Phytochemistry, Vol. 21, No. 8, pp. 2147–2149, 1982.
Printed in Great Britain.

0031-9422/82/082147-03$03.00/0

AQUILLOCHIN, A COUMARINOLIGNAN FROM *AQUILARIA AGALLOCHA**

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(*Revised received* 2 *December* 1981)

Key Word Index—*Aquilaria agallocha*; Thymelaeaceae; coumarinolignan; aquillochin.

Abstract—Aquillochin, isolated from the whole plant of *Aquilaria agallocha*, has been shown to be a coumarinolignan, and a structure has been proposed on the basis of chemical and physical studies.

In a previous paper [1], we described the characterization of gmelofuran and a new sesquiterpene, agarol, from the hexane–ether eluates of the silica gel chromatography of the chloroform-soluble fraction of the alcoholic extract of *Aquilaria agallocha* Roxb. The processing of the subsequent $CHCl_3$–EtOAc eluates of the chromatography of this fraction has resulted in the isolation of a new coumarinolignan, aquillochin, and studies on its structure elucidation are reported here.

Aquillochin (**1**) was obtained as colourless needles, $C_{21}H_{20}O_9$ (M^+ at m/z 416.1129), which developed a yellow colour with dilute alkali, fluoresced under UV and showed a positive $FeCl_3$ test for phenols. The presence of the coumarin moiety was revealed from the UV maxima (326 nm), IR bands (1715, 1620 cm^{-1}) and ^1H NMR (doublets at δ 6.24 and 7.85, $J = 10$ Hz characteristic of C-3 and C-4 protons and the lone aromatic proton (δ 6.82, *s*) of C-5 in the coumarin nucleus) [2]. Its ^1H NMR also revealed the presence of three aryl methoxyl groups, one methylol group, one oxymethine proton (δ 4.26), a mono-oxybenzylic proton (δ 4.92, *d*, $J = 8$ Hz) and two aryl protons.

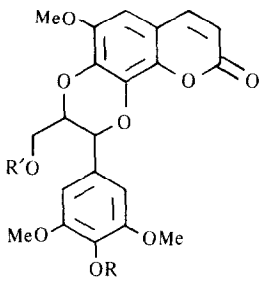
On methylation with CH_2N_2, it yielded the monomethyl ether, **2**, whereas on acetylation it gave a diacetate, **3**, having a phenolic and an alcoholic acetoxy methyl at δ 2.24 and 1.96, respectively. The remaining two oxygens must, therefore, be present as ether linkages and most probably constitute the required additional dioxane ring with the remaining C_6–C_3 fragment of the molecule, which was indicated by the presence of the MS fragment at m/z 208 due to cation **a** ($C_{10}H_8O_5^+$), due to the coumarin nucleus bearing one methoxyl group and two *ortho* aryloxy groups. [3].

In the ^1H NMR spectrum of the diacetate, the carbinolic methylene signal at δ 3.7 was now shifted downfield by 0.33 ppm, which indicated that C-9′ bears a primary OH group. The existence of the C_6–C_3 unit as $C_6H_2$3′,5′-OMe(4′-OH)–CH–CH–CH_2OH was indicated by the ^1H NMR spectrum showing two equivalent aromatic protons (δ 6.68, *s*) and two vicinal aliphatic oxymethines linked to a phenyl group (δ 4.92, *d*, $J = 8$ Hz) and to a $-CH_2OH$ group [4] (δ 4.26, *m*) and was confirmed by DNMR experiments and the presence of a most abundant retro-Diels–Alder fragment ion at m/z 210 (**b**) [2, 3] in the MS of **1** and the corresponding ion at m/z 224 in the MS of monomethyl ether **2**. This was also supported by the fragment at m/z 167 due to the cation $C_9H_{11}O_3$ (**c**) in the MS of **1** and the relevant ion at m/z 181 in the case of **2**. The *trans* arrangement of the substituents at C-7′ and C-8′ was inferred from the coupling constant values of H-7′ and H-8′ signals in **1**, **2** and **3**, which were of the order of 8 Hz.

