Acta Crystallographica Section C
Crystal Structure Communications
ISSN 0108-2701

Taxiphyllin from *Henriettella fascicularis*

Angela I. Calderón,[a] Christian Terreaux,[a] Mahabir P. Gupta,[b] Kurt Hostettmann[a] and Kurt J. Schenk[c]*

[a]Institut de Pharmacognosie et Phytochimie, Université de Lausanne, BEP, CH-1015 Lausanne, Switzerland, [b]Centre for Pharmacognostic Research on Panamanian Flora (CIFLORPAN), College of Pharmacy, Panama University, Panama City, Republic of Panama, and [c]Institut de Cristallographie, Université de Lausanne, BSP Dorigny, CH-1015 Lausanne, Switzerland
Correspondence e-mail: kurt.schenk@ic.unil.ch

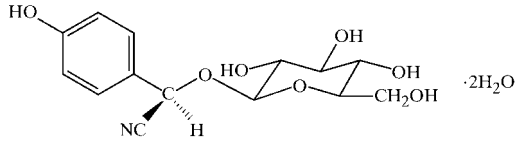
Received 6 November 2002
Accepted 15 January 2003
Online 28 February 2003

(2*R*)-α-(β-D-Glucopyranosyloxy)-4-hydroxybenzeneacetonitrile (taxiphyllin) dihydrate, $C_{14}H_{17}NO_7\cdot 2H_2O$, is a naturally occurring cyanogenetic glycoside which has been isolated from *Henriettella fascicularis* (Sw.) C. Wright (Melastomataceae). Its structure is stabilized by a wealth of intermolecular O—H···O and O—H···N hydrogen bonds spun into a three-dimensional network. Further stabilization arises from an intramolecular O—H···O bond and weak intermolecular C—H···O interactions. The very anisotropic growth speeds of the basal pinacoids from methanol mirror a certain structural inhomogeneity.

Comment

Henriettella fascicularis (Sw.) C. Wright (Melastomataceae) occurs mainly in the provinces of Herrera, Darién and Panama, Republic of Panama (Woodson *et al.*, 1965). The methanol extract of the branches of *Henriettella fascicularis* yields the cyanogenetic glycoside taxiphyllin, which has previously been isolated from *Triglochin maritima* var. Debilis M. E. Jones (Juncaginaceae) (Nahrstedt *et al.*, 1979). The occurrence of taxiphyllin in *H. fascicularis* represents the first report of cyanogenetic glycosides in the genus *Henriettella*. The presence of this compound, which is toxic to humans and herbivores, in *H. fascicularis* explains the absence of any ethnomedical claim for this plant in Panamanian traditional medicine. The crystal structure of taxiphyllin dihydrate from *H. fascicularis*, (I), is presented here. This is a novel solvate; until now only the ethanolate (m.p. 441–442 K) and the pentaacetate (417.0–417.8 K) had been known (Towers *et al.*, 1964). Strangely, pure taxiphyllin is not mentioned in the literature, contrary to its diastereomer dhurrin, which has been described without solvent molecules (m.p. 436–438 K; Mao *et al.*, 1965).

The average bond lengths in the molecule of (I) (Fig. 1) fall well within the ranges listed in *International Tables for Crystallography* (1992, Vol. C). Following the example of Desiraju (1996), normalized O—H and C—H distances were used for the preparation of Table 1, rather than those obtained directly from the refined model. These normalized distances were based on neutron work, namely on α-D-glucose (Brown & Levy, 1979; O—D = 0.966–0.973 Å, C—O—D = 106.70–112.13° and C—D 1.094–1.107 Å), on methanol from a powder study (Torrie *et al.*, 1989; O—D = 1.010 Å, C—O—D = 110.17° and C—D 1.058–1.089 Å) and on heavy water at 223 K (Peterson & Levy, 1957; O—D = 1.011–1.015 Å and D—O—D = 109.10–109.87°).



