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The Crystal Structures of Verrucarin E (4-Acetyl-3-hydroxymethylpyrrole) and its $\frac{1}{3}$ Hydrate

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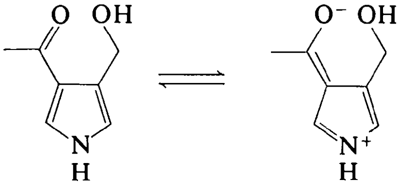
Verrucarin E (4-acetyl-3-hydroxymethylpyrrole) (I), a secondary metabolite of the soil fungus *Myrothecium verrucaria*, crystallizes in space group $P\bar{1}$ with a = 8·214 (8), b = 12·420 (14), c = 7·793 (7) Å, α = 99·87 (10), β = 112·08 (9), γ = 92·79 (8)°, Z = 4; its $\frac{1}{3}$ hydrate (II) crystallizes in space group $P2_1/c$, a = 19·687 (6), b = 15·922 (9), c = 7·161 (2) Å, β = 98·51 (3)°, Z = 12. The structures were solved by direct methods and refined to R = 0·053 and 0·064 respectively. Strong intramolecular O—H···O hydrogen bonding between the 3-hydroxymethyl and 4-acetyl O atoms is observed in one of the independent molecules of (I) and (II) respectively (bond lengths 2·73 and 2·79 Å). The 3-hydroxy C—O bond adopts an *anti*, and the 4-acetyl C=O bond a *syn* orientation to the C(3)—C(4) pyrrole-ring bond in the remaining independent molecules. The crystal structures of (I) and (II) are stabilized by a complex network of intermolecular hydrogen bonds which involve the pyrrole N, the 3-hydroxy and 4-acetyl O and, in the case of (II), the water O atoms. The presence of the electron-withdrawing β-acetyl substituent leads to a distortion of the pyrrole-ring geometry with respect to the parent system. The N(1)—C(5) and C(2)—C(3) bonds (average 1·342 and 1·357 Å) are significantly shorter than the N(1)—C(2) and C(4)—C(5) bonds (average 1·374 and 1·385 Å). This and the shortness of C(4)—C(41) [1·466 *vs* 1·499 Å for C(3)—C(31)] are in accordance with a significant resonance contribution from a dipolar structure with charge localization at the N and β-acetyl O atoms. Bond lengths and angles are similar in all five independent molecules.

Introduction

The number of known microbial metabolites, which are simple pyrrole derivatives, is relatively small (Gossauer, 1974). The secondary metabolite verrucarin E was isolated in the pure crystalline form from the soil fungus *Myrothecium verrucaria* by Härri, Loeffler, Sigg, Stähelin, Stoll, Tamm & Wiesinger (1962); Fetz & Tamm (1966) later assigned it the structure 4-acetyl-2-hydroxymethylpyrrole on the basis of spectroscopic data. A subsequent synthesis and re-examination of the spectroscopic information showed it to be, in fact, the isomeric 4-acetyl-3-hydroxymethylpyrrole (Pfäffli & Tamm, 1969). A rational high-overall-yield total synthesis of verrucarin E has recently been reported (Gossauer & Suhl, 1976).

Two aspects of the molecular structure of verrucarin E are of particular interest:

(1) The presence of the electron-withdrawing β-acetyl substituent should lead to a marked alteration of the pyrrole-ring geometry with respect to the parent system. The reduced reactivity of the carbonyl group to nucleophilic attack in pyrrolyl ketones has often been rationalized in terms of a significant resonance contribution from the dipolar structure (III).



(I) (III)

(2) Model considerations suggest that a strong intramolecular O—H···O hydrogen bond should be possible between the 3-hydroxy and 4-acetyl O atoms. A qualitative measure of the strength of such bonds could be gauged by observing them in the crystalline state in competition with a palette of possible intermolecular hydrogen bonds involving the pyrrole-ring N and possibly solvent-molecule O atoms, in addition to the 3-hydroxy and 4-acetyl functions.

