PERGAMON

Phytochemistry 50 (1999) 863–868

PHYTOCHEMISTRY

Furocoumarins of three species of the genus *Dorstenia*

Susana Rojas-Lima [a], Rosa Luisa Santillan [a,*], Miguel-Angel Domínguez [b], Atilano Gutiérrez [c]

[a] *Departamento de Química, Centro de Investigación y de Estudios, Avanzados del IPN, Apdo. Postal 14-740, 07000 Mexico D.F., Mexico*
[b] *Instituto de Ciencias Básicas, Universidad Veracruzana, Av. Dos Vistas s/n, Carretera Xalapa-Las Trancas, 91000 Xalapa, Veracruz, Mexico*
[c] *Lab. de RMN, Universidad Autónoma Metropolitana, Av. Michoacán y la Purísima s/n, Col. Vicentina, 09340 Ixtapalapa, Mexico D.F., Mexico*

Received 3 June 1998

Abstract

Phytochemical studies of the roots of *Dorstenia excentrica* afforded a diastereoisomer of prandiol having the 2′*S*,1″*S* configuration, 4-[3-(4,5-dihydro-5,5-dimethyl-4-oxo-2-furanyl)-butoxy]-7H-furo[3,2-g][1]1benzopyran-7-one, psoralen and 7-hydroxycoumarin. The furocoumarins 5-[3-(4,5-dihydro-5,5-dimethyl-4-oxo-2-furanyl)-butoxyl]-7H-[3,2-[1]benzopyran-7-one and bergapten were also present in the roots of *D. drakena*, while 7-hydroxycoumarin, psoralen and the psoralen dimer were isolated from *D. lindeniana*. The structure of the psoralen dimer was established by X-ray diffraction analysis.

Keywords: *Dorstenia excentrica*; *Dorstenia lindeniana*; *Dorstenia drakena*; Moraceae; Rhizomes; Furocoumarin

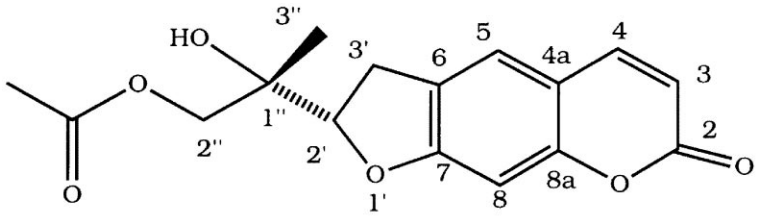
1. Introduction

The roots of several *Dorstenia* species are used in Mexican folk medicine against skin diseases. To our knowledge, phytochemical studies on the genus *Dorstenia* to date include *D. bryoniifolia* (Pozetti, 1988; Vilegas, Lancas, Vilegas, & Pozetti, 1993) which afforded isobergapten and pimpinellin, psoralen, bergapten and isopimpinellin; *D. contrajerva* which afforded 4-[3-(4,5-dihydro-5,5-dimethyl-4-oxo-2-furanyl)-butoxy]-7H-furo[3,2-g][1]-benzopyran-7-one (**2**) (Terreaux et al., 1995) previously thought to be 4-(3,4-epoxy-2,7-dimethyl-6,7-octenoyl)psoralen (Swain, Quirke, Winkle, & Downum, 1991); *D. brasiliensis* which afforded psoralen, bergapten and furocoumarin **2** (Kuster, Bernardo, Da Silva, Parente, & Mors, 1994; Koch, 1936), the latter compound has also been isolated from *D. cayapiaa* (Llabres, Baiwir, Vilegas, Pozetti, & Vilegas, 1992; Vilegas, Vilegas, & Pozetti, 1994); *D. barnimiana* which afforded styrenes (Woldu, Abegaz, Botta, Delle Monache, & Delle Monache, 1988); *D. heringeri* Car. and Val. (Vilegas, Vilegas, & Pozetti, 1992) and biological studies of *D. multiradiata* (Iwu, Klayman, Jackson, Tally, & Andersen, 1994), *D. foetida*, *D. zanzibrica* and *D. contrajerva* (Swain & Downum, 1990), as well as other species of the genus (Vilegas, Vilegas, de F. Camiloti, & Pozetti, 1990).