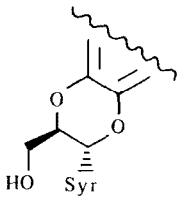
The substitution pattern of the coumarin nucleus was elucidated by NOE experiments. The three methoxyl groups in the diacetyl derivative **3** appeared as two singlets of six and three protons, the latter belonging to the coumarin moiety. The irradiation of the 3H singlet at δ 3.79 caused an increase of 19.5% in the integrated intensity of the C-5 proton signal [3] at δ 6.44 while the H-2′, H-6′ and H-4 signals at δ 6.54 and 7.48 remained unaffected, which was compatible with the placement of the methoxyl group at C-6. Conversely, the saturation of the 6H singlet at δ 3.72 caused a 17.39% increase in the integrated intensity of the aromatic 2H singlet at δ 6.54 in accordance with the presence of two methoxyl groups at C-3′ and C-5′.

The ^{13}C NMR spectrum of aquillochin diacetate, **3** (Table 1), provided further evidence for the structure of aquillochin. Only 21 signals for 25 carbons were observed in the pnd spectrum, which were assigned with the aid of off-resonance decoupled spectrum and the reported literature data on related compounds [3, 5]. However, the chemical shift of C-1′ at 131.59 ppm clearly indicates the equatorial disposition of the syringacyl group in the molecule in analogy with ^{13}C NMR chemical shift data of the analogous carbon atom in furanolignans [6], wherein it has been shown

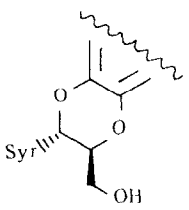
*CDRI communication No. 2988.



1 R = R′ = H
2 R = Me; R′ = H
3 R = R′ = COMe

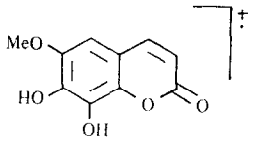


1a

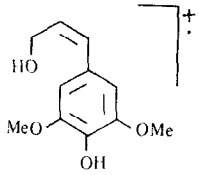


1b

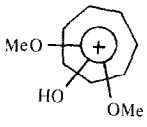
Syr = syringacyl



a *m/z* 208



b *m/z* 210



c *m/z* 167

that the chemical shift of this carbon is characteristic of the stereochemistry of attachment to the basic skeleton. Thus aquillochin can be represented either as **1a** or **1b**.

Table 1. ^{13}C NMR spectral data* of aquillochin diacetate (**3**)

Carbon assigned	Chemical shift	Carbon assigned	Chemical shift
C-2	160.25(*s*)	C-1′	131.59(*s*)
C-3	114.15(*d*)	C-2′	104.48(*d*)
C-4	143.49(*d*)	C-3′	152.68(*s*)
C-5	100.97(*d*)	C-4′	138.67(*s*)
C-6	145.79(*s*)	C-5′	152.68(*s*)
C-7	136.96(*s*)	C-6′	104.48(*d*)
C-8	133.09(*s*)	C-7′	77.03(*d*)
C-9	145.69(*s*)	C-8′	75.02(*d*)
C-10	111.85(*s*)	C-9′	62.34(*t*)
		3 × 0 Me	56.25(*q*)
		Me (acetyl)	21.04(*q*)
			21.24(*q*)
		C=O (acetyl)	168.20(*s*)
		C=O	170.10(*s*)

*pnd and sford spectra were recorded in $CDCl_3$: ppm from TMS.

Aquillochin is the third member of a new class of coumarino-lignoids. The other members of this class have been very recently reported from *Cleome viscosa* seeds [3] and *Protium opacum* [2].

EXPERIMENTAL

Mps are uncorr. The ^1H NMR spectra were recorded in $CDCl_3$, unless stated otherwise, with TMS as internal standard. The NOE experiment was performed on a Perkin–Elmer R-32 NMR spectrometer.

