Available online at www.sciencedirect.com
SCIENCE DIRECT®
PERGAMON
Phytochemistry 64 (2003) 583–587
PHYTOCHEMISTRY
www.elsevier.com/locate/phytochem

Furanonaphthoquinones, atraric acid and a benzofuran from the stem barks of *Newbouldia laevis*

Rainer Gormann[a], Maki Kaloga[a], Xing-Cong Li[b], Daneel Ferreira[b], Dieter Bergenthal[c], Herbert Kolodziej[a,*]

[a]*Institut für Pharmazie, Freie Universität Berlin, D-14195 Berlin, Germany*
[b]*NCNPR, School of Pharmacy, The University of Mississippi, University, MS 38677, USA*
[c]*Institut für Pharmazeutische Chemie, Universität Münster, D-48149 Münster, Germany*

Received 9 January 2003; received in revised form 26 March 2003
Dedicated to the memory of Professor Jeffrey B. Harborne

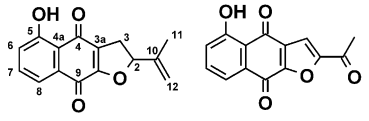
Abstract

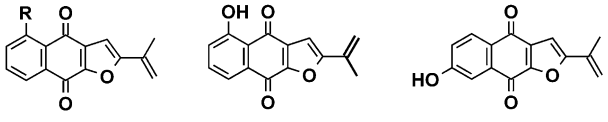
The series of naturally occurring furanonaphthoquinones is extended by identification of the derivatives 2-(1′-methylethenyl)-5-hydroxynaphtho[2,3-*b*]furan-4,9-dione and 2-(1′-methylethenyl)-7-hydroxynaphtho[2,3-*b*]furan-4,9-dione. They are accompanied in the stem barks of *Newbouldia laevis* by the known analogues 5-hydroxy-dehydro-iso-α-lapachone, 2-acetyl-5-hydroxynaphtho[2,3-*b*]furan-4,9-dione and 2-(1′-methylethenyl)naphtho[2,3-*b*]furan-4,9-dione along with the rare atraric acid and the new 2-(1′-methylethenyl)-6-hydroxy-2,3-dihydrobenzofuran. The structures of these compounds were established from spectroscopic studies.

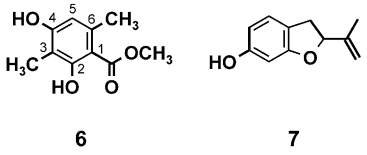
Keywords: *Newbouldia laevis*; Bignoniaceae; Furanonaphthoquinones; Atraric acid; Benzofuran derivative

1. Introduction

Newbouldia laevis SEEM. (Bignoniaceae) is a shrub or small tree distributed in the tropical rain forest and Savannah zones of Western Africa. The use of this plant by traditional healers for a wide-ranging list of ailments is well documented (Burkill, 1985). For example, the roots are commonly employed to cure migraine, ear-ache and stomach-ache, while the leaves are used to combat eye-disease and breast cancer, and the stem barks to treat dysentery, rheumatoid arthritis, epilepsy and skin infections. However, chemical studies have hitherto been confined to the root material of *N. laevis* and have revealed the presence of 2,3-dehydrofuranonaphthoquinones (Houghton et al., 1994; Gafner et al., 1996, 1998), pyrazole alkaloids (Adesanya et al., 1994; Houghton et al., 1994; Aladesanmi et al., 1998) and phenylpropanoid glycosides (Gafner et al., 1997). The medicinal uses of the stem barks of the title plant and the lack of information regarding their chemical constituents prompted the present investigation of bark metabolites. We now disclose our results on the isolation and characterization of five furanonaphthoquinones (**1**–**5**) including two new analogues (**4**) and (**5**), along with the rarely found atraric acid **6** and the new benzofuran **7**.







* Corresponding author. Tel.: +30-838-53731; fax: +30-838-53729.
E-mail address: kolpharm@zedat.fu.berlin.de (H. Kolodziej).