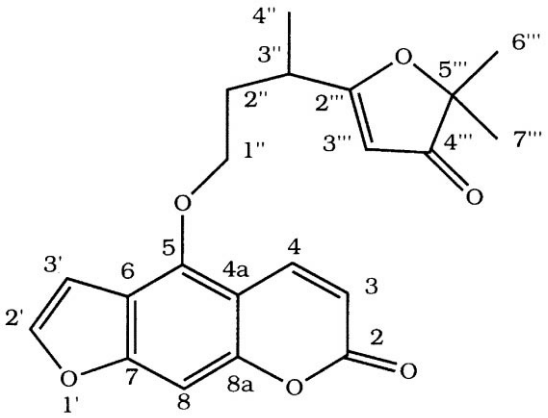
In this paper we report the isolation and structural characterization of a new diastereoisomer of prandiol acetate (**1**) from *D. excentrica*, in addition to the known furocoumarin **2**, psoralen, 7-hydroxycoumarin, β-amyrin acetate, sitosteryl acetate and 3-*O*-β-glucosyl-sitosterol acetate. The dihydrofurocoumarin with undefined stereochemistry known as prandiol, has been isolated from *Apium graveolens* (Garg, Sharma, & Gupta, 1981) and *Prangos biebersteinii* (Abyshev & Brodskii, 1974), and its glycoside derivative from *Angelica archangelica* (Lemmich, Havelund, & Thastrup, 1983). In the case of *D. drakena* the known furocoumarin **2**, bergapten and sitosterol were found as plant constituents; while small quantities of psoralen and the psoralen dimer (**3**)were found in *D. lindeniana*. The structures were elucidated on the basis of spectral data and by comparison with authentic samples while that of the psoralen dimer was established by X-ray structure analysis and characterized by high field

* Corresponding author.

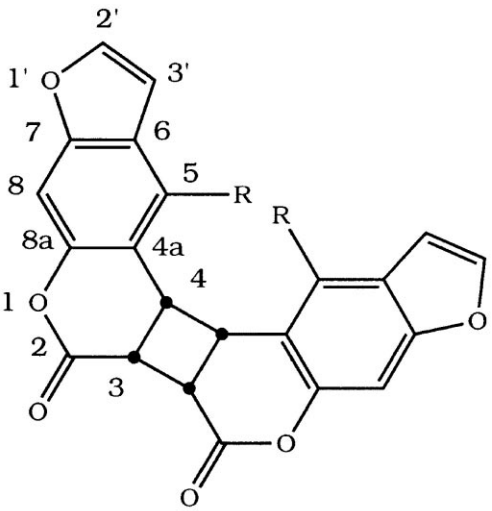
0031-9422/99/$ - see front matter
PII: S0031-9422(98)00520-2



1



2



3: R=H **4**: R=OMe

NMR spectroscopy. Moreover, the psoralen and bergapten dimers (Caffieri & Dall'Acqua, 1987; Rodighiero & Cappellina, 1965) were obtained by irradiation of the corresponding furocoumarin in acetone.

2. Results and discussion

Dihydrofurocoumarin **1** was obtained after acetylation of the chloroform extract of *D. excentrica*. The structure was established based on the 400 MHz ^{1}H NMR spectrum which showed the characteristic coumarin doublets at δ 7.60 and 6.23 (J = 9.5 Hz) for H-4 and H-3; and two singlets at δ 7.24 and 6.75 for H-5 and H-8, respectively. The H-2′ proton gives rise to a triplet at δ 4.88 (J = 9.3 Hz), while the diastereotopic protons at position C-2″ gives rise to an AB system at δ 4.34 and 4.12 (J = 11.5 Hz). The ddd at δ 3.36 and 3.19 were ascribed to the methylene at the C-3′ position. The remaining singlets at δ 2.13 and 1.25 were assigned to the acetate and methyl groups. The ^{13}C NMR spectra was assigned by comparison with the data previously reported for marmesin (Elgamal, Elewa, Elkhrisy, & Duddeck, 1979) and confirm by an HETCOR experiment.

