Fungal Metabolites. Part 7.[1] Structures of C_{25} Compounds from *Aspergillus variecolor*

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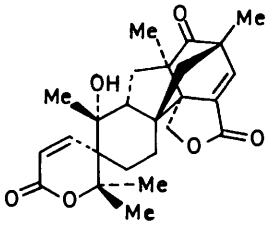
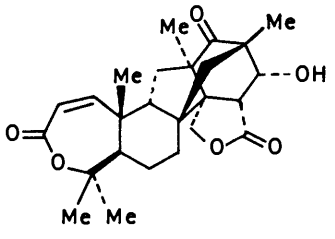
Spectroscopic evidence is presented for the structures of four novel C_{25} metabolites of *Aspergillus variecolor*.

We have briefly reported the structures of two metabolites isolated from a static culture of a pure strain of the fungus, *Aspergillus variecolor*,[2,3] and the isolation of two other closely similar compounds.[3] We present here the full evidence for the structures of andibenin [2] and andilesin [3] which were analysed by *X*-ray diffraction methods. Determination of the structures of andibenin and andilesin (now named andilesin-A) allowed us to formulate structures for two other metabolites, andilesin-B and andilesin-C, by consideration of ^{1}H n.m.r., i.r., u.v., and mass spectra. The structures of all four compounds (1)—(4) are shown.



(1)



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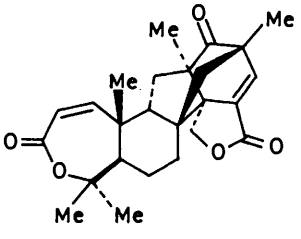

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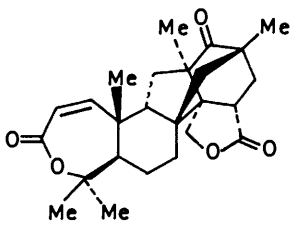

(4)

EXPERIMENTAL

This work began as an attempt to isolate metabolites of a fungus, *Phoma* NRRL 3188 but, during isolation of metabolites, we identified two pigments, shamixanthone and tajixanthone,[4] in the mycelium. These pigments together with the isolation of 6-methoxymellein, siderin, and terrein from the growth liquors suggested we were not working with a *Phoma* species but with *Aspergillus*. This supposition was confirmed by the Commonwealth Mycological Institute where the fungus was identified as a pure strain of *Aspergillus variecolor*, but the strain was not identified. We have in our laboratories several strains of *Aspergillus variecolor* and it now seems clear a substitution must have occurred at an early stage in the work.[2,5] It has been observed subsequently that many of our strains produce andibenin and the andilesins, which are not therefore peculiar to one strain; this latter work will be reported by others.[6]

Aspergillus variecolor was grown for 17 days at 25° in static culture on a medium of glucose (20 g), malt extract (2 g), mycological peptone (2 g), potassium orthophosphate (2 g), magnesium sulphate (2 g), and distilled water (1 l). The mycelium and liquor were separated by filtration. The liquors were concentrated to *ca.* 200 ml and extracted with ethyl acetate (5 × 200 ml). Evaporation of the solvent gave a brown oil which, when dissolved in hot acetone and allowed to cool, deposited crystals of terrein.[5] After evaporation of acetone from the filtrate, the residue was chromatographed by thick-layer chromatography [20 × 100 cm plates coated with 1 mm thick silica PF 254 (Merck); 1 g residue per plate] eluting with MeOH–$CHCl_3$ (4 : 96). Bands were removed from the plates and purified by similar t.l.c. using multiple and/or continuous elution (20 × 20 cm plates) to yield 6-methoxymellein, siderin, an unknown substance (X), andibenin, and andilesin-A—C.

6-Methoxymellein.—This was isolated in a yield of 4.4 mg l^{-1} of culture liquors, m.p. 73—74° (lit.,[7] 76°) (Found: C, 63.6; H, 5.9. Calc. for $C_{11}H_{12}O_4$: C, 63.5; H, 5.8%), $[\alpha]_D^{27}$ −52.7° (*c* 1.135; MeOH); *m/e* 208.070 7 (*M*,

$C_{11}H_{12}O_4$); δ($CDCl_3$) 1.48 (3 H, d, *J* 6.5 Hz), 2.87 (2 H, d, *J* 7.5 Hz), 3.86 (3 H, s), 4.73 (1 H, m), and 6.5 (2 H, m).

