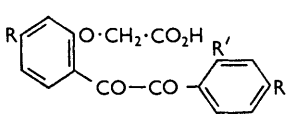
1015. *Cyclisation of Benzil and Deoxybenzoin Derivatives to Coumarones and Isoflavones.*

By S. A. N. N. Bokhari and W. B. Whalley.

The cyclisation of various *o*-carboxymethoxybenzils and deoxybenzoins has been investigated.

We have previously shown [1] that cyclisation of 2-carboxymethoxy-2′-methoxybenzil (I; R = H, R′ = OMe) and of 2-carboxymethoxy-4,2′,4′-trimethoxybenzil (I; R = R′ = OMe) furnishes the corresponding isoflavones rather than the isomeric 3-aroylcoumarones (II). After our development [2] of a general route to methoxylated *o*-hydroxy-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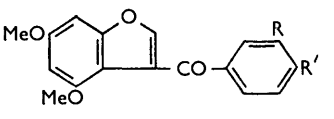
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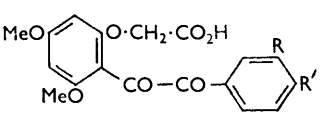
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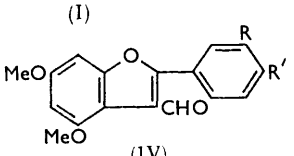
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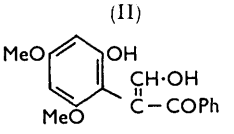
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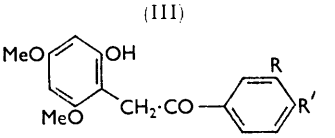
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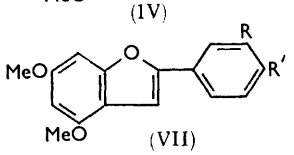
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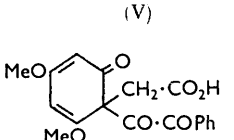
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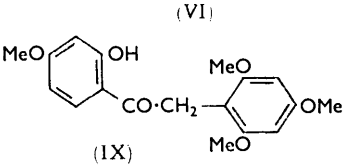
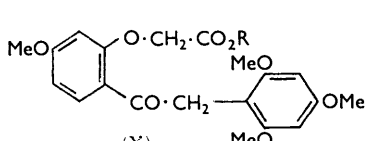

(IX)

benzils we have further investigated the potentialities of *o*-carboxymethoxybenzils as a source of isoflavones.

2-Hydroxy-4,6,4′-trimethoxybenzil [3] gave the phenoxyacetic acid (III; R = H,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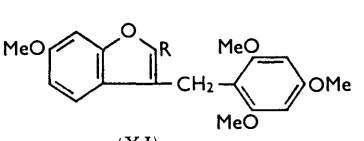
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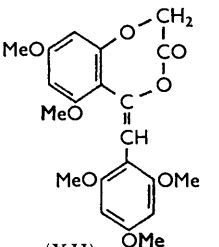
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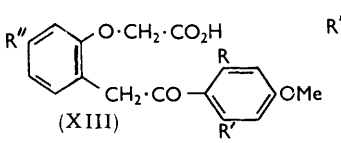
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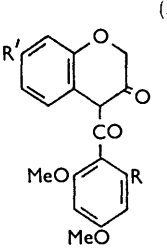
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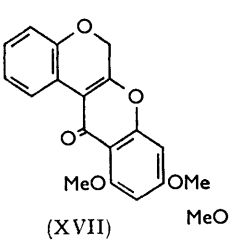
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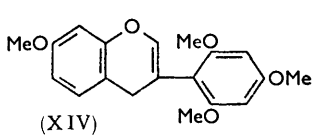
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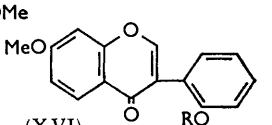
(XVI)