Comparison of the ^{1}H NMR data of **1** with that reported for prandiol derivatives (Garg et al., 1981; Abyshev & Brodskii, 1974; Lemmich et al., 1983) shows that in the prandiol acetate of undefined stereochemistry previously reported (Abyshev & Brodskii, 1974) the H-3′ and H-2″ protons are equivalent giving rise to a doublet and a singlet, respectively, while in dihydrocoumarin **1** these protons are diastereotopic; also, the mp for the known prandiol acetate (129–130°C, Abyshev & Brodskii, 1974) differs considerably from that of **1** (178–180°C). The 2′*S*-configuration for **1** was unambiguously established based on the similarity in CD extrema with 5,6-dihydro-(*S*)-marmesin (Lemmich et al., 1983).

In order to establish the configuration at the C-1″ position, the carbamate derivative of **1** was prepared using trichloroacetyl isocyanate (TAI) (Bose & Srinivasan, 1975; Trehan & Monder, 1968). Considering the most stable conformers of **1**, introduction of a bulky group at the terciary alcohol should lead to induced shifts in the ^{1}H NMR spectrum at the H-3′ position in the 2′*S*,1″*R* diastereomer. Therefore, based on the low field shift induced at the protons in the C-2′ ($\Delta\delta$ = 0.43) and C-2″ ($\Delta\delta$ = 0.38) compared

to C-3′ ($\Delta\delta = 0.05$) of the carbamate derivative, the *S*-configuration at C-1″ was established.

Furocoumarin **2** was isolated from the chloroform extracts of *D. drakena* and *D. excentrica* by repeated column chromatography followed by crystallization. Although the compound was already known (Terreaux et al., 1995; Swain et al., 1991; Kuster et al., 1994) and its structure established by X-ray analysis (Terreaux et al., 1995), careful evaluation of the NMR data revealed inconsistencies in the assignments of the C-5, C-8a and C-2‴, C-4‴ quaternary carbons, as well as the C-4″, C-6‴ and C-7‴ methyl signals. In turn, the proton resonances for **2** are found in agreement with the literature data and were corroborated by HMQC and COSY experiments.

The ^{13}C NMR spectral assignments for **2** were confirmed by 1D and 2D spectra where the HMBC spectrum showed a long range coupling between C-4‴ at δ 207.01 and H-3‴ (δ 5.43), as well as C-2‴ (δ 193.96) with H-3″ and H-2″. Also, from the intensity of the resonances in the 1D spectrum, the signal at δ 22.73 was assigned to C-6‴ and C-7‴ while the signal at δ 17.75 corresponds to C-4″. As for the signals at δ 152.48 and 148.35 for C-5 and C-8a, the latter shows coupling to H-4 (δ 8.11) and was assigned to C-8a. These assignments were found in agreement with those of Terreaux (Terreaux et al., 1995).

The chloroform extracts of *D. lindeniana* afforded, after column chromatography, the psoralen dimer (**3**) (Caffieri & Dall'Acqua, 1987; Rodighiero & Cappellina, 1965) in small quantities as evidenced by the absence of the coumarinic double bond. This is supported by the ^{13}C NMR spectra where the two signals at δ 39.65 and 38.83 correspond to the saturated carbons of the cyclobutane moiety.

Moreover, the ^{1}H NMR spectrum of the psoralen dimer (**3**) shows an AA′BB′ system at δ 4.16 and 4.38, which corresponds to H-3 and H-4, the coupling constants were calculated using the LAOCOON program (version 3.1), the two doublets at δ 7.66 and 6.58 ($J = 2$ Hz) were assigned to H-2′ and H-3′ and the two singlets at δ 7.07 and 6.97 correspond to H-5 and H-8, respectively.

Assignment of the individual proton resonances for the cyclobutane ring was based on homonuclear correlation experiments as well as the long distance correlations observed in the HMBC spectrum. Thus, the COSY spectrum shows that the signal at δ 7.07 (H-5) shows correlation to H-4 (δ 4.38) while H-3 (δ 4.16) shows correlation only to H-4 (δ 4.38). The HMBC spectrum shows that the signal at δ 4.38 (H-4) correlates with that at δ 112.72 (C-4a); H-3 (δ 4.16) shows correlation with H-4 in the COSY spectrum, in the HMQC with the signal at δ 38.83 (C-3) and in the HMBC with the carbonyl signal at δ 164.33 (C-2) and the signal at δ 39.65 (C-4).