Siderin.—This was isolated in a yield of 0.1 mg l^{-1} of liquors, m.p. 191—192° (lit.,[8] 194—195°); $\lambda_{max.}$(EtOH) 307 (ε 14 700), 314 (12 700), and 288 nm (11 600); $\nu_{max.}$ (Nujol) 1 720, 1 625, and 1 610 cm^{-1}; δ($CDCl_3$) 2.59 (3 H, s), 3.80 (3 H, s), 3.90 (3 H, s), 5.50 (1 H, s), 6.61 (2 H, m); *m/e* 220.073 8 (M^+, $C_{12}H_{12}O_4$).

Unknown (*X*).—This was isolated in a yield of 1.7 mg l^{-1} of liquors, m.p. 132—133° (Found: C, 67.2; H, 7.6. Calc. for $C_{15}H_{20}O_4$: C, 68.2; H, 7.6%); $[\alpha]_D^{27}$ +20.2° (*c* 0.98, EtOH).

Andibenin.—This was isolated in a yield of 3.3 mg l^{-1} of liquors, m.p. 219—220° (from MeOH) (Found: C, 70.1; H,

TABLE 1

Andilesin-A. Fractional atomic co-ordinates (× 10^4 for C and O) with estimated standard deviations in parentheses

Atom	*x*	*y*	*z*
C(1)	0.814(3)	0.492 4(6)	0.041(2)
C(2)	0.682(3)	0.498 0(8)	0.110(2)
C(3)	0.651(3)	0.477 0(8)	0.210(2)
C(4)	0.965(3)	0.452 4(8)	0.245(2)
C(5)	0.998(3)	0.429 8(6)	0.138(1)
C(6)	1.182(2)	0.404 1(7)	0.136(2)
C(7)	1.238(2)	0.388 7(7)	0.023(2)
C(8)	1.099(2)	0.386 6(6)	−0.064(1)
C(9)	0.959(2)	0.428 8(6)	−0.058(2)
C(10)	0.975(2)	0.462 0(6)	0.043(2)
C(11)	0.780(2)	0.403 7(6)	−0.070(1)
C(12)	0.825(2)	0.357 6(6)	−0.129(2)
C(13)	0.986(2)	0.339 7(6)	−0.066(1)
C(14)	1.085(3)	0.299 7(6)	−0.122(2)
C(15)	1.106(3)	0.307 5(7)	−0.242(2)
C(16)	1.082(3)	0.362 4(7)	−0.259(2)
C(17)	0.887(3)	0.372 3(6)	−0.241(2)
C(18)	1.136(2)	0.497 0(7)	0.022(2)
C(19)	0.665(3)	0.324 3(7)	−0.139(2)
C(20)	1.140(4)	0.376 9(8)	−0.368(2)
C(21)	1.041(2)	0.502 8(7)	0.265(2)
C(22)	1.025(3)	0.419 8(8)	0.337(2)
C(23)	0.932(3)	0.314 9(6)	0.038(2)
C(24)	0.996(3)	0.255 2(7)	−0.080(2)
C(25)	1.182(3)	0.387 3(7)	−0.173(2)
O(26)	0.507(2)	0.479 2(6)	0.248(1)
O(27)	0.773(2)	0.453 3(6)	0.268(1)
O(28)	0.913(2)	0.265 7(4)	0.011(1)
O(29)	0.998(2)	0.215 9(5)	−0.120(1)
O(30)	0.972(2)	0.284 5(5)	−0.301(1)
O(31)	0.791(2)	0.391 3(5)	−0.302(1)

