

## 2-(4-Dibenzofuranyloxy)-2-methylpropionic Acid

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**Abstract.**  $C_{16}H_{14}O_4$ , orthorhombic,  $Pbca$ ,  $a = 9.986(4)$ ,  $b = 11.056(2)$ ,  $c = 25.280(6)$  Å,  $d_c = 1.287$ ,  $d_o = 1.28$  Mg m<sup>-3</sup>,  $Z = 8$ , m.p. 397–399 K. The structure was solved by direct methods and refined by least-squares methods to an  $R$  value of 0.036. The two benzene rings are planar with a dihedral angle of 1.7 (9)°. The C–C bond distance in the furan ring is 1.452 (4) Å.

**Introduction.** The ethyl ester of 2-(4-dibenzofuranyloxy)-2-methylpropionic acid has been found to possess pronounced plasma cholesterol- and triglyceride-lowering properties (Bondesson, Hedbom, Högberg, Magnusson, Stjernström & Carlsson, 1974). The crystal structure of the title compound has been determined in order to correlate structure and hypolipidemic effect in a series including closely related acids. So far the series of hypolipidemic compounds consists of three substances of which the present compound is the most active. The two others are 2-[2-(phenoxy)phenoxy]-2-methylpropionic acid (Wägner & Malmros, 1979) and 2-[6*H*-4-dibenzo[*b,d*]pyranyloxy]-2-methylpropionic acid (Wägner, 1979). Further discussion concerning these substances will be presented elsewhere (Bondesson, Högberg, Stjernström & Wägner, 1979).

Crystals of 2-(4-dibenzofuranyloxy)-2-methylpropionic acid crystallized from ligroin/ethyl acetate were supplied by Dr N. E. Stjernström, Astra Pharmaceuticals AB, Sweden. The cell dimensions were obtained from a powder photograph, taken in a Guiner–Hägg focusing camera with strictly monochromatized Cu  $K\alpha_1$  radiation at 298 K ( $\lambda = 1.54056$  Å) and KCl as internal standard ( $a = 6.2930$  Å). Intensity data were collected on a computer-controlled single-crystal diffractometer (Philips PW 1100) using graphite-monochromatized Cu  $K\alpha$  radiation. 2254 reflexions with  $2\theta < 120^\circ$  were measured by the  $\theta$ – $2\theta$  scan technique at a  $2\theta$  scan rate of 0.035° s<sup>-1</sup>. The scan range used was 1.4° in  $2\theta$ . Backgrounds were measured by stationary counts on each side of the peaks. Only 1146 reflexions with  $\sigma(I)/I < 0.303$  were used in the subsequent calculations. Lorentz and polarization factors were applied but no corrections were made for absorption or extinction.

The structure was solved by direct methods using the *MULTAN* program system (Germain, Main & Woolfson, 1970). The 20 highest peaks in the resulting  $E$  map yielded all non-hydrogen atomic positions. Least-squares refinement of all non-hydrogen atomic positions with anisotropic thermal parameters gave an  $R$  value of 0.087. In the least-squares refinement weights were assigned as  $1/\sigma^2(F_o)$ , where  $\sigma(F_o)$  was determined from the  $\sigma_{cs}(F)$  yielded by counting statistics with a 2.0% addition for instrumental instability according to the formula:

$$\frac{\sigma(F_o)}{F_o} = \left[ \left( \frac{\sigma_{cs}(F_o)}{F_o} \right)^2 + \left( \frac{2.0}{100} \right)^2 \right]^{1/2}$$

From a difference Fourier synthesis all H atomic positions could be found unambiguously. Further least-squares refinement including isotropic refinement of the temperature factors for the H atoms resulted in an  $R$  value of 0.036\* for  $R = \sum |F_o| - |F_c| / \sum |F_o|$  and

\* Lists of structure factors and thermal parameters have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 34441 (7 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

Table 1. Fractional coordinates of the non-hydrogen atoms

Estimated standard deviations are given in parentheses.

	<i>x</i>	<i>y</i>	<i>z</i>
C(1)	0.4526 (3)	0.2168 (2)	0.1699 (1)
C(2)	0.3922 (3)	0.1165 (3)	0.1929 (1)
C(3)	0.2765 (3)	0.0733 (3)	0.1704 (1)
C(4)	0.2205 (3)	0.1274 (3)	0.1259 (1)
C(5)	0.2783 (3)	0.2268 (3)	0.1022 (1)
C(6)	0.3941 (3)	0.2687 (2)	0.1259 (1)
C(8)	0.5744 (3)	0.3780 (3)	0.1421 (1)
C(9)	0.6725 (3)	0.4660 (3)	0.1378 (1)
C(10)	0.7747 (3)	0.4584 (4)	0.1750 (1)
C(11)	0.7760 (4)	0.3695 (4)	0.2138 (1)
C(12)	0.6753 (3)	0.2845 (3)	0.2180 (1)
C(13)	0.5713 (3)	0.2886 (3)	0.1807 (1)
C(15)	0.1007 (3)	0.2809 (3)	0.0398 (1)
C(15A)	0.1009 (4)	0.3548 (3)	–0.0110 (2)
C(15B)	0.0077 (4)	0.3354 (4)	0.0811 (2)
C(16)	0.0595 (3)	0.1540 (2)	0.0248 (1)
O(7)	0.4660 (2)	0.3680 (2)	0.1078 (1)
O(14)	0.2386 (2)	0.2853 (2)	0.0571 (1)
O(16A)	0.1527 (2)	0.0890 (2)	0.0020 (1)
O(16B)	–0.0552 (2)	0.1184 (2)	0.0315 (1)

