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Lignans from the roots of *Echinops giganteus*

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Abstract

Two new lignans, (+)-4-(3-methylbutanoyl)-2,6-di(3,4-dimethoxy)phenyl-3,7-dioxabicyclo[3.3.0]octane and (+)-4-hydroxy-2,6-di(3,4-dimethoxy)phenyl-3,7-dioxabicyclo[3.3.0]octane, together with the known lupeol and sitosteryl β-D-glucopyranoside, have been isolated from the roots of *Echinops giganteus* var. *lelyi* C. D. Adams (Compositae). The structures were elucidated on the basis of spectral studies and comparison with published data.

Keywords: *Echinops giganteus*; Compositae; Unsymmetrical lignans; Furofuran derivatives

1. Introduction

Echinops giganteus var. *lelyi* C. D. Adams (Compositae) is an erect branched herb of 60–150 cm high, a species of Cameroon and Nigeria (Hutchinson and Dalziel, 1963). The rhizomes are added to culinary preparations to prevent heart and gastric troubles. Previous studies revealed the presence of sesquiterpenoids from the essential oil of the roots of this plant (Menut et al., 1997; Weyerstahl et al., 1998). In the course of our continuing search for new efficient agents from Cameroonian medicinal plants (Tene et al., 2000), we here present the isolation and structural elucidation of two novel furofuran derivatives, (+)-4-(3-methylbutanoyl)-2,6-di(3,4-dimethoxy)phenyl-3,7-dioxabicyclo[3.3.0]octane (**1**) and (+)-4-hydroxy-2,6-di(3,4-dimethoxy)phenyl-3,7-dioxabicyclo[3.3.0]octane (**2**). The known compounds, lupeol (Tane et al., 1995) and sitosteryl β-D-glucopyranoside (Kojima et al., 1990), were also isolated.

2. Results and discussion

The MeOH–CH_2Cl_2 (1:1) extract of *E. giganteus* was subjected to a sequential liquid–liquid partition with hexane, CH_2Cl_2 and EtOAc. On the basis of their TLC profiles, the CH_2Cl_2 and EtOAc fractions were combined and fractionated on Si gel column chromatography to give several fractions which were further purified by sephadex LH-20 permeation, medium pressure liquid chromatography and re-crystallization to afford compounds **1** and **2** together with lupeol and sitosteryl β-D-glucopyranoside.

Lupeol (Tane et al., 1995) and sitosteryl β-D-glucopyranoside (Kojima et al., 1990) were, respectively, identified by comparison with authentic sample and published data.

Compound **1** was analyzed for the molecular formula $C_{27}H_{34}O_8$ by HREIMS ($[M]^+$ m/z 486.2253; requires 486.2254). The IR spectrum revealed absorption bands corresponding to carbonyl (1745 cm^{-1}) and aromatic rings (1600, 1516 and 920 cm^{-1}), confirmed in the UV spectrum with maxima at 232 and 279 nm. A methylbutanoyl moiety and a lignan framework of the furofuran type (Pelter et al., 1976) made up of two benzene moieties with four methoxy groups (2,6-di(3,4-dimethoxy)phenyl-3,7-dioxabicyclo[3.3.0]octane) were