(I)

The χ^2 value (goodness-of-fit) of 0.860 is quite remarkable, since it has been achieved with experimental weights. Indeed, a δR_{exp} *versus* δR_{stat} normal probability plot (NPP; Abrahams & Keve, 1971) displays a slope of 0.731 (1) and a δR_{exp} axis intercept of 0.037 (1). Since the NPP is perfectly straight between ±2 with the expected bent tails, this low χ^2 value means that the experimental s.u. values have been overestimated by 27% on average (this is contrary to the usual tendency of underestimating s.u. values). The very small intercept and the other usual plots confirm the sound nature of this data collection, which is furthermore mirrored in only 12 inconsistent equivalents. Despite the presence of one N and quite a few O atoms and the good quality of the data, the structure does not possess a high enough enantiomorph-discriminating capacity (Flack & Bernardinelli, 2000) to furnish the absolute configuration of the six asymmetric C atoms. Since the cyanogenetic glycosides belong to the secondary metabolism products of plants, which typically consist of an α-hydroxynitrile-type aglycone and a D-glucose moiety (Vetter, 2000), we have given preference to the configuration shown in Fig. 1. The relative configurations are therefore *R*, *R*, *R*, *S*, *S* and *R* for atoms C1*A*, C2, C2*A*, C3*A*, C4*A* and C5*A*, respectively.

The structure of (I) may be said to be built up of three types of (001) layers (Fig. 2), namely sheets of *p*-hydroxymandelonitrile, followed by sheets of β-D-glucopyranoside and finally walls of water molecules. The aromatic moieties are not quite parallel within their layer, with a pair of molecules related by a twofold axis spanning an angle of roughly 30°. These pairs are then piled on top of each other, much resembling a stack of shuttlecocks. A similar situation exists in the structure of phenol (Scheringer, 1963; Zavodnik *et al.*, 1987), which consists of layers of phenol rings, and O—H···O chains and chains of pure phenol rings. In the structure of phenol, the phenol rings also span an angle of ∼40°, but are shifted with respect to each other, much in the way of a zip.

  DOI: 10.1107/S0108270103001355

In (I), as well as in phenol, the strong O—H···O hydrogen bonds determine the packing. In phenol (three equally strong H···O bonds of $\simeq$ 1.73 Å and O—H···O angles of $\simeq$ 159°), this leads to a rather unfavourable packing ($k \simeq 0.67$; Kitaigorodski, 1979). In (I), with somewhat weaker hydrogen bonds (Table 1), the packing, thanks to the presence of sugar and water moieties, is more compact ($k \simeq 0.73$), but is still looser than that of suberin A, a molecule quite similar to (I) (Olafsdottir *et al.*, 1991), for which $k \simeq 0.75$. The absence of phenol rings in suberin A allows for stronger hydrogen bonds (H···O = 1.80–2.02 Å and O—H···O = 153–162°) and quite a few respectable C—H···O and C—H···N hydrogen-bond interactions; the hydrogen-bond network is three-dimensional and very strong. This explains the much higher melting point of suberin A (470–471 K) compared with that of (I) (406–409 K). In view of the rather disparate melting points of the various solvates, we shall embark on a more systematic study of these compounds and their physical properties.

The van der Waals shape of (I) is much more unwieldy than that of suberin A and it is probably only because of the water molecules that its k value is even this high. It is noteworthy that benzene and its derivatives do not seem to lend themselves to compact packing, since even pure benzene ($k \simeq 0.659$; Bacon *et al.*, 1964) and benzoic acid ($k \simeq 0.693$; Feld *et al.*, 1981) display rather low k values.

The shortest C—C distance between two phenol rings in (I) is 3.396 (5) Å; this distance is 3.09 Å in benzene at 138 K (Bacon *et al.*, 1964). This, together with their non-parallelism, indicates the absence of any π–π-stacking interactions (Magistrato *et al.*, 2001).

The ten atoms H7O, O7, C3–C8, C2 and H2 lie in a plane, with a mean deviation of 0.042 Å. The sugar moieties and the water molecules are connected *via* a quite complex three-dimensional network of strong hydrogen bonds (Table 1). All but two of these are two-centre bonds, but atoms H6O and H22*W* are involved in three-centre bonds. Neither of these