TABLE 2

Andilesin-A. Bond lengths (Å) with standard deviations in parentheses

Bond	Length	Bond	Length
C(1)–C(2)	1.34(3)	C(10)–C(18)	1.59(3)
C(2)–C(3)	1.42(3)	C(11)–C(12)	1.53(2)
C(3)–O(26)	1.19(2)	C(12)–C(13)	1.54(2)
C(3)–O(27)	1.35(2)	C(12)–C(17)	1.56(3)
C(4)–O(27)	1.49(2)	C(12)–C(19)	1.53(2)
C(4)–C(5)	1.52(3)	C(13)–C(14)	1.52(2)
C(4)–C(21)	1.55(3)	C(13)–C(23)	1.54(2)
C(4)–C(22)	1.55(3)	C(14)–C(15)	1.55(3)
C(5)–C(6)	1.56(3)	C(14)–C(24)	1.51(3)
C(5)–C(10)	1.51(3)	C(15)–C(16)	1.56(3)
C(6)–C(7)	1.55(3)	C(15)–O(30)	1.41(2)
C(7)–C(8)	1.53(2)	C(16)–C(17)	1.52(3)
C(8)–C(9)	1.59(2)	C(16)–C(20)	1.50(3)
C(8)–C(13)	1.57(3)	C(16)–C(25)	1.50(3)
C(8)–C(25)	1.53(3)	C(17)–O(31)	1.19(2)
C(9)–C(10)	1.58(2)	C(23)–O(28)	1.43(2)
C(9)–C(11)	1.53(2)	C(24)–O(28)	1.34(3)
C(10)–C(1)	1.48(3)	C(24)–O(29)	1.21(2)

TABLE 3

Andilesin-A. Bond angles with standard deviations in parentheses

Angle	Size (°)	Angle	Size (°)
2–1–10	132(2)	11–12–17	107(1)
1–2–3	131(2)	11–12–19	113(2)
2–3–26	119(2)	13–12–17	109(2)
2–3–27	125(2)	13–12–19	118(1)
26–3–27	115(2)	17–12–19	109(2)
5–4–21	118(2)	8–13–14	111(1)
5–4–27	110(2)	8–13–12	100(1)
21–4–22	108(2)	8–13–23	121(1)
21–4–27	108(2)	12–13–14	113(2)
22–4–27	98(2)	12–13–23	112(2)
22–4–5	112(2)	14–13–23	101(1)
4–5–6	111(2)	13–14–15	114(2)
4–5–10	116(2)	13–14–24	103(2)
6–5–10	111(2)	15–14–24	121(2)
5–6–7	113(2)	14–15–16	105(2)
6–7–8	119(1)	14–15–30	113(2)
7–8–9	113(2)	16–15–30	107(2)
7–8–13	115(1)	15–16–17	106(2)
7–8–25	112(1)	15–16–20	111(2)
9–8–13	105(1)	15–16–25	108(2)
9–8–25	108(1)	17–16–20	112(2)
13–8–25	103(2)	17–16–25	107(2)
8–9–10	115(2)	20–16–25	113(2)
8–9–11	104(1)	12–17–16	112(2)
10–9–11	115(2)	12–17–31	122(2)
1–10–5	117(2)	16–17–31	125(2)
1–10–9	105(2)	13–23–28	105(2)
1–10–18	106(1)	14–24–28	109(2)
5–10–9	107(1)	14–24–29	127(2)
5–10–18	114(2)	28–24–29	124(2)
9–10–18	107(2)	8–25–20	117(2)
9–11–12	104(1)	3–27–4	125(2)
11–12–13	101(1)	23–28–24	112(2)

Refer to Figure 2 for atom numbering, *e.g.* 2–1–10 is C(2)–C(1)–C(10).

TABLE 4

Andibenin. Fractional atomic co-ordinates (× 10^4 for C and O) with estimated standard deviations in parentheses

