Extractives from Guttiferae. Part XXVI.† Isolation and Structure of Six Xanthones, a Biflavanoid, and Triterpenes from the Heartwood of *Pentaphalangium solomonse* Warb.

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Two new naturally occurring xanthones, 6,11-dihydroxy-3,3-dimethylpyrano[2,3-*c*]xanthen-7(3*H*)-one (1) and its probable biogenetic precursor, 1,3,5-trihydroxy-4-(3-methylbut-2-enyl)xanthen-9-one, have been isolated from *Pentaphalangium solomonse* Warb. Other xanthones found were 1,3,7-trihydroxy-2-(3-methylbut-2-enyl)-, 1,3,6,7-tetrahydroxy-, and 5-hydroxy-1-methoxy-xanthen-9-one. The isolation of a 3–8 linked biflavanone, GB-1a, and of a sterol mixture is reported.

As part of our studies on the plant family Guttiferae we now report the isolation and structures of some xanthones, a biflavanone, and sterol constituents from the heartwood of *Pentaphalangium solomonse* Warb.

Extraction of the wood shavings with hot chloroform gave a solution containing phenols. The solution was concentrated to deposit a solid X. Removal of the solvent from the filtrate gave a dark brown oil which was separated into five fractions by column chromatography on silica gel.

The first fraction gave 6,11,dihydroxy-3,3-dimethylpyrano[2,3-*c*]xanthen-7(3*H*)-one (1), the angular isomer of 6-deoxyjacareubin (2), more commonly known as 6-deoxyisojacareubin, together with a mixture of sterols. These could not be separated by preparative t.l.c. (p.l.c.) but a separation was achieved by crystallisation of the pyranoxanthone (1), a new metabolite whose structure follows from its spectroscopic properties. Its u.v. spectrum was typically xanthonoid and in good agreement with other tri-oxygenated pyranoxanthones (see the Table). The i.r. spectrum showed hydroxy and xanthone carbonyl absorptions at 3300 and 1650 cm^{-1}, respectively. High resolution mass spectrometry gave a molecular formula of $C_{18}H_{14}O_5$, and a loss of 15 m.u. to give the base peak at *m/e* 295 was indicative of a 2,2-dimethylpyran system.[1] The pyranoxanthonoid structure was confirmed by the n.m.r. spectrum in deuteriochloroform. Thus, the hydrogen-bonded hydroxy-group at C-6 (1) appears at τ −2·95 and the other hydroxy-group is a broad band at 6·42; both signals are removed on addition of D_2O. In the aliphatic region two superimposed methyl group signals at τ 8·58 and two doublets (*J* 10 Hz) each due to olefinic protons at 3·06 and 4·35 are characteristic of the 2,2-dimethylpyran part of a chromen ring system.[2]

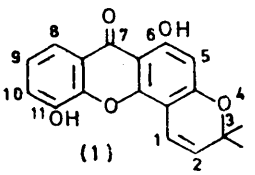
Three of the four aromatic signals are coupled and appear at lower field than the fourth, a singlet at τ 3·92. Consideration of the dimethylpyran ring and the hydrogen-bonded hydroxy-group led us to postulate that the aromatic proton at τ 3·92 should be located at C-2 ‡ or C-4 ‡ in ring B. Comparison of suitable reference compounds indicates that the other hydroxy-group is in the 5‡-position.[3] Thus, the signal of the lowest field aromatic proton at C-8,‡ the A part of an AXY system, appears as a quartet at τ 2·43, owing to *ortho*- and *meta*-splitting (*J* 7 and 3 Hz, respectively) by the XY protons at C-6 ‡ and C-7,‡ which give rise to the complex signal, centred at τ 2·8.

U.v. spectra of some trioxygenated xanthones measured in methanol

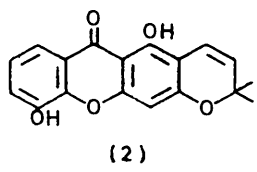
Compound	λ/nm (log ε)							Reference
(1)	232 (4·26)	250 (4·54)	268 (4·51)		308 (3·92)	329 (4·02)		
(2)	243 (4·22)		270 * (4·39)	296 (4·53)	310 * (4·23)		370 (3·38)	*a*
(3)	234 * (4·24)	239 (4·25)	262 (4·22)		313 (3·93)		376 (3·59)	
(4)	233 (4·55)		264 (4·64)		299 (4·42)		370 (3·84)	*b*
(6)	244 (4·52)	253 * (4·43)	262 (4·39)	270 (4·25)	309 (4·24)		359 (3·68)	*a*
(9)	239 (4·48)	244 (4·48)	256 (4·45)		310 * (4·11)	318 (4·15)	368 (3·62)	
(15)	235 * (4·37)	242 (4·63)			304 (4·48)		352 (3·81)	

* Shoulder.

