, 1962). Earlier pharmacological and phytochemical studies on this plant reported the analgesic and antipyretic activities of the ethanol extract (Mascolo et al., 1988). In addition, *T. nobilis* was reported to possess a number of quinoline and furoquinoline alkaloids (Yenesew and Dagne, 1988; Dagne and Yenesew, 1987). In continuation of our earlier investigation, we now report on the isolation and structure elucidation of five new furoquinoline alkaloids, namely tecleabine (**1**), tecleoxine (**2**), isotecleoxine (**3**), methylnkolbisine (**4**) and chlorodesnkolbisine (**5**) from the aerial parts of *T. nobilis*. In addition, this material also yielded seven known furoquinolines, pteleine (**6**) (Pusset et al., 1991), isohaplopine-3,3′-dimethylallylether (**7**) (Wondimu et al., 1988; Grina et al., 1982), nobiline (**8**) (Yenesew and Dagne, 1988), haplopine-3, 3′-dimethylallylether (**9**) (Bessonova et al., 1974), anhydroevoxine (**10**) (Bessonova et al., 1982), kokusaginine (**11**) (Pusset et al., 1991), 8-methoxyflindersine (**12**) (Campbell et al., 1990), and the known acridone alkaloid arborinine (**13**) (Bergenthal et al., 1979), as well as the known flavanone 4′,5-dihydroxy-7-prenyloxyflavanone (**14**) (Bohlmann and Ates, 1984).

2. Results and discussion

Repeated CC and centrifugal preparative thin-layer chromatography of the MeCN fraction of the hexane extract of *T. nobilis* yielded 12 furoquinoline alkaloids (**1**–**12**), and one acridone alkaloid (**13**), together with the flavanone **14**. The structures of the known compounds **6**–**14** were determined by comparison of their physical and spectral data with those reported in the literature.

Compound **1** was obtained as colorless needles and its molecular formula $C_{18}H_{19}NO_4$ was determined by ESIHRMS. The UV spectrum exhibited absorption bands at λ_{max} 248, 295,307, 339 and 353 nm, characteristic of a furoquinoline alkaloid (Sangster and Stuart,

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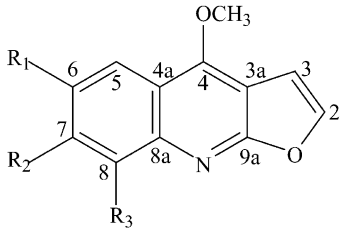
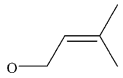
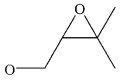
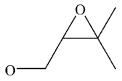
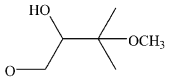
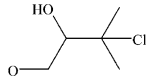
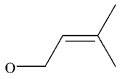
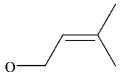
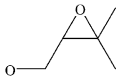
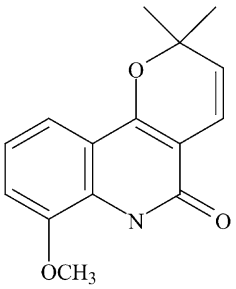


Compound #	R_1	R_2	R_3
1	OMe	H	
2		OMe	H
3	OMe		H
4		OMe	H
5		OMe	H
6	OMe	H	H
7	H	OMe	
8	OMe		H
9	H		OMe
10	H		OMe
11	OMe	OMe	H