Atom	*x*	*y*	*z*
C(1)	0.311 1(9)	0.556 5(8)	0.863 0(1)
C(2)	0.408 5(10)	0.574 1(9)	0.879 7(1)
C(3)	0.580 3(11)	0.558 7(9)	0.876 8(1)
C(4)	0.535 6(8)	0.605 2(8)	0.838 0(1)
C(5)	0.368 3(9)	0.527 5(8)	0.840 0(1)
C(6)	0.256 0(8)	0.617 4(8)	0.824 2(1)
C(7)	0.115 6(9)	0.517 4(8)	0.816 2(1)
C(8)	0.178 3(8)	0.379 6(8)	0.802 0(1)
C(9)	0.331 2(7)	0.300 9(8)	0.812 0(1)
C(10)	0.355 2(8)	0.338 5(8)	0.836 2(1)
C(11)	0.315 1(9)	0.123 0(8)	0.806 7(1)
C(12)	0.178 6(9)	0.111 1(8)	0.790 1(1)
C(13)	0.061 5(9)	0.238 7(8)	0.798 2(1)
C(14)	−0.057 5(8)	0.273 9(9)	0.781 1(1)
C(15)	−0.004 7(10)	0.317 3(10)	0.761 5(1)
C(16)	0.173 7(8)	0.330 6(9)	0.760 6(1)
C(17)	0.237 1(9)	0.167 6(9)	0.767 4(1)
C(18)	0.494 2(9)	0.244 0(8)	0.845 9(1)
C(19)	0.112 5(10)	−0.057 7(10)	0.787 6(1)
C(20)	0.239 1(11)	0.383 7(11)	0.738 4(1)
C(21)	0.525 3(10)	0.788 1(9)	0.839 7(1)
C(22)	0.632 3(9)	0.561 2(10)	0.818 3(1)
C(23)	−0.045 9(9)	0.185 8(9)	0.817 3(1)
C(24)	−0.218 7(10)	0.238 1(11)	0.788 5(1)
C(25)	0.221 0(8)	0.445 5(8)	0.778 9(1)
O(26)	0.673 0(7)	0.538 3(6)	0.891 6(1)
O(27)	0.639 2(6)	0.556 3(6)	0.856 4(1)
O(28)	−0.207 2(6)	0.178 1(8)	0.808 7(1)
O(29)	−0.345 9(7)	0.254 9(10)	0.779 7(1)
O(30)	0.213 1(6)	0.291 2(6)	0.847 8(1)
O(31)	0.320 5(7)	0.086 0(7)	0.756 3(1)

TABLE 5

Andibenin. Bond lengths (Å) with standard deviations in parentheses

Bond	Length	Bond	Length
C(1)–C(2)	1.323(10)	C(10)–C(18)	1.531(9)
C(2)–C(3)	1.458(12)	C(10)–O(30)	1.444(8)
C(3)–O(26)	1.212(8)	C(11)–C(12)	1.535(9)
C(3)–O(27)	1.348(8)	C(12)–C(13)	1.535(10)
O(27)–C(4)	1.482(8)	C(12)–C(17)	1.555(9)
C(4)–C(5)	1.552(10)	C(12)–C(19)	1.529(10)
C(4)–C(21)	1.540(10)	C(13)–C(14)	1.479(10)
C(4)–C(22)	1.506(11)	C(13)–C(23)	1.544(9)
C(5)–C(6)	1.551(9)	C(14)–C(15)	1.336(10)
C(5)–C(1)	1.509(9)	C(14)–C(24)	1.457(10)
C(5)–C(10)	1.607(9)	C(15)–C(16)	1.501(11)
C(6)–C(7)	1.528(10)	C(16)–C(17)	1.526(10)
C(7)–C(8)	1.542(9)	C(16)–C(20)	1.537(10)
C(8)–C(9)	1.569(9)	C(16)–C(25)	1.535(9)
C(8)–C(13)	1.552(9)	C(17)–O(31)	1.195(8)
C(8)–C(25)	1.564(9)	C(23)–O(28)	1.456(9)
C(9)–C(10)	1.537(8)	O(28)–C(24)	1.341(10)
C(9)–C(11)	1.533(9)	C(24)–O(29)	1.205(9)

7.1. $C_{25}H_{30}O_6$ requires C, 70.4; H, 7.1%), *m/e* 426.204 9 (M^+, $C_{25}H_{30}O_6$); $[\alpha]_D^{27}$ −277° (*c* 1.59, EtOH); $\lambda_{max.}$(EtOH) 247 (ε 4 100) and 310 nm (800); $\nu_{max.}$ (Nujol) 3 470, 1 745, 1 705, 1 695, 1 655, and 1 610 cm^{-1}; δ($CDCl_3$) 1.05 (3 H, s), 1.20 (3 H, s), 1.38 (3 H, s), 1.41 (3 H, s), 1.47 (3 H, s), 1.55—2.10 (8 H, m), 2.18 (1 H, s, exchanges with D_2O), 2.55 (1 H, dt, *J* 4 and 12 Hz), 4.24 (1 H, d, *J* 12 Hz), 4.84 (1 H, d, *J* 12 Hz), 6.06 (1H, d, *J* 10 Hz), 6.74 (1 H, d, *J* 10 Hz), and 7.04 (1 H, s); c.d. (EtOH) 320 (shoulder, Δε −19.3), 312 (−25.8), 303 (shoulder, −22.5), 249 (+15.3), 220 (−6.4), and 195 nm (−11.1).