The EI mass spectrum of **3** shows an ion peak at m/z 186 (base peak) which evidences half of the dimer structure. The fragmentation pattern for this compound shows successive losses of m/z 28 due to the CO fragment which is characteristic of linear furocoumarins.

Further evidence for the dimeric structure is the absence of a strong absorption band at 310 nm in the UV spectra indicating a loss of conjugation in psoralen.

Proof of the structure of psoralen (**3**) and bergapten dimers (Caffieri & Dall'Acqua, 1987; Rodighiero & Cappellina, 1965) was obtained by irradiation of the corresponding furocoumarin using a 450 W Hanovia medium pressure mercury vapor lamp with Pyrex filter. In both cases UV irradiation gave a mixture of isomers, the head to head *cis–syn* dimer being the major product. The ^{1}H NMR and ^{13}C NMR spectra of the natural dimer isolated from the roots of *D. lindeniana* were identical to the synthetic one.

Since the [2 + 2] cyclodimerization of psoralen or bergapten can lead to eight possible configurational isomers (Krauch, Farid, & Schenck, 1966) observation of a single dimer in the crude extracts, and the absence of signals due to products from photoxidation constitutes supportive evidence for formation of **3** in the plant material (Zdero, Bohlmann, & Niemeyer, 1990).

The *cis–syn* stereochemistry of **3** was established by X-ray diffraction analysis (Fig. 1). The puckering angle formed by the C(5)–C(4)–C(20) and C(19)–C(4)–C(20) planes is 27.14°C and may be attributed to interactions of the substituents at the cyclobutane ring. Analysis of the bond lengths for the cyclobutane ring shows that C(4)–C(19) = 1.565(4) and C(5)–(20) = 1.583(4) Å are longer than the mean bond distance for a C–C sp^3 in unsubstituted cyclobutanes (1.553(2) Å) (Allen et al., 1987).

3. Experimental

^{1}H NMR and ^{13}C NMR spectra were determinated on a Jeol eclipse +400 MHz and Brucker DMX500 spectrometer at 400 and 500 MHz using DMSO-d_6 or $CDCl_3$ and TMS as internal standard. UV spectra were obtained on a Unicam SP800 spectrophotometer. IR spectra were recorded on a Perkin Elmer 16F-PC FT-IR spectrophotometer. MS spectra were recorded on a HP 5989A spectrometer coupled to a Hewlett Packard 5890 GC. Optical rotation was measured on a Perkin Elmer 241 polarimeter. DC spectrum was recorded on a Jasco J-720 spectropolarimeter. X-ray analysis were performed using a CAD4-Enraf–Nonius diffractometer. Melting points were determined on a GallenKamp MFB-595 apparatus and are uncorrected, silica gel 230–400 (Merck) was used.