0031-9422/03/$ - see front matter © 2003 Elsevier Ltd. All rights reserved.
doi:10.1016/S0031-9422(03)00277-2

2. Results and discussion

The dichloromethane extract of dried and powdered stem barks of *Newbouldia laevis* was initially subjected to column chromatography on silica gel using petroleum ether-ethyl acetate gradient systems to afford yellow-coloured eluants that were grouped according to their TLC patterns. Subsequent chromatographic purification of appropriate fractions by prep. TLC or HPLC purification yielded a series of chromatographically homogeneous furanonaphthoquinones (**1**–**5**). Structural assessment of these derivatives was effected by analyses of MS and ^{1}H and ^{13}C NMR spectroscopic data. Allocation of signals was facilitated by COSY, HMQC and HMBC experiments.

Known compounds amongst the quinone metabolites included 5-hydroxy-dehydroiso-α-lapachone (**1**) (Wagner et al., 1989), 2-acetyl-5-hydroxynaphtho[2,3-*b*]furan-4,9-dione (**2**) (Wagner et al., 1989) and 2-isopropenylnaphtho[2,3-*b*]furan-4,9-dione (**3**) (Inouye et al., 1981), which were readily identified by comparison of the physical and spectroscopic properties with those reported in the literature. Since the ^{13}C NMR spectral data of **3** were not previously recorded (Inouye et al., 1981), these are included for comparative purposes (see Experimental). Noteworthy is that compounds **2**–**5** including the new naphthoquinone derivatives **4** and **5** (*vide infra*) represent the first furanonaphthoquinones encountered in this plant source, while earlier studies on the root metabolites have invariably revealed the presence of 2,3-dihydro analogues. This presumably suggests an ecologically driven reduction of the 2,3-dihydro metabolites to their furano-based analogues, once they have left the metabolic root pool.

Compound **4** was obtained as an amorphous solid and its molecular formula, $C_{15}H_{10}O_4$, was established from HR-EIMS ($M^{+\cdot}$ at *m*/*z* 254.05728; calc. 254.05731). Initial identification of **4** as a naphthoquinone derivative clearly followed from its typical yellow colour and characteristic UV maxima at λ 263 and 408 nm (Thomson, 1971), taking into account the IR bands at 1661 and 1639 cm^{-1} for carbonyl absorptions. In the ^{13}C NMR spectrum, the carbonyl carbons resonated at δ_C 186.5 and 172.3 ppm, the large deshielding of the former ^{13}C resonance being indicative of a hydroxyl group *peri* to either carbonyl function. Supporting evidence for the presence of a hydrogen bonded OH-group was also available from the conspicuous downfield position of the OH-signal at δ 12.18 in the ^{1}H NMR spectrum of **4**. Besides the carbonyl carbons, the ^{13}C NMR spectrum displayed 13 resonances, for 1×CH_3, 1×CH_2, 4×CH and 7×C. Analysis of the ^{1}H NMR spectrum of **4** indicated the presence of an ABC-spin system (δ 7.26, *dd*, $J=0.9$ and 8.2 Hz; δ 7.61, *dd*, $J=7.5$ and 8.2 Hz; δ 7.76, *dd*, $J=0.9$ and 7.5 Hz) in the aromatic region as well as an isolated one-proton singlet at δ 6.82 (H-3), and aliphatic proton signals arising from a 1-methylethenyl side chain (δ 2.14, s, CH_3; δ 5.36 and 5.95, each *s*, vinylic H-12 in *cis* and *trans* configuration relative to the methyl group, respectively). The location and orientation of the 1-methylethenyl substituent were accessible via NOE studies. Thus, the NOE association of H-3 with H_3-11 and vice versa indicated a preferred s-*trans* configuration **4a** about the C-2/C-10 bond under the experimental conditions. Irradiation of the H_3-11 signal additionally indicated association with H_a-12 (δ 5.36), hence permitting differentiation of the vinylic H_2-12 regarding their configuration relative to H_3-11. Similar NOE experiments using the vinylic H_2-12 signals as references confirmed this structural arrangement.