R′ = OMe) which on cyclisation with sodium acetate in acetic anhydride gave 3-*p*-anisoyl-4,6-dimethoxycoumarone (II; R = H, R′ = OMe) rather than the isomeric 5,7,4′-trimethoxyisoflavone. The constitution of the product was established by its non-identity

[1] Lloyd and Whalley, *J.*, 1956, 3213.
[2] Mee, Robertson, and Whalley, *J.*, 1957, 3093.
[3] Robertson, Suckling, and Whalley, *J.*, 1949, 1571.

with the isomeric isoflavone and by its behaviour towards alkali which, under mild conditions, furnished the isomeric 3-formyl-4,6-dimethoxy-2-*p*-methoxyphenylcoumarone (IV; R = H, R′ = OMe) with carbonyl absorption at 1618 cm.$^{-1}$, by way of the intermediate of type (V) (cf. Lloyd and Whalley [1]). In more vigorous conditions the coumarone (II; R = H, R′ = OMe) gave 2′-hydroxy-4,4′,6′-trimethoxydeoxybenzoin (VI; R = H, R′ = OMe) which was converted into 4,6-dimethoxy-2-*p*-methoxyphenylcoumarone (VII; R = H, R′ = OMe) on distillation.

Cyclisation of 2-carboxymethoxy-4,6,3′,4′-tetramethoxybenzil (III; R = R′ = OMe) similarly gave 3-(3,4-dimethoxybenzoyl)-4,6-dimethoxycoumarone (II; R = R′ = OMe) which was rearranged to 3-formyl-2-(3,4-dimethoxyphenyl)-4,6-dimethoxycoumarone (IV; R = R_1 = OMe). The derived 2′-hydroxy-3,4,4′,6′-tetramethoxydeoxybenzoin (VI; R = R′ = OMe) cyclised spontaneously to 2-(3,4-dimethoxyphenyl)-4,6-dimethoxycoumarone (VII; R = R′ = OMe). Condensation of ethyl bromoacetate with 2-hydroxy-4,6-dimethoxybenzil gave a mixture of esters, which, after hydrolysis, was separated into 2-carboxymethoxy-4,6-dimethoxybenzil (III; R = R′ = H) and an isomeric acid which is formulated as the cyclohexadienone (VIII), in agreement with its stability to the prolonged action of boiling acetic anhydride containing sodium acetate and with the infrared and ultraviolet spectral data. Thus, whilst 2-carboxymethoxy-4,6-dimethoxybenzil has absorption bands at 1761 (phenoxy-acid) and 1667 (aromatic α-diketone) cm.$^{-1}$, the product (VIII) has three bands in the carbonyl region at 1751 (phenoxy-acid), 1704 (aryl ketone), and 1613 (αβ,γδ-unsaturated ketone) cm.$^{-1}$. In addition, this product has long-wavelength ultraviolet absorption with $\lambda_{max.}$ 296 mμ (log ε 4·27). The parent dienone [4] would have $\lambda_{max.}$ 245 mμ. Additional increments [4] of +12 (β-methoxyl), +18 (δ-methoxyl), and +18 (δ-alkyl substituent) give an estimated value of $\lambda_{max.}$ 293 mμ, which is satisfactorily close to the observed value. 3-Benzoyl-4,6-dimethoxycoumarone (II; R = R′ = H), having carbonyl absorption at 1651 cm.$^{-1}$, was obtained from the benzil (III; R = R′ = H). A re-investigation of the cyclisation of 2-carboxymethoxy-4,2′,4′-trimethoxybenzil has confirmed the formation [1] of 7,2′,4′-trimethoxyisoflavone; it is accompanied, however, by minor amounts of the isomeric 3-(2,4-dimethoxybenzoyl)-6-methoxycoumarone.