Andilesin-A.—This was isolated in a yield of 2.3 mg l^{-1} of liquors, m.p. 310° (decomp.) (from propan-2-ol) (Found: C, 67.3; H, 7.6. $C_{25}H_{32}O_6 \cdot H_2O$ requires C, 67.2; H, 7.7%), *m/e* 428.223 0 (M^+, $C_{25}H_{32}O_6$); $[\alpha]_D^{27}$ −9.5° (*c* 0.52, EtOH); $\lambda_{max.}$(EtOH) end absorption; $\nu_{max.}$ (Nujol) 3 620, 1 775, 1 710, 1 680, 1 640, and 1 595 cm^{-1}; δ($CDCl_3$) 1.12 (3 H, s), 1.14 (3 H, s), 1.30 (3 H, s), 1.35 (3 H, s), 1.44 (3 H, s), 1.0—2.10 (10 H, m), 1.78 (1 H, s, exchanges with D_2O), 2.91 (1 H, d, *J* 8 Hz), 4.05 (1 H, d, *J* 8 Hz), 4.08 (1 H, d, *J* 10 Hz), 4.23 (1 H, d, *J* 10 Hz), 5.72 (1 H, d, *J* 12 Hz), and 5.90 (1 H, d, *J* 12 Hz); c.d. (EtOH) 296 (Δε −1.76), 250 (+3.80), and 214 nm (+5.82).

Andilesin-B.—This was isolated in a yield of 0.5 mg l^{-1} of liquors, m.p. 310° (decomp.) (from MeOH) (Found: C, 70.3; H, 7.6. $C_{25}H_{30}O_5 \cdot H_2O$ requires C, 70.1; H, 7.5%), *m/e* 410.206 6 (M^+, $C_{25}H_{30}O_5$); $[\alpha]_D^{27}$ −214° (*c* 0.69, EtOH); $\lambda_{max.}$(EtOH) 248 (ε 2 500) and 310 nm (700); $\nu_{max.}$ (Nujol) 1 755, 1 710, 1 675, and 1 635 cm^{-1}; δ($CDCl_3$) 0.99 (3 H, s), 1.36 (3 H, s), 1.38 (3 H, s), 1.40 (3 H, s), 1.49 (3 H, s), 1.00—2.10 (10 H, m), 4.45 (2 H, s), 5.74 (1 H, d, *J* 13 Hz), 5.94 (1 H, d, *J* 13 Hz), and 7.13 (1 H, s).