In this context it should be noted that the observed selective line-broadening of the H_3-11 and the *trans* olefinic H-12 signals at ambient temperatures initially suggested restricted rotation about the C-2/C-10 bond. However, temperature studies did not show any evidence of rotational isomerism about this C–C bond. Molecular Mechanics (MM2) calculations using the Chem 3D Pro™ program showed two preferred conformations with slight preference for the s-*cis* form **4b** but also indicated that the steric energy difference between this ($E=13.8085$ kcal/mol) and the s-*trans* conformation **4a** ($E=14.3235$ kcal/mol) is too small to cause restricted rotation about this bond and hence broadening of ^{1}H NMR signals. This notion is supported by the NOE associations of H-3 and both the H_3-11 and the *trans* olefinic H-12 clearly indicating a high degree of free rotation about the C-2/C-10 bond. The apparent broadening of the H_3-11 and the *trans* olefinic H-12 signals is thus the result of secondary couplings ($J<1$ Hz). Line-shape analysis at considerably high resolutions related it to the anticipated *geminal* (vinyl $H_{a,b}$-12) and long range couplings between H_3-11 and $H_{a,b}$-12 ($^{4}J_{HH}$), respectively between these side chain protons and H-3 ($^{5}J_{HH}$).

Although the chemical shift of the hydroxyl group (δ 12.18) suggested its location at C-5 (Wagner et al., 1989), unambiguous proof for this allocation was provided by three bond C-H correlations in the HMBC experiments of the deshielded H-3 (δ 6.82) with the carbonyl carbon C-4 (δ_C 186.5), and also by the key connectivity of H-8 (δ 7.76) with both the carbonyl carbon C-9 (δ_C 172.3) and C-6. Additional significant HMBC associations were the connectivities of H-3 with both C-2 and C-3a, couplings between H-8 and C-4a, while H-6 showed two- or three-bond correlations with C-4a, C-5 and C-8, and 5-OH exhibited correlations with C-4a, C-5 and C-6, respectively. These spectral features defined **4** as the new furanonaphthoquinone 2-(1′-methylethenyl)-5-hydroxynaphtho[2,3-*b*]furan-4,9-dione.

Compound **5** was isolated as a solid, possessing again the elemental composition of $C_{15}H_{10}O_4$ as concluded

from the HR-EIMS. Close structural similarity of **4** and **5** followed from the general congruence of ^{1}H resonances due to H-3 (δ 6.83), and the protons of the 1-methylethenyl side chain (δ 2.14, s, CH_3; δ 5.34 and 5.95, each *s*, vinylic H_2-12), while the aromatic protons appeared as a similar ABM spin system (δ 7.13, *dd*, $J = 2.6$ and 8.4 Hz; δ 7.60, *d*, $J = 2.6$ Hz; δ 8.11, *d*, $J = 8.4$ Hz). Notable differences included the absence of the hydrogen bonded hydroxyl group and the coupling pattern of the aromatic protons. These features localized the hydroxyl group in either position C-6 or C-7. Although the low quantity of **5** precluded HMBC experiments, the similarity in the chemical shifts of the aromatic protons of **5** and those of the structurally proven analogue 7-hydroxy-dehydro-α-lapachone (Gafner et al., 1996) strongly suggested the location of the hydroxyl group at C-7. Comparison of chemical shift data of the 7- and 6-hydroxy analogues indicated that functionalization at the former position is associated with conspicuous deshielding effects ($\Delta\delta$ ca. 0.2 ppm). Thus, compound **5** was identified as the new 2-(1′-methylethenyl)-7-hydroxy-naphtho[2,3-*b*]furan-4,9-dione.