[a] B. Jackson, H. D. Locksley, and F. Scheinmann, *J. Chem. Soc.* (*C*), 1967, 2500. [b] H. D. Locksley, I. Moore, and F. Scheinmann, *J. Chem. Soc.* (*C*), 1966, 2265.



(1)



(2)

These data do not allow for unambiguous differentiation between the linear and the angular orientation of the dimethyl pyran ring in relation to the xanthone nucleus, because 2- and 4-protons in a phloroglucinol ring of xanthones are known to have very similar chemical shifts.[4a,b] However, analytical t.l.c. com-

† Part XXV, A. J. Quillinan and F. Scheinmann, *J.C.S. Perkin I*, 1972, 1382.

‡ Xanthone numbering as in *e.g.* (3) and (4).

[1] C. S. Barnes and J. L. Occolowitz, *Austral. J. Chem.*, 1964, **17**, 975.

[2] B. Jackson, H. D. Locksley, and F. Scheinmann, *J. Chem. Soc.* (*C*), 1966, 178.

[3] D. Barraclough, H. D. Locksley, F. Scheinmann, M. T. Magalhaes, and O. R. Gottlieb, *J. Chem. Soc.* (*B*), 1970, 603.

[4] (*a*) A. Jefferson and F. Scheinmann, *J. Chem. Soc.* (*C*), 1966, 175; (*b*) E. D. Burling, A. Jefferson, and F. Scheinmann, *Tetrahedron*, 1965, **21**, 2653.

parison of the natural product and 6-deoxyjacareubin (2) showed that these metabolites were not identical and suggested that the natural product from *P. solomonse* Warb. was the angular isomer (1). This was confirmed by comparison with a synthetic sample, kindly provided by Dr. J. R. Lewis.[5]

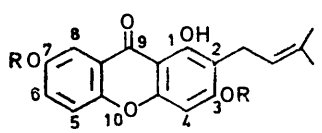
A further fraction contained a compound whose R_F value was indicative of a trihydroxyxanthone. It was isolated and purified by p.l.c. and recrystallised from acetone–light petroleum (60—80°). The metabolite had a molecular formula of $C_{18}H_{16}O_5$ from accurate mass measurement of the molecular ion and its u.v. spectrum suggested a 1,3,7-trioxygenated xanthone. The n.m.r. spectrum possessed signals characteristic of a 3-methylbut-2-enyl system.[2,6,7] Methylation with an excess of ethereal diazomethane in methanol gave the dimethyl ether (4) which is identical with an authentic sample.[7] The natural product is thus the unmethylated metabolite 1,3,7-trihydroxy-2-(3-methyl-but-2-enyl)xanthen-9-one (3).

Two fractions were shown by n.m.r. to be devoid of methoxy-groups. The first of these was methylated with diazomethane and contained two components. The structural elucidation of one of these components, a biphenyl (5) involves synthetic work and will be the subject of a separate paper.

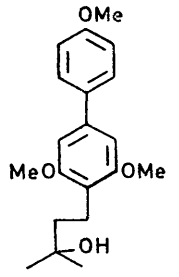
The other component was isolated by p.l.c. and proven to be 1-hydroxy-3,5-dimethoxy-4-(3-methylbut-2-enyl)-xanthen-9-one (9). Accurate mass measurement of the molecular ion gave a molecular formula of $C_{20}H_{20}O_5$ and its u.v. absorption maxima (Table) suggest a 1,3,5- or a 1,3,7-trioxygenated xanthone system. The i.r. spectrum shows the xanthone–carbonyl group at 1650 cm^{-1}. The n.m.r. spectrum possesses signals characteristic of the 3-methylbut-2-enyl system.[2,6,7] The remaining signals belong to two methoxy-groups (τ 6·13 and 6·18), a hydrogen-bonded hydroxy-group at −2·82, and four aromatic protons, three of which are coupled and at a lower field than the fourth (a singlet at τ 3·74). The pattern of the coupled aromatic protons is very similar to that already encountered in the spectrum of 6-deoxyisojacareubin (1) and is attributed to ring A; this assigns one of the methoxy-groups to C-5. Since only one high-field aromatic proton is present, and this uncoupled, the 3-methylbut-2-enyl side-chain is assigned to the phloroglucinol ring B at either C-2 or C-4. Comparison with authentic 1-hydroxy-3,5-dimethoxy-2-(3-methylbut-2-enyl)xanthen-9-one (6) shows that the two are not identical. Failure of the side-chain to form the pyranoxanthone (7) in the presence of formic acid[4] provided further support for the location of the side-chain at C-4.