This structural study was undertaken in view of these aspects and on account of the putative antifungal and

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cytostatic activities of verrucarin E (Härri *et al.*, 1962). Two different crystalline forms were obtained during the course of crystallization attempts from various solvent mixtures. Preliminary photographic studies established that the plate-shaped crystals (I) grown by slow evaporation of a methylene dichloride/benzene (*pro analyse*) mixture were in space group $P\bar{1}$, presumably with two independent molecules per unit cell ($Z = 4$), whereas the needle-shaped crystals (II), which were obtained by diffusion of petroleum ether (b.p. 30–50°C) into a benzene solution, were in space group $P2_1/c$ with three independent molecules per unit cell ($Z = 12$). The subsequent solution of the structure of (II) revealed the presence of one independent water molecule in the unit cell, which must presumably have resulted from the use of 'wet' benzene.

Experimental

Crystal and refinement data for (I) and (II) are summarized in Table 1. Cell parameters were determined by a least-squares fit to the settings for 15 reflexions ($\pm hkl$) on a Syntex $P2_1$ diffractometer [(I) with Cu $K\alpha$, $\lambda = 1{\cdot}54178$ Å, (II) with Mo $K\alpha$, $\lambda = 0{\cdot}71069$ Å]. Intensities were collected with graphite-monochromated radiation. Measurements were carried out in the θ–2θ mode at scan speeds varying linearly between 2·93° min^{-1} (150 c.p.s. and below) and 29·30° min^{-1} (5000 c.p.s. and above). The net intensity of each reflexion (scaled to counts per minute) was assigned a standard deviation, based on the counting statistics, of $\sigma(I) = t(N_s + N_b)^{1/2}$, where t is the scan rate, N_s the gross count and N_b the total background count. Lorentz and polarization corrections were applied, but no absorption correction was made.

Table 1. *Crystal and refinement data*

	(I)	(II)
Stoichiometry	$C_7H_9NO_2$	$C_7H_9NO_2.\frac{1}{3}H_2O$
Space group	$P\bar{1}$	$P2_1/c$
a (Å)	8·214 (8)	19·687 (6)
b (Å)	12·420 (14)	15·922 (9)
c (Å)	7·793 (7)	7·161 (2)
α (°)	99·87 (10)	
β (°)	112·08 (9)	98·51 (3)
γ (°)	92·79 (8)	
U (Å^3)	720·2 (10)	2219·9 (16)
Z	4	12
M_r	139·2	145·2
D_c (g cm^{-3})	1·28	1·30
Radiation	Cu $K\alpha$	Mo $K\alpha$
μ (cm^{-1})	6·99	0·61
2θ range (°)	3·0–135·0	3·0–50·0
F rejection criterion	$<3{\cdot}0\sigma(F)$	$<4{\cdot}0\sigma(F)$
Number of reflexions	2179	2184
Reflexions/parameter	8·89	5·75
R	0·053	0·064
$R_w (= \Sigma w^{1/2}\Delta/\Sigma w^{1/2}F_o)$	0·052	0·064
$R_G[=(\Sigma w\Delta^2/\Sigma wF_o^2)^{1/2}]$	0·052	0·073
k*	1·0	1·9739
g*	0·0	0·001245
Largest shift/e.s.d.†	0·11	0·11
Highest difference Fourier peak† (e Å^{-3})	0·16	0·29

* $w = k[\sigma^2(F_o) + gF_o^2]^{-1}$.

† Refers to the last refinement cycle.

Structure solution and refinement

All reflexions were included in the direct-methods structure solutions, those with $I < 1{\cdot}0\sigma(I)$ being assigned a value of $0{\cdot}25\sigma(I)$. The structure of (II) was solved with difficulty by an automatic multisolution technique (*SHELX* 76, G. M. Sheldrick) in which 2^{20} sign permutations were expanded by the Σ_2 formula. During the sign expansion the progressive M(abs.) test (Germain, Main & Woolfson, 1970) was used to reduce the number of surviving permutations. A 'similarity' test was also applied to avoid the calculation of closely similar E maps. In this case only one E map was obtained, which revealed, however, only nine atoms of one verrucarin E molecule and seven atoms of a second molecule. The remaining 15 heavy atoms were located in subsequent difference syntheses. Attempts to solve the structure of (I) by automatic sign expansion were fruitless. Eventually the solution was obtained by multisolution tangent refinement using a restricted set of E values [E(min.) = 1·7, 172 reflexions] and seven multisolution phases. The third best E map revealed 18 of the 20 independent atoms.