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suggested by the ^1H and ^{13}C NMR spectroscopic analysis. The ^1H NMR spectrum showed resonances for the methylbutanoyl moiety at δ 0.93 (3H, *d*, $J = 6.5$ Hz), 0.94 (3H, *d*, $J = 6.5$ Hz), 2.07 (1H, *m*) and 2.16 (2H, *d*, $J = 7.5$ Hz) (see Table 1). This was confirmed in the ^{13}C NMR spectrum with signals at δ 172.4, 43.9, 25.8, 22.8 and 22.7 (see Table 2). ^1H and ^{13}C NMR spectral data (see Tables 1 and 2) of the aromatic moieties indicated that the methylbutanoyl moiety was linked to the furofuran system rendering **1** an unsymmetrical lignan. The four signals at δ 149.6, 149.5, 149.2 and 149.0 were attributed to the oxygenated aromatic carbon atoms (C-3′, C-3″, C-4′ and C-4″) and the four methoxyl carbon atoms were assigned with δ 56.4, 56.3, 56.3 and 56.2. Carbon C-1′ and C-1″ resonated, respectively, at δ 134.2 and 134.5 confirming the equatorial positions of the two veratryl groups (Pelter et al., 1976; Iida et al., 1982). The proton sequence of the aliphatic and aromatic rings was made using the ^1H–^1H COSY spectrum and the gradient HMQC spectrum while the HMBC spectrum permitted the construction of the skeleton of **1**. In the HMBC spectrum, cross-peak were observed between H-4 (δ 6.48) and C-2 (δ 89.3), C-6 (δ 83.5), C-5 (δ 61.7), C-1 (δ 52.7) and C-1‴ (δ 172.4). The latter indicated that the methylbutanoyl moiety was attached to carbon C-4 (δ 102.1). The stereochemistry of the carbon atoms in compound **1** was deduced from NOE Difference spectra with NOEs between H-1/H-5 (8.1%), H-1/ H-8eq (δ 4.31) (5.6%), H-2/H-4 (3.1%), H-2/H-6 (1.1%), H-2/H-8ax (δ 4.06) (1.3%), H-6/H-4 (10.8%) and H-8ax/H-8eq (18.8%). Hence, the equatorial position of the methylbutanoyl moiety is also established. In addition, the acetal proton appeared as a broad singlet confirming this equatorial orientation (Abe and Yamauchi, 1988). On the basis of all spectroscopic and physical evidences compound **1**, a derivative of eudesmin (**3**), was the novel lignan (+)-4-(3-methylbutanoyl)-2,6-di(3,4-dimethoxy) phenyl-3,7-dioxabicyclo[3.3.0]octane.

Compound **2** was analyzed for the molecular formula $C_{27}H_{34}O_8$ by HREIMS ($[M]^+$ m/z 402.1663; requires 402.1679). The IR spectrum showed absorption bands due to hydroxyl (3508 cm^{-1}) and aromatic rings (1606, 1518 and 914 cm^{-1}). The UV spectrum indicated maxima at 232 and 279 nm which correspond to the furofuran type of lignan viz. 2,6-diaryl-3,7-dioxabicyclo [3.3.0]octane (Matsushita et al., 1991). ^1H and ^{13}C NMR spectral data of **2** (data given in Tables 1 and 2) were similar to those of **1** except that the methylbutanoyl moiety in **1** was replaced by an hydroxyl group in **2**. In the ^1H–^1H COSY spectrum, a cross-peak was observed between H-4 and the hydroxyl proton (*d*, $J = 3.0$ Hz). Acetylation of **2** afforded the monoacetate **2a**. The acetal proton (H-4, δ 6.43) of **2a** appeared as a broad singlet similar to that of **1**. Reduction of **2** with sodium

Table 1
^1H (400.13 MHz) NMR data (δ; multiplicity; *J*) for **1**, **2**, **2a** and **2b** in $CDCl_3$ with the $CDCl_3$ signal (δ 7.26) as reference