Table 2. Fractional coordinates of the hydrogen atoms

Estimated standard deviations are given in parentheses.

	<i>x</i>	<i>y</i>	<i>z</i>
H(2)	0.429 (2)	0.087 (2)	0.224 (1)
H(3)	0.229 (3)	0.003 (3)	0.185 (1)
H(4)	0.147 (3)	0.096 (2)	0.111 (1)
H(9)	0.672 (3)	0.529 (3)	0.108 (1)
H(10)	0.848 (3)	0.525 (3)	0.174 (1)
H(11)	0.853 (3)	0.368 (3)	0.240 (1)
H(12)	0.668 (3)	0.219 (2)	0.248 (1)
H(15A1)	0.120 (3)	0.448 (3)	0.001 (1)
H(15A2)	0.007 (3)	0.357 (3)	-0.027 (1)
H(15A3)	0.164 (3)	0.319 (3)	-0.035 (1)
H(15B1)	0.043 (3)	0.429 (3)	0.086 (1)
H(15B2)	0.009 (3)	0.292 (2)	0.112 (1)
H(15B3)	-0.086 (3)	0.349 (3)	0.062 (1)
H(16)	0.110 (3)	0.001 (4)	-0.011 (1)

0.033 for  $R_w = [\sum w(|F_o| - |F_c|)^2 / \sum w|F_o|^2]^{1/2}$ . The *R* value computed for all 1146 reflexions was 0.045. Owing to extinction, the 28 strongest reflexions were excluded in the last refinement cycle. The atomic scattering factors used for C, O and H are those listed in *International Tables for X-ray Crystallography* (1974). The final positional parameters are given in Tables 1 and 2.

**Discussion.** Bond distances and bond angles for non-hydrogen atoms are given in Fig. 1.

Fig. 2 shows a perspective view of the molecule. The torsion angles for the side chain are C(4)–C(5)–O(14)–C(15) = 25.5 (5), C(16)–C(15)–O(14)–C(5) = -64.9 (3) and O(14)–C(15)–C(16)–O(16A) = -35.9 (3)°. The individual six- and five-membered rings are planar within 0.01 Å but the dibenzofuran part shows a small deviation of 0.03 Å from planarity. Equations for the least-squares planes through the individual rings as well as for the dibenzofuran ring system are given in Table 3 together with the deviations in Å from these least-squares planes. The C–H bond distances vary between 0.90 and 1.10 Å,

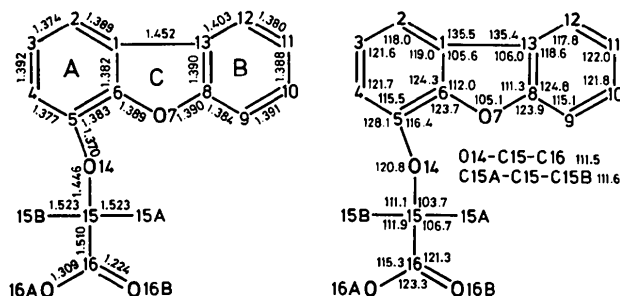


Fig. 1. Bond distances (Å) and bond angles (°) involving non-hydrogen atoms only. The e.s.d.'s range between 0.003–0.005 Å and 0.2–0.3°.

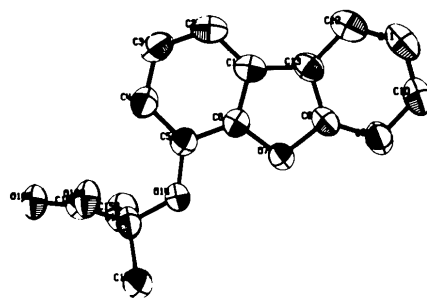


Fig. 2. View of the molecule perpendicular to the dibenzofuran plane.

