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The Crystal Structure of 3,3′,5,5′,7-Pentahydroxy-4′-methoxy-2,3-*cis*-flavane Tetrahydrate

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The title compound crystallizes in the space group $P2_1$ with a unit cell of dimensions a=8.760(1), b=19.892(8), c=10.251(1) Å and β=97.53(1)°. The structure has been determined from single crystal X-ray diffraction data and refined by full matrix least-squares to an R value of 0.044. The asymmetric unit contains two independent molecules and eight water molecules of hydration. The molecules are stacked in rows extending in the a-direction. Between these rows water molecules are accommodated. Together with the flavane hydroxyl groups they form an extensive hydrogen bond network.

Several flavonoids[1,2] have been isolated from the root bark of the tree *Elaeodendron balae* Kosterm. growing in Sri Lanka. The major constituent among these flavonoids, 3,3′,5,5′,7-pentahydroxy-4′-metoxy-2,3-*cis*-flavane which has muscle-relaxant activity, could be obtained in crystalline form. In this paper we report the crystal structure of the compound. The analysis was performed to confirm the earlier reported structure[1] which was based solely on spectroscopic data.

EXPERIMENTAL

A crystal with the dimensions 0.36×10×0.05 mm was selected and intensity data were collected on an Enraf-Nonius CAD4F-11 diffractometer using monochromated Cu$K\alpha$ radiation. The angular settings of 25 reflections were measured to calculate the lattice parameters. The $\theta/2\theta$ scan method was employed and the scan width was 1.6° plus a dispersion term. The scan speed ranged from 6.7 to 1.0 (2θ)min^{-1} so that weaker reflections were measured more slowly. Three standard reflections which were checked every second hour showed non-significant intensity fluctuations. In all 2849 independent reflections within the range $1<\theta<60°$ were measured. 1931 reflections with $I>3\sigma(I)$ were considered observed. The intensities were corrected for Lorentz and polarization effects but not for extinction or absorption.

Crystal data. Molecular formula $C_{16}H_{16}O_7.4H_2O$, space group $P2_1$, unit cell a=8.760(1), b=19.892(8), c=10.25(1) Å and β=97.53(1)°, V=1771 Å^3, Z=4, M=392.357, D_c=1.472 gcm^{-3}, μ(Cu$K\alpha$)=13.2 cm^{-1}

STRUCTURE DETERMINATION AND REFINEMENT

The structure was solved with the multisolution program system MULTAN.[3] Among the 64 phase sets generated the one with the highest combined figure of merit contained the correct

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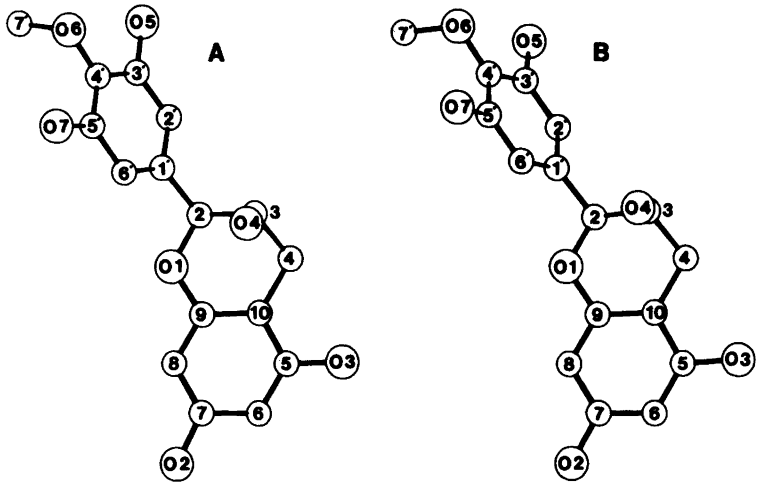

Fig. 1. The conformation and atom-numbering system for the two independent molecules A and B. Both molecules are oriented so that C8, C9 and C10 are in the plane of the paper.