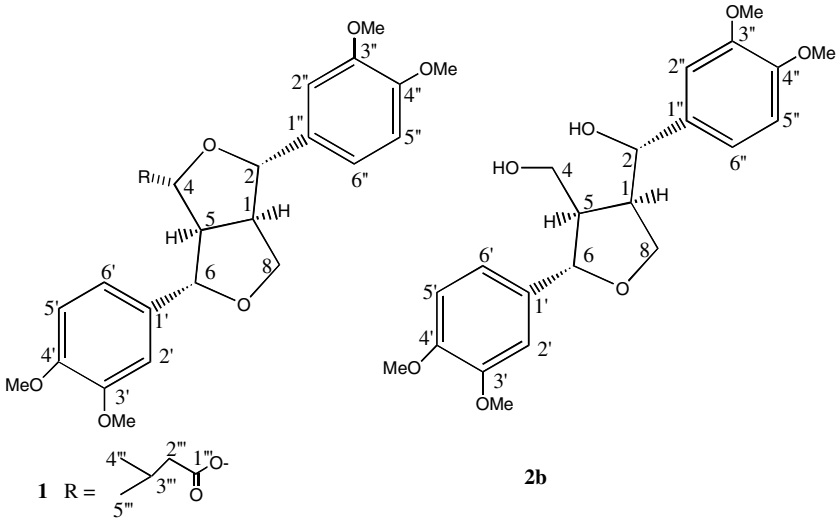
H	^1H (δ; multiplicity; *J*)			
	1	**2**	**2a**	**2b**
1	3.28; *m*	3.28; *m*	3.28; *m*	2.60; *m*
2	5.14; *d*; 6.1	5.01; *d*; 6.5	5.13; *d*; 6.1	4.83; *d*; 10.4
4	6.48; *br s*	5.62; *d*; 3.0	6.43; *br s*	4.05; *br t*; 10.7
				3.75; *dd*; 3.8, 12.0
5	3.06; *br t*; 7.3	3.04; *br t*; 7.6	3.05; *br t*; 7.6	2.90; *m*
6	5.00; *d*; 6.9	4.90; *d*; 7.1	4.94; *d*; 7.2	4.57; *d*; 7.3
8	4.31; *dd*; 5.8, 9.1	4.28; *dd*; 6.0, 9.1	4.32; *dd*; 5.9, 9.1	3.72; *dd*; 7.3, 9.1
	4.09; *dd*; 2.5, 9.1	4.04; *dd*; 2.6, 9.1	4.07; *dd*; 2.8, 9.1	3.41; *dd*; 7.3, 9.1
2′	6.99; *d*; 1.7	6.93; *br s*	6.96; *br s*	6.87; *br s*
5′	6.87; *d*; 8.4	6.87; *d*; 8.0	6.85; *d*; 8.2	6.85; *d*; 7.9
6′	6.97; *dd*; 1.7, 8.4	6.92; *br d*; 8.0	6.93; *br d*; 8.2	6.85; *d*; 7.9
2″	7.01; *d*; 1.7	7.11; *d*; 1.9	7.00; *d*; 1.9	6.92; *d*; 1.7
5″	6.89; *d*; 8.4	6.86; *d*; 8.2	6.87; *d*; 8.0	6.86; *d*; 8.2
6″	6.95; *dd*; 1.7, 8.4	6.99; *dd*; 1.9, 8.2	6.92; *dd*; 1.9, 8.0	6.89; *dd*; 1.7, 8.2
2‴	2.16; *d*; 7.4			
	2.16; *d*; 7.4			
3‴	2.07; *m*			
4‴ (Me)	0.93; *d*; 6.5			
5‴ (Me)	0.94; *d*; 6.5			
4 × OMe	3.94; *s*	3.92; *s*	3.92; *s*	3.90; *s*
	3.92; *s*	3.91; *s*	3.91; *s*	3.89; *s*
	3.91; *s*	3.90; *s*	3.90; *s*	3.89; *s*
	3.90; *s*	3.90; *s*	3.89; *s*	3.87; *s*
OAc			2.02; *s*	
2-OH				3.27; *br s*
4-OH		3.16; *d*; 3.0		3.27; *br s*

borohydride afforded the diol **2b** arising from the cleavage of the furan ring containing the hemiacetal carbon. In the ^{1}H NMR spectrum of **2b**, the methylene protons at δ 3.75 and 4.05, instead of a singlet peak at δ 5.62 in the spectrum of **2**, was assigned to the newly formed primary carbinyl protons (see Table 1), and the hemiacetal carbon signal of **2** (δ 102.2, *d*, C-4) was shift up field and was transformed to a primary carbinyl

Table 2
^{13}C (100.6 MHz) NMR data (δ; multiplicity) for **1**, **2**, **2a**, **2b** and **3**[a] (eudesmin) in $CDCl_3$ with the $CDCl_3$ signal (δ 77.0) as reference

Carbon	**1**	**2**	**2a**	**2b**	**3**[a]
1	52.7; *d*	53.4; *d*	52.4; *d*	52.6; *d*	54.3; *d*
2	89.3; *d*	88.6; *d*	89.0; *d*	73.9; *d*	85.8; *d*
4	102.1; *d*	102.2; *d*	101.5; *d*	61.3; *t*	71.7; *t*
5	61.7; *d*	62.4; *d*	61.2; *d*	49.2; *d*	54.3; *d*
6	83.5; *d*	83.7; *d*	83.2; *d*	83.4; *d*	85.8; *d*
8	72.9; *t*	72.7; *t*	72.7; *t*	70.8; *t*	71.7; *t*
1′	134.2; *s*	134.2; *s*	133.6; *s*	134.6; *s*	134.0; *s*
2′	109.1; *d*	109.4; *d*	108.7; *d*	109.4; *d*	109.7; *d*
3′, 3″, 4′, 4″	149.6; *s*	149.7; *s*	149.3; *s*	149.7; *s*	148.9; *s*
	149.5; *s*	149.7; *s*	149.1; *s*	149.6; *s*	149.5; *s*
	149.2; *s*	149.2; *s*	148.8; *s*	149.5; *s*	
	149.0; *s*	149.1; *s*	148.7; *s*	149.1; s	
5′	111.4; *d*	111.3; *d*	111.0; *d*	111.4; *d*	111.5; *d*
6′	118.0; *d*	118.6; *d*	117.8; *d*	118.7; *d*	118.4; *d*
1″	134.5; *s*	135.0; *s*	134.1; *s*	135.5; *s*	134.0; *s*
2″	109.9; *d*	110.2; *d*	109.4; *d*	109.7; *d*	109.7; *d*
5″	111.5; *d*	111.5; *d*	111.1; *d*	111.4; *d*	111.5; *d*
6″	118.9; *d*	119.3; *d*	118.5; *d*	119.4; *d*	118.4; *d*
4 × OMe	56.4; *q*	56.4; *q*	56.0; *q*	56.3; *q*	55.6; *q*
	56.3; *q*	56.4; *q*	56.0; *q*	56.3; *q*	55.9; *q*
	56.3; *q*	56.3; *q*	56.0; *q*	56.3; *q*	
	56.2; *q*	56.3; *q*	55.8; *q*	56.3; *q*	
1‴	172.4; *s*		170.0; *s*		
2‴	43.9; *t*		21.3; *q*		
3‴	25.8; *d*				
4‴	25.7; *q*				
5‴	22.8; *q*				