The furanonaphthoquinones **1**–**5** were accompanied by the β-resorcylic acid **6** and the benzofuran **7**, both trace constituents in this plant source. The former compound had a molecular formula of $C_{10}H_{12}O_4$ as deduced from the HR-EIMS and contained a phenolic group hydrogen bonded to a carbonyl group as was evident from the typical chemical shift of an OH-signal at δ 12.03 in its ^{1}H NMR spectrum. The structure of **6** was established by application of ^{1}H NOE difference spectroscopy and HMBC experiments, defining it as methyl ß-orcinolcarboxylate (atraric acid). The NMR spectral data are in agreement with those previously reported (Ahad et al., 1991; Lee et al., 2001). Noteworthy is that atraric acid (**6**) represents a rarely found metabolite of higher plants (Dictionary of Natural Products, 2002) with significant nematocidal activity (Ahad et al., 1991).

In the EI-MS of **7** an $[M]^{+\cdot}$ peak was detected at *m*/*z* 176, consistent with a molecular formula $C_{11}H_{12}O_2$. Analysis of its ^{1}H NMR spectrum indicated the presence of an ABX spin system [δ 7.12, *dd*, $J = 2.6$ and 8.4 Hz (H-5); δ 7.48, *d*, $J = 2.6$ Hz (H-7); δ 8.01, *d*, $J = 8.4$ Hz (H-4)] assignable to a 1,2,4-trisubstituted benzene ring. The partial structure of a 1-methylethenyl group was inferred from a sharp three-proton singlet at δ 1.80 and two broad one-proton signals at δ 5.00 and 5.13. Furthermore, the set of signals consisting of a one-proton double doublet at δ 5.40 (H-2) and two one-proton double doublets at δ 3.02 and 3.33 (H_2-3) established the presence of a 2-substituted dihydrofuran structural moiety (Bhakuni and Chaturvedi, 1984) and hence the presence of a 2-(1′-methylethenyl)-2,3-dihydro-benzo[*b*]furan skeleton. The position of the hydroxyl group, assigned to C-6, was verified through similar chemical shifts of the aromatic protons as those of **5**. Compound **7** was, therefore, defined as 2-(1′-methylethenyl)-6-hydroxy-2,3-dihydrobenzo[*b*]furan. Owing to decomposition of the sample in $CDCl_3$ we could not measure its optical rotation with a view to define absolute configuration at C-2. This is the first demonstration of the natural occurrence of this benzofuran **7.**

3. Experimental

3.1. General

UV spectra were recorded on a Shimadzu UV-240 spectrophotometer and optical rotations were measured on a Perkin Elmer Polarimeter 341. ^{1}H NMR (400 MHz) and ^{13}C NMR (100.6 MHz) spectra were obtained using a Bruker DPX-400 and a Varian Mercuryplus 400 instrument; the chemical shifts are given in δ (ppm) relative to that of residual $CHCl_3$ (δ_H 7.26; δ_C 77.0). HMBC experiments were optimised for $^{2\text{-}3}J_{H/C} = 8$ Hz. EIMS and HR-EIMS were acquired with a Varian MAT CH_7A and a Finnigan MAT 711 spectrometer, respectively. HPLC separations were done with a Shimadzu instrument, equipped with a gradient former and a photodiode array detector, and Class M10-A software. Experimental conditions: Eurospher 100C-18 (5 μm; 8×250 mm); oven temperature, 40 °C; mobile phase, H_2O–MeOH gradient 1:0→0:1 (40 min, flow rate 4 ml/min); detection at 254 nm. CC was carried out on silica gel (63–200 mesh; Merck). After the emergence of yellow material, 15 ml fractions were collected. Precoated TLC plates were used without activation (silica gel 60 F_{254}, 0.25 mm, Merck). Compounds were visualised by their typical yellow colour in the daylight and by exposure to UV (366 nm).

3.2. Plant material

The stem barks of *Newbouldia laevis* were collected in Abuja (Nigeria) in 1997 and authenticity of the plant material was confirmed by Dr M. Azuine, National Institute for Pharmaceutical Research and Development, Abuja, Nigeria. A voucher specimen is deposited at the Institut für Pharmazie, Pharmazeutische Biologie, Berlin, Germany.