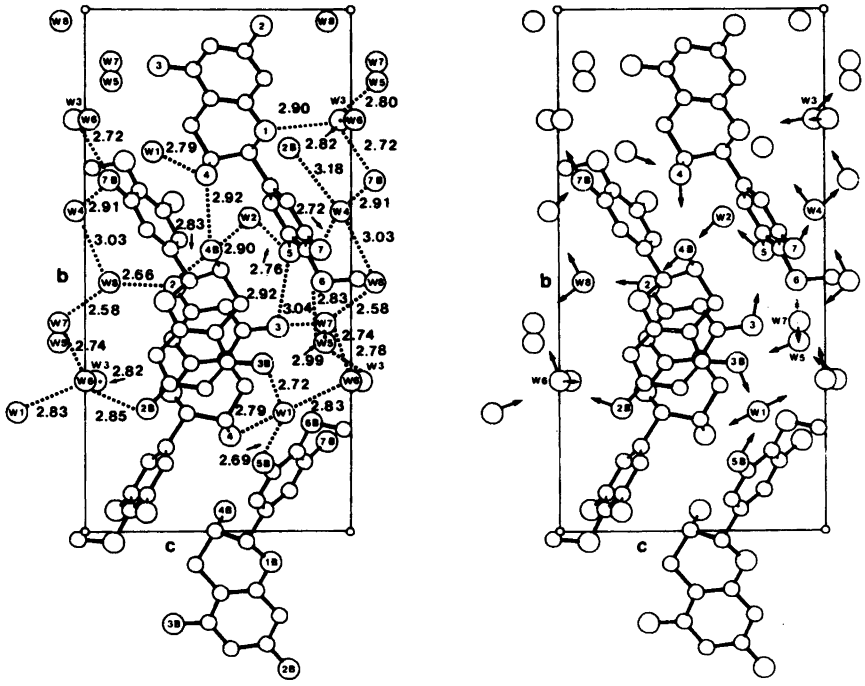

Fig. 2. Molecular packing and hydrogen bond interactions. The structure is projected onto the *bc*-plane. *Left:* Dotted lines indicate intermolecular O···O distances less than 3.2 Å. *Right:* Arrows indicate hydrogen bond donor directions. Labeled atoms are surrounded by oxygen atoms at a distance less than 3.2 Å. For W2 and W7 the position of only the hydrogen atom could be determined.

Table 1. Atomic fractional coordinates and equivalent isotropic temperature factors ($\times 10^2$) for the non-hydrogen atoms. $U_{eq}=(1/3)(U_{11}+U_{22}+U_{33}+2*U_{13}*\cos\beta)$

	Atom	x	y	z	U_{eq}
Molecule A	O1	0.3473(6)	0.7684(–)	0.6756(5)	3.9(0.3)
	C2	0.4509(8)	0.7255(4)	0.6165(6)	3.2(0.4)
	C3	0.3945(8)	0.7127(4)	0.4711(7)	3.3(0.4)
	C4	0.3885(9)	0.7787(4)	0.4000(7)	3.8(0.4)
	C5	0.2292(10)	0.8846(4)	0.4058(7)	4.1(0.4)
	C6	0.1456(9)	0.9300(4)	0.4681(8)	4.3(0.4)
	C7	0.1343(8)	0.9214(4)	0.6013(8)	3.7(0.4)
	C8	0.2057(9)	0.8681(4)	0.6667(7)	3.8(0.4)
	C9	0.2858(8)	0.8226(4)	0.6038(6)	3.0(0.4)
	C10	0.3016(8)	0.8298(4)	0.4704(7)	3.4(0.4)
	C1′	0.4759(8)	0.6616(4)	0.6955(6)	2.9(0.4)
	C2′	0.6186(8)	0.6299(4)	0.6976(7)	3.5(0.4)
	C3′	0.6457(9)	0.5703(4)	0.7655(8)	4.0(0.4)
	C4′	0.5334(9)	0.5408(4)	0.8310(7)	3.7(0.4)
	C5′	0.3908(9)	0.5718(4)	0.8256(7)	3.7(0.4)
	C6′	0.3638(8)	0.6338(4)	0.7593(7)	3.4(0.4)
	C7′	0.6242(19)	0.4842(6)	1.0223(10)	9.6(0.8)
	O2	0.0520(6)	0.9694(3)	0.6568(6)	4.9(0.3)
	O3	0.2493(8)	0.8924(3)	0.2777(6)	6.2(0.4)
	O4	0.2427(6)	0.6842(2)	0.4557(5)	3.9(0.3)