1965). The ^{1}H and ^{13}C NMR spectra of **1** (Tables 1 and 2) suggested a furoquinoline base skeleton (Ayafor and Okogun, 1982) and its ^{13}C NMR spectrum (Table 2) showed 18 signals, resolved by DEPT, as four methyls, one methylene, five methines, and eight quaternary carbons. The ^{1}H NMR spectrum displayed two vinylic methyl groups at δ 1.78 and 1.79 (each 3H, *s*), an olefinic proton at δ 5.65 (*t*, 1H, $J=6.4$ Hz, H-2′) and two oxymethylene protons at δ 4.79 (*d*, 2H, $J=6.4$ Hz, H-1′), assigned to a prenyloxy side chain. The ^{1}H NMR spectrum also showed signals at δ 4.43 and δ 3.92, the former is characteristic of a C-4 methoxy group of 4-methoxyfuroquinoline alkaloids (Ayafor and Okogun, 1982), while the latter was assigned to a C-6-OMe group. A pair of AB doublets at δ 7.61 and 7.03 (each 1H, *d*, $J=2.8$ Hz; H-2 and H-3, respectively) corresponded to two furan protons, while the other two *meta*-coupled aromatic protons at δ 7.08 and 6.74 (each 1H, d, $J=2.8$ Hz) were assigned to H-5 and H-7, respectively, which was confirmed by HMBC experiments (vide infra). The positions of the prenyloxy substituent at C-8 and the methoxy groups at C-4 and C-6 were established by 2D NMR ^{1}H–^{13}C HMBC experiments. The HMBC spectrum showed ^3J correlations between δ 7.08 (H-5), $\delta_{C\text{-}4}$ 155.6, $\delta_{C\text{-}8a}$ 134.1 and $\delta_{C\text{-}7}$ 102.6, and between δ 4.43 (4-OMe) and $\delta_{C\text{-}4}$ 155.6, confirming the placement of the OMe group at C-4. The HMBC spectrum also showed ^3J correlations between δ 4.79 (H-1′), $\delta_{C\text{-}8}$ 154.6 and $\delta_{C\text{-}3}$ 137.1, as well as ^2J correlations between H-1′ and $\delta_{C\text{-}2'}$ 120.0, H-7 (δ 6.74) and C-8, H-5 and $\delta_{C\text{-}6}$ 156.0, and $\delta_{6\text{-}OMe}$ 3.92 and C-6, confirming the placement of the dimethylallyloxy group at position C-8 and the second methoxy group at C-6. These findings unambiguously established the structure of tecleabine (**1**) as 4,6-dimethoxy-8-prenyloxyfuroquinoline.



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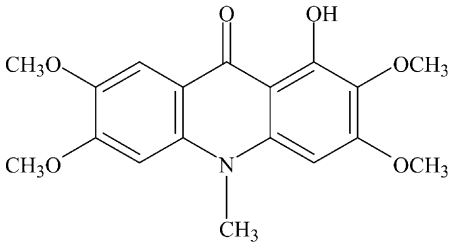

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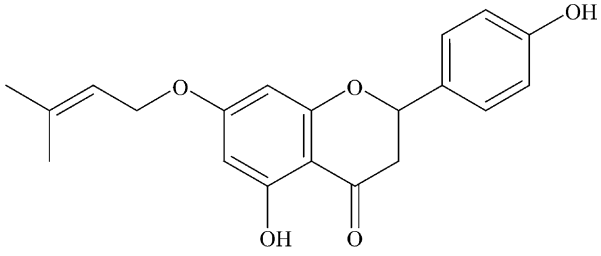

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Table 1
^{1}H NMR spectral data and coupling constants (in parentheses, in Hz) for compounds **1**–**5**[a]

Proton	**1**	**2**	**3**	**4**	**5**
2	7.61 *d* (2.8)	7.45 *d* (2.7)	7.51 *d* (2.7)	7.49 *d* (2.7)	7.93 *d* (2.7)
3	7.03 *d* (2.8)	6.89 *d* (2.7)	6.97 *d* (2.7)	6.97 *d* (2.7)	6.38 *d* (2.7)
5	7.08 *d* (2.8)	7.39 *s*	7.41 *s*	7.46 *s*	7.45 *s*
7	6.74 *d* (2.8)	–	–	–	–
8	–	7.23 *s*	7.32 *s*	7.25 *s*	7.27 *s*
1′	4.79 *d* (6.4)	4.23 *m*	4.36 *m*	4.26 *dd* (3.1, 9.5)	4.33 *dd* (1.6, 9.8)
		4.17 *dd* (4.7, 11.1)	4.21 *dd* (5.9, 11.1)	4.05 *t* (9.5)	3.96 *m*
2′	5.65 *t* (6.4)	3.21 *dd* (4.7, 7.5)	3.28 *dd* (4.5, 5.9)	3.99 *dd* (2.8, 8.9)	3.67 *dd* (1.6, 7.7)
4′	1.79 *s*	1.35 *s*	1.38 *s*	1.22[b] *s*	1.15[b] *s*
5′	1.78 *s*	1.35 *s*	1.38 *s*	1.24[b] *s*	1.20[b] *s*
3′-OMe	–	–	–	3.23 *s*	–
4-OMe	4.43 *s*	4.28 *s*	4.36 *s*	4.36 *s*	4.41 *s*
6-OMe	3.92 *s*	–	3.97 *s*	–	–
7-OMe	–	3.94 *s*	–	3.92 *s*	3.93 *s*

[a] Spectra for **1**–**5** were recorded at 500 MHz in $CDCl_3$.
[b] Interchangeable protons in the same column.