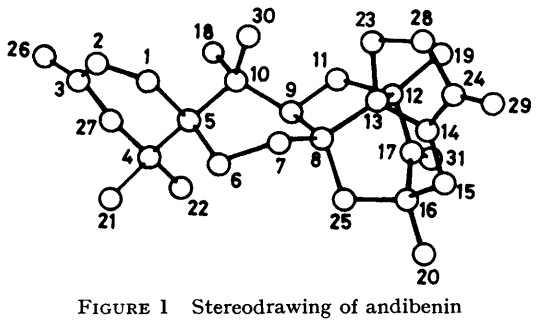

FIGURE 1 Stereodrawing of andibenin

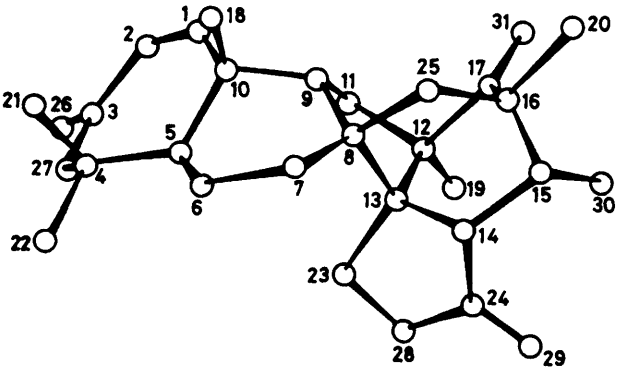

FIGURE 2 Stereodrawing of andilesin-A

Andilesin-C.—This was isolated in a yield of 0.1 mg l^{-1} of liquors, m.p. 290° (decomp.) (from MeOH), *m/e* 412.227 9 (M^+, $C_{25}H_{32}O_5$); $\lambda_{max.}$(EtOH) end absorption, $\nu_{max.}$ (Nujol) 1 765, 1 710, 1 680, and 1 640 cm^{-1}; δ($CDCl_3$) 1.04 (3 H, s), 1.13 (3 H, s), 1.39 (3 H, s), 1.48 (3 H, s), 1.0—2.2 (12 H, m), 2.87 (1 H, t, *J* 10 Hz), 4.16 (1 H, d, *J* 10 Hz), 4.27 (1 H, d, *J* 10 Hz), 5.80 (1 H, d, *J* 12 Hz), 5.94 (1 H, d, *J* 12 Hz).

TABLE 6

Andibenin. Bond angles with standard deviations in parentheses

Angle	Size (°)	Angle	Size (°)
2–1–5	123.3(7)	9–11–12	105.7(5)
1–2–3	120.3(7)	11–12–13	102.5(5)
2–3–26	123.6(8)	11–12–17	110.0(6)
2–3–27	118.6(7)	11–12–19	113.4(7)
26–3–27	117.7(8)	13–12–17	106.3(5)
27–4–5	110.7(5)	13–12–19	116.5(6)
27–4–21	105.0(6)	17–12–19	107.8(6)
27–4–22	103.3(6)	12–13–8	100.1(6)
5–4–21	111.2(6)	12–13–14	109.9(6)
5–4–22	116.6(6)	12–13–23	114.8(6)
21–4–22	109.1(6)	8–13–14	112.3(6)
4–5–6	107.2(5)	8–13–23	118.3(6)
4–5–10	117.7(6)	14–13–23	101.7(6)
1–5–4	107.1(6)	13–14–15	118.2(6)
1–5–6	108.4(6)	13–14–24	111.4(6)
1–5–10	105.9(6)	15–14–14	130.2(7)
6–5–10	110.3(5)	14–15–16	112.7(6)
5–6–7	113.9(6)	15–16–17	105.7(6)
6–7–8	109.4(6)	15–16–20	114.3(7)
7–8–9	111.8(5)	15–16–25	106.0(6)
7–8–13	116.1(6)	17–16–20	112.3(7)
7–8–25	109.1(6)	17–16–25	105.7(5)
9–8–13	104.7(5)	20–16–25	112.2(6)
9–8–25	108.5(5)	16–17–12	114.2(6)
13–8–25	106.2(5)	16–17–31	124.1(6)
8–9–10	113.7(5)	12–17–31	121.7(7)
8–9–11	104.7(5)	13–23–28	106.1(6)
10–9–11	114.7(5)	14–24–28	107.4(7)
5–10–9	110.7(5)	14–24–29	131.1(8)
5–10–18	113.7(6)	28–24–29	121.5(8)
5–10–30	104.8(5)	8–25–16	112.6(5)
9–10–18	111.8(5)	3–27–4	119.3(6)
9–10–30	108.3(5)	23–28–24	112.8(6)
18–10–30	107.1(5)		

Refer to Figure 1 for atom numbering.

X-Ray Diffraction Data.—Basic crystal data and details of crystallographic measurements have been reported.[2,3] Atomic co-ordinates, bond lengths, and bond angles are given in Tables 1—6 whilst stereodrawings of andibenin and andilesin-A, with atom numbering, are shown in Figures

1 and 2. Other data are given in Supplementary Publication No. SUP 22503 (62 pp.).*

RESULTS AND DISCUSSION

The small quantities of difficultly isolable andibenin and the andilesins precluded extensive chemical investigation into their structures. Their i.r., ^{1}H n.m.r., and mass spectra clearly suggested an underlying similarity between the four compounds but, in the absence of any basic knowledge on their structures, were not helpful. For example, their ^{1}H n.m.r. spectra showed similarities but absence of extended proton–proton coupling prevented their full structural significance being realised.

Each of the four compounds contained two strongly coupled hydrogens well downfield, although, for andibenin, these resonances centred at δ 6.06 and 6.74 were well separated and significantly further downfield than those of the andilesins near δ 5.7 and 5.9. Andibenin and andilesin-B gave signals at δ 7.04 and 7.13 respectively, suggesting an olefinic hydrogen on a conjugated double bond. Andibenin and andilesin-A each contained a hydroxylic proton. All four compounds contained five uncoupled methyls and an AB coupled $-CH_2-O-$ grouping (singlet in andilesin-B) near δ 4.2.