A sample of the xanthone (9) prepared by Claisen rearrangement of 3,5-dihydroxy-1-(3-methylbut-2-enyloxy)xanthen-9-one (8) was identical with our dimethyl ether. The new natural product is thus 1,3,5-trihydroxy-4-(3-methylbut-2-enyl)xanthen-9-one (10), the probable biogenetic precursor of 6-deoxyisojacareubin (1).

T.l.c. examination of the second fraction devoid of methoxy-groups revealed the presence of 1,3,6,7- and/or 1,3,5,6-tetrahydroxyxanthones (11) and (14) respectively. Methylation with an excess of diazomethane



(3) R = H
(4) R = Me



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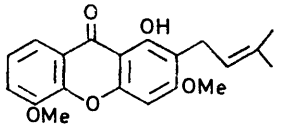

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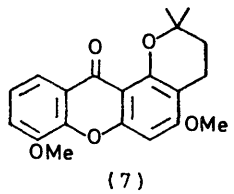
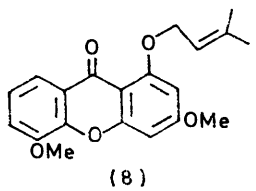
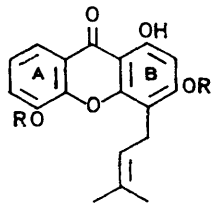


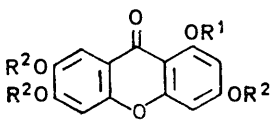
(7)



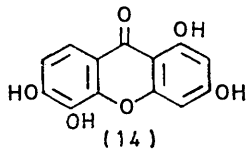
(8)



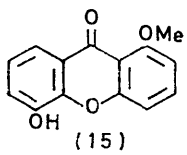
(9) R = Me
(10) R = H



(11) $R^1 = R^2 = H$
(12) $R^1 = H, R^2 = Me$
(13) $R^1 = R^2 = Me$



(14)



(15)

and with an excess of dimethyl sulphate yielded the trimethyl ether (12) and the tetramethyl ether (13),[8] respectively, of only one of the two isomers, and confirmed that the metabolite was 1,3,6,7-tetrahydroxyxanthen-9-one (11).

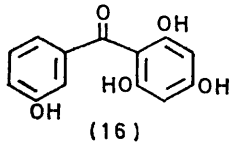
[5] J. R. Lewis and R. B. Reary, *J. Chem. Soc.* (*C*) 1970, 1662.
[6] H. D. Locksley, I. Moore, and F. Scheinmann, *J. Chem. Soc.* (*C*), 1966, 2265.
[7] B. Jackson, H. D. Locksley, and F. Scheinmann, *J. Chem. Soc.* (*C*), 1967, 2500.
[8] H. D. Locksley and I. G. Murray, *Phytochemistry*, 1971, **10**. 3179.

5-Hydroxy-1-methoxyxanthen-9-one (15) was obtained from the acetone eluate of the column. Accurate mass measurement gave a molecular formula of $C_{14}H_{10}O_4$. The i.r. spectrum has absorptions typical of hydroxy and xanthone carbonyl groups and the u.v. spectrum is similar to those of 1,5-dioxygenated xanthen-9-ones.[9] Comparison with an authentic sample of 5-hydroxy-1-methoxyxanthen-9-one (14) previously isolated from *Mammea africana* L.,[9] confirmed the structure of the metabolite.