	O5	0.7842(6)	0.5369(3)	0.7700(6)	4.9(0.3)
	O6	0.5587(7)	0.4792(3)	0.8906(5)	4.8(0.3)
	O7	0.2826(7)	0.5393(3)	0.8838(6)	5.9(0.4)
Molecule B	O1	0.3166(6)	0.4421(3)	0.3018(5)	3.9(0.3)
	C2	0.4195(8)	0.4809(4)	0.3923(7)	3.2(0.4)
	C3	0.3418(9)	0.5003(4)	0.5113(7)	3.6(0.4)
	C4	0.3089(9)	0.4371(4)	0.5841(7)	3.9(0.4)
	C5	0.1795(9)	0.3240(4)	0.5349(8)	4.2(0.4)
	C6	0.1163(10)	0.2754(4)	0.4485(9)	4.4(0.5)
	C7	0.1203(9)	0.2829(4)	0.3178(9)	4.5(0.5)
	C8	0.1933(9)	0.3375(4)	0.2695(8)	4.3(0.4)
	C9	0.2550(8)	0.3861(4)	0.3562(7)	3.3(0.4)
	C10	0.2497(8)	0.3813(4)	0.4896(7)	3.6(0.4)
	C1′	0.4751(8)	0.5408(4)	0.3231(7)	3.3(0.4)
	C2′	0.6247(8)	0.5602(4)	0.3531(7)	3.3(0.4)
	C3′	0.6838(8)	0.6151(4)	0.2960(8)	3.9(0.4)
	C4′	0.5879(9)	0.6528(4)	0.2010(7)	3.2(0.4)
	C5′	0.4345(9)	0.6340(4)	0.1732(7)	3.6(0.4)
	C6′	0.3771(8)	0.5791(4)	0.2312(7)	3.7(0.4)
	C7′	0.6999(11)	0.6962(4)	0.0245(9)	5.3(0.5)
	O2	0.0516(8)	0.2348(3)	0.2334(6)	6.1(0.4)
	O3	0.1741(7)	0.3216(3)	0.6661(5)	5.5(0.3)
	O4	0.2053(6)	0.5386(3)	0.4744(5)	4.2(0.3)
	O5	0.8358(7)	0.6317(3)	0.3317(6)	5.3(0.3)
	O6	0.6452(6)	0.7093(3)	0.1475(5)	4.1(0.3)
	O7	0.3353(6)	0.6728(3)	0.0908(5)	4.9(0.3)
Water molecules	OW1	0.0190(6)	0.7277(3)	0.2541(5)	4.8(0.3)
	OW2	0.0253(8)	0.1006(4)	0.3848(8)	8.1(0.5)
	OW3	0.3823(8)	0.7878(3)	0.9593(6)	6.2(0.4)
	OW4	0.0513(10)	0.6145(5)	0.9610(10)	11.2(0.6)
	OW5	0.3793(13)	0.3613(4)	0.8992(9)	11.2(0.6)
	OW6	0.0762(9)	0.7878(5)	0.0146(8)	8.5(0.5)
	OW7	0.9480(19)	0.9035(9)	0.0954(14)	17.8(1.2)
	OW8	0.9752(20)	0.9813(8)	0.8982(13)	17.6(1.2)