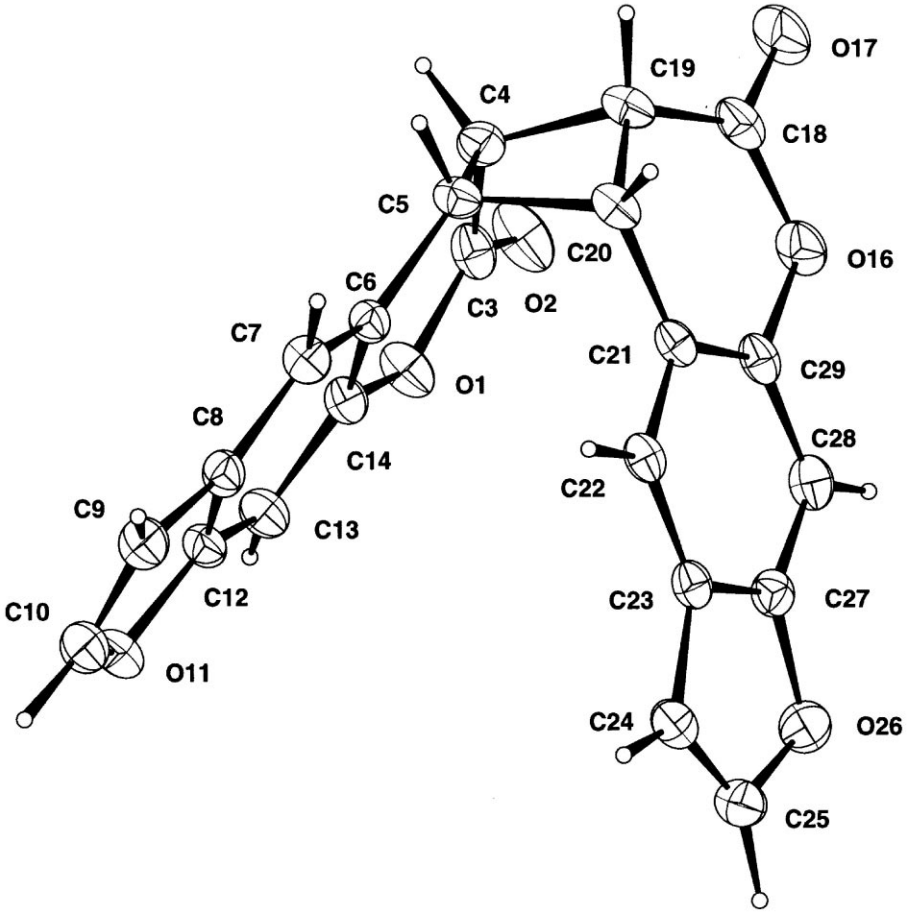


Fig. 1. ORTEP drawing of psoralen dimer (**3**).

3.1. X-ray structure determination of psoralen dimer

An Enraf Nonius-CAD4 automated diffractometer using graphite monochromated Mo Kα radiation and $\omega/2\theta$ scan technique was used for cell determination and data collection. Data reduction, structure solution and refinement were achieved by using the crystals software package. Determination of the unit cell and data collection were performed at 298 K.

3.1.1. Crystal data

$C_{22}H_{12}O_6$ (MW = 372.33) colorless square prism size $0.24 \times 0.30 \times 0.40$, monoclinic, space group P $2_1/n$ (No. 14) $a = 9.947(1)$, $b = 12.754(1)$, $c = 13.432(1)$ Å, $\beta = 104.91(1)^\circ$, $V = 1646.76(1)$ Å^3 by least square refinement on diffractometer angles for 24 automatically centered reflections, $\rho = 1.50$ g cm^{-3}, $Z = 4$; $\mu = 0.1034$ mm^{-1}, $F(000) = 600$.

3.1.2. Data collection

Monitoring of check reflections showed no signs of decay. A total of 3210 unique reflections were measured ($2 < \theta < 25$), 2880 were found as independent and 1583 were considered observed ($F_o > 3\sigma(F_o)$). No absorption correction was performed ($T_{min} = 0.9594$ and $T_{max} = 0.9754$).

3.1.3. Solution and refinement

Direct methods, all non-hydrogen atoms were refined anisotropically, all hydrogen atoms were located by difference Fourier map and refined with fixed isotropic U, 291 parameters refined, $R = 3.3\%$ and $Rw = 2.9\%$, $w = 1/\sigma^2$, GOOF = 1.81, data-to parameters ratio 1:5.4, largest difference peak/hole 0.12/-0.15 e/Å^3.

3.1.4. Supplementary material available

Tables of atomic coordinates, thermal parameters, bond lengths and angles, observed and calculated structure factors have been deposited at the Cambridge Crystallographic Data Center.

3.2. Plant material

The roots of *D. excentrica* were collected in November 1991, at Palmas Altas, Municipio de

Ixcatepec, State of Veracruz, Mexico (voucher No. 79603), those of *D. drakena* were collected in May 1990, at Puente Nacional, State of Veracruz, Mexico (voucher No. 99132) and identified by J. I. Calzada. The roots of *D. lindeniana* were collected in December 1990 at Cerro del Madrigal, Municipio de Tepeaca, State of Tabasco, Mexico (voucher No. 21113) and identified by F. Ventura. Specimens of the plants were deposited at the herbarium of the Institute of Ecology, A.C. (XAL) Xalapa Veracruz, Mexico.