The $CHCl_3$-soluble fraction (9.6 g) of the ethanolic extract of the plant was chromatographed over Si gel (200 g) in hexane–Et_2O. Twenty-five fractions (350 ml each) were collected and the tail and $CHCl_3$–EtOAc (1:1) eluates were concd (4.3 g) and rechromatographed on Si gel in $CHCl_3$ with increasing amounts of MeOH. The residue from the $CHCl_3$–MeOH (98:2) eluate 16–20 (0.426 g) crystallized from MeOH to give aquillochin (**1**), mp 220° dec., R_f 0.5 (2% $CHCl_3$–MeOH). UV λ_{max}^{MeOH} nm: 326 (log ε 3.687). IR ν_{max}^{KBr} cm^{-1}: 3400 (OH), 2920, 1715, 1620 (α-pyrone), 1610, 1564 (Ar), 1420, 1418, 1316, 1300, 1118, 1010 and 840. ^1H NMR (DMSO-d_6): δ 3.7 (2H, *m*, $-CH_2OH$), 3.74 (9H, *s*, 3-OMe), 4.26 (1H, *m*, –CHO–), 4.92 (1H, *d*, J = 8 Hz, Ar–CH–O–), 6.24 (1H, *d*, J = 10 Hz, C-3H), 6.68 (2H, *s*, -C-2′, 6′ H), 6.82 (1H, *s*, C-5H), 7.85 (1H, *d*, J = 10 Hz, C-4H). MS (rel. int.) *m/z*: 416.1129 $[M]^+$ (25), 398 $[M-18]^+$ (5), 249 (12.8), 219 (11.4), 210 ($C_{11}H_{14}O_4$, 100), 208 ($C_{10}H_8O_5$, 52.8), 193 (21.4), 182 (44.4), 167 ($C_9H_{11}O_3$, 66.4), 154 (26.1), 137 (17.1), 121 (13.5), 107 (11.4), 91 (12.1) and 79 (25.7).

Aquillochin methyl ether (**2**). **1**, on reaction with CH_2N_2 at 0°, gave pale yellow needles (MeOH), mp 256°. ^1H NMR: δ 3.5 (2H, *m*, $-CH_2OH$), 3.86 (12H, *s*, 4-OMe), 4.1 (1H, *m*, –CHO–), 5.05 (1H, *d*, J = 8 Hz, Ar–CH–O–), 6.3 (1H, *d*, J = 10 Hz, C-3H), 6.52 (1H, *s*, C-5H), 6.66 (2H, *s*, C-2′, 6′ H), 7.58 (1H, *d*, J = 10 Hz, C-4H), MS *m/z*: 430 $[M]^+$, 412, 400, 397, 372, 249, 224, 181, 168, 149, 137, 124, 111, 97 and 71.

Aquillochin diacetate (**3**). Acetylation of **1** (Ac_2O–C_5H_5N overnight at room temp.) yielded a diacetate as colourless needles (MeOH), mp 188°, R_f 0.5 (1% $CHCl_3$–MeOH); IR ν_{max}^{KBr} cm^{-1}: 2920, 1740, 1690, 1684, 1610, 1562, 1420, 1418, 1316, 1118, 1010 and 840. ^1H NMR: δ 1.96 (3H, *s*, -OAc), 2.24 (3H, *s*, Ar–OAc), 3.72 (6H, *s*, 2-OMe), 3.79 (3H, *s*, C-6 -OMe), 4.03 (2H, *m*, $-CH_2OAc$), 4.31 (1H, *m*, –CH–O–), 4.88 (1H, *d*, J = 8 Hz, Ar–CH–O–), 6.18 (1H, *d*, J = 10 Hz, C-3H), 6.44 (1H, *s*, C-5H), 6.54 (2H, *s*, C-2′, 6′H), 7.48 (1H, *d*, J = 10 Hz, C-4H). MS *m/z*: 500 $[M]^+$, 458 $[M-42]^+$, 398 $[M-42-60]^+$, 370, 357, 325, 291, 257, 219, 210, 208, 207, 191, 181, 161, 149, 133, 121, 105, 103, 91, 79 and 77.