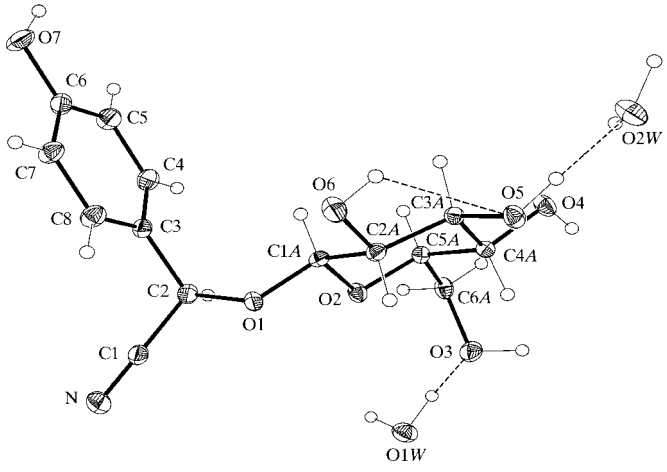


Figure 1
A view of the molecular structure of (I) with the atom-numbering scheme. Displacement ellipsoids are drawn at the 30% probability level and H atoms are shown as small spheres of arbitrary radii. Intramolecular hydrogen bonds are shown as dashed lines.

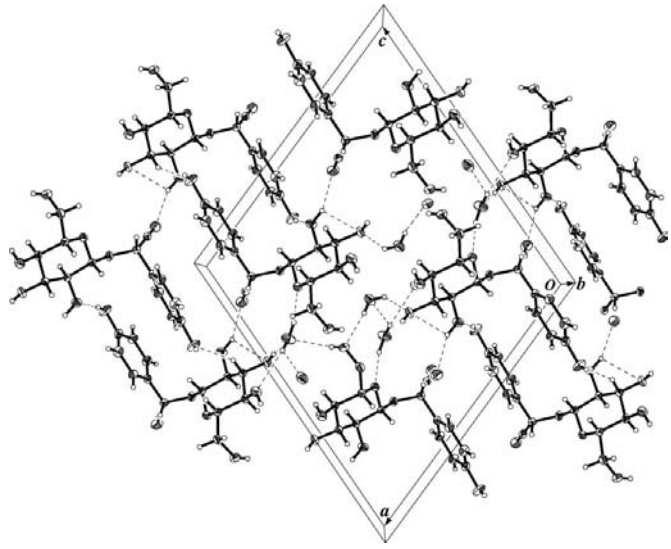


Figure 2
The hydrogen bonds (dashed lines) in the *ac* plane of (I).

satisfies the 0.2 Å criterion (Taylor *et al.*, 1984). This failure might be linked to the fact that the difference maps indicate some degree of disorder that needs to be clarified using a low-temperature or neutron study. Five of the bonds lie within the range expected for ice (Jeffrey & Saenger, 1991).

Besides that listed in Table 1, there are also other weak C—H···O interactions which are not included, since, in view of the low acidity of the participating H atoms, their contribution to the cohesive energy would have to be checked by non-trivial experimental (IR or NMR spectrosocopies) or theoretical [SCF–MO (self-consistent field–molecular orbital) or MP2 *ab initio* computations] means. The same assessment would also have to be applied to the intramolecular O6—H6O···O5 bond.

The growth speeds of the basal pinacoids in methanol are very anisotropic indeed, with $v_c < v_a << v_b$. It might be conjectured that the small v_c and v_a speeds are related to a certain incompatibility of the packing of the aromatic and sugar moieties. The sugar and water moieties, on the other hand, are easily fixed with respect to each other by a wealth of rather strong hydrogen bonds (Table 1), and thus growth can proceed quickly along [010].

Experimental

Branches of *Henriettella fascicularis* (660 g) were extracted with dichloromethane and the resulting residue was extracted three times with MeOH at room temperature. The solvent was removed by evaporation at reduced pressure, and the residue was successfully fractionated with EtOAc and water. The EtOAc fraction was separated by medium-pressure liquid chromatography (MPLC) on a LiChroprep RP-18 column (450 × 20 mm), using MeOH–H_2O (25:75) to yield a fraction containing the title compound, and then using MeOH–H_2O (35:65) to obtain a fraction containing ellagic acid (3,3′-dimethyl ether-*O*-β-D-glucopyranoside; 16 mg, 0.002% *w*/*w*). The title compound was further purified by gel filtration on Sephadex LH-20 (45 × 3 cm), using MeOH 100% (3.7 mg, 0.006% *w*/*w*); m.p.