Table 3. Least-squares planes and deviations (Å) of the atoms from the planes

The equations are given in a Cartesian coordinate system where *x*, *y* and *z* are in Å relative to the axes *a*, *b* and *c*. Estimated standard deviations are given in parentheses.

$$\begin{aligned} \text{Plane A: } & -0.540(3)x + 0.601(2)y + 0.589(2)z - 1.53 = 0 \\ \text{Plane B: } & -0.52(1)x + 0.60(1)y + 0.61(1)z - 1.75 = 0 \\ \text{Plane C: } & -0.538(2)x + 0.600(2)y + 0.592(2)z - 1.55 = 0 \\ \text{Plane D: } & -0.531(8)x + 0.601(8)y + 0.597(3)z - 1.59 = 0 \end{aligned}$$

	Plane A	Plane B	Plane C	Plane D*
C(1)	-0.002 (3)		0.000 (3)	0.011 (3)
C(2)	0.000 (3)			0.012 (3)
C(3)	0.001 (3)			-0.001 (3)
C(4)	0.000 (3)			-0.016 (3)
C(5)	-0.003 (3)			-0.020 (3)
C(6)	0.003 (3)		-0.001 (3)	0.001 (3)
O(7)			0.001 (2)	0.006 (2)
C(8)		-0.009 (3)	-0.001 (3)	0.015 (3)
C(9)		0.008 (3)		0.015 (3)
C(10)		0.000 (3)		-0.017 (3)
C(11)		-0.008 (4)		-0.029 (4)
C(12)		0.008 (3)		0.004 (3)
C(13)		0.001 (3)	0.001 (3)	0.020 (3)

\* Including all non-hydrogen atoms in the dibenzofuran part.

the average C–H bond distance being 1.01 Å. The O–H distance is 1.11 (4) Å and the H–O(16A)–C(16) angle is 109.6 (17)°. The H–C–H angles vary between 101.5 and 117.9° with an average of 110.9°.

The dihedral angle between the two benzene rings is 1.7 (9)°. The angles between the five-membered ring and benzene rings A and B are 0.3 (2) and 1.5 (6)° respectively. These angles are in accordance with those of other dibenzofuran structures, e.g. dibenzofuran (Banerjee, 1973; Dideberg, Dupont & André, 1972), ruscodibenzofuran (ElSohly, Slatkin, Knapp, Doorenbos, Quimby, Schiff, Gopalakrishna & Watson, 1977) and 2,8-dimethoxydibenzofuran (Berg, Karlsson, Pilotti & Söderholm, 1978).

There is a significant difference between the C(1)–C(13) bond distance of 1.452 (4) Å in the

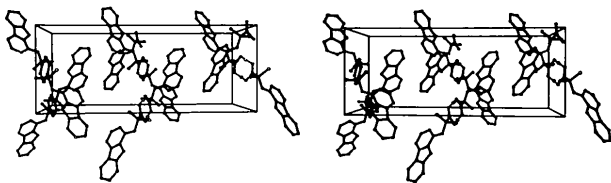


Fig. 3. Stereoview of the packing of the molecules. Only the H atoms of the hydrogen bonds in the dimers are included. The unit cell is oriented with the *c* axis horizontal, the *a* axis vertical and the *b* axis pointing towards the reader.

present structure and the corresponding distance in dibenzofuran of 1.480 (6) Å (Banerjee, 1973) and 1.481 (3) Å (Dideberg, Dupont & André, 1972).

The C(1)–C(13) bond distance may also be compared to the theoretically calculated distance of Banerjee (1973) of 1.468 Å. The shortening of the C(1)–C(13) bond in the present structure indicates an increased  $\pi$  bond order, compared to the dibenzofuran structure. CNDO calculations show a slight degree of asymmetry in the furan ring, the total net charge on C(1) being +0.034 and on C(13) –0.035 e.

The C(4)–C(5)–O(14) angle is enlarged to 128.1°, which is also the case for the corresponding angle in leucothelephoric acid hexamethyl ether (Silverton, 1973), deoxyanisoin and *p,p*-dimethoxybenzophenone (Norment & Karle, 1962). This is probably due to steric interactions between H(4) and the H atoms of the methyl groups of the side chain [e.g. the H(4)···H(15A1) distance is 2.56 Å], as proposed by Norment & Karle (1962).

Two centrosymmetrically related molecules form a dimer held together by hydrogen bonds at the carboxylic ends of the molecules at a distance of 2.632 (3) Å. Fig. 3 shows the dimers and the packing of the molecules. The dibenzofuran groups are not parallel

(Banerjee, 1973; Dideberg, Dupont & André, 1972; Silverton, 1973) but oriented perpendicularly towards each other.

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## 2-[2-(Phenoxy)phenoxy]-2-methylpropionic Acid

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**Abstract.** C<sub>16</sub>H<sub>16</sub>O<sub>4</sub>, monoclinic, *P*2<sub>1</sub>/*n*, *a* = 9.005 (3), *b* = 20.023 (3), *c* = 8.119 (3) Å,  $\beta$  = 105.91 (3)°, *d*<sub>c</sub> = 1.28 Mg m<sup>-3</sup>, *Z* = 4. The structure was solved by direct methods and refined by least-squares methods to an *R* value of 0.041. The two benzene rings are twisted

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out of the C–O–C plane linking the two phenyl groups together, with torsion angles of 177 and –75°.

**Introduction.** 2-[2-(Phenoxy)phenoxy]-2-methylpropionic acid was synthesized as part of a programme of © 1979 International Union of Crystallography