

Hydrogen bonding and π - π stacking in dimethylgenistein

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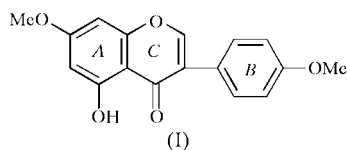
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The title compound, 5-hydroxy-4',7-dimethoxyisoflavone, $C_{17}H_{14}O_5$, is composed of a benzopyranone moiety, a phenyl moiety and two methoxy groups. The benzopyranone ring is not coplanar with the phenyl ring, the dihedral angle between them being $56.28(3)^\circ$. The two methoxy groups are nearly coplanar with their corresponding rings, having C—C—O—C torsion angles of $2.9(2)$ and $5.9(2)^\circ$. The molecules are linked by C—H \cdots O hydrogen bonds into sheets containing classical centrosymmetric $R_2^2(8)$ rings. The sheets are further linked by aromatic π - π stacking interactions and C—H \cdots O hydrogen bonds into a supramolecular structure.

Comment

Hydrogen bonds and π - π stacking interactions are an important research area in supramolecular chemistry and crystal engineering (MacDonald & Whitesides, 1994). These interactions play an important role in self-assembly and recognition of aromatic compounds (Janiak, 2000; Hunter & Sanders, 1990) as auxiliary stabilizing short contacts (William *et al.*, 1999; Luque *et al.*, 2001; Kaafarani *et al.*, 2001). In biomacromolecular systems, stacking interactions and hydrogen bonds are important for the double-helical DNA structure (Hunter, 1993); they can direct the intercalation of drugs into DNA (Wang *et al.*, 1984) and they contribute to the stability of the tertiary structure of proteins (Burley & Petsko, 1985).



Genistein, a natural soy isoflavone, has potential phytoestrogen (Hua *et al.*, 2003; Warren, 2002) and antioxidant activities (Ian *et al.*, 1995). Studies have also found genistein

effective in inhibiting cardiovascular disease (Hwang *et al.*, 2001), tyrosine kinases (Nevala *et al.*, 2002) and cancer cell growth (Yuan *et al.*, 2003; W. F. Chen *et al.*, 2003), and in accelerating the formation of bone cells (X. W. Chen *et al.*, 2003). The title compound, namely 5-hydroxy-4',7-dimethoxyisoflavone, (I), is a derivative of genistein and has potential medical applications. We report here the crystal structure of (I).

The title compound is composed of a benzopyranone moiety, a phenyl moiety and two methoxy groups (Fig. 1). The geometry of the isoflavone skeleton of (I) is similar to that of its analogue dalspinin (Lakshmi, *et al.*, 1996) with respect to most of the bond distances and angles. The atoms of the benzopyranone moiety, composed of rings A (C1–C6) and C (O1/C1/C6–C9), are almost coplanar, the dihedral angle between the rings being $1.37(8)^\circ$. To avoid steric conflicts, the two rigid ring systems, *viz.* benzene ring B (C10–C15) and the benzopyranone moiety, are rotated by $56.28(3)^\circ$ with respect to one another. The methoxy group at atom C3 is nearly coplanar with ring A, as indicated by the C16–O4–C3–C2 torsion angle [$2.9(2)^\circ$]; the methoxy group at atom C13 is also coplanar with the attached ring, the C17–O5–C13–C12 torsion angle being $5.9(2)^\circ$.

Fig. 2 shows how a cyclic dimer is formed through a supramolecular synthon, $R_2^2(8)$. Methoxy atom O4 acts as a hydrogen-bond acceptor, *via* atom H4, to atom C4 of ring A. In this manner, a centrosymmetric $R_2^2(8)$ ring is formed. Hydroxy atoms O2 from the two molecules linked by the $R_2^2(8)$ ring act as hydrogen-bond acceptors, *via* atoms H14, to atoms C14 of rings B in adjacent molecules. The combination of the C14–H14 \cdots O2 interaction and the $R_2^2(8)$ supramolecular synthon generates a $(10\bar{1})$ sheet, which includes two A, two B and two C rings from four molecules, and these six rings are almost coplanar; furthermore, these dimers are also linked into (100) chains by C11–H11 \cdots O3 interactions (Fig. 3). The combination of the $(10\bar{1})$ sheets and the (100) chains generates a three-dimensional framework. An independent O2–H2O \cdots O3 intramolecular hydrogen bonds generates a characteristic intramolecular $S(6)$ motif. Details of the hydrogen bonding are given in Table 1.