[a] Pelter et al. (1976).



1 R =

2b

2 R = OH

2a R = OAc

3 R = H

carbon signal (δ 61.3, *t*) in the ^{13}C NMR spectrum of **2b**. NOEs observed for **2** between H-4/ H-2 (3.2%) and H-4/ H-6 (11.2%) suggested the 4-hydroxyl group of **2** to be equatorial. Hydrogen bond between the hydroxyl group and H-2″ (δ 7.11) and between the hydroxyl group and H-6″ (δ 6.99) also confirmed this orientation (Abe and Yamauchi, 1988). Lignan **2**, identified as (+)-4-hydroxy-2,6-di(3,4-dimethoxy)phenyl-3,7-dioxabicyclo[3.3.0]octane, was also novel. Its synthetic 4-ax isomer (Khan and Shoeb, 1985) has been isolated.

3. Experimental

3.1. General experimental procedures

Melting points (uncorr.) were determined on a Kofler apparatus. Optical rotations were measured on a AA Series Automatic Polarimeter Polaar-2000 at 22 °C. ^1H NMR (400.13 MHz) and ^{13}C NMR (100.6 MHz) with DEPT program were recorded at room temperature in $CDCl_3$, unless otherwise stated, using a Bruker DPX 400 spectrometer. The chemical shifts (δ) are reported in parts per million (ppm) with the solvent signals, δ_H 7.26 and δ_C 77.0 as reference relative to TMS ($\delta = 0$) as internal standard, while the coupling constants (*J* values) are given in Hertz (Hz). COSY, HMQC and HMBC experiments were recorded with gradient enhancements using sine shape gradient pulses. The IR spectra were recorded with a JASCO FT-IR-410 spectrophotometer and the UV spectra recorded with a Shimadzu UV-3101 PC spectrophotometer. EIMS, HREIMS spectra (direct inlet, EI at 70 eV) were recorded with a Jeol JMS-700 spectrometer. Column chromatography was run on Merck Si gel 60 and gel permeation on sephadex LH-20, while TLC were carried out on Si gel GF_{254} pre-coated plates with detection accomplished by spraying with 50% H_2SO_4 followed by heating at 100 °C or by visualizing with an UV lamp at 254 and 366 nm.

3.2. Plant material

The roots of *E. giganteus* var. *lelyi* C. D. Adams were collected at Bansoa, West province, Cameroon, in January 2000. Authentication was done by Mr. Paul Mezili, a retired botanist of the Cameroon National Herbarium, Yaoundé. A voucher specimen (BUD 0607) has been deposited at the Botany Department, University of Dschang.