Table 2
^{13}C NMR spectral data for compounds **1**–**5**

Carbon	1	2	3	4	5
2	143.8	142.7	142.8	142.2	143.4
3	104.2	104.9	105.0	104.3	105.6
3_a	104.1	102.2	102.7	101.9	102.3
4	155.6	155.9	155.9	155.4	155.5
4_a	119.7	113.1	113.6	112.7	112.6
5	91.4	102.7	101.1	102.3	101.3
6	156.0	147.0	148.3	146.8	147.5
7	102.6	153.1	152.0	152.7	153.0
8	154.6	107.2	108.3	106.2	106.8
8[a]	134.1	143.1	142.6	142.6	142.0
9[a]	161.9	163.5	163.3	163.0	162.8
1′	66.0	68.1	68.3	70.1	71.4
2′	120.0	61.6	61.1	74.6	76.1
3′	137.1	58.8	58.6	75.9	70.9
4′	25.8	24.9	25.0	21.1[a]	25.3[a]
5′	18.3	19.4	19.4	20.4[a]	28.3[a]
3′-OMe	–	–	–	49.2	–
4-OMe	58.9	59.2	59.2	58.6	60.1
6-OMe	55.4	–	56.4	–	–
7-OMe	–	56.3	–	55.7	56.5

[a] Interchangeable carbons in the same column.

Compound **2**, analyzed for $C_{18}H_{19}NO_5$ by ESIHRMS, was isolated as needles and its UV spectrum exhibited absorption bands at λ_{max} 244, 251, 309, 320 and 333 nm, typical for a furoquinoline alkaloid. The ^{1}H and ^{13}C NMR spectra of **2** (Tables 1 and 2) were found to be similar to those of **1**, except for the presence of the 2′,3′-epoxyprenyl and methoxy groups at C-6 and C-7 positions, respectively, instead of the methoxy and prenyloxy groups at C-6 and C-8 positions in **1**. The NMR spectrum of **2** showed the presence of two aromatic singlets at δ 7.39 (δ_C 102.7) and 7.23 (δ_C 107.2), assigned to H-5 and H-8, respectively, while the ^{13}C NMR spectrum showed signals at $\delta_{C\text{-}1'}$ 68.1, $\delta_{C\text{-}2'}$ 61.6, $\delta_{C\text{-}3'}$ 58.8, $\delta_{C\text{-}4'}$ 24.9 and $\delta_{C\text{-}5'}$ 19.4, attributed to the 2′,3′-epoxyprenyl group. The ^{1}H NMR spectrum exhibited an epoxymethine proton at δ 3.21 (*dd*, J=4.7, 7.5 Hz) and two oxymethylene protons at δ 4.23 and 4.17, assigned to H-2′ and H-1′, respectively. The positions of the two methoxy substituents at C-4 and C-7 were confirmed by HMBC experiments, which showed ^3J correlations between δ 7.39 (H-5), $\delta_{C\text{-}4}$ 155.9, $\delta_{C\text{-}8a}$ 143.1 and $\delta_{C\text{-}7}$ 153.1, and δ 3.94 (7-OMe) and C-7. The HMBC also showed correlations between δ 7.23 (H-8), $\delta_{C\text{-}4a}$ 113.1 and $\delta_{C\text{-}6}$ 147.0, and C-6 and δ 4.23, 4.17 (H_2-1′), confirming the position of the epoxyprenyl group at C-6. Based on the foregoing data, the structure of tecleoxine (**2**) was established as shown.

The molecular formula $C_{18}H_{19}NO_5$, and ^{1}H and ^{13}C NMR data of compound **3** (Tables 1 and 2) were very similar to those of **2**, suggesting that they are indeed positional isomers. Analysis of the HMBC spectrum of **3** confirmed the placement of the epoxyprenyl group at C-7, by showing ^3J HMBC correlations between δ 7.41 (H-5), $\delta_{C\text{-}4}$ 155.9, $\delta_{C\text{-}8a}$ 142.6 and $\delta_{C\text{-}7}$ 152.0, the latter showed correlations with both the oxymethylene protons at δ 4.36 and 4.21 (H_2-1′). The HMBC spectrum also exhibited correlations between δ 7.32 (H-8), $\delta_{C\text{-}4a}$ 113.6 and $\delta_{C\text{-}6}$ 148.3, and between C-6 and δ 3.97 (6-OMe), confirming the position of the methoxy group at C-6. These findings collectively established the structure of isotecleoxine (**3**).