3.3. Extraction and isolation

Dried and powdered stem barks of *N. laevis* (2.5 kg) were exhaustively extracted with CH_2Cl_2 at room temperature to afford 25 g of a brownish residue on evaporation of the solvent. A portion of the extractives (4.5 g) was subsequently applied to a silica gel G 60 column (6×140 cm) using a petroleum ether–EtOAc gradient system (19:1→0:1). The content of test tubes 165–305

eluted with petroleum ether-EtOAc (19:1) was subjected to prep TLC separation with petroleum ether–EtOAc–HOAc (18:1:1) to yield pure compounds **3** and **4**. Compound **2** was obtained from fractions 306–409 (93 mg), **1** and **6** from fractions 410–720 (334 mg) by further purification using HPLC separations with the H_2O–MeOH gradient system described above. Elution with petroleum ether–EtOAc (9:1) and subsequent similar HPLC purification of the fractions 831–1060 (104 mg) afforded **5**, while fractions 1061–1250 (527 mg) eluted with petroleum ether–EtOAc (8:2) yielded **7**.

3.4. 5-Hydroxy-dehydro-iso-α-lapachone (1)

Yellow solid (4 mg). R_f 0.28; R_t 14.1–14.4; $[\alpha]_D^{20}$ −31.6° ($c = 0.38$ in CH_2Cl_2). UV (CH_2Cl_2) λ_{max} nm (log ε): 232 (3.96), 247 (3.96), 294 (3.79), 410 (3.42). IR ν_{max} ($CHCl_3$) cm^{-1}: 2958, 2925, 2855, 1728, 1682, 1636, 1614, 1457. HR-EIMS *m/z* 256.07341 ($M^{+\cdot}$, calc. for $C_{15}H_{12}O_4$ 256.07356); EI-MS *m/z* (rel. int.): 256 $[M]^{+\cdot}$ (100), 241 $[M\text{-}Me]^+$ (27), 213 (64). NMR data corresponded to those in the literature (Wagner et al., 1989).

3.5. 2-Acetyl-5-hydroxy-naphtho-[2,3-b]-furan-4,9-dione (2)

Yellow solid (7 mg). R_f 0.29; R_t 11.1–11.4; UV (CH_2Cl_2) λ_{max} nm (log ε): 275 sh (3.98), 296 sh (3.73), 254 (4.17) 413 (3.45). HR-EIMS *m/z* 256.03695 ($M^{+\cdot}$, calc. for $C_{14}H_8O_5$ 256.03718); EI-MS *m/z* (rel. int.): 256 $[M]^{+\cdot}$ (62), 241 $[M\text{–}Me]^+$ (100), 213 (10). NMR data were consistent with those previously reported (Wagner et al., 1989).

3.6. 2-(1′-Methylethenyl)naphtho[2,3-b]furan-4,9-dione (3)

Yellow material (5 mg). R_f 0.33; R_t 14.5–14.6; UV (CH_2Cl_2) λ_{max} nm (log ε): 253 (4.28), 280 (3.92), 340 (3.35). IR ν_{max} (KBr) cm^{-1}: 1628, 1574, 1525, 1499. HR-EIMS *m/z* 238.06304 ($M^{+\cdot}$, calc. for $C_{15}H_{10}O_3$ 238.06300); EI-MS *m/z* (rel. int.): 238 $[M]^{+\cdot}$ (59), 210 $[M\text{–}CO]^+$ (5). ^1H NMR ($CDCl_3$): δ 2.14 (*br s*, H_3-11), 5.36 (*br s*, H-12, *cis* to H_3-11), 5.95 (*s*, H-12, *trans* to H_3-11), 6.84 (*s*, H-3), 7.74 (*m*, H-6 and H-7), 8.17 (*ddd*, $J = 7.3$, 2.4 and 1.5 Hz, H-5), 8.22 (*ddd*, $J = 7.3$, 2.4 and 1.5 Hz, H-8). ^{13}C NMR: 19.2 (C-11), 104.0 (C-3), 117.0 (C-12), 126.9 (C-8 and C-5), 131.5 (C-10), 131.8 (C-8a), 132.5 (C-3a), 132.9 (C-4a), 133.6 (C-7), 133.9 (C-6), 151.5 (C-2), 161.0 (C-9a), 173.3 (C-9), 180.8 (C-4).