Consequently, it is apparent that the cyclisation of 2-carboxymethoxybenzils may produce the isoflavone, the isomeric 3-aroylcoumarone, or a mixture of both. The determining factor is undoubtedly the methoxylation pattern of the benzil (cf., *e.g.*, the differences in reactivity of methoxydeoxybenzoins [1,5]). In this connexion it is significant that, although numerous methoxydeoxybenzoins have been converted, in varying yields, into benzils,[2] 2-hydroxy-4,2′,4′,6′-tetramethoxydeoxybenzoin (IX) is extremely resistant to oxidation and the corresponding benzil could not be obtained. Further, although 2-carboxymethoxy-4,2′,4′,6′-tetramethoxydeoxybenzoin (X; R = H) which has infrared bands at 1767 (phenoxy-acid) and 1645 (*p*-methoxyaryl ketone) cm.$^{-1}$, is easily converted into 6-methoxy-3-(2,4,6-trimethoxybenzylcoumarone (XI; R = H) with sodium acetate and acetic anhydride,[1] attempts to cyclise the analogue (X; R = H) and the corresponding methyl ester (X; R = Me) to 2-carboxy-6-methoxy-3-(2,4,6-trimethoxybenzyl)coumarone (XI; R = CO_2H) or its ester (XI; R = CO_2Me) with, *e.g.*, sodium methoxide were unsuccessful. However, with phosphorus pentoxide, the acid (X; R = H) gave a neutral product from which the parent acid is easily regenerated by alkali. Since the infrared spectrum is devoid of a band in the aromatic carbonyl region but exhibits absorption at 1761 cm.$^{-1}$ (vinyl ester) the product may be formulated as the lactone (XII).

In the light of these results we investigated the cyclisation of *o*-phenoxyacetic acids

[4] Data from Jaffé and Orchin, " Theory and Applications of Ultraviolet Spectroscopy," Wiley, New York, 1962.

[5] Badcock, Cavill, Robertson, and Whalley, *J.*, 1950, 2961.

of type (XIII). 2'-Carboxymethoxy-2,4,6,4'-tetramethoxydeoxybenzoin (XIII; R = R' = R'' = OMe) was readily cyclised by sodium methoxide to the chromanone (XV; R = R' = OMe). The constitution of this follows from, *inter alia*, its intense ferric reaction in alcohol, the solubility in dilute sodium hydroxide solution, the formation of two isomeric acetates (see Experimental section), and the quantitative hydrolysis to the parent acid (XIII; R = R' = R'' = OMe) by boiling alkali. No evidence for the formation of the isomeric 7,2',4',6'-tetramethoxyisoflav-2-ene (XIV) was obtained. Similarly, cyclisation of 2'-carboxymethoxy-2,4-dimethoxydeoxybenzoin (XIII; R = OMe, R' = R'' = H), prepared from 7-methoxy-2'-hydroxyisoflavone (XVI; R = H) by way of the stages (XVI; R = CH_2·CO_2Et), (XVI; R = CH_2·CO_2H), and (XIII; R' = R'' = H, R = OH) furnished 4-(2,4-dimethoxybenzoyl)chroman-3-one (XV; R = R' = H).

The formation of the chroman-3-ones (XV) from deoxybenzoins of type (XIII) is in accord with the synthesis [6] of the chromonochromone (dehydrorotenone) nucleus (XVII) from intermediates of type (XIII; R = OH) and represents the first stage in this double cyclisation.

Experimental

4,6-*Dimethoxy*-2-p-*methoxyphenylcoumarone* (VII; R = H, R' = OMe).—Condensation of 2-hydroxy-4,6,4'-trimethoxybenzil [3] (4 g.) with ethyl bromoacetate (3 g.) in boiling acetone (100 ml.) containing potassium carbonate (7 g.) was complete in 9 hr. Hydrolysis of the crude ester (4·5 g.) with potassium hydroxide (4 g.) in water (50 ml.) occurred during 12 hr., to furnish 2-*carboxymethoxy*-4,6,4'-*trimethoxybenzil* (2 g.) in needles, m. p. 160° (from ethyl acetate) (Found: C, 61·5; H, 5·0. $C_{19}H_{18}O_8$ requires C, 61·0; H, 4·9%). A mixture of this acid (1 g.), sodium acetate (2 g.), and acetic anhydride (10 ml.) was refluxed for 3 hr. and diluted with water (50 ml.). Next day, purification of the solid product from methanol gave 3-p-*anisoyl*-4,6-*dimethoxycoumarone* (0·5 g.) in plates, m. p. 130° (Found: C, 68·9; H, 5·1. $C_{18}H_{16}O_5$ requires C, 69·2; H, 5·2%). 5,7,4'-Trimethoxyisoflavone has m. p. 171°.