The structures were refined by blocked-full-matrix least squares, $\Sigma w\Delta^2$ being minimized; anisotropic temperature factors were introduced for all nonhydrogen atoms, with the exception of O(41) and C(42) in molecule (II*c*) for which disorder was observed. The site-occupation factors for the disordered O and C atoms, which were assigned two group isotropic temperature factors, refined to 0·731 (26) and 0·269 (26). The O(41) and C(42) temperature factors were then 0·041 (1) and 0·050 (2) Å^2 respectively. Difference syntheses revealed the positions of the H atoms, which were included with isotropic temperature factors [for the C(42) methyl H atoms in (I*a*) and (I*b*) with two group temperature factors] in the final cycles. The O(31) H atoms for (I*b*) and (II*a*) refined towards the middle of their respective O—H···O hydrogen bonds [for (I*b*) intermolecular, for (II*a*) intramolecular] and were associated with unreasonably high isotropic temperature factors. They were, therefore, excluded from the final refinement. The weights were given by $w = k[\sigma^2(F_o) + gF_o^2]^{-1}$. Complex neutral-atom scattering factors (Cromer & Waber, 1965; Cromer & Liberman, 1970) were employed for the nonhydrogen atoms. The final atomic coordinates are listed in Table 2. H atom positional parameters and isotropic temperature factors are presented in Table 3, and bond lengths and bond angles for the nonhydrogen atoms in Tables 4 and 5. The numbering system throughout is that shown in the perspective drawings of the two independent molecules in the structure of (I), *i.e.* the atoms are assigned as N(X1), C(X2) *etc.*, where X = 1, 2 for independent molecules (I*a*), (I*b*), and X = 1, 2, 3 for independent molecules (II*a*), (II*b*) and (II*c*) respectively. Figs. 1–3, which show the molecules in perspective and the projections of the unit-cell contents, were drawn by *MIRAGE* (W. S. Sheldrick & D. N. Lincoln).*