3.3. Extraction and isolation

The dried powdered plant material (3 kg) was extracted by percolation with a mixture of CH_2Cl_2–MeOH (1:1) at room temp. The crude organic extract (195 g) was partitioned between hexane and 80% aqueous MeOH, and the MeOH–H_2O phase was diluted with water to 60% aqueous MeOH and extract with CH_2Cl_2. Finally the MeOH–H_2O layer was further diluted to 50% and exhaustively extracted with EtOAc. Evaporation of the solvents under reduced pressure from the hexane, CH_2Cl_2 and EtOAc extracts afford 105, 38 and 22 g, respectively. The hexane extract, mainly oil, was not further investigated in this work. A TLC analysis showed that the CH_2Cl_2 and EtOAc extracts were qualitatively similar and thus were combined, and a portion (40 g) was subjected to CC on Si gel (70–230 mesh) eluting with a gradient mixture of hexane–EtOAc. Sixty nine fractions of 250 ml each were collected and combined on the basis of their TLC profiles to give four major fractions: I (16 g, hexane–EtOAc 9:1 and 4:1), II (2.8 g, hexane–EtOAc 7:3 and 3:2), III (3.4 g, hexane–EtOAc 1:1) and IV (6.3 g, EtOAc). Further purification of these fractions was achieved by chromatography on Baeckström AB Separo columns (15 mm i.d.) with a continuous gradient of hexane–EtOAc. Fraction I yielded lupeol (30 mg) and a mixture of sterols (38 mg). Fraction II afforded (+)-4-(3-methylbutanoyl)-2,6-di(3,4-dimethoxy)phenyl-3,7-dioxabicyclo[3.3.0]octane (**1**) (83 mg). Fraction III yielded (+)-4-hydroxy-2,6-di(3,4-dimethoxy)phenyl-3,7-dioxabicyclo[3.3.0]octane (**2**) (113 mg) while fraction IV afforded sitosteryl β-D-glucopyranoside (500 mg) and a complex mixture. For the isolates an additional purification by CC on LH-20 gel eluted with hexane–CH_2Cl_2 1:1 (lupeol) and CH_2Cl_2–MeOH 1:1 (**1** and **2**) was required to obtain analytically pure samples (this removed the last traces of fats). Sitosteryl β-D-glucopyranoside was purified by re-crystallization in MeOH.

3.3.1. (+)-4-(3-Methylbutanoyl)-2,6-di(3,4-dimethoxy)phenyl-3,7-dioxabicyclo[3.3.0]octane (**1**)

White powder (MeOH), m.p. 94–95°, $[\alpha]_D^{22}$ +9.7° ($CHCl_3$; *c* 0.35). UV(EtOH) λ_{max} (log ε) nm: 201 (4.82), 232 (4.14), 279 (3.73). IR($CHCl_3$) ν_{max} cm^{-1}: 3030, 2965, 1745 (C=O), 1600 (C=C), 1516, 1465, 1381, 1361, 1263, 1237, 1161, 1142, 1081, 1028, 920, 708. ^1H NMR ($CDCl_3$, 400.13 MHz), see Table 1; ^{13}C NMR ($CDCl_3$, 100.6 MHz), see Table 2. Analysis found: C 66.64, H 7.05% $C_{27}H_{34}O_8$ requires C 66.65, H 7.04%; EIMS: 70 eV (rel. int.) *m*/*z*: 486 $[M]^+$ (80), 384$[M - C_5H_{10}O_2]^+$ (10), 355 (30), 219 (55), 177 (100), 165 (63), 151 (60), 85 (22), 83 (35), 57 (28).

3.3.2. (+)-4-Hydroxy-2,6-di(3,4-dimethoxy)phenyl-3,7-dioxabicyclo[3.3.0]octane (**2**)

White powder (EtOAc), m.p. 171–173°, $[\alpha]_D^{22}$ +29.5° ($CHCl_3$; *c* 0.45). UV(EtOH) λ_{max} (log ε) nm: 203 (4.96), 205 (4.86), 232 (4.18), 279 (3.65). IR(KBr) ν_{max} cm^{-1}: 3508 (OH), 3070, 2935, 2898, 1606 (C=C), 1593, 1518, 1452, 1379, 1344, 1263, 1225, 1155, 1140, 1078, 1059, 1022, 914, 835, 818, 762. ^1H NMR data ($CDCl_3$, 400.13 MHz), see Table 1; ^{13}C NMR data ($CDCl_3$, 100.6 MHz), see Table 2. Analysis found: C 65.65, H 6.52%

$C_{22}H_{26}O_7$ requires C 65.66, H 6.51%; EIMS: 70 eV (rel. int.) m/z: 402 $[M]^+$ (100), 384 $[M - H_2O]^+$ (5), 355 (15), 177 (95), 165 (75), 151 (55), 83 (30).