3.3. Isolation of constituents

3.3.1. D. excentrica

Dried and crushed rhizomes (608 g) were extracted successively with hexane, $CHCl_3$ and MeOH. Evaporation of the hexane extract afforded a residue (11.70 g) which was chromatographed on silica gel (230–400 mesh) eluting with hexane–$CHCl_3$ mixtures (1:1) to give psolaren (2.13 g) and β-amyrin acetate. The $CHCl_3$ extract (16.3 g) was chromatographed on silica gel (230–400) using hexane–$CHCl_3$ mixtures to give psoralen (11.2 g), furocoumarin **2** (12 mg) and 7-hydroxycoumarin (8 mg). The polar fractions from the $CHCl_3$ extract were acetylated using pyridine and Ac_2O to give prandiol acetate isomer (**1**) (10 mg) and *O*-glucosyl-sitosteryl acetate. A fraction (24 g) of the total MeOH extract (83.9 g) was hydrolyzed with HCl and chromatographed on silica gel using $CHCl_3$–acetone mixtures to give additional psoralen (57 mg), 7-hydroxycoumarin (20 mg) and 5-hydroxymethyl furfural (85 mg). The polar fractions from the MeOH extract were acetylated using pyridine and Ac_2O to give **1** (10 mg).

3.3.2. D. drakena

Dried and crushed rhizomes (512.6 g) were extracted successively with hexane, $CHCl_3$ and MeOH. The hexane extract was evaporated to dryness and the residue (8.3 g) chromatographed on silica gel eluting with hexane–EtOAc mixtures of increasing polarity to give bergapten (1.38 g), *β*-sitosterol (131 mg) and furocoumarin **2** (40 mg). The $CHCl_3$ extract was washed with Et_2O and the solid chromatographed on silica gel eluting with CH_2Cl_2 to yield 1.32 g of bergapten. The fraction soluble in Et_2O was chromatographed on silica gel eluting with CH_2Cl_2–hexane (8:2) followed by mixtures of increasing polarity of CH_2Cl_2–AcOEt to yield 0.390 g of bergapten and 3.70 g of furocoumarin **2**.

3.3.3. D. lindeniana

Dried and crushed rhizomes (507.9 g) were extracted successively with hexane, $CHCl_3$ and MeOH. The hexane and $CHCl_3$ extracts were chromatographed several times with hexane–EtOAc of increasing polarity. The former afforded psoralen (146.2 mg) while the latter yielded β-amyrin, psoralen (200 mg), psoralen dimer **3** (5 mg) and 7-hydroxycoumarin (3 mg).

3.3.4. (2′S,1″S)-2,3-Dihydro-2(2-acetoxy-1-hydroxymethylethyl)-7H-furo[3,2-g][1]benzopyran-7-one (*1*)