Table 2. *Positional parameters* ($\times 10^4$) *for the nonhydrogen atoms*

	x	y	z
Molecule (I)			
N(11)	441 (2)	7713 (1)	776 (2)
C(12)	779 (2)	7754 (1)	2649 (3)
C(13)	9852 (2)	6861 (1)	2800 (2)
C(14)	8886 (2)	6247 (1)	902 (2)
C(15)	9302 (2)	6817 (1)	9711 (2)
C(131)	9963 (3)	6563 (2)	4620 (3)
O(131)	8275 (2)	6347 (1)	4724 (2)
C(141)	7701 (2)	5242 (1)	307 (2)
O(141)	7348 (2)	4804 (1)	1464 (2)
C(142)	6867 (3)	4700 (2)	8267 (3)
N(21)	5435 (2)	2785 (1)	1334 (2)
C(22)	5151 (2)	2642 (1)	2923 (2)
C(23)	4080 (2)	1692 (1)	2505 (2)
C(24)	3662 (2)	1227 (1)	554 (2)
C(25)	4531 (2)	1938 (1)	9901 (2)
C(231)	3411 (3)	1241 (2)	3810 (3)
O(231)	3922 (2)	1975 (1)	5578 (2)
C(241)	2558 (2)	204 (1)	9469 (2)
O(241)	1955 (2)	9592 (1)	230 (2)
C(242)	2152 (3)	9887 (2)	7394 (3)
Molecule (II)			
N(11)	2754 (1)	3514 (2)	9605 (6)
C(12)	3232 (2)	3203 (3)	11005 (7)
C(13)	3868 (1)	3385 (2)	10611 (6)
C(14)	3771 (1)	3840 (2)	8855 (5)
C(15)	3069 (2)	3898 (2)	8296 (6)
C(131)	4534 (2)	3094 (3)	11716 (7)
O(131)	4978 (1)	3751 (2)	12358 (5)
C(141)	4293 (2)	4160 (2)	7825 (6)
O(141)	4904 (1)	4158 (2)	8547 (4)
C(142)	4094 (2)	4493 (3)	5874 (7)
N(21)	9791 (1)	1162 (2)	8449 (5)
C(22)	458 (1)	872 (2)	8715 (6)
C(23)	889 (1)	1539 (2)	8955 (5)
C(24)	469 (1)	2277 (2)	8815 (5)
C(25)	9794 (1)	2001 (2)	8506 (6)
C(231)	1659 (1)	1509 (2)	9259 (6)
O(231)	1918 (1)	664 (1)	9442 (4)
C(241)	703 (1)	3142 (2)	8941 (5)
O(241)	1319 (1)	3312 (1)	9245 (4)
C(242)	194 (2)	3844 (2)	8686 (6)
N(31)	3689 (1)	5993 (2)	1953 (5)
C(32)	3047 (2)	5635 (2)	1781 (6)
C(33)	2574 (1)	6265 (2)	1735 (5)
C(34)	2947 (1)	7045 (2)	1856 (5)
C(35)	3637 (2)	6835 (3)	1985 (6)
C(331)	1809 (2)	6163 (2)	1551 (7)
O(331)	1598 (1)	5308 (2)	1269 (5)
C(341)	2671 (2)	7891 (2)	1838 (5)
O(341)	2043 (3)	8020 (3)	1635 (14)
C(342)	3177 (6)	8604 (7)	1847 (16)
O(341)′	2068 (7)	7008 (9)	−2748 (39)
C(342)′	3093 (17)	6284 (21)	−2941 (47)
O(W)	1535 (1)	5391 (2)	7265 (5)

Table 3. *Hydrogen-atom positional parameters* ($\times 10^3$) *and isotropic temperature factors* ($\times 10^3$)

	x	y	z	U (Å^2)
Molecule (I)				
H(11)	90 (3)	828 (2)	41 (3)	86 (9)
H(12)	157 (3)	838 (2)	356 (3)	75 (7)
H(15)	887 (2)	663 (2)	835 (3)	53 (6)
H(131)	61 (3)	725 (2)	578 (4)	94 (8)
H(132)	56 (3)	582 (2)	477 (3)	88 (8)
H(133)	767 (3)	568 (2)	371 (4)	105 (10)
H(141)	688 (4)	390 (3)	801 (4)	136 (7)
H(142)	732 (4)	500 (3)	745 (4)	136 (7)
H(143)	581 (4)	478 (3)	779 (5)	136 (7)
H(21)	614 (3)	343 (2)	122 (3)	83 (8)
H(22)	573 (2)	318 (2)	406 (3)	54 (6)
H(25)	456 (3)	194 (2)	857 (3)	67 (6)
H(231)	381 (2)	51 (2)	404 (3)	44 (5)
H(232)	198 (3)	110 (2)	334 (3)	55 (6)
H(241)	759 (5)	88 (3)	1294 (5)	156 (8)
H(242)	783 (5)	946 (3)	1312 (5)	156 (8)
H(243)	907 (5)	49 (3)	1325 (5)	156 (8)
Molecule (II)				
H(11)	234 (2)	344 (3)	940 (6)	74 (14)
H(12)	311 (2)	291 (2)	1213 (6)	63 (12)
H(15)	280 (2)	411 (2)	724 (5)	60 (12)
H(131)	443 (2)	289 (2)	1288 (5)	55 (12)
H(132)	497 (1)	280 (1)	1104 (3)	2 (7)
H(141)	436 (3)	422 (3)	502 (8)	111 (7)
H(142)	359 (3)	445 (4)	541 (8)	111 (7)
H(143)	427 (3)	505 (4)	606 (8)	111 (7)
H(21)	945 (2)	85 (2)	835 (5)	60 (12)
H(22)	53 (2)	32 (2)	863 (5)	36 (10)
H(25)	940 (1)	230 (2)	837 (4)	20 (8)
H(231)	188 (2)	180 (2)	1052 (5)	47 (11)
H(232)	187 (2)	179 (3)	797 (6)	69 (13)
H(233)	182 (2)	45 (2)	839 (6)	62 (12)
H(241)	988 (3)	379 (3)	960 (8)	111 (7)
H(242)	992 (3)	382 (3)	764 (8)	111 (7)
H(243)	42 (3)	446 (4)	887 (8)	111 (7)
H(31)	408 (2)	933 (2)	698 (5)	46 (12)
H(32)	299 (2)	997 (3)	669 (6)	56 (13)
H(35)	406 (2)	779 (2)	711 (6)	52 (12)
H(331)	155 (2)	848 (2)	555 (5)	37 (11)
H(332)	164 (2)	868 (3)	764 (6)	45 (13)
H(333)	156 (3)	519 (3)	1014 (7)	79 (21)
H(341)	292 (4)	586 (5)	682 (12)	111 (7)
H(342)	319 (4)	618 (5)	568 (12)	111 (7)
H(343)	359 (4)	643 (5)	699 (11)	111 (7)
HW(1)	162 (3)	501 (4)	632 (9)	107 (23)
HW(2)	170 (2)	576 (3)	706 (7)	48 (20)

