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2′,4′-Dihydroxy-3-methoxy-*α*,*β*-dihydrochalcone and 2′,4-dihydroxy-*α*,*β*-dihydrochalcone: supramolecular structures formed by O—H···O, C—H···O and stacking interactions

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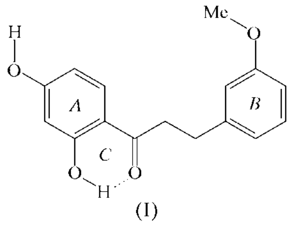
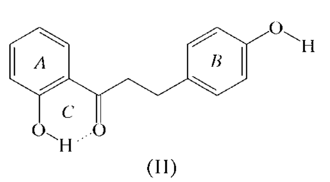
The crystal structures of 2′,4′-dihydroxy-3-methoxy-*α*,*β*-dihydrochalcone, $C_{16}H_{16}O_4$, and 2′,4-dihydroxy-*α*,*β*-dihydrochalcone, $C_{15}H_{14}O_3$, have been determined. In both compounds, the structure consists of two nearly planar six-membered aromatic rings connected by a propanal chain, which is bent in the methoxy compound and almost straight in the other compound. In the crystal structures, the molecular units of both compounds are linked by O—H···O hydrogen bonds to form infinite one-dimensional chains. Hydrogen bonds and C—H···O contacts in the crystal structures were studied by topological analysis of charge density based on Hartree–Fock calculations. Almost all of the investigated C—H···O contacts should be characterized as weak hydrogen bonds.

Comment

Chalcones are the biogenetic precursors of the flavonoids in higher plants. Dihydrochalcones, together with chalcones, are often isolated from various plants (Achenbach *et al.*, 1988; Masaoud *et al.*, 1995; Thuy *et al.*, 1998; Sinz *et al.*, 1999). These compounds display a wide variety of pharmacological effects, including antibacterial, antiviral, antimutagenic, antimitotic, anti-inflammatory, antiulcerative and hepatoprotective activities (Batt *et al.*, 1993; Sogawa *et al.*, 1994; Arty *et al.*, 2000). Since some chalcones inhibit various enzymes involved in the generation of reactive oxygen species (5-lipoxygenase, 12-lipoxygenase, cyclooxygenase, *etc.*), the majority of their pharmacological properties are supposed to be related to their antioxidative effect (Sogawa *et al.*, 1993; Forejtníková *et al.*, 2005). The biological effects are often connected with electron distribution around the molecule and the capability of entering into intermolecular interactions during formation of supramolecular complexes with biomacromolecules. The crystal structures described here were studied as model systems in the course of theoretical characterization of intermolecular O—H···O and C—H···O interactions.



(I)



(II)

The structures of 2′,4′-dihydroxy-3-methoxy-*α*,*β*-dihydrochalcone, (I) (Fig. 1 and Table 1), and 2′,4-dihydroxy-*α*,*β*-di-

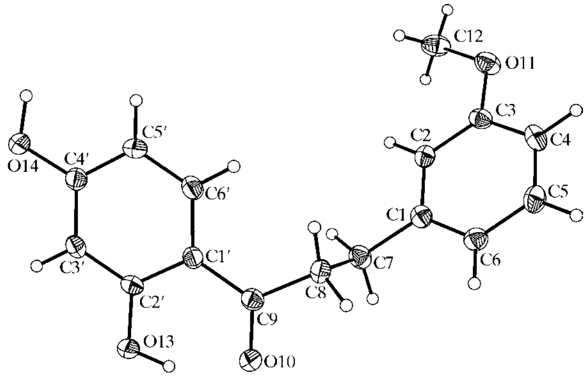


Figure 1
A view of (I). Displacement parameters for non-H atoms are drawn at the 50% probability level.