3.7. 2-(1′-Methylethenyl)-5-hydroxynaphtho[2,3-b]furan-4,9-dione (4)

A yellow solid (14 mg). R_f 0.33; R_t 14.4–15.7; UV (MeOH) λ_{max} nm (log ε): 231 (4.48), 263 (4.57), 408 (3.90); UV (CH_2Cl_2) λ_{max} nm (log ε) 235 (4.35), 252 (4.38), 304 (3.97), 412 (3.73). IR ν_{max} ($CHCl_3$) cm^{-1}: 2921, 2851, 1661, 1639, 1453, 1376, 1302, 1225,628, 753. HR-EIMS *m/z* 254.05740 ($M^{+\cdot}$, calc. for $C_{15}H_{10}O_4$ 254.05791); EI-MS *m/z* (rel. int.): 254 $[M]^{+\cdot}$ (100), 226 $[M\text{–}CO]^+$ (15). ^1H NMR ($CDCl_3$): δ 2.14 (*br s*, H_3-11), 5.36 (*br s*, H-12, *cis* to H_3-11), 5.95 (*s*, H-12, *trans* to H_3-11), 6.82 (*s*, H-3), 7.26 (*dd*, $J = 8.2$ and 0.9 Hz, H-6), 7.61 (*dd*, $J = 8.2$ and 7.5 Hz, H-7), 7.76 (*dd*, $J = 7.5$, and 0.9 Hz, H-8), 12.18 (*s*, 5-OH). ^{13}C NMR: 19.4 (C-11), 103.6 (C-3), 115.2 (C-4a), 117.2 (C-12), 119.9 (C-8), 125.1 (C-6), 131.3 (C-10), 131.7 (C-3a), 132.9 (C-8a), 136.2 (C-7), 151.4 (C-2), 161.1 (C-9a),162.2 (C-5), 172.3 (C-9), 186.5 (C-4).

3.8. 2-(1′-Methylethenyl)-7-hydroxynaphtho[2,3-b]furan-4,9-dione (5)

Orange material (1 mg). R_f 0.26; R_t 12.8–13.0; UV (CH_2Cl_2) λ_{max} nm (log ε): 229 (3.67), 259 (3.65), 348 (2.85). HR-EIMS *m/z* 254.05777 ($M^{+\cdot}$, calc. for $C_{15}H_{10}O_4$ 254.05791); EI-MS *m/z* (rel. int.): 254 $[M]^{+\cdot}$ (100). ^1H NMR ($CDCl_3$): δ 2.14 (*br s*, H_3-11), 5.34 (*br s*, H-12, *cis* to H_3-11), 5.95 (s, H-12, *trans* to H_3-11), 6.83 (s, H-3), 7.13 (*dd*, $J = 8.4$ and 2.6 Hz, H-6), 7.60 (*d*, $J = 2.6$ Hz, H-8), 8.11 (*d*, $J = 8.4$ Hz, H-5).

3.9. Atraric acid (6)

Yellow amorphous material (4 mg). R_f 0.25; R_t 11.8–12.1 min. UV (CH_2Cl_2) λ_{max} nm (log ε): 229 (3.99), 264 (3.98), 304 (2.4). HR-EIMS *m/z* 196.07376 ($M^{+\cdot}$, calc. for $C_{10}H_{12}O_4$ 196.07356); EI-MS *m/z* (rel. int.): 196 $[M]^{+\cdot}$ (46), 164^+ (100), 136 (66). ^1H and ^{13}C NMR data corresponded to those previously reported (Ahad et al., 1991; Lee et al., 2001).