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* Lists of structure factors and anisotropic thermal parameters have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 33157 (16 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 13 White Friars, Chester CH1 1NZ, England.

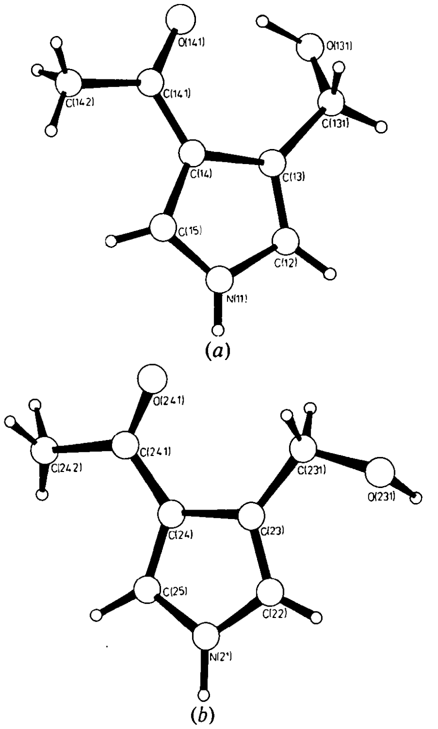

Fig. 1. Molecules (*a*) (I*a*) and (*b*) (I*b*) in perspective.

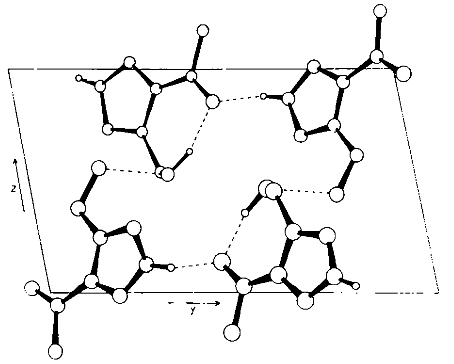

Fig. 2. Unit-cell contents of (I) perpendicular to [100].

Discussion

The crystal structures of both (I) and (II) are characterized by their complex network of hydrogen bonds (Table 6). However, whereas the independent molecules (I*a*) and (II*a*) both display strong intramolecular O—H···O hydrogen bonds between the 3-hydroxy and 4-acetyl O atoms, the remaining molecules (I*b*), (II*b*) and (II*c*) only take part in intermolecular hydrogen

Table 4. *Bond lengths* (Å)