406–409 K. Spectroscopic analysis, $[\alpha]_D^{25}$ −32.0° (*c* 0.0029, MeOH); ^{1}H NMR (500 MHz, CD_3OD, δ): 7.39 (2H, *d*, *J* = 8.3 Hz, H4, H8), 6.84 (2H, *d*, *J* = 8.3 Hz, H5, H7), 5.80 (1H, *s*, H2), 4.17 (1H, *d*, *J* = 6.3 Hz, H1*A*), 3.90 (1H, *d*, *J* = 10.7 Hz, H6*A*1), 3.68 (1H, *dd*, *J* = 5.8 and 6.4 Hz, H6*A*2), 3.28 (3H, *m*, H2*A*, H4*A*, H5*A*; signal pattern unclear due to overlapping), 3.18 (1H, *t*, *J* = 6.3 and 8.3 Hz, H3*A*); ^{13}C NMR (125 MHz, CD_3OD, δ): 160.3 (C6), 130.9 (C4, C8), 125.1 (C3), 119.7 (C1), 116.8 (C5, C7), 101.0 (C1*A*), 78.3 (C3*A*), 77.9 (C5*A*), 74.7 (C2*A*), 71.5 (C4*A*), 67.9 (C2), 62.8 (C6*A*). Crystals of (I) grew as [010] laths from evaporating methanol; the measured specimen was bounded by {100}, {010} and {001} pinacoids.

Crystal data

$C_{14}H_{17}NO_7\cdot 2H_2O$	D_x = 1.434 Mg m^{-3}
M_r = 347.32	Mo $K\alpha$ radiation
Monoclinic, *C*2	Cell parameters from 754 reflections
a = 16.055 (4) Å	θ = 2.6–25.9°
b = 6.2858 (17) Å	μ = 0.12 mm^{-1}
c = 16.895 (5) Å	*T* = 293 (2) K
β = 109.299 (5)°	Lath, colourless
V = 1609.2 (8) Å^3	0.35 × 0.03 × 0.01 mm
Z = 4	

Data collection

Bruker SMART CCD area-detector diffractometer	R_{int} = 0.058
ω scans	θ_{max} = 25°
3421 measured reflections	*h* = −18 → 18
1551 independent reflections	*k* = −7 → 7
1049 reflections with $I > 2\sigma(I)$	*l* = −18 → 20

Refinement

Refinement on F^2	H atoms treated by a mixture of independent and constrained refinement
$R[F^2 > 2\sigma(F^2)]$ = 0.033	$(\Delta/\sigma)_{max}$ < 0.001
$wR(F^2)$ = 0.047	$\Delta\rho_{max}$ = 0.17 e Å^{-3}
S = 0.84	$\Delta\rho_{min}$ = −0.15 e Å^{-3}
1551 reflections	
234 parameters	

Table 1
Normalized inter- and intramolecular hydrogen-bonding geometry (Å, °) in (I).

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
O3—H3O···O2*W*^{i}	0.97	1.92	2.849 (4)	159
O4—H4O···O1*W*^{ii}	0.97	1.89	2.828 (3)	164
O5—H5O···O2*W*	0.97	1.81	2.764 (4)	170
O6—H6O···N^{iii}	0.97	2.09	2.970 (4)	150
O7—H7O···O6^{iv}	0.97	1.75	2.694 (4)	166
O1*W*—H11*W*···O3	1.01	1.78	2.725 (4)	157
O1*W*—H12*W*···O5^{v}	1.01	1.95	2.807 (3)	140
O2*W*—H21*W*···O2^{iii}	1.01	1.89	2.901 (3)	175
O2*W*—H22*W*···O4	1.01	2.29	3.060 (4)	132
O2*W*—H22*W*···O1*W*^{iii}	1.01	2.22	2.943 (4)	127
C3*A*—H3*A*···O7^{iv}	1.10	2.34	3.342 (4)	151
O6—H6O···O5	0.97	2.43	2.860 (3)	107

Symmetry codes: (i) $1-x, y, 1-z$; (ii) $\frac{1}{2}-x, y-\frac{1}{2}, 1-z$; (iii) $x+\frac{1}{2}, y-\frac{1}{2}, z$; (iv) $\frac{1}{2}-x, y-\frac{1}{2}, -z$; (v) $x-\frac{1}{2}, y-\frac{1}{2}, z$.