The ^{1}H and ^{13}C NMR spectra (Tables 1 and 2) of **4** ($C_{19}H_{23}NO_6$) were in close agreement with those of nkolbisine (Sener et al., 1990; Ayafor et al., 1982), except for the presence of a methoxy group at C-3′, instead of a hydroxyl group. The NMR spectrum revealed the presence of an additional methoxy group at δ 3.23 (3H, *s*; $\delta_{C\text{-}3'\text{-}OMe}$ 49.2), and its location was established by HMBC experiments which showed correlations between δ 3.23 (3′-OMe) and δ_C 75.9 (C-3′), and δ 3.99 (H-2′), $\delta_{C\text{-}4'}$ 21.1 and $\delta_{C\text{-}5'}$ 20.4. The position of the 2′-hydroxy-3′-methoxyisoprenyl side chain at C-6 was also confirmed by the HMBC cross peaks between $\delta_{C\text{-}6}$ 146.8 and H_2-1′ (δ 4.05, 4.26). These data established the structure of **4** as the *O*-methyl derivative of nkolbisine.

The last compound (**5**), obtained as needles, gave a positive Beilstein reaction, indicative for the presence of halogen (Mann and Saunders, 1974). The ^{1}H and ^{13}C NMR spectral data of **5** (Tables 1 and 2) were in close agreement with those of **4**, except for the presence of a chlorine atom at C-3′ ($\delta_{C\text{-}3'}$ 70.9) instead of a methoxy group ($\delta_{C\text{-}3'}$ 75.9 for **4**). The ESIHRMS showed the molecular ion at m/z 366 ($[M+H]^+$; $C_{18}H_{20}NClO_5+H$; 100%), together with a prominent peak at m/z 368 (36.6%) due to ^{37}Cl isotope, confirming the presence of a chlorine atom (Silverstein and Webster, 1998). In addition, the ^{13}C NMR spectrum (Table 2) showed shielding of the quaternary carbon at C-3′ (δ 70.9 vs. 75.9 for **4**), due to the electronegative chlorine atom. The location of the C-3′ chlorine substituent was further supported by HMBC experiments, which showed ^2J correlations between $\delta_{C\text{-}3'}$ 70.9, $\delta_{H\text{-}2}$ 3.67, δ 1.15 and 1.20 (H-4′ and 5′). The chlorinated prenyl substituent of **5**, to our knowledge, is unique in quinoline class of alkaloid. The cyclized version of it have been reported in some acridone class of alkaloid, e.g. gravacridonechlorine isolated from callus cultures of various *Ruta* species (Baumert et al., 1992).

The possibility of an artifact for compound **5**, derived from compound **2**, can be ruled out since it has been consistently detected by TLC in the crude hexane extract. Furthermore, compound **5** was isolated from MeCN fraction, obtained after partitioning between hexane/MeCN. In addition, furoquinoline alkaloids with epoxide moiety in their side chain similar to compound **2** and **3** have been reported in the literatures (Manske, 1960; Manske and Rodrigo, 1979), which generally converted to diol, ketone or/and alkene derivatives upon treatment with acid, and no chlorinated derivatives have been reported from these compounds.

During the course of isolation of the above compounds, *T. nobilis* yielded seven known furoquinolines (**6**–**12**), one acridone alkaloid (**13**) and one flavanone (**14**). These compounds were identified by comparison of their physical and spectroscopic data with those reported in the literatures. Furthermore, the ^{13}C NMR data for compounds **9** (Yenesew and Dagne, 1988), **10** (Bessonova et al., 1974), **11** (Bessonova et al., 1982) and **14** (Bohlmann et al., 1984) have not been reported previously and are reported herein for the first time (see Section 3). Upon subjecting compounds **1**–**14** to antimicrobial activity tests against *Staphylococcus aureus*, methicillin-resistant *S. aureus*, *Candida albicans* and *Cryptococcus neoformans* (ATCC 29213, 43300, 90028 and 90113, respectively), none of them demonstrated any activity at a concentration of 100 μg/ml. In addition, antimalarial activity evaluations of these compounds revealed no activity against the chloroquine sensitive D6 and the chloroquine resistant W2 clones at a concentration of 47.6 μg/ml of the test compound. This is the first report of the furoquinolines **1**–**5** from a natural source, as well as the first report of compounds **6**, **10**, **11**, **13** and **14** from the genus *Teclea* and **7**, **8** and **12** from the species *T. nobilis*.