Acetylation of **2**: Compound **2** (10 mg) was treated with Ac_2O (1 ml) and pyridine (1 ml) at room temp. for overnight. The usual work up of the reaction mixture gave **2a** (10 mg), obtained as white powder in hexane–EtOAc (9:1); m.p. 130–131°, $[\alpha]_D^{22}$ +14° ($CHCl_3$; *c* 0.7). ^1H NMR data ($CDCl_3$, 400.13 MHz), see Table 1; ^{13}C NMR data ($CDCl_3$, 100.6 MHz), see Table 2. EIMS: 70 eV (rel. int.) m/z: 444 $[M]^+$ (100), 384$[M - AcOH]^+$ (10), 355 (20), 219 (40), 177 (90), 165 (70), 151 (69), 83 (75), 43 (18).

Reduction of **2**: Lignan **2** (10 mg) was dissolved in the mixture $CHCl_3$/MeOH (5 ml each) and stirred with $NaBH_4$ (10 mg) at room temp. for 2 h. The reaction mixture was then washed with water (3 × 20 ml) and the $CHCl_3$ residue dried with dry Na_2SO_4. Evaporation of $CHCl_3$ and re-crystallization of the product in EtOAc afforded **2b** (8 mg): white powder, m.p. 123–124°, $[\alpha]_D^{22}$ −46° ($CHCl_3$; *c* 0.45). UV(EtOH) $\lambda_{max}(\log \varepsilon)$ nm: 231 (4.08), 280 (3.61). IR(KBr) ν_{max} cm^{-1}: 3500–3255 (OH), 2930, 2837, 1595, 1520, 1462, 1385, 1263, 1238, 1161, 1053, 1022, 980, 860, 810, 760. ^1H NMR ($CDCl_3$, 400.13 MHz), see Table 1; ^{13}C NMR ($CDCl_3$, 100.6 MHz), see Table 2. EIMS: 70 eV (rel. int.) m/z: 404 $[M]^+$ (50), 386$[M - H_2O]^+$ (52), 355 (15), 238 (30), 177 (90), 165 (100), 151 (73), 110 (55).

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References

Abe, F., Yamauchi, T., 1988. 9α-Hydroxypinoresinol, 9α-hydroxymedio-resinol and related lignans from *Allamanda neriifolia*. Phytochemistry 27, 575–577.

Hutchinson, J., Dalziel, J.M., 1963. In: Hepper, F.N. (Ed.), Flora of West Tropical Africa, 2. Crown Agents for Oversea Governments and Administration, London, p. 291. Part 1.

Iida, T., Nakano, M., Ito, K., 1982. Hydroperoxysesquiterpene and lignan constituents of *Magnolia kobus*. Phytochemistry 21, 673–675.

Khan, K.A., Shoeb, A., 1985. A lignan from *Lonicera hypoleuca*. Phytochemistry 24, 628–630.

Kojima, H., Sato, N., Hatano, A., Ogura, H., 1990. Sterol glucosides from *Prunella vulgaris*. Phytochemistry 29, 2351–2355.

Matsushita, H., Miyase, T., Ueno, A., 1991. Lignan and terpene glycosides from *Epimedium sagittarium*. Phytochemistry 30, 2025–2027.

Menut, C., Lamaty, G., Weyerstahl, P., Marshall, H., Seelmann, I., Amvam, Z.P.H., 1997. Aromatic plants of tropical Central Africa. Part XXXI. Tricyclic sesquiterpenes from the root essential oil of *Echinops giganteus* var. *lelyi* C. D. Adams. Flavour and Fragrance Journal 12, 415–421.

Pelter, A., Ward, R.S., Rao, E.V., Sastry, K.V., 1976. Revised structures for pluviatilol, methylpluviatilol and xanthoxylol. General methods for the assignment of stereochemistry to 2,6-diaryl-3,7-dioxabicyclo[3.3.0]octane lignans. Tetrahedron 12, 2783–2788.

Tane, P., Bergquist, K-E., Tene, M., Ngadjui, B.T., Ayafor, J.F., Sterner, O., 1995. Cyclodione, an unsymmetrical dimeric diterpene from *Cylicodiscus gabunensis*. Tetrahedron 51, 11595–11600.

Tene, M., Wabo, H.K., Kamnaing, P., Tsopmo, A., Tane, P., Ayafor, J.F., Sterner, O., 2000. Diarylheptanoids from *Myrica arborea*. Phytochemistry 54, 975–978.

Weyerstahl, P., Marshall, H., Seelman, I., Jakupovic, J., 1998. Cameroonane, prenopsane and nopsane, three new tricyclic sesquiterpene skeletons. European Journal of Organic Chemistry 6, 1205–1212.