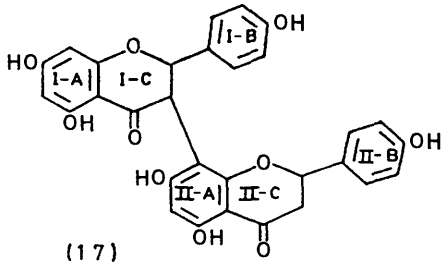
The co-occurrence of the 1,3,5- and 1,3,7-trioxygenated xanthones in the same heartwood source suggests that these xanthones are derived from the same benzophenone precursor (16) by oxidative cyclisation *ortho* and *para* to the 3-hydroxy-group.

The mother liquors from the crystallisation of the xanthen-7(3*H*)-one (1) were evaporated and yielded a white powder which recrystallised from acetone as white needles. Low resolution mass spectrometry indicated a mixture of sterols and the n.m.r. spectrum showed complex absorptions only in the aliphatic region. Combined g.l.c.–mass spectrometric techniques showed that the terpenoid mixture had three components and by comparison with authentic samples these proved to be sitosterol, stigmasterol, and campesterol having molecular formulae $C_{29}H_{50}O$, $C_{29}H_{48}O$, and $C_{28}H_{46}O$, respectively. Fragmentations for all three compounds agree with their identifications.[10] The very high level of stigmasterol (80%) in comparison to sitosterol seems to distinguish this species from many plants where sitosterol often exceeds stigmasterol.[11]

Solid X was examined by t.l.c. and found to consist of one major component. Its u.v. spectrum shows maxima in the regions of 292 and 329 nm, typical of an acylphloroglucinol chromophore such as that found in



(16)



(17)

flavanones, but having extinction coefficients almost double those for typical flavanoids. The low resolution mass spectrum shows a molecular ion at *m/e* 542. These two facts are indicative of flavanone dimers.[12] A study of the mass spectral breakdown pattern and comparison of the i.r. and n.m.r. spectra with those of the GB series of metabolites indicated that the biflavanone GB-1a (17) had been isolated.

This is the second instance of the isolation of a 3–8 linked biflavanone outside the *Garcinia* species (the other being the isolation of biflavanones from *Allanblackia floribunda* Oliver).[13] Their isolation serves to add weight to the botanist's classification of *Pentaphalangium* as a near neighbour of *Garcinia* since both genera are classified as members of the Clusioideae subfamily of Guttiferae.

EXPERIMENTAL

U.v. spectra (solutions in methanol) were measured with a Unicam SP 800 recording spectrophotometer and i.r. spectra with a Perkin-Elmer 257 grating instrument. N.m.r. spectra, unless otherwise stated, were determined for solutions in deuteriochloroform with Varian A60 and HA100 instruments. Low resolution mass spectra were determined with an A.E.I. MS12 spectrometer and high resolution mass spectra and accurate mass measurements with an A.E.I. MS902 spectrometer.

T.l.c. was performed with silica gel G (Merck Kieselgel G) and column chromatography with Hopkin and Williams silica gel M.F.C. and Merck Kieselgel (ART 7734).

A section of the heartwood of *Pentaphalangium solomonse* Warb. was reduced to shavings. Extraction with boiling chloroform, followed by removal of the solvent under reduced pressure to a volume of 5 l and standing overnight caused the precipitation of a light brown solid which was filtered off and dried (named solid X). Evaporation of the filtrate gave a brown oily residue (17·0 g, 1% w/w of the heartwood extracted). Column chromatography of the oil on silica gel made up in chloroform, and elution with increasing ratios of ethyl acetate–chloroform and finally with acetone, gave, after combination, six major fractions (A—E).

Fraction A [*eluted with Ethyl Acetate–Chloroform* (1 : 19)]. —(a) *Isolation of* 6-*deoxyisojacareubin* (1). Removal of the solvent gave a yellow solid which, on t.l.c. examination (ethyl acetate–benzene 1 : 9) was found to be a mixture with similar R_F values. Separation was effected by recrystallisation from benzene. Filtration gave 6,11-*dihydroxy*-3,3-*dimethylpyrano*[2,3-c]*xanthen*-7(3H)-*one* (1) (commonly known as 6-*deoxyisojacareubin*) as a yellow amorphous powder, m.p. 250—252°, R_F 0·5 (ethyl acetate–benzene 1 : 19), $\nu_{max.}$ 1650 cm^{-1} (xanthone C=O); $\lambda_{max.}$ Table; τ [$(CD_3)_2CO$] −2·95 (1H, s, 6-OH, exchangeable), 2·43 (1H, q, 8-H), 2·8 (2H, complex, 9- and 10-H), τ_A 3·06 (d), τ_B 4·35 (d), τ_{Me} 8·58 (s) (J_{AB} 10 Hz, $CH_A{=}CH_B{\cdot}CMe_2{\cdot}O$), 3·92 (1H, s, 5-H), and 6·42br (1H, 11-OH, exchangeable), M^+, 310·0832 ($C_{18}H_{14}O_5$ requires 310·0841).