	(I*a*)	(I*b*)	(II*a*)	(II*b*)	(II*c*)	Average
N(1)—C(2)	1·371 (3)	1·381 (3)	1·363 (6)	1·378 (5)	1·376 (6)	1·374
N(1)—C(5)	1·342 (2)	1·342 (2)	1·345 (6)	1·336 (6)	1·345 (7)	1·342
C(2)—C(3)	1·361 (3)	1·350 (3)	1·354 (6)	1·354 (5)	1·366 (6)	1·357
C(3)—C(4)	1·439 (2)	1·432 (3)	1·440 (6)	1·433 (5)	1·439 (5)	1·437
C(4)—C(5)	1·385 (3)	1·383 (3)	1·384 (5)	1·385 (5)	1·388 (6)	1·385
C(3)—C(31)	1·497 (3)	1·496 (4)	1·500 (6)	1·501 (6)	1·501 (5)	1·499
C(31)—O(31)	1·434 (3)	1·415 (3)	1·398 (7)	1·438 (5)	1·429 (5)	1·423
C(4)—C(41)	1·437 (3)	1·447 (2)	1·444 (6)	1·451 (6)	1·452 (6)	1·446
C(41)—O(41)	1·242 (3)	1·230 (3)	1·237 (5)	1·229 (5)	1·241 (6)*	1·236
C(41)—C(42)	1·490 (3)	1·499 (3)	1·492 (7)	1·495 (6)	1·505 (13)*	1·496

* Refers to the disordered atoms with site-occupancy factors of 0·7315.

Table 5. *Bond angles* (°)

	(I*a*)	(I*b*)	(II*a*)	(II*b*)	(II*c*)	Average
C(2)—N(1)—C(5)	109·8 (2)	109·0 (2)	109·8 (3)	109·4 (3)	110·1 (4)	109·6
C(3)—C(2)—N(1)	108·9 (2)	109·1 (2)	109·2 (4)	108·7 (3)	108·1 (4)	108·8
C(4)—C(3)—C(2)	106·3 (2)	106·5 (2)	106·4 (3)	106·9 (3)	107·0 (3)	106·6
C(5)—C(4)—C(3)	106·7 (2)	106·9 (2)	106·5 (4)	106·3 (3)	106·4 (4)	106·6
C(4)—C(5)—N(1)	108·3 (2)	108·4 (2)	108·1 (4)	108·7 (3)	108·3 (4)	108·4
C(31)—C(3)—C(2)	125·3 (2)	126·5 (2)	125·9 (4)	126·5 (4)	126·4 (4)	126·1
C(31)—C(3)—C(4)	128·2 (2)	127·0 (2)	127·5 (4)	126·6 (3)	126·6 (3)	127·2
C(41)—C(4)—C(3)	127·8 (2)	126·8 (3)	127·7 (3)	126·8 (3)	127·7 (3)	127·4
C(41)—C(4)—C(5)	125·4 (2)	126·3 (2)	125·8 (4)	126·8 (4)	125·8 (4)	126·0
O(41)—C(41)—C(4)	121·4 (2)	120·9 (2)	120·5 (4)	121·1 (4)	121·4 (4)*	121·1
O(41)—C(41)—C(42)	118·5 (2)	119·7 (2)	119·8 (4)	118·8 (4)	121·5 (6)*	119·7
C(42)—C(41)—C(4)	120·2 (2)	119·4 (2)	119·7 (4)	120·0 (3)	116·7 (5)*	119·2
O(31)—C(31)—C(3)	113·9 (2)	112·0 (2)	113·5 (4)	112·3 (3)	112·5 (3)	112·8

* Refers to the disordered atoms with site-occupancy factors of 0·7315.

bonds. The pyrrole-ring N proton is involved in N—H···O bonds to the carbonyl O(41) for all molecules except (II*b*), where it forms a hydrogen bond to the O of the solvent water molecule. This water O atom is involved in its maximum number of four hydrogen bonds, twice to (II*b*) and twice to (II*c*). Both of the disordered O(41) atoms in (I*c*) take part in O···H—O(*W*) bonds of similar length (2·78 Å). As may be seen from Fig. 1 and Table 7, it is necessary for O(31) in (I*a*) and (II*a*) to adopt a position well out of the pyrrole-ring least-squares plane (−0·91 and −0·96 Å respectively) in order for it to take part in strong O—H···O intramolecular hydrogen bonding. The remaining three independent molecules all display basically similar conformations with the C(31)—O(31) bond in an *anti* orientation to the C(3)—C(4) bond. The C(41)—O(41) carbonyl bond is *syn* to the C(3)—C(4) bond, as in (I*a*) and (II*a*). In (I*b*) and (II*c*) the displacement of O(31) from the pyrrole plane is relatively small (−0·178 and −0·140 Å respectively); this should