3. Experimental

3.1. General

Mp uncorr.; UV spectra were recorded on a Hewlett-Packard HP-845 UV–Vis spectrophotometer; FTIR spectra were obtained on a Nicolet Impact 410 spectrophotometer; Specific rotation measurements were recorded on a Perkin-Elmer 242 MC polarimeter; NMR spectra were acquired in $CDCl_3$ on a Brüker Avance DRX-500 instrument at 500 (^1H) and 125 (^{13}C) MHz using the residual solvent signal as int. standard; Standard Brüker pulse programs were used for APT. DEPT, 2D NMR COSY, HMBC and HMQC spectra; HRMS were obtained on a Bruker Bioapex-FTMS with electro spray ionization; EIMS were measured using an E.I. Finnigan model 4600 quadrupole system or a Shimadzu QP500 GC/mass spectrometer; TLC: silica gel 60 F254 (Merck) plate; solvent: EtOAc–hexane (1:1); CC: silica gel 60/230–400 mesh (EM Science); Centrifugal preparative TLC (CPTLC; using Chromatotron®, Harrison Research Inc. model 7924): 1 or 4 mm silica gel P_{254} disc. The isolated compounds were visualized under short- and long-wave UV light, followed by spraying with Dragendorff's reagent.

3.2. Plant material

Teclea nobilis Delile was collected in March, 1999 from Al-Namas, Saudi Arabia and identified by Dr. Sultanul Abidin, College of Pharmacy, King Saud University, Riyadh, Saudi Arabia. A voucher specimen (# 14050) was deposited at the herbarium of the College of Pharmacy, KSU.

3.3. Extraction and isolation

The air-dried aerial parts (1.15 kg) of *T. nobilis* were successively extracted with hexane, followed by EtOH, in a Soxhlet for 72 h (yields 46 and 85 g, respectively). The gummy residue of the hexane extract, obtained after evaporation in vacuo, was partitioned between hexane (300 ml) and MeCN (4×100 ml) presaturated with each other, which afforded 21 and 22 g, respectively. The MeCN fraction (22 g) was subjected to flash chromatography on silica gel (450 g) using hexane and then increasing concentrations of EtOAc (10–45%) in hexane to give 25 fractions; fr. 10 (1.27 g), fr. 11–15 (5.36 g), fr. 16 (1 g), fr. 17 (0.54 g), fr. 18–20 (3.9 g), fr. 21 (1.75 g), fr. 22 and fr. 23–25 (0.50 and 1 g, respectively). Fraction 10 was separated by CPTLC (4 mm silica gel disc) using $CHCl_3$ as a solvent to afford sub-fractions A–C. Sub-fraction A (780 mg) was subjected to repeated CC over silica gel using $CHCl_3$ as solvent to give **6** as long threads (33.2 mg, mp 136–137 °C, lit. Pusset et al., 1991, 136–138 °C), followed by **14** as fine needles (34 mg, mp 69–70 °C, lit. Bohlmann and Ates, 1984, 69 °C). Fraction 11–15 was crystallized from acetone to afford **7** as plates (3.45 g, mp 118–119 °C, lit. Wondimu et al., 1988, 118–119 °C), and the mother liquor was subjected to repeated CC over silica gel using $CHCl_3$ as solvent to give **8** (5.5 mg), followed by **9** (91 mg). Fraction 16 was separated by silica gel CC, using 3% MeCN–CH_2Cl_2 to afford sub-fractions A–C. Sub-fraction A was subjected to CPTLC, using 1 mm silica gel disc and 0.5% MeCN–CH_2Cl_2 as eluent to give **1** (32 mg), while sub-fraction C yielded **10** (20 mg) upon CPTLC (1 mm silica gel disc, solvent 1% MeCN–CH_2Cl_2). Fraction 17 was purified by silica gel CC using 3% MeCN–CH_2Cl_2 as solvent to yield **11** as plates (665 mg, mp 164–165 °C, lit. Pusset et al., 1991, 168–169 °C). Fraction 18–20 was crystallized from ether to give **2** as needles (1.385 g) and its mother liquor was separated by CC over silica gel, using acetone–toluene (5–95%) as solvent to afford three sub-fractions A–C. The sub-fraction B was re-chromatographed on silica gel, using 2% acetone: toluene to give **3** (20 mg), followed by **12** as white needles (10.2 mg, mp 156–157 °C, lit. Campbell et al., 1990, 136–138 °C), while sub-fraction C was purified by CPTLC (1 mm silica gel disc, solvent: 1% MeCN–$CHCl_3$) to give **4** (16.2 mg). Finally, fraction 21 was subjected to silica gel CC, using MeOH–$CHCl_3$ (0.5–99.5) as solvent, to give 14 fractions. Fraction 1 and 13 afforded **13** (7.3 mg) and **5** (110 mg), respectively, upon repeated re-crystallization from ether.