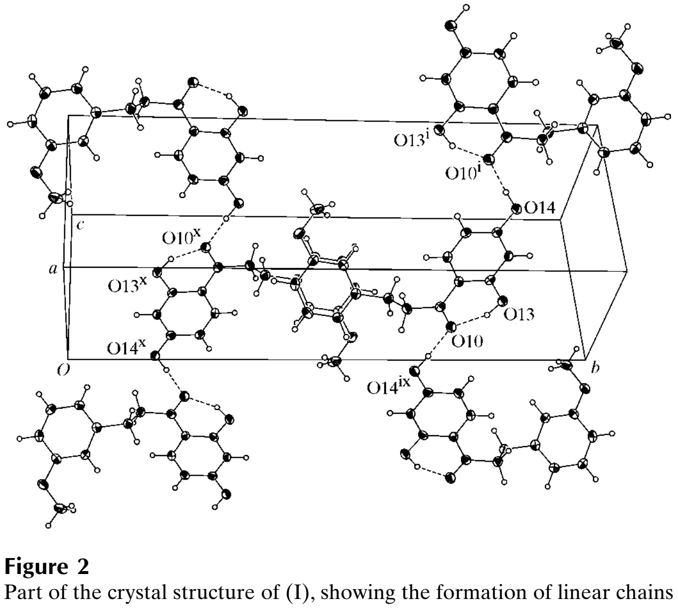


Figure 2
Part of the crystal structure of (I), showing the formation of linear chains of hydrogen-bonded molecules and stacking interactions between coplanar *B* rings of adjacent molecular units of (I). [Symmetry codes: (i) $1 + x, \frac{3}{2} - y, \frac{1}{2} + z$; (ix) $x - 1, \frac{3}{2} - y, z - \frac{1}{2}$; (x) $-x, 1 - y, 1 - z$.]

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hydrochalcone, (II) (Fig. 2 and Table 3), are similar to that of 2′,4′-dihydroxy-4,6′-dimethoxy-α,β-dihydrochalcone (De Matheus *et al.*, 1991). They consist of two nearly planar six-membered aromatic rings (*A* and *B*), with maximum deviations from the (I*A*), (I*B*), (II*A*) and (II*B*) planes of 0.0056 (15), 0.0085 (15), 0.0089 (13) and 0.0095 (13) Å, respectively. The interplanar angle between rings *A* and *B* is 43.66 (5)° in (I) and 67.40 (4)° in (II). The atoms connected to rings *A* and *B* are slightly displaced out of the corresponding planes (the deviations from the planes are summarized in Table 5). Rings *A* and *B* are connected by a propanal chain, which is bent in (I) and almost straight in (II) (as shown by the C1′—C9—C8—C7 and C9—C8—C7—C1 torsion angles; Tables 1 and 3).

In the crystal structures of (I) and (II), the molecules are involved in extensive networks of O—H···O and C—H···O hydrogen bonds [Fig. 3 and Table 2 for (I), and Fig. 4 and Table 4 for (II)]. The two shortest intra- and intermolecular O—H···O bonds in (I) [O13···O10 = 2.5499 (16) Å and O14···O10$^{\rm i}$ = 2.7005 (16) Å; symmetry code: (i) $1 + x, \frac{3}{2} - y, \frac{1}{2} + z$] connect molecules into linear chains in the (201) direction; the two shortest bonds in (II) [O13···O10 = 2.5482 (13) Å and O11···O13$^{\rm v}$ = 2.8147 (13) Å; symmetry code: (v) $x - 1, y, z - 1$] form linear chains in the (101) direction.

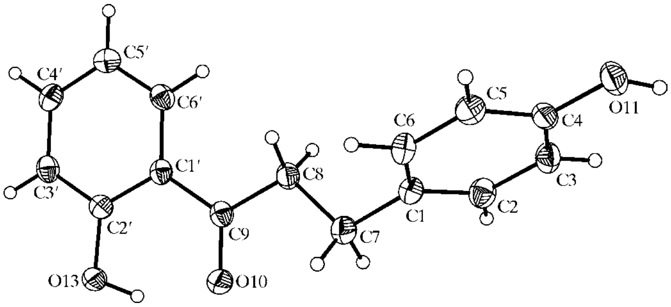

Figure 3
A view of (II). Displacement parameters for non-H atoms are drawn at the 50% probability level.