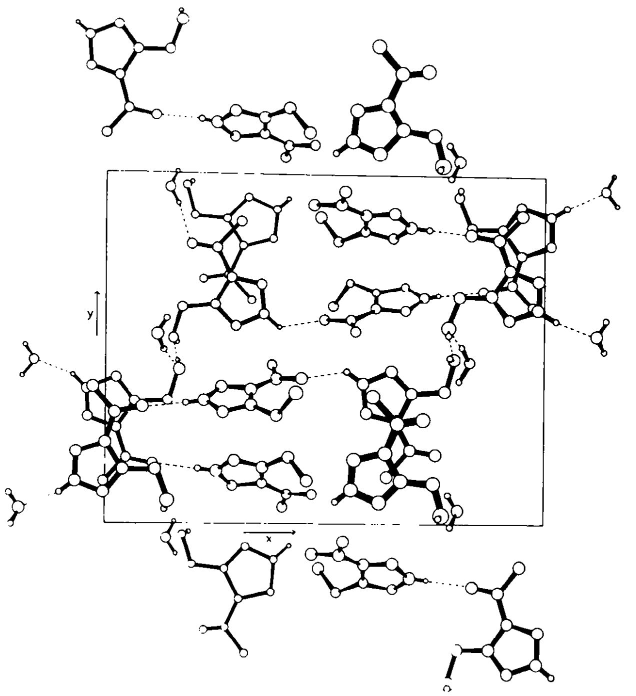

Fig. 3. Unit-cell contents of (II) perpendicular to [001].

Table 7. *Distances of atoms* (Å) *from pyrrole-ring least-squares plane*

	(I*a*)	(I*b*)	(II*a*)	(II*b*)	(II*c*)
N(1)	0·003	0·004	0·002	0·003	0·005
C(2)	−0·003	−0·004	0·002	0·050	−0·006
C(3)	0·001	0·003	−0·004	0·100	0·004
C(4)	0·000	−0·000	0·005	0·045	−0·001
C(5)	−0·002	−0·002	−0·004	0·002	−0·003
C(31)	0·096	−0·033	0·105	−0·336	−0·00
O(31)	−0·909	−0·178	−0·960	−0·513	−0·140
C(41)	−0·007	0·011	0·002	−0·009	−0·011
O(41)	−0·054	0·115	−0·157	−0·232	−0·068*
C(42)	−0·453	−0·098	0·215	0·218	−0·264*

* Refers to the disordered atoms with site-occupancy factors of 0·7315.

Table 6. *Hydrogen bonding*

	(I*a*)	(I*b*)	(II*a*)	(II*b*)	(II*c*)
(1) N—H···O					
N···O (Å)	2·762	2·859	2·818	2·862	2·855
H···O (Å)	1·88	1·88	2·00	2·06	2·11
N—H (Å)	0·92 (3)	1·00 (3)	0·83 (4)	0·83 (4)	0·92 (4)
O atom involved	O(41)	O(41)	O(41)	O(*W*)	O(41)
Molecule involved	(I*b*)	(I*a*)	(II*b*)	H_2O	(II*a*)
Symmetry transformation	*x*,*y*,*z*	1·0 + *x*, 1·0 + *y*, *z*	*x*, *y*, *z*	−*x*, 0·5 + *y*, 1·5 − *z*	1·0 − *x*, 1·0 − *y*, 1·0 − *z*
(2) O(31)—H···O					
O···O (Å)	2·728	2·805	2·788	2·745	2·853
H···O (Å)	1·82	—*	—*	1·94	2·08
O—H (Å)	0·99 (3)	—	—	0·83 (4)	0·82 (5)
O atom involved	O(41)	O(31)	O(41)	O(31)	O(*W*)
Molecule involved	(I*a*)	(I*a*)	(II*a*)	(II*c*)	H_2O
Symmetry transformation	*x*,*y*,*z*	−*x*, −*y*, 1·0 − *z*	*x*,*y*,*z*	*x*, 0·5 − *y*, −0·5 + *z*	*x*, *y*, 1·0 + *z*
(3) O···H—O(*W*)					
O···O (Å)				2·819	2·777/2·776†
H···O (Å)				1·93	2·06/2·08
O(*W*)—H (Å)				0·90 (6)	0·73 (6)
O atom involved				O(31)	O(41)/O(41)′
Molecule involved				—	—
Symmetry transformation				*x*, 0·5 − *y*, 0·5 + *z*	*x*, 1·5 − *y*, −0·5 + *z*