364 Friedel pairs were averaged. H atoms bonded to C atoms were placed in calculated positions (C—H = 0.93–0.98 Å) and then refined using a riding model, with U_{iso}(H) = 1.2U_{eq}(C). The hydroxy and water H atoms were located in difference Fourier maps, but were refined with restraints (O—H = 0.82 Å) and with U_{iso}(H) = 1.5U_{eq}(O).

Data collection: *SMART* (Bruker, 1998); cell refinement: *SMART*; data reduction: *SAINT* (Bruker, 1998); program(s) used to solve structure: *SIR*97 (Altomare *et al.*, 1997); program(s) used to refine structure: *SHELXL*97 (Sheldrick, 1997); molecular graphics: *SHELXTL* (Siemens, 1996); software used to prepare material for publication: *SHELXTL* and *PLATON* (Spek, 2001).

Supplementary data for this paper are available from the IUCr electronic archives (Reference: LN1156). Services for accessing these data are described at the back of the journal.

References

Abrahams, S. C. & Keve, E. T. (1971). *Acta Cryst.* A**27**, 157–165.
Altomare, A., Cascarano, C., Giacovazzo, C., Guagliardi, A., Moliterni, A. G. G., Burla, M. C., Polidori, G., Camalli, M. & Spagna, R. (1997). *SIR*97. University of Bari, Italy.
Bacon, G. E., Curry, N. A. & Wilson, S. A. (1964). *Proc. R. Soc. London Ser. A*, **279**, 98–110.
Brown, G. M. & Levy, H. A. (1979). *Acta Cryst.* B**35**, 656–659.
Bruker (1998). *SMART* and *SAINT*. Versions 5.0. Bruker AXS Inc., Madison, Wisconsin, USA.
Desiraju, G. (1996). *Acc. Chem. Res.* **29**, 441–449.
Feld, R., Lehmann, M. S., Muir, K. W. & Speakman, J. C. (1981). *Z. Kristallogr.* **157**, 215–231.
Flack, H. D. & Bernardinelli, G. (2000). *J. Appl. Cryst.* **33**, 1143–1148.
Jeffrey, G. A. & Saenger, W. (1991). *Hydrogen Bonding in Biological Structures*, Table 7.7. Berlin: Springer-Verlag.
Kitaigorodski, A. I. (1979). *Molekülkristalle*. Berlin: Akademie-Verlag.
Magistrato, A., Pregosin, P. S., Albinati, A. & Röthlisberger, U. (2001). *Organometallics*, **20**, 4178–4184.
Mao, C.-H., Blocher, J. P., Anderson, L. & Smith, D. C. (1965). *Phytochemistry*, **4**, 297–303.
Nahrstedt, A., Hösel, W. & Walther, A. (1979). *Phytochemistry*, **18**, 1137–1141.
Olafsdottir, E. S., Sørensen, A. M., Cornett, C. & Jaroszewsky, J. W. (1991). *J. Org. Chem.* **56**, 2650–2655.
Peterson, S. W. & Levy, H. A. (1957). *Acta Cryst.* **10**, 70–76.
Scheringer, C. (1963). *Z. Kristallogr.* **119**, 273–283.
Sheldrick, G. M. (1997). *SHELXL*97. University of Göttingen, Germany.
Siemens (1996). *SHELXTL*. Version 5.05. Siemens Analytical X-ray Instruments Inc., Madison, Wisconsin, USA.
Spek, A. L. (2001). *PLATON*. University of Utrecht, The Netherlands.
Taylor, R., Kennard, O. & Versichel, W. (1984). *J. Am. Chem. Soc.* **106**, 244–248.
Torrie, B. H., Weng, S.-X. & Powell, B. M. (1989). *Mol. Phys.* **67**, 575–581.
Towers, G. H. N., McInnes, A. G. & Neish, A. C. (1964). *Tetrahedron*, **20**, 71–77.
Vetter, J. (2000). *Toxicon*, **38**, 11–36.
Woodson, R. E., Schery, R. S. W. & Gleason, H. A. (1965). *Ann. Mo Bot. Gard.* **45**, 360–362.
Zavodnik, V. E., Bel'skii, V. K. & Zorkii, P. M. (1987). *J. Struct. Chem.* **28**, 793–795.