Intermolecular stacking *via* aromatic π - π interactions is also present (Fig. 3), the two molecules being offset by partial overlap of rings B (π rich) and C (π deficient). Ring B of one

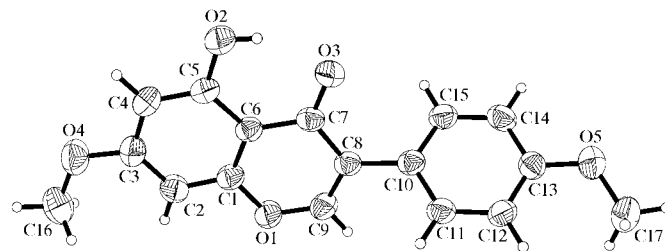
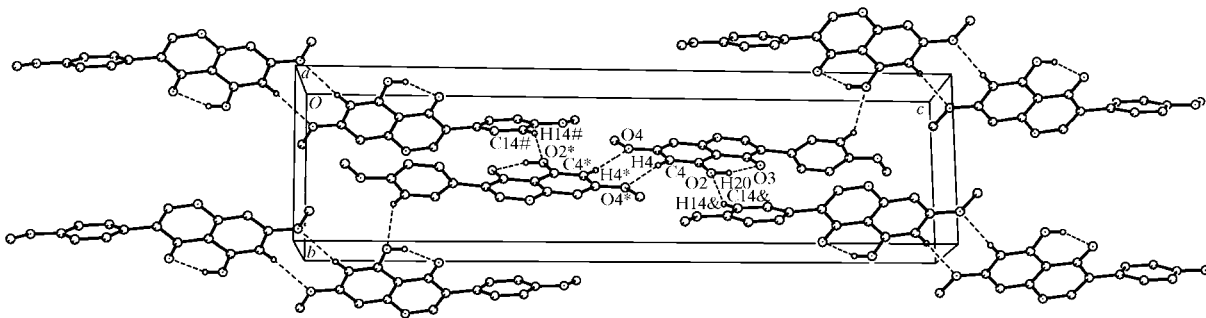
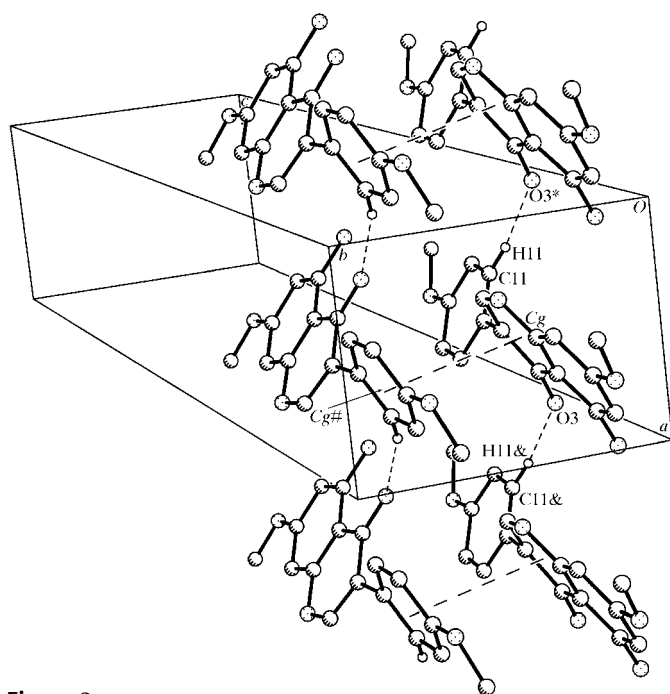


Figure 1

A view of the molecule of (I), showing the atom-numbering scheme and 50% probability displacement ellipsoids. H atoms are shown as spheres of arbitrary radii.


Figure 2

Part of the crystal structure of (I), showing the formation of the $(10\bar{1})$ sheets *via* hydrogen bonds. Atoms marked with an asterisk (*), hash (#) or ampersand (&) are at the symmetry positions $(1-x, 1-y, 1-z)$, $(x-\frac{1}{2}, \frac{1}{2}-y, z-\frac{1}{2})$ and $(\frac{3}{2}-x, \frac{1}{2}+y, \frac{3}{2}-z)$, respectively. For clarity, some H atoms have been omitted.


Figure 3

Part of the crystal structure of (I), showing the formation of the (100) chains *via* hydrogen bonds and π - π stacking interactions. Labels C_g represent the centroids of rings A and C. Atoms marked with an asterisk (*), hash (#) or ampersand (&) are at the symmetry positions $(1-x, y, z)$, $(\frac{1}{2}-x, \frac{1}{2}+y, \frac{3}{2}-z)$ and $(1+x, y, z)$, respectively. For clarity, some H atoms have been omitted.

molecule and ring C of a neighbouring molecule are almost parallel, with a dihedral angle between them of $8.02(7)^\circ$. The perpendicular plane-to-plane distance between the rings is 3.311 \AA , and the corresponding $C_g \cdots C_g\#$ distance is 3.693 \AA [C_g represents the centroids of rings A and C; symmetry code: (#) $\frac{1}{2}-x, \frac{1}{2}+y, \frac{3}{2}-z$], indicating that a strong π - π stacking interaction exists in the title compound. Hydrogen bonds and aromatic π - π stacking interactions play a key role in assembling the supramolecular structure.