The i.r. spectra confirmed the presence of OH in andibenin and andilesin-A and its absence in andilesin-B and -C. Three clearly defined carbonyl stretching frequencies were observed between 1 765 and 1 675 cm^{-1}.

The u.v. spectra of andibenin and andilesin-B showed moderate long-wavelength absorption near 310 nm, whereas andilesin-A and -C showed only end absorption.

Analysis of the *X*-ray diffraction data on andibenin and andilesin-A gave the structures (1) and (2) shown in Figures 1 and 2.

For andilesin-A, a structure was only obtained after using a recent version of MULTAN.[9] The successful trial used 247 *E* values with $|E| \geqslant 1.4$, 4 000 Σ2 relationships, and 6 reflections in the starting set (not counting the origin-defining reflections). Employing the magic integer permutation, 448 sets of phases were calculated. The set with the highest combined figure-of-merit revealed, in the derived *E* map, 30 of the expected 31 atoms of the molecule. Refinement proceeded by Fourier and least-squares methods which immediately revealed the region in which a propan-2-ol solvent molecule was located. However, the region was ill defined and is probably disordered. While refinement of the molecular skeleton proceeded smoothly, it is still not possible to define the solvent atoms satisfactorily. Hence, the temperature factors for the atoms concerned are so high as to be physically meaningless and the atom positions of the solvent do not correspond to a sensible molecule. Nevertheless, the structure of andilesin-A is unambiguously determined to the extent that, after anisotropic convergence, a difference map revealed the majority of the hydrogen atoms and these were subsequently included in the computations at fixed positions (the hydrogen atom of the hydroxy-group could not be found and was omitted as its position could not be calculated). Oxygen atoms were identified by their temperature factors and by the heights of the corresponding Fourier peaks. Final stages of refinement were with the skeletal atoms in one least-squares block and the solvent atoms (treated isotropically) in a second block. Currently, the maximum shift/standard deviation is 0.26 with the average being much less than 0.1; *R* is 8.8%. Not surprisingly, the standard deviations of the parameters are much larger than would be expected for a completely determined structure. Table 1 shows the fractional co-ordinates, Table 2 the bond lengths, and Table 3 the bond angles of andilesin-A.

For andibenin, a structure was obtained, again with some difficulty, using MULTAN which eventually revealed 28 of the 31 atoms in the molecule. The remaining atoms were located readily by Fourier methods. Oxygen atoms were identified from their isotropic temperature factors and Fourier peak heights. Refinement was by full-matrix least-squares with carbon and oxygen treated anisotropically. Hydrogen atoms, which were located on a difference map, were included in the refinement in calculated positions (with the exception of the hydroxy-hydrogen which was included in its found position). The final cycles employed a weighting scheme of the form, $W = 1/\{1 + [F_o - A)/B]^2\}$ with *A* 17.0 and *B* 10.0. At convergence, the maximum positional shift was 0.05σ and *R* was 5.7%.

Table 4 gives the fractional co-ordinates, Table 5 the bond-lengths, and Table 6 the bond angles of andibenin.

Apart from MULTAN, crystallographic computations were done using the Oxford CRYSTALS package, and the drawings were prepared using PLUTO.

All the spectroscopic features of andibenin and andilesin-A are nicely accommodated by the structures found by *X*-ray analysis and their c.d. curves allowed an assignment of absolute configuration.

Unsaturated lactones absorb u.v. radiation near 205 nm with ε values near 11 000[10] and so the two lactones in the andibenin structure (1) are not expected to contribute to the long wavelength absorption observed near 310 nm. However, $n \longrightarrow \pi^*$ absorption bands for saturated ring ketones are found near 290 nm, and for αβ-unsaturated ketones, near 340 nm with $\pi \longrightarrow \pi^*$ transitions at much shorter wavelengths.[10] Structure (1) contains a βγ-unsaturated ring ketone, the u.v. behaviour of which is well documented. Thus, if the geometry is appropriate, interaction of *n*- and π-orbitals of the homoconjugated carbonyl occurs, and enhances and bathochromically shifts the ' forbidden ' $n \longrightarrow \pi^*$ transition of saturated ring ketones to near 300—315 nm.[11] Such interactions are accompanied by high optical activity.[12] We ascribe the moderately strong band near 310 nm in both the u.v. and c.d. spectra of andibenin to such an $n \longrightarrow \pi^*$ transition of the βγ-unsaturated ketone system. By use of the modified Octant Rule for such ketones,[13] in which the sign of the Cotton effect depends on the

* For details of Supplementary Publications see Notice to Authors No. 7 in *J.C.S. Perkin I*, 1978, Index issue.

helicity of the system, the absolute configuration (1) was deduced.