(b) *Isolation of campesterol, sitosterol, and stigmasterol.* The mother liquors from the recrystallisation of 6-deoxyisojacareubin from benzene were evaporated. The resulting white powder was recrystallised from acetone yielding white needles, m.p. 159—160°, $\nu_{max.}$ 3420, 3340, and 1600 cm^{-1}, τ 4·75 (1H, d, 6-H), 5·04 (t, H-22 and H-23), and 7·8—9·4

[9] I. Carpenter, H. D. Locksley, and F. Scheinmann, *J. Chem. Soc.* (*C*), 1969, 2421.
[10] B. A. Knights, *J. Gas Chromatography*, 1967, 273.
[11] L. J. Goad, personal communication.
[12] B. Jackson, H. D. Locksley, F. Scheinmann, and W. A. Wolstenholme, *J. Chem. Soc.* (*C*), 1971, 3791.
[13] H. D. Locksley and I. G. Murray, *J. Chem. Soc.* (*C*), 1971, 1332.

(complex region of methylene and methyl protons), *m/e* 414 (β-sitosterol), 412 (stigmasterol), and 400 (campesterol). Combined g.l.c.–mass spectroscopy on SE30 (5 ft) column at 230° in cyclohexane gave campesterol (3%), stigmasterol (80%), and sitosterol (17%).

Fraction B [*eluted with ethyl acetate–chloroform* (1 : 9)]. Evaporation to dryness furnished a yellow solid which, on recrystallisation from acetone–light petroleum (b.p. 60—80°) gave 1,3,7-*trihydroxy*-2-(3-*methylbut*-2-*enyl*)*xanthen*-9-*one* (3) as yellow needles, m.p. 218—220°, R_F 0·35 (in ethyl acetate–benzene 3 : 17), $\nu_{max.}$ 1650 cm^{-1} (xanthone C=O), $\lambda_{max.}$ Table, τ [$(CD_3)_2CO$] −3·02 (1H, s, 1-OH, exchangeable), 2·53 (1H, d, *J* 2·5 Hz, 8-H), 2·74 (2H, complex, 6-H and 5-H), 3·63 (1H, s, 4-H), 4·80 (1H, t, –CH=C), 6·71 (2H, d, CH_2·C), 8·26 (3H, s, CMe), and 8·38 (3H, s, CMe), M^+, 312·1008 (Calc. for $C_{18}H_{16}O_5$: 312·0998).

The xanthone (3) (100 mg) in methanol was treated with an excess of ethereal diazomethane for 15 min, to give the dimethyl ether (4) which was crystallised from acetone, m.p. 139—140° (lit.,[6] 140·5°), $\lambda_{max.}$ Table, identical (mixed m.p. and i.r. spectrum) with an authentic sample.

Fraction C [*eluted with ethyl acetate–chloroform* (15 : 85)]. Evaporation of the solvent yielded a brown oil which was shown by n.m.r. spectroscopy to be devoid of methoxy-groups. It was methylated with an excess of ethereal diazomethane in methanol for 30 min, and t.l.c. showed two main components (i) and (ii). These were separated and isolated by p.l.c.

(i) Removal of the main band followed by washing the silica gel with acetone yielded a yellow powder. Recrystallisation from ethanol gave 1-*hydroxy*-3,5-*dimethoxy*-4-(3-*methylbut*-2-*enyl*)*xanthen*-9-*one* (9) as yellow needles, m.p. 184—185°, R_F 0·85 (ethyl acetate–benzene 3 : 17), $\nu_{max.}$ 1660 cm^{-1} (xanthone C=O), $\lambda_{max.}$ Table, τ −2·82 (1H, s, 1-OH, exchangeable), 2·34 (1H, q, *J* 6·5 and 4 Hz, 8-H), 2·92 (2H, m, H-6 and H-7), 3·74 (1H, s, 2-H), 4·82 (1H, t, *J* 8 Hz, –CH=), 6·13 (3H, s, OMe), 6·18 (3H, s, OMe), 6·56 (2H, d, *J* 8 Hz, CH_2), and 8·20 and 8·38 (both 3H, s, Me), M^+ 340·1318 ($C_{20}H_{20}O_5$ requires *M*, 340·1311).