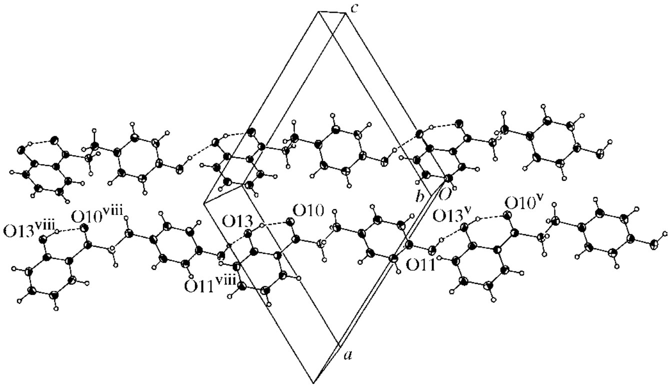

Figure 4
Part of the crystal structure of (II), showing the formation of linear chains of hydrogen-bonded molecules. [Symmetry codes: (v) $x - 1, y, z - 1$; (viii) $x + 1, y, z + 1$.]

In order to characterize individual hydrogen bonds, a topological analysis in the framework of the Bader (2003) 'atoms in molecules' (AIM) theory was applied. According to this theory, the bond is characterized by the charge density and the Laplacian of charge density in its bond critical point (BCP). The BCP has an extremum at the electron-density surface with one positive and two negative eigenvalues of the matrix of second derivatives of $\rho(r_c)$. BCPs belonging to the particular intermolecular contact were found, and the charge density and the Laplacian of the charge density at the BCP were calculated as described in the *Experimental* section (Tables 2 and 4). The largest values of $\nabla^2\rho(r_c)$ were obtained for intramolecular O—H···H hydrogen bonds forming the stable six-membered ring *C* (see scheme). Intermolecular O—H···O hydrogen bonds are somewhat weakened. However, all of the C—H···O contacts summarized in Tables 2 and 4 should be classified as weak hydrogen bonds (Desiraju & Steiner, 1999), because the calculated values of $\rho(r_c)$ and $\nabla^2\rho(r_c)$ fall within the ranges specified in the literature [0.013–0.236 e Å^{-3} for $\rho(r_c)$ and 0.58–3.35 e Å^{-5} for $\nabla^2\rho(r_c)$; Koch & Popelier, 1995]. The only exception from the determined set is represented by the C7—H7*A*···O13 shortened contact, which should be characterized rather by the van der Waals concept. It is evident from this study that aromatic C—H fragments are capable of forming stronger attractive hydrogen bonds than their standard aliphatic counterparts.

In the crystal structure of (I), the molecular packing is such that stacking interactions between rings *B* of adjacent molecules are optimized (Fig. 2). If *CgB* is the centroid of ring *B* and *CgB*$^{\rm x}$ is that of ring *B*$^{\rm x}$ [symmetry code: (x) $-x, 1 - y, 1 - z$], the *CgB*···*CgB*$^{\rm x}$ distance is 3.577 Å and the distance of *CgB* from the plane through the *B*$^{\rm x}$ ring atoms is 3.357 Å.

Experimental

Dihydrochalcones (I) and (II) were prepared by hydrogenation of the appropriate chalcones over 10% palladium on activated carbon as a catalyst (Davis & Chen, 1993). The catalyst was added to a solution of 2′,4-dihydroxychalcone (2 g) in ethyl acetate (5 ml); the mixture was hydrogenated at normal pressure and room temperature for 30 min, after which the catalyst was removed by filtration and the solution was evaporated to dryness, giving a 98% yield of crude (I). A similar procedure was used for the preparation of (II) from 2′,4′-dihydroxy-3-*O*-methylchalcone, where hydrogenation took 60 min and gave crude (II) in a 89% yield. Colorless crystals of both (I) and (II) were prepared by recrystallization from methanol at room temperature under normal pressure.