* H atom could not be refined satisfactorily.
† O(41) in molecule (II*c*) is disordered.

represent the most sterically favourable conformation of a verrucarin E molecule without O—H···O intramolecular bonding, as it will enable the two C(31) H atoms to adopt a staggered position with respect to O(41). The larger deviation of O(31) in (II*b*) from the pyrrole plane (—0·513 Å) is presumably a result of its taking part in two intermolecular O—H···O bonds.

The pyrrole-ring geometry in verrucarin E is markedly altered from that of the parent compound (Nygaard, Nielsen, Kirchheimer, Maltesen, Rastrup-Andersen & Sorensen, 1969). The C(41) and O(41) atoms of the β-acetyl group lie close to the pyrrole plane in all five independent molecules of (I) and (II), as would be expected for an optimized interaction with the aromatic π system. The bond-length distribution is in accordance with a significant resonance contribution from the dipolar structure (III). An analogous perturbation of the pyrrole-ring bonding was also observed for 4-acetyl-2-ethoxycarbonyl-3-ethyl-5-methylpyrrole (Bonnett, Hursthouse & Neidle, 1972), in which case, however, a dipolar structure between the N and the 2-ethoxycarbonyl O was found to be more important than that with the 4-acetyl O. In verrucarin E, the N(1)—C(5) and C(2)—C(3) bonds are very significantly shorter than N(1)—C(2) and C(4)—C(5), in accordance with a higher degree of double-bond character. The average C(4)—C(41) bond length is likewise 0·053 Å shorter than C(3)—C(31). With the exception of the short C(31)—O(31) distance of 1·398 (7) Å in (II*a*) (average value 1·423 Å) bond lengths and angles are similar in all five independent molecules.

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References

BONNETT, R., HURSTHOUSE, M. B. & NEIDLE, S. (1972). *J. Chem. Soc. Perkin Trans.* 2, pp. 902–906.

CROMER, D. T. & LIBERMAN, D. (1970). *J. Chem. Phys.* **53**, 1891–1898.

CROMER, D. T. & WABER, J. T. (1965). *Acta Cryst.* **18**, 104–109.

FETZ, E. & TAMM, C. (1966). *Helv. Chim. Acta*, **49**, 349–359.

GERMAIN, G., MAIN, P. & WOOLFSON, M. M. (1970). *Acta Cryst.* B**26**, 274–285.

GOSSAUER, A. (1974). *Die Chemie der Pyrrole. Organische Chemie in Einzeldarstellungen*, Vol. 15, pp. 190–208. Berlin, Heidelberg, New York: Springer-Verlag.

GOSSAUER, A. & SUHL, K. (1976). *Helv. Chim. Acta*, **59**, 1698–1704.

HÄRRI, E., LOEFFLER, W., SIGG, H. P., STÄHELIN, H., STOLL, C., TAMM, C. & WIESINGER, D. (1962). *Helv. Chim. Acta*, **45**, 839–853.

NYGAARD, L., NIELSEN, J. T., KIRCHHEIMER, J., MALTESEN, G., RASTRUP-ANDERSEN, G. & SORENSEN, G. O. (1969). *J. Mol. Struct.* **3**, 491–506.

PFÄFFLI, P. & TAMM, C. (1969). *Helv. Chim. Acta*, **52**, 1911–1929.