Table 2. Interatomic distances (Å) and angles (°) for the non-hydrogen atoms.

Molecule A				Molecule B			
O1–C2	1.436(9)	C2–O1–C9	117.6(5)	O1–C2	1.432(8)	C2–O1–C9	114.6(5)
O1–C9	1.375(7)	O1–C2–C3	110.3(6)	O1–C9	1.386(9)	O1–C2–C3	110.3(6)
C2–C3	1.531(9)	O1–C2–C1′	109.2(5)	C2–C3	1.525(11)	O1–C2–C1′	109.6(5)
C2–C1′	1.508(10)	C3–C2–C1′	112.9(6)	C2–C1′	1.502(10)	C3–C2–C1′	112.6(6)
C3–C4	1.500(11)	C2–C3–C4	108.4(6)	C3–O4	1.509(11)	C2–C3–C4	108.6(6)
C3–O4	1.435(9)	C2–C3–O4	110.4(6)	C3–C4	1.426(9)	C2–C3–C4	111.7(6)
C4–C10	1.509(12)	C4–C3–O4	108.6(6)	C4–C10	1.519(10)	C4–C3–O4	111.6(6)
C5–C6	1.373(12)	C3–C4–C10	110.1(6)	C5–C6	1.378(11)	C3–C4–C10	111.3(6)
C5–C10	1.386(11)	C6–C5–C10	122.3(7)	C5–C10	1.404(11)	C6–C5–C10	120.8(8)
C5–O3	1.359(10)	C6–C5–O3	121.4(7)	C5–O3	1.356(10)	C6–C5–O3	123.5(8)
C6–C7	1.396(12)	C10–C5–O3	116.3(7)	C6–C7	1.355(13)	C10–C5–O3	115.6(7)
C7–C8	1.363(11)	C5–C6–C7	119.1(7)	C7–C8	1.383(12)	C5–C6–C7	120.0(8)
C7–O2	1.366(10)	C6–C7–C8	119.4(7)	C7–O2	1.377(10)	C6–C7–C8	121.0(7)
C8–C9	1.358(11)	C6–C7–O2	115.6(7)	C8–C9	1.376(11)	C6–C7–O2	118.8(7)
C9–C10	1.403(10)	C8–C7–O2	124.9(7)	C9–C10	1.380(10)	C8–C7–O2	120.2(8)
C1′–C2′	1.397(10)	C7–C8–C9	121.1(7)	C1′–C2′	1.362(10)	C7–C8–C9	118.7(8)
C1′–C6′	1.367(11)	O1–C9–C8	117.3(6)	C1′–C6′	1.413(10)	O1–C9–C8	116.4(6)
C2′–C3′	1.380(11)	O1–C9–C10	121.4(6)	C2′–C3′	1.372(11)	O1–C9–C10	121.3(6)
C3′–C4′	1.392(12)	C8–C9–C10	121.3(7)	C3′–C4′	1.416(10)	C8–C9–C10	122.2(7)
C3′–O5	1.378(10)	C4–C10–C5	121.9(7)	C3′–O5	1.374(9)	C4–C10–C5	120.6(7)
C4′–C5′	1.388(11)	C4–C10–C9	121.3(6)	C4′–C5′	1.388(11)	C4–C10–C9	122.1(7)
C4′–O6	1.375(9)	C5–C10–C9	116.8(7)	C4′–C6	1.374(9)	C5–C10–C9	117.2(7)
C5′–C6′	1.412(11)	C2–C1′–C2′	117.1(6)	C5′–C6′	1.371(11)	C2–C1′–C2′	118.7(6)
C5′–O7	1.350(10)	C2–C1′–C6′	122.4(6)	C5′–O7	1.368(9)	C2–C1′–C6′	122.6(6)
C7′–O6	1.401(12)	C2′–C1′–C6′	120.5(7)	C7′–O6	1.433(11)	C2′–C1′–C6′	118.7(7)
		C1′–C2′–C3′	119.3(7)			C1′–C2′–C3′	122.3(7)
		C2′–C3′–C4′	121.3(7)			C2′–C3′–C4′	119.5(7)
		C2′–C3′–O5	121.5(7)			C2′–C3′–O5	118.9(7)
		C4′–C3′–O5	117.1(7)			C4′–C3′–O5	121.5(7)
		C3′–C4′–C5′	118.9(7)			C3′–C4′–C5′	118.1(7)
		C3′–C4′–O6	120.5(7)			C3′–C4′–O6	119.6(6)
		C5′–C4′–O6	120.4(7)			C5′–C4′–O6	122.1(6)
		C4′–C5′–C6′	120.2(7)			C4′–C5′–C6′	121.7(7)
		C4′–C5′–O7	116.7(7)			C4′–C5′–O7	119.7(7)
		C6′–C5′–O7	123.3(7)			C6′–C5′–O7	118.6(7)
		C1′–C6′–C5′	119.9(7)			C1′–C6′–C5′	119.6(7)
		C4′–O6–C7′	112.9(6)			C4′–O6–C7′	112.7(6)

solution. The nonhydrogen atom parameters were refined by the full matrix least-squares method using anisotropic temperature factors. When the refinement had converged, all hydrogen atom positions but two could be found from a difference Fourier map. The hydrogen atoms were included with isotropic temperature factors and the refinement was continued. Eight of the hydrogen atoms did not correctly respond to the refinement. Their positional parameters were reset to their original values and were kept fixed during the last four cycles of the refinement. At $R=0.044$ and $R_w=0.058$ the refinement was terminated. The weighting scheme used in the later part of the refinement was $w=1/(1+((|F_{obs}|-14)/12)^2)$.[4] The form factors used were those given by Cromer and Mann.[5] All calculations have been performed on a DEC-system-10 computer using mainly the X-ray 72 program system.[6]

DESCRIPTION OF THE STRUCTURE

The coordinates and the equivalent isotropic temperature factors of the non-hydrogen atoms are given in Table 1. Structure factor tables and listings of anisotropic temperature factors and hydrogen atom parameters can be obtained from the Department of Structural Chemistry. Bond distances and angles are given in Table 2. Atom numbering and molecular conformation of the two independent molecules A and B are shown in Fig. 1. The conformation of the two molecules differs slightly with respect to the torsion angles O1–C2–C1′–C2′ [A: −149.5(0.9), B: −141.1(0.9)°] and C3′–C4′–O6–C7′ [A: 90.9(1.0), B: 95.9(1.0)°]. The geometry of the heterocyclic ring agrees closely to the one reported for 3-hydroxy-7-methoxy-3′-4′-methylenedioxyflavan.[7,*] The molecules of the title compound are stacked in the *a*-direction with alternating A and B molecules with their chroman skeletons in van der Waals contact and with the phenyl groups of the A and B molecules extending in opposite direction to each other. Between the rows of flavane molecules thus formed water molecules are accommodated which together with the flavane hydroxyl groups form an extensive hydrogen bond network. In Fig. 2 the molecular packing and the hydrogen bonding system is shown. The hydrogen bonding system, however, is not complete since the position of only one hydrogen atom of the water molecules W2 and W7 was found.

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* The title compound, for which the absolute configuration has not been determined, was chosen to have the same configuration as this compound.