A solution of this coumarone (0·5 g.) in water (10 ml.) and methanol (20 ml.) containing potassium hydroxide (0·5 g.) was refluxed for 1½ hr., cooled, and acidified, to yield hydrated 2'-*hydroxy*-4,4',6'-*trimethoxydeoxybenzoin* in stout prisms (0·4 g.) (from aqueous methanol), m. p. 140° (Found: C, 63·9; H, 6·3. $C_{17}H_{18}O_5$,H_2O requires C, 63·7; H, 6·3%). This compound is readily soluble in 2N-sodium hydroxide, is devoid of a ferric reaction, and on distillation at 1 mm. is converted quantitatively into 4,6-*dimethoxy*-2-p-*methoxyphenylcoumarone*, forming prisms, m. p. 99°, from aqueous methanol (Found: C, 71·5; H, 5·9. $C_{17}H_{16}O_4$ requires C, 71·8; H, 5·7%). A solution of 3-*p*-anisoyl-4,6-dimethoxycoumarone (0·5 g.) in methanol (15 ml.) containing 50% aqueous potassium hydroxide (1 ml.) was refluxed for 15 min., cooled, and acidified, and the product was purified from methanol, to give 3-*formyl*-4,6-*dimethoxy*-2-p-*methoxyphenylcoumarone* (0·2 g.) in pale yellow needles, m. p. 146° (Found: C, 69·0; H, 5·3. $C_{18}H_{16}O_5$ requires C, 69·2; H, 5·2%). The compound is devoid of a ferric reaction and gives an immediate reaction with 2,4-dinitrophenylhydrazine sulphate solution. The 2,4-*dinitrophenylhydrazone* separated from ethyl acetate in crimson needles, m. p. 246° (decomp.) (Found: N, 10·8. $C_{24}H_{20}N_4O_8$ requires N, 11·4%). 2'-Hydroxy-4,4',6'-trimethoxydeoxybenzoin (50 mg.) was isolated from the mother-liquors after the separation of the major product.

2-(3,4-*Dimethoxyphenyl*)-4,6-*dimethoxycoumarone* (VII; R = R' = OMe).—Reaction of 2-hydroxy-4,6,3',4'-tetramethoxybenzil (4 g.), potassium carbonate (8 g.), and ethyl bromoacetate (3 g.) in boiling acetone (100 ml.) during 10 hr., followed by hydrolysis of the crude ester, gave 2-*carboxymethoxy*-4,6,3',4'-*tetramethoxybenzil*, prisms (2·7 g.), m. p. 196° (from ethyl acetate) (Found: C, 59·9; H, 5·3. $C_{20}H_{20}O_9$ requires C, 59·4; H, 5·0%). Cyclisation of this acid (1·8 g.) in refluxing acetic anhydride containing sodium acetate gave 3-(3,4-*dimethoxybenzoyl*)-4,6-*dimethoxycoumarone* (0·8 g.) in prisms, m. p. 149° (from ethyl acetate) (Found: C, 66·9; H, 5·4. $C_{19}H_{18}O_6$ requires C, 66·7; H, 5·3%). A mixed m. p. with 5,7,3',4'-tetramethoxyisoflavone (m. p. 166°) was *ca.* 135°. When a solution of this coumarone (0·5 g.) in methanol (20 ml.) containing water (10 ml.) and potassium hydroxide (5 g.) was refluxed for 1 hr. and the product was isolated with ether, 2-(3,4-*dimethoxyphenyl*)-4,6-*dimethoxycoumarone* separated from methanol in prisms (0·4 g.), m. p. 127° (Found: C, 68·8; H, 5·9. $C_{18}H_{18}O_5$