3.4. Tecleabine (1)

Needles, mp 107–108 °C; UV λ_{max} (MeOH) nm (log ϵ): 248 (3.22), 295 (4.16), 307 (4.18), 339 (4.29), 353 (4.31); IR (MeOH) ν_{max} cm^{-1}: 3100, 2910, 2850, 1620, 1510, 1350, 1310, 1290, 1150, 1070 and 960; ^1H and ^{13}C NMR: see Tables 1 and 2, respectively; EIMS *m/z* (rel. int.%) 313 $[M]^+$ (3), 245 (39.3), 230 (14.7), 85 (66), 83 (99.5), 48 (15.5), 47 (36.7), 44 (100) and 41 (23.3); ESIHRMS: 314.1379 ($[M+H]^+$); (calc. for $[C_{18}H_{19}NO_4+H]$ 314.1387).

3.5. Tecleoxine (2)

Needles, mp 120–121 °C; $[\alpha]_D$ +10° (*c*; 0.05 in MeOH); UV λ_{max} (MeOH) nm (log ϵ): 244 (3.24), 251 (3.23), 309 (3.95), 320 (3.95), 333 (4.08); IR (MeOH) ν_{max} cm^{-1}: 2940, 2910, 2850, 2825, 1615, 1585, 1550, 1510, 1480, 1470, 1420, 1355, 1305, 1250, 1210, 1195, 1165, 1155, 1095, 1050, 1020, 940 and 840; ^1H and ^{13}C NMR: see Tables 1 and 2, respectively; EIMS *m/z* (rel. int.%) 329 $[M]^+$ (40.4), 245 (100), 230 (33.3), 142 (13.7), 85 (16.6), 59 (37.4), 44 (24.9) and 43 (23.5); ESIHRMS: 330.1336 ($[M+H]^+$); (calc. for $[C_{18}H_{19}NO_5+H]$ 330.1336).

3.6. Isotecleoxine (3)

Solid, $[\alpha]_D$ −13.3° (*c*; 0.06 in MeOH); UV λ_{max} (MeOH) nm (log ϵ): 244 (3.41), 309 (4.05), 321 (4.02), 334 (4.11); IR (MeOH) ν_{max} cm^{-1}: 2935, 2910, 2840, 1615, 1575, 1485, 1460, 1430, 1355, 1310, 1250, 1210, 1165, 1140, 1075 and 995; ^1H and ^{13}C NMR: see Tables 1 and 2, respectively; EIMS *m/z* (rel. int.%) 329 $[M]^+$ (28.4), 245 (71.9), 230 (47), 85 (75.3), 83 (55.8), 69 (17.9), 59 (100), 57 (38.8), 55 (24.3), 47 (23.2), 45 (37.1), 44 (91.7), 43 (68.1) and 41 (66.3); ESIHRMS: 330.1350 ($[M+H]^+$); (calc. for $[C_{18}H_{19}NO_5+H]$ 330.1336).

3.7. Methylnkolbisine (4)

Needles, mp 168–169 °C; $[\alpha]_D$−2.8° (*c*; 0.04 in MeOH); UV λ_{max} (MeOH) nm (log ϵ): 245 (3.26), 251 (3.25), 308 (3.98), 320 (3.97), 334 (4.11); IR (MeOH) ν_{max} cm^{-1}: 3450, 3340, 2970, 2920, 2860, 2830, 1615, 1575, 1530, 1490, 1460, 1415, 1400, 1350, 1305, 1255, 1205, 1190, 1140, 1080, 1035, 1000, 980, 940 and 835; ^1H and ^{13}C NMR: see Tables 1 and 2, respectively; ESIHRMS: 362.1566 ($[M+H]^+$); (calc. for $[C_{19}H_{23}NO_6+H]$ 362.1525).