3.10. 2-(1′-Methylethenyl)-6-hydroxybenzo[b]furan (7)

Amorphous material (1 mg). R_f 0.13; R_t 10.4–10.6 min. EI-MS *m/z* (rel. int.): 176 $[M]^{+\cdot}$ (20). ^1H NMR ($CDCl_3$): δ 1.80 (s, CH_3), 3.02 (*dd*, $J = 17.2$ and 8.8 Hz, H-3a), 3.33 (*dd*, $J = 17.2$ and 10.9 Hz, H-3b), 5.00 and 5.13 (each 1H, *s*, vinylic H_2), 5.40 (*dd*, $J = 10.9$ and 8.8Hz, H-2), 5.53 (br *s*, 6-OH), 7.12 (*dd*, $J = 8.4$ and 2.8 Hz, 5-H), 7.48 (*d*, $J = 2.6$ Hz, 7-H), 8.01 (*d*, $J = 8.4$ Hz, 4-H).

Acknowledgements

Particular thanks is due to Mrs U. Ostwald, Institute of Organic Chemistry, Freie Universität Berlin, for her engagement in the measurement of HR-EIMS spectra. Sincere appreciation is also expressed to Dr A. Schäfer of the same Institute for performing the crucial NOE

and HMBC experiments of atraric acid. This work was supported in part by the United States Department of Agriculture, Agricultural Research Service Specific Cooperative Agreement No. 58-6408-2-0009.

References

Adesanya, S.A., Nia, R., Fontaine, C., Pais, M., 1994. Pyrazole alkaloids from *Newbouldia laevis*. Phytochemistry 35, 1053–1055.

Ahad, A.M., Goto, Y., Kiuchi, F., Tsuda, Y., Kondo, K., Sato, T., 1991. Nematocidal principles in "oakmoss absolute" and nematocidal activity of 2,4-dihydroxybenzoates. Chemical and Pharmaceutical Bulletin 39, 1043–1046.

Aladesanmi, A.J., Nia, R., Nahrstedt, A., 1998. New pyrazole alkaloids from the root bark of *Newbouldia laevis*. Planta Med. 64, 90–91.

Bhakuni, D.S., Chaturvedi, R., 1984. Chemical constituents of *Crotolaria madurensis*. Journal of Natural Products 47, 585–591.

Burkill, H.M. (1985). The Useful Plants of West Tropical Africa, Vol. 1, Royal Botanic Gardens, Kew, London, 1985.

Dictionary of Natural Products on CD-ROM, version 11:1. Chapman and Hall, 2002.

Gafner, S., Wolfender, J.-L., Nianga, M., Stoeckli-Evans, H., Hostettmann, K., 1996. Antifungal and antibacterial naphthoquinones from *Newbouldia laevis* roots. Phytochemistry 42, 1315–1320.

Gafner, S., Wolfender, J.-L., Nianga, M., Hostettmann, K., 1997. Phenylpropanoid glycosides from *Newbouldia laevis* roots. Phytochemistry 44, 687–690.

Gafner, S., Wolfender, J.-L., Nianga, M., Hostettmann, K., 1998. A naphthoquinone from *Newbouldia laevis* roots. Phytochemistry 48, 215–216.

Houghton, P.J., Pandey, R., Hawkes, J.E., 1994. Naphthoquinones and an alkaloid from roots of *Newbouldia laevis*. Phytochemistry 35, 1602–1603.

Inoue, K., Chen, C.-C., Inouye, H., 1981. Quinones and related compounds in higher plants. Part 16. Naphthoquinones from *Radermachera sinica* Hemsl. (Bignoniaceae). Journal of the Chemical Society, Perkin Transactions 1, 2764–2770.

Lee, S.-S., Chang, S.-M., Chen, C.-H., 2001. Chemical constituents from *Alseodaphne andersonii*. Journal of Natural Products 64, 1548–1551.

Thomson, R.H., 1971. Naturally Occurring Quinones. Academic Press, London.

Wagner, H., Kreher, B., Lotter, H., Hamburger, M.O., Cordell, G.A., 1989. Structure determination of new isomeric naphtha[2,3-b]furan-4,9-diones from *Tabebuia avellanedae* by the selective-INEPT technique. Helvetica Chimica Acta 72, 659–667.