Experimental

Genistein (1.0 g) was dissolved in Na_2CO_3 (20 ml, 5%) and dimethyl sulfate (0.5 ml) was added dropwise to the solution with stirring. The

mixture was stirred for 4 h at room temperature and a colourless precipitate began to appear. The precipitate was filtered off and washed with water until the pH of the filtrate was 8. After recrystallization from ethyl acetate, the product had a melting point of 428 K. Crystals of (I) suitable for X-ray analysis were obtained by slow evaporation from ethyl acetate after 7 d at room temperature.

Crystal data

$\text{C}_{17}\text{H}_{14}\text{O}_5$
 $M_r = 298.28$
 Monoclinic, $P2_1/n$
 $a = 5.7754(8) \text{ \AA}$
 $b = 7.9446(12) \text{ \AA}$
 $c = 30.044(5) \text{ \AA}$
 $\beta = 93.807(12)^\circ$
 $V = 1375.4(4) \text{ \AA}^3$
 $Z = 4$

$D_x = 1.441 \text{ Mg m}^{-3}$
 Mo $K\alpha$ radiation
 Cell parameters from 34 reflections
 $\theta = 2.7\text{--}15.9^\circ$
 $\mu = 0.11 \text{ mm}^{-1}$
 $T = 296(2) \text{ K}$
 Prism, colourless
 $0.58 \times 0.54 \times 0.50 \text{ mm}$

Data collection

Siemens P4 diffractometer
 ω scans
 3089 measured reflections
 2485 independent reflections
 1673 reflections with $I > 2\sigma(I)$
 $R_{\text{int}} = 0.010$
 $\theta_{\text{max}} = 25.3^\circ$

$h = -6 \rightarrow 6$
 $k = 0 \rightarrow 9$
 $l = -36 \rightarrow 36$
 3 standard reflections
 every 97 reflections
 intensity decay: 0.4%

Refinement

Refinement on F^2
 $R[F^2 > 2\sigma(F^2)] = 0.035$
 $wR(F^2) = 0.087$
 $S = 0.90$
 2485 reflections
 203 parameters
 H-atom parameters constrained

$w = 1/[\sigma^2(F_o^2) + (0.0522P)^2]$
 where $P = (F_o^2 + 2F_c^2)/3$
 $(\Delta/\sigma)_{\text{max}} = 0.001$
 $\Delta\rho_{\text{max}} = 0.19 \text{ e \AA}^{-3}$
 $\Delta\rho_{\text{min}} = -0.15 \text{ e \AA}^{-3}$
 Extinction correction: SHELXL97
 Extinction coefficient: 0.0233 (18)

Table 1

Hydrogen-bonding geometry (\AA , $^\circ$).

$D\text{--}H \cdots A$	$D\text{--}H$	$H \cdots A$	$D \cdots A$	$D\text{--}H \cdots A$
$\text{O2--H2O} \cdots \text{O3}$	0.82	1.86	2.590 (2)	148
$\text{C4--H4} \cdots \text{O4}^i$	0.93	2.54	3.459 (2)	171
$\text{C11--H11} \cdots \text{O3}^{ii}$	0.93	2.56	3.464 (2)	164
$\text{C14--H14} \cdots \text{O2}^{iii}$	0.93	2.58	3.399 (2)	147

Symmetry codes: (i) $1-x, 1-y, 1-z$; (ii) $x-1, y, z$; (iii) $\frac{3}{2}-x, y-\frac{1}{2}, \frac{3}{2}-z$.

H atoms were placed at calculated positions and treated as riding, with C-H distances in the range $0.93\text{--}0.96 \text{ \AA}$ and $U_{\text{iso}}(\text{H})$ values of $1.2U_{\text{eq}}(\text{C})$ of the attached C atom [$1.5U_{\text{eq}}(\text{C})$ for methyl H atoms].

Data collection: *XSCANS* (Siemens, 1996); cell refinement: *XSCANS*; data reduction: *SHELXTL* (Siemens, 1997); program(s) used to solve structure: *SHELXS97* (Sheldrick, 1990); program(s) used to refine structure: *SHELXL97* (Sheldrick, 1997); molecular graphics: *SHELXTL*; software used to prepare material for publication: *SHELXTL*.

Supplementary data for this paper are available from the IUCr electronic archives (Reference: FR1473). Services for accessing these data are described at the back of the journal.

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