[6] Robertson, *J.*, 1933, 489.

requires C, 68·8; H, 5·8%). Alternatively, hydrolysis of the coumarone (0·5 g.) with 50% potassium hydroxide (1 ml.) in methanol (15 ml.) during 15 min. at the b. p. gave 2-(3,4-*dimethoxyphenyl*)-3-*formyl*-4,6-*dimethoxycoumarone* (0·2 g.) which formed pale yellow needles, m. p. 134°, from methanol (Found: C, 66·5; H, 5·7. $C_{19}H_{18}O_6$ requires C, 66·7; H, 5·3%). This compound is insoluble in alkali, is devoid of a ferric reaction and gives a 2,4-*dinitrophenylhydrazone* in deep red needles, m. p. 247° (decomp.) (from benzene) (Found: N, 10·5. $C_{25}H_{22}N_4O_9$ requires N, 10·7%).

Cyclisation of 2-*Carboxymethoxy*-4,2′,4′-*trimethoxybenzil* (with A. B. NOLAN).—Oxidation of 2-hydroxy-4,2′,4′-trimethoxydeoxybenzoin (1 g.) in acetone (75 ml.) with potassium permanganate (2·5 g.) in water (75 ml.) furnished 2-hydroxy-4,2′,4′-trimethoxybenzil [1] in yellow prisms (0·2 g.), m. p. and mixed m. p. 110° (from methanol) [Found: C, 64·1; H, 5·2; OMe, 29·0. Calc. for $C_{14}H_7O_3(OMe)_3$: C, 64·6; H, 5·1; OMe, 29·4%]. A solution of 2-carboxymethoxy-4,2′,4′-trimethoxybenzil [1] (0·5 g.), prepared from the preceding benzil in acetic anhydride (15 ml.) containing sodium acetate (2 g.), was refluxed for 2 hr. and then diluted with water (200 ml.). Purification of the product from alcohol gave 7,2′,4′-trimethoxyisoflavone, (0·25 g.), m. p. and mixed m. p. 148° (Found: C, 68·8; H, 5·1. Calc. for $C_{18}H_{16}O_5$: C, 69·2; H, 5·2%). The mother-liquors deposited a second crop of crystals which on purification from methanol furnished 3-(2,4-*dimethoxybenzoyl*)-6-*methoxycoumarone* (70 mg.) in prisms, m. p. 119° (Found: C, 68·8; H, 5·1. $C_{18}H_{16}O_5$ requires C, 69·2; H, 5·2%).

3-*Benzoyl*-4,6-*dimethoxycoumarone* (II; R = R′ = H).—Interaction of 2-hydroxy-4,6-dimethoxybenzil [3] (7 g.) and ethyl bromoacetate (5 g.) in boiling acetone (150 ml.) containing potassium carbonate (15 g.) during 3 hr. gave an oil which was hydrolysed to a mixture of acids. Purification from ethyl acetate gave two products. (*a*) The first was α-(1-*benzoylformyl*)-2,4-*dimethoxy*-6-*oxocyclohexa*-2,4-*dienylacetic acid* (VIII) (3 g.), stout prisms, m. p. 188°, devoid of a ferric reaction and readily soluble in 2N-sodium hydrogen carbonate [Found: C, 62·2; H, 5·1; OMe, 18·3. $C_{16}H_{10}O_5(OMe)_2$ requires C, 62·8; H, 4·7; OMe, 18·0%]. The same acid (4 g.), m. p. 186°, was obtained by the condensation of 2-hydroxy-4,6-dimethoxybenzil (7 g.) with ethyl bromoacetate (5 g.) in boiling alcohol (50 ml.) containing sodium (0·4 g.) during 8 hr., followed by hydrolysis. This acid is recovered unchanged after prolonged boiling with sodium acetate in acetic anhydride. The *methyl ester* formed tablets, m. p. 146°, from methanol [Found: C, 63·3; H, 5·2; OMe, 26·0. $C_{16}H_9O_4(OMe)_3$ requires C, 63·7; H, 5·1; OMe, 26·0%]. (*b*) The second product was 2-*carboxymethoxy*-4,6-*dimethoxybenzil* (1·3 g.), stout prisms, m. p. 147° [Found: C, 63·1; H, 4·9; OMe, 18·3. $C_{16}H_{10}O_5(OMe)_2$ requires C, 62·8; H, 4·7; OMe, 18·0%]. The *methyl ester* formed pale yellow prisms, m. p. 118°, from methanol [Found: C, 63·3; H, 5·2; OMe, 26·0. $C_{16}H_9O_4(OMe)_3$ requires C, 63·7; H, 5·1; OMe, 26·0%].