Acknowledgements—We thank Messrs. B. B. P. Srivastava, R. K. Singh and Mrs. K. Kapoor for spectral data and Prof. Dr. F. Bohlmann, Berlin, for high resolution MS.

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Phytochemistry, Vol. 21, No. 8, pp. 2149–2151, 1982.
Printed in Great Britain.

0031-9422/82/082149-03$03.00/0

BAKUCHALCONE, A DIHYDROFURANOCHALCONE FROM THE SEEDS OF *PSORALEA CORYLIFOLIA**

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(*Received* 17 *November* 1981)

Key Word Index—*Psoralea corylifolia*; Leguminosae; 4, 2'-dihydroxy-2"-(1-hydroxy-1-methylethyl)-2", 3"-dihydrofurano(4", 5":3', 4')chalcone; (±)-6-acetyl-3, 5-dihydroxy-2, 2-dimethylchroman; (±)-8-acetyl-3, 5-dihydroxy-2, 2-dimethylchroman; (±)-5-acetyl-2, 3-dihydro-2(1-hydroxy-1-methylethyl)-4-hydroxybenzofuran.

Abstract—A new dihydrofuranochalcone has been identified in seeds of *Psoralea corylifolia* and its structure confirmed by synthesis.

In continuation of our earlier investigations [1–7] on the phytochemistry of the seeds of *Psoralea corylifolia*, we now report the isolation of a minor constituent, bakuchalcone. It was obtained by repeated CC of the ether extract of the defatted seeds over Si gel.

Bakuchalcone (**1**) crystallized from acetone–*n*-hexane as pale-yellow needles mp 204–205°. The molecular ion at 340.1262 gave its molecular formula as $C_{20}H_{20}O_5$. Its chalcone structure was indicated by the UV bands at 366, 308, and 240 nm, which showed a bathochromic shift of 64 nm in the longer wavelength band with an increase in the intensity with sodium methoxide, indicative of the presence of a OH-4 group. A bathochromic shift of 54 nm with aluminium chloride–hydrochloric acid showed the presence of a chelated hydroxyl group. Its IR (KBr) showed characteristic absorption at 1637 cm^{-1} due to a chalcone carbonyl, at 1372 and 1360 cm^{-1} due to a gem dimethyl and at 838 cm^{-1} due to a *para*-substituted benzene ring. The compound formed a diacetate indicating the presence of two hydroxyl groups.

^1H NMR (Me_2CO-d_6) of the compound gave a singlet at δ 1.25 for gem dimethyl protons. A doublet at δ 3.1 showed the presence of two benzylic protons. A triplet for a methine proton appearing at δ 4.75 was characteristic of a dihydrobenzofuran ring substituted at the 2-position. The two *ortho*-coupled doublets centred at δ 6.89 and 7.65, each integrating for two protons, were due to two sets of protons at C-3, C-5 and C-2, C-6 (A_2B_2 system of a *para*-substituted B-ring). An *ortho*-coupled doublet at δ 6.33 integrating for one proton could be assigned to the C-5' proton indicating that the 5'- and 6'-positions of the A-ring are free. The corresponding downfield doublet for C-6' proton appeared at δ 7.98 while the α- and β-protons of the chalcone molecule appeared as a singlet at δ 7.73. ^1H NMR ($CDCl_3$) of the diacetate showed the presence of only two hydroxyl groups. That one of these is present in the 4-position was confirmed by subjecting bakuchalcone to alkali hydrolysis; *p*-hydroxybenzoic acid was identified as one of the products. The bathochromic shift in the longer wavelength UV band with aluminium chloride confirmed the presence of a OH-2' group and ruled out the possibility of a dihydrofuran ring attachment to ring A at C-2' and C-3'. The above data accounted

*Communication no. RRL/81-011.