Compound (I)

Crystal data

$C_{16}H_{16}O_4$
M_r = 272.29
Monoclinic, $P2_1/c$
a = 7.3074 (9) Å
b = 22.968 (3) Å
c = 7.8343 (9) Å
β = 91.972 (10)°
V = 1314.1 (3) Å^3
Z = 4

D_x = 1.376 Mg m^{-3}
Mo $K\alpha$ radiation
Cell parameters from 3635 reflections
θ = 2.7–27.9°
μ = 0.10 mm^{-1}
T = 120 (2) K
Prism, colorless
0.50 × 0.30 × 0.20 mm

Data collection

Kuma KM-4 diffractometer with a CCD detector
ω scans
8679 measured reflections
2312 independent reflections
1831 reflections with $I > 2\sigma(I)$

$R_{\rm int} = 0.043$
$\theta_{\rm max} = 25.0°$
$h = -8 \rightarrow 8$
$k = -27 \rightarrow 25$
$l = -9 \rightarrow 9$

Refinement

Refinement on F^2
$R[F^2 > 2\sigma(F^2)] = 0.040$
$wR(F^2) = 0.091$
$S = 1.03$
2312 reflections
190 parameters
H-atom parameters constrained

$w = 1/[\sigma^2(F_o^2) + (0.0425P)^2 + 0.1P]$ where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{\rm max} < 0.001$
$\Delta\rho_{\rm max} = 0.14$ e Å^{-3}
$\Delta\rho_{\rm min} = -0.19$ e Å^{-3}

Table 1
Selected torsion angles (°) for (I).

C6′—C1′—C9—C8	2.0 (2)	C9—C8—C7—C1	−168.34 (14)
C1′—C9—C8—C7	100.22 (18)	C8—C7—C1—C2	117.24 (16)

Table 2
Hydrogen-bonding geometry (Å, °), electron density [$\rho(r_c)$, e Å^{-3}] and Laplacian of electron density [$\nabla^2\rho(r_c)$, e Å^{-5}] at bond critical points.

D—H···A	D—H	H···A	D···A	D—H···A	$\rho(r_c)$	$\nabla^2\rho(r_c)$
O13—H13···O10	0.942 (10)	1.691 (14)	2.5499 (16)	150.0 (19)	0.216	2.87
O14—H14···O10$^{\rm i}$	0.953 (10)	1.749 (10)	2.7005 (16)	176 (2)	0.175	2.19
C5—H5···O14$^{\rm ii}$	0.95	2.56	3.407 (2)	148	0.067	0.84
C7—H7A···O13$^{\rm iii}$	0.99	2.58	3.569 (2)	174	0.027	0.41
C6′—H6′···O11$^{\rm iv}$	0.95	2.58	3.508 (2)	167	0.067	0.82

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

Compound (II)

Crystal data

$C_{15}H_{14}O_3$
$M_r = 242.26$
Monoclinic, $P2_1/c$
$a = 12.2802$ (17) Å
$b = 9.4904$ (10) Å
$c = 11.5764$ (15) Å
$\beta = 116.637$ (16)°
$V = 1206.0$ (3) Å^3
$Z = 4$
$D_x = 1.334$ Mg m^{-3}

Mo $K\alpha$ radiation
Cell parameters from 2425 reflections
$\theta = 3.0$–27.2°
$\mu = 0.09$ mm^{-1}
$T = 120$ (2) K
Prism, colorless
0.50 × 0.30 × 0.20 mm

Data collection

Kuma KM-4 diffractometer with a CCD detector
ω scans
6218 measured reflections
2114 independent reflections
1741 reflections with $I > 2\sigma(I)$

$R_{\rm int} = 0.026$
$\theta_{\rm max} = 25.0°$
$h = -12 \rightarrow 14$
$k = -11 \rightarrow 10$
$l = -13 \rightarrow 10$

Refinement

Refinement on F^2
$R[F^2 > 2\sigma(F^2)] = 0.032$
$wR(F^2) = 0.084$
$S = 1.04$
2114 reflections
171 parameters
H-atom parameters constrained

$w = 1/[\sigma^2(F_o^2) + (0.0460P)^2 + 0.1P]$ where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{\rm max} = 0.005$
$\Delta\rho_{\rm max} = 0.15$ e Å^{-3}
$\Delta\rho_{\rm min} = -0.19$ e Å^{-3}

Table 3
Selected torsion angles (°) for (II).