Mp 178–180°C (lit. for prandiol acetate of undefined stereochemistry: 129–130°C, Abyshev & Brodskii, 1974). MS 15 eV, *m/z* 304 [M^+, 54] 226 (26), 213 (38), 188 (100), 187 (85). UV λ_{max} nm (log ε): 360 (4.02), 300 (3.61), 259 (3.48), 248 (3.53), 231 (3.60). $[\alpha]_D = +45$ ($CHCl_3$, *c* 1); CD extrema $\Delta\varepsilon_{230}$ +0.71, $\Delta\varepsilon_{251}$ −0.68, $\Delta\varepsilon_{328}$ −1.17 (MeOH, *c* 5.26×10^{-5} M) (lit. for 5,6-dihydro-(*S*)-marmesin: CD extrema $\Delta\varepsilon_{245}$ −0.6, $\Delta\varepsilon_{303}$ −0.6 (0.1 N NaOH in MeOH, *c* 1.7×10^{-4} M), Lemmich et al., 1983); IR ν_{max}^{KBr} cm^{-1}: 3440 (OH), 1700 (CO), 1628 and 1570 (arom). ^1H NMR (400 MHz, $CDCl_3$): δ 7.60 (1H, d, *J* = 9.5 Hz, H-4), 7.24 (1H, s, H-5), 6.75 (1H, s, H-8), 6.23 (1H, d, *J* = 9.5 Hz, H-3), 4.88 (1H, t, *J* = 9.3, H-2′), 4.34 and 4.12 (2H, AB, *J* = 11.5, H-2′), 3.36 (1H, ddd, *J* = 16, 9.3, 1 Hz, H-3′), 3.19 (1H, ddd, *J* = 16, 9, 1 Hz, H-3′), 2.28 (1H, br, OH), 2.13 (3H, s, $COCH_3$), 1.25 (3H, s, CH_3-3″). ^{13}C NMR (100.53 MHz, $CDCl_3$): δ 170.92 (CO), 162.79 (C-7), 161.28 (C-2), 155.64 (C-8a), 143.55 (C-4), 124.45 (C-6), 123.40 (C-5), 112.98 (C-4a), 112.57 (C-3), 98.18 (C-8), 87.71 (C-2′), 72.70 (C-1″), 68.35 (C-2″), 29.04 (C-3′), 20.87 (CH_3–COO), 20.11 (C-3″).

3.3.5. Bergapten

Mp 195–196°C (lit. 190–191°C, Terreaux et al., 1995).

3.3.6. 4-[3-(4,5-Dihydro-5,5-dimethyl-4-oxo-2-furanyl)-butoxy]-7H-furo[3,2-g][1]benzopyran-7-one (*2*)

Mp 140–143°C (lit. 141–142°C, Terreaux et al., 1995).

3.3.7. Psoralen

Mp 160–161°C (lit. 165°C, Rodighiero & Cappellina, 1965).

3.3.8. Psoralen dimer (*3*)

Mp 282–285°C (lit. 289–290°C, Rodighiero & Cappellina, 1965). MS 70 eV, *m/z* 186 (100), 158 (87), 130 (24), 102 (50), 75 (33), 51 (61); UV λ_{max} nm (log ε) 214 (1.82). IR ν_{max}^{KBr} cm^{-1}: 1756 (CO), 860 (cyclobutane). ^1H NMR (500 MHz, DMSO-d_6): δ 7.66 (1H, d, *J* = 2 Hz, H-2′), 7.07 (1H, s, H-5), 6.97 (1H, s, H-8), 6.58 (1H, d, *J* = 2, H-3′), 4.38 (1H, ddd, *J* = 9.5, 6.5 and 1.5, H-4), 4.16 (1H, ddd, *J* = 9.5, 6.5 and 1.5, H-3); ^{13}C NMR (125.77 MHz, DMSO-d_6): δ 164.33 (C-2), 153.66 (C-7), 149.08 (C-8a), 145.86 (C-2′), 123.69 (C-6), 120.69 (C-5), 112.72 (C-4a), 105.69 (C-3′), 99.21 (C-8), 39.65 (C-4), 38.83 (C-3).

*3.3.9. Bergapten dimer (**4**)*

Mp 288–290°C (lit. 242°C, Rodighiero & Cappellina, 1965). MS 70 eV, *m/z* 216 (100), 201 (21), 173 (33), 145 (17), 89 (14), 51 (11), UV λ_{max} nm (log ε) 260 (0.2), IR ν_{max}^{KBr} cm^{-1}: 2848 (C–H) 1752 (CO), 826 (cyclobutane). ^1H NMR (400 MHz, DMSO-d_6): δ 7.92 (1H, d, $J = 2.4$ Hz, H-2′), 7.58 (1H, d, $J = 2.4$, H-5), 7.08 (1H, s, H-8), 4.08 (1H, d, $J = 7.5$, H-4), 3.90 (3H, s, OMe), 3.85 (1H, d, $J = 7.5$, H-3); ^{13}C NMR (125.77 MHz, DMSO-d_6): δ 169.2 (C-2), 157.0 (C-7), 151.74 (C-5), 151.11 (C-8a), 146.72 (C-2′), 114.4 (C-6), 107.98 (C-4a), 107.01 (C-3′), 95.17 (C-8), 61.10 (OMe) 41.3 and 40.9 (C-3 and C-4).