(ii) The other major component was stripped from the silica gel with acetone and yielded a biphenyl (5) whose structure elucidation will be discussed in a forthcoming communication.

Fraction D. This was eluted with ethyl acetate–benzene (2 : 3) and evaporation yielded a brown oil. T.l.c. showed one major spot having an R_F corresponding to 1,3,5,6- and/or 1,3,6,7-tetrahydroxyxanthen-9-ones (13) and (10) respectively. These two xanthones cannot be separated by t.l.c. so the brown oil was divided into two portions and each portion methylated (i) with an excess of ethereal diazomethane in methanol and (ii) with an excess of dimethyl sulphate in acetone in the presence of anhydrous potassium carbonate.

(i) Yielded 1-hydroxy-3,6,7-trimethoxyxanthen-9-one (11) as a white solid, m.p. 232—233° (from methanol), R_F 0·75 (ethyl acetate–benzene 3 : 17), n.m.r., i.r., and u.v. spectra identical with those from an authentic sample (Found: M^+, 302·0798. Calc. for $C_{16}H_{14}O_6$: 302·0790).

(ii) Yielded 1,3,6,7-tetramethoxyxanthen-9-one (12) as a cream solid, m.p. 210—212°, R_F 0·35 (ethyl acetate–benzene 4 : 1), i.r., u.v., and n.m.r. spectra identical with those from an authentic sample.[8]

Fraction E. This fraction, eluted with acetone, when evaporated to a small volume, deposited a solid which crystallised from methanol (charcoal) to give 5-hydroxy-1-methoxyxanthen-9-one (15) as white needles, m.p. 248—250° (lit.,[9] 250—252°). T.l.c. showed one spot, R_F 0·4 (chloroform–ethyl acetate 4 : 1), $\nu_{max.}$ 1650 cm^{-1} (xanthone C=O), $\lambda_{max.}$ Table, τ [$(CD_3)_2CO$ + 1 drop $(CD_3)_2SO$] 2·1—3·1 (6H, complex) and 6·17 (3H, s, 1-OMe) (Found: M^+, 242·0585. Calc. for $C_{14}H_{10}O_4$: *M*, 242·0579).

The xanthone (15) was identical (mixed m.p. and i.r. spectrum) with an authentic sample.[9]

Isolation of the Biflavanone GB-1a (17).—Solid X was examined by t.l.c. and found to consist mainly of one band. The appearance and R_F value of the main component under u.v. light resembled those of the 3–8 linked biflavanone GB-1a (17) and comparison with an authentic sample [12] confirmed that the neutral product was GB-1a, m.p. 330° (decomp.), $\nu_{max.}$ 1655, 1620, 1290, 1185, 1110, 850, and 740 cm^{-1}, $\lambda_{max.}$ 291 (log ε 4·38) and 335sh nm (3·91), τ [$(CD_3)_2SO$] 4·31 (3H, m, H-6 in rings I-A and II-A, and H-8 in ring I-A), 2·98 and 3·07 (both 2H, d, *J* 9 Hz, H-2 and H-6 in rings I-B and II-B), 3·41 and 3·52 (both 2H, d, *J* 9 Hz, H-3 and H-5 in rings I-B and II-B), 4·62 and 5·57 (both 1H, d, *J* 11 Hz, H-2 and H-3 in ring I-c), 4·84 (1H, q, *J* 12 Hz, H-2 in ring II-c), and 7·17 and 7·49 (both 1H, m, H-3 in ring II-c) (Found: M^+, 542·1198. Calc. for $C_{30}H_{22}O_{10}$: *M*, 542·1212), *m/e* 296·0309 (Calc. for $C_{16}H_8O_6$: 296·0321), 126·0316 (Calc. for $C_6H_6O_3$: 126·0317), 107·0496 (Calc. for C_7H_7O: 107·0497).

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