C6′—C1′—C9—C8	3.37 (18)	C9—C8—C7—C1	−172.51 (11)
C1′—C9—C8—C7	171.12 (11)	C8—C7—C1—C2	−109.99 (14)

Table 4
Hydrogen-bonding geometry (Å, °), electron density [$\rho(r_c)$, e Å^{-3}] and Laplacian of electron density [$\nabla^2\rho(r_c)$, e Å^{-5}] at bond critical points.

D—H···A	D—H	H···A	D···A	D—H···A	$\rho(r_c)$	$\nabla^2\rho(r_c)$
O13—H13···O10	0.947 (9)	1.678 (12)	2.5482 (13)	151.0 (16)	0.216	2.89
O11—H11···O13$^{\rm v}$	0.935 (9)	1.915 (10)	2.8147 (13)	160.9 (15)	0.155	1.83
C6′—H6′···O11$^{\rm vi}$	0.95	2.44	3.2731 (16)	146	0.081	1.04
C5′—H5′···O13$^{\rm vii}$	0.95	2.49	3.4212 (16)	167	0.081	0.96

Symmetry codes: (v) $x-1, y, z-1$; (vi) $1-x, 1-y, -z$; (vii) $x, \frac{3}{2}-y, z-\frac{1}{2}$.

Table 5
Selected geometrical parameters (Å, °) in compounds (I) and (II).

Geometric parameters	(I)	(II)
Dihedral angle A *versus* B	43.66 (5)	67.40 (4)
Deviation of C9 from A	0.0331 (16)	0.0308 (13)
Deviation of O10 from A	0.0247 (12)	0.0896 (10)
Deviation of O13 from A	0.0386 (12)	0.0479 (9)
Deviation of O14 from A	0.0008 (12)	–
Deviation of C7 from B	0.0094 (17)	0.0481 (14)
Deviation of O11 from B	0.0482 (12)	0.0632 (10)
Deviation of C12 from B	0.0455 (18)	–
Angle plane B–plane $B^{\rm x}$	0	–
Distance CgB–$CgB^{\rm x}$	3.577	–
Distance CgB–plane $B^{\rm x}$	3.357	–

Symmetry code: (x) $-x, 1-y, 1-z$.

H atoms attached to C atoms were positioned geometrically, with C—H = 0.95–0.99 Å, and with isotropic displacement parameters equal to $1.2U_{\rm eq}$(C) [$1.5U_{\rm eq}$(C) for methyl atoms]. The parameters of H atoms attached to O atoms were refined with the O—H distances restrained to 0.95 (1) Å. The electron density and Laplacian of electron density in the BCP were calculated for X-ray geometry with optimized positions of the H atoms. Geometry optimizations by the AM1 method and calculations of wavefunctions at basis RHF/6-31G** were performed using the *GAUSSIAN98* package (Frisch *et al.*, 1998). Topological analyses based on the theory of Bader *et al.* (1982*a*,*b*) were carried out using the *EXTREME* program in the *AIMPAC* program package (Biegler-König *et al.*, 1982).

For both title compounds, data collection: *CrysAlis CCD* (Oxford Diffraction, 2004); cell refinement: *CrysAlis RED* (Oxford Diffraction, 2004); data reduction: *CrysAlis RED*; program(s) used to solve structure: *SHELXS97* (Sheldrick, 1990); program(s) used to refine structure: *SHELXL97* (Sheldrick, 1997); molecular graphics: *ORTEPIII* (Johnson & Burnett, 1996); software used to prepare material for publication: *SHELXL97* and *PARST* (Nardelli, 1995).

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Supplementary data for this paper are available from the IUCr electronic archives (Reference: SK1835). Services for accessing these data are described at the back of the journal.

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