Lack of a βγ-unsaturated ketone system in andilesin-A and -C is reflected in their u.v. spectra, showing apparent end absorption only, without clear absorption bands, and in their c.d. spectra, with much smaller optical rotations. The c.d. spectrum of andilesin-A showed that this end absorption effect was due to unresolved, overlapping weak absorption bands which, with opposite rotational effects, were clearly resolved in the c.d. spectrum. The low-intensity, long-wavelength u.v. absorption at 296 nm in andilesin-A is ascribed to the expected six-membered ring ketonic $n \longrightarrow \pi^*$ transition.[10] From the usual Octant Rule [14] and the use of Dreiding models, structure (2), lying almost entirely in the upper and lower back negative quadrants, is predicted to give the negative Cotton effect observed.

Andilesin-B, formerly named deoxyandibenin,[3] has an αβ-unsaturated γ-lactone band at 1 755 cm^{-1} like andibenin but no hydroxy-band. Similarly, andilesin-B has a proton resonance at δ 7.13 due to an olefinic hydrogen, like that of andibenin at δ 7.04. However, the hydrogens resonating at δ 5.74 and 5.94 are very similar to those found in the αβ-unsaturated ε-lactone system of andilesin-A (δ 5.72 and 5.90) rather than those found in the αβ-unsaturated δ-lactone of andibenin (δ 6.06 and 6.74). The u.v. long wavelength absorption band of andilesin-B at 310 nm corresponds to that found for the βγ-unsaturated ketone system in andibenin and, similarly, andilesin-B has a large negative optical rotation, associated with this u.v. band. These and the other spectroscopic data, along with its molecular formula, allow us to formulate structure (3) for andilesin-B.

Andilesin-C, formerly deoxydihydroandibenin,[3] has a γ-lactone band at 1 765 cm^{-1} and no hydroxy-band in its i.r. spectrum. Additionally, the molecular formula and absence of proton resonance near δ 7.0 confirm the absence of a double bond conjugated to the γ-lactone. Further evidence for the absence of a double bond exocyclic to the γ-lactone is found in the triplet at δ 2.87, due to a hydrogen on carbon adjacent to the γ-lactone carbonyl coupling to an adjacent methylene group. The resonances of the hydrogens on the double bond of the αβ-unsaturated ε-lactone system found in andilesin-C are in similar positions (δ 5.80 and 5.94) to those found for andilesin-A and -B. This, and the other spectroscopic evidence, provides structure (4) for andilesin-C.

The structures (1)—(4) show that the compound first isolated, andibenin,[2] is presently exceptional in having a six-membered δ-lactone, whereas the other three contain an apparently strained seven-membered ε-lactone. The bond lengths of the double-bond (1.34 Å) and carbonyl (1.19 Å) of the ε-lactone of andilesin-A are about those normally expected for such bonds. However, the torsional angle between the two groups [C(1)–C(2)–C(3)–O(26)] is *ca.* 16° so they do not have the coplanarity required for full conjugation. This reduced conjugation probably accounts for the hydrogens on the double bond of the αβ-unsaturated ε-lactone appearing upfield of the corresponding hydrogens of the unstrained δ-lactone of andibenin, in which coplanarity is achieved. For the ε-lactone, the hydrogen resonances have close chemical shifts and occur between the resonances normally found for hydrogen on a simple double bond and those on a double bond conjugated with a carbonyl group. The reduced conjugation in the ε-lactone would be expected to shift the $n \longrightarrow \pi^*$ u.v. transition to shorter wavelength compared with the δ-lactone and supports the attribution of the c.d. band at 296 nm in andilesin-A to the saturated six-membered carbocyclic ring ketone.

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