Cyclisation of 2-carboxymethoxy-4,6-dimethoxybenzil in boiling acetic anhydride containing sodium acetate during ½ hr. gave an almost quantitative yield of 3-*benzoyl*-4,6-*dimethoxycoumarone*, plates, m. p. 107° (from aqueous methanol) [Found: C, 72·1; H, 5·2; OMe, 21·3. $C_{15}H_8O_2(OMe)_2$ requires C, 72·3; H, 5·0; OMe, 22·0%]. The mixed m. p. with 5,7-dimethoxyisoflavone (m. p. 106°) was *ca.* 95°. When a solution of the coumarone (1·5 g.) in methanol (20 ml.) containing 5N-potassium hydroxide solution (10 ml.) was kept at 50° for 15 min. and at room temperature for a further 45 min. and then acidified 3-*formyl*-4,6-*dimethoxy*-2-*phenylcoumarone* separated. From aqueous methanol it formed pale yellow needles (1·5 g.), m. p. 140° [Found: C, 71·8; H, 5·0; OMe, 21·9. $C_{15}H_8O_2(OMe)_2$ requires C, 72·3; H, 5·0; OMe, 22·0%]. This substance is insoluble in 2N-sodium hydroxide and devoid of a ferric reaction. The *oxime* separated from aqueous methanol in needles, m. p. 153° (Found: N, 5·0. $C_{17}H_{15}NO_4$ requires N, 4·7%). The 2,4-*dinitrophenylhydrazone* formed deep red needles, m. p. 188°, from ethyl acetate (Found: C, 59·9; H, 4·0; N, 12·2. $C_{23}H_{18}N_4O_7$ requires C, 59·7; H, 3·9; N, 12·1%).

Hydrolysis of 3-benzoyl-4,6-dimethoxycoumarone (2 g.), when kept in boiling methanol (25 ml.) containing water (10 ml.) and potassium hydroxide (10 g.) during 2 hr., furnished a quantitative yield of 2′-*hydroxy*-4′,6′-*dimethoxydeoxybenzoin* on acidification. Purified from aqueous methanol, this ketone formed hydrated prisms, m. p. 120° (decomp.) readily soluble in 2N-sodium hydroxide and devoid of a ferric reaction (Found: C, 66·2; H, 6·6. $C_{16}H_{16}O_4$ requires C, 70·6; H, 5·9. $C_{16}H_{16}O_4,H_2O$ requires C, 66·2; H, 6·3%). Purification from light petroleum (b. p. 60—80°) gave the anhydrous *form*, prisms, m. p. 90° (Found: C, 70·1; H, 6·1. $C_{16}H_{16}O_4$ requires C, 70·6; H, 5·9%). This deoxybenzoin was recovered unchanged after distillation at 14 mm.

Cyclisation of 2-Carboxymethoxy-4,2′,4′,6′-tetramethoxydeoxybenzoin (X; R = H).—The acid [1] (1 g.) in benzene (35 ml.) containing phosphorus pentoxide (5 g.) was refluxed for 1¼ hr., then the benzene solution was separated