The known compounds 7-hydroxycoumarin, β-amyrin acetate, sitosteryl acetate and 3-*O*-β-sitosterol glucoside acetate were identified by their spectral data and comparison with authentic samples.

Acknowledgements

R. Santillan acknowledges financial support from CONACYT (Project 3529P-E9607).

References

Abyshev, A. Z., & Brodskii, I. V. (1974). *Khimiya Prirodnykh Soedininenii, 10,* 574 Chemical Abstract, 1975, 82, 121643p.

Allen, F. H., Kennard, O., Watson, D. G., Brammer, L., Orpen, A. G., & Taylor, R. (1987). *Journal of the Chemical Society, Perkin Transactions, 2,* S1.

Bose, A. K., & Srinivasan, P. R. (1975). *Tetrahedron, 31,* 3025.

Caffieri, S., & Dall'Acqua, F. (1987). *Photochemistry and Photobiology, 45,* 13.

Elgamal, M. H. A., Elewa, N. H., Elkhrisy, E. A. M., & Duddeck, H. (1979). *Phytochemistry, 18,* 139.

Garg, S. K., Sharma, N. D., & Gupta, S. R. (1981). *Planta Medica, 43,* 306.

Iwu, M. M., Klayman, D. L., Jackson, J. E., Tally, J. D. and Andersen, S. L., U.S. US 5,290,553; Chemical Abstract, 1994, 121, 125208x.

Koch, L. (1936). *Archiv der Pharmazie, 274,* 343.

Krauch, C. H., Farid, S., & Schenck, G. O. (1966). *Chemische Berichte, 99,* 625.

Kuster, R. M., Bernardo, R. R., Da Silva, A. J. R., Parente, J. P., & Mors, W. B. (1994). *Phytochemistry, 36,* 221.

Lemmich, J., Havelund, S., & Thastrup, O. (1983). *Phytochemistry, 22,* 553.

Llabres, G., Baiwir, M., Vilegas, W., Pozetti, G. L., & Vilegas, J. H. Y. (1992). *Spectrochimica Acta, 48A,* 1347.

Macias, F. A., Massanet, G. M., Rodriguez-Luis, F., & Salvá, J. (1990). *Magnetic Resonance in Chemistry, 28,* 219.

Pozetti, G. L. (1988). *Ecletica Quimica, 13,* 41.

Rodighiero, G., & Cappellina, V. (1965). *Gazzetta Chimica Italiana, 91,* 103.

Swain, L. A., & Downum, K. R. (1990). *Biochemical Systematics and Ecology, 18,* 153.

Swain, L. A., Quirke, J. M. E., Winkle, S. A., & Downum, K. R. (1991). *Phytochemistry, 30,* 4196.

Terreaux, C., Maillard, M., Stoeckli-Evans, H., Gupta, M. P., Downum, K. R., Quirke, J. M. E., & Hostettmann, K. (1995). *Phytochemistry, 39,* 645.

Trehan, I. R. and Monder, C. (1968). *Tetrahedron Letters*, 67.

Vilegas, J. H. Y., Lancas, F. M., Vilegas, W., & Pozetti, G. L. (1993). *Phytochemical Analysis, 4,* 230.

Vilegas, J. H. Y., Vilegas, W., Camiloti, C. de F. & Pozetti, G. L. (1990). *Revista de Ciencias Farmaceúticas*, *12*, 89.

Vilegas, W., Vilegas, J. H. Y., & Pozetti, G. L. (1992). *Revista de Ciencias Farmaceúticas, 14,* 133.

Vilegas, W., Vilegas, J. H. Y., & Pozetti, G. L. (1994). *Revista Latinoamericana de Quimica, 23,* 78.

Woldu, Y., Abegaz, B., Botta, B., Delle Monache, G., & Delle Monache, F. (1988). *Phytochemistry, 27,* 1227.

Zdero, C., Bohlmann, F., & Niemeyer, H. M. (1990). *Phytochemistry, 29,* 326.