3.8. Chlorodesnkolbisine (5)

Needles, mp 181–182 °C; $[\alpha]_D$ +40° (*c*; 0.02 in MeOH); UV λ_{max} (MeOH) nm (log ϵ): 244 (3.17), 251 (3.16), 308 (3.88), 320 (3.88), 334 (4.02); IR (MeOH) ν_{max} cm^{-1}: 3330, 3095, 3030, 2940, 2920, 2880, 2840, 2820, 1610, 1580, 1535, 1495, 1485, 1445, 1420, 1355, 1305, 1280, 1240, 1195, 1160, 1145, 1090, 1070, 1045, 1010, 980, 970, 935, 920, 825, 755 and 730; ^1H and ^{13}C NMR: see Tables 1 and 2, respectively; EIMS *m/z* (rel. int.%) 365/367 $[M]^+$ (14.8:5.2), 245 (100), 230 (44.7), 43 (39.1) and 41 (52.4); ESIHRMS: 366.1082 ($[M+H]^+$); (calc. for $[C_{18}H_{20}NClO_5+H]$ 366.1102).

3.9. Nobiline (8)

Brown plates, mp 125–126 °C (lit. Yenesew and Dagne, 1988, 117–119 °C). The UV, IR, MS and ^1H NMR data were indistinguishable from those reported (Yenesew and Dagne, 1988). ^{13}C NMR: 142.6 (C-2), 105.0 (C-3), 102.4 (C-3a), 155.9 (C-4), 113.2 (C-4a), 100.6 (C-5), 148.4 (C-6), 152.3 (C-7), 107.9 (C-8), 142.8 (C-8a), 163.3 (C-9a), 59.2 (4-OMe), 56.3 (7-OMe), 66.1 (C-1′), 119.7 (C-2′), 138.6 (C-3′), 26.2 (C-4′) and 18.7 (C-5′).

3.10. Haplopine-3,3′-dimethylallylether (9)

Yellow needles, mp 100–101 °C (lit. Bessonova et al., 1974, 105–106 °C). The UV, IR, MS and ^1H NMR data were indistinguishable from those reported (Bessonova et al., 1974). ^{13}C NMR: 143.3 (C-2), 105.0 (C-3), 102.3 (C-3a), 157.5 (C-4), 115.3 (C-4a), 118.2 (C-5), 114.7 (C-6), 151.8 (C-7), 143.2 (C-8), 141.9 (C-8a), 164.6 (C-9a), 59.3 (4-OMe), 61.9 (8-OMe), 67.2 (C-1′), 120.5 (C-2′), 138.2 (C-3′), 26.1 (C-4′) and 18.7 (C-5′).

3.11. Anhydroevoxine (10)

Needles, mp 133–134 °C (lit. Bessonova and Yunusov, 1982, 136–138 °C). The UV, IR, MS and ^1H NMR data were indistinguishable from those reported (Bessonova and Yunusov, 1982). ^{13}C NMR: 143.2 (C-2), 104.6 (C-3), 102.3 (C-3a), 157.1 (C-4), 115.6 (C-4a), 118.1 (C-5), 114.8 (C-6), 151.1 (C-7), 143.1 (C-8), 141.6 (C-8a), 164.3 (C-9a), 59.0 (4-OMe), 61.7 (8-OMe), 69.4 (C-1′), 61.6 (C-2′), 58.3 (C-3′), 24.6 (C-4′) and 19.0 (C-5′).

3.12. 4′,5-Dihydroxy-7-prenyloxyflavanone (14)

Fine needles, mp 69–70 °C (lit. Bohlmann and Ates, 1984, 69 °C). The UV, IR, MS and ^1H NMR data were indistinguishable from those reported by Bohlmann and Ates (1984). ^{13}C NMR: 78.9 (C-2), 43.2 (C-3), 196.1 (C-4), 164.0 (C-5), 94.9 (C-6), 162.9 (C-7), 95.8 (C-8), 167.4 (C-9), 103.1 (C-10), 130.4 (C-1′), 128.0 (C-2′ and C-6′), 115.7 (C-3′ and C-5′), 156.3 (C-4′), 65.4 (C-1″), 118.5 (C-2″), 139.2 (C-3″), 25.8 (C-4″) and 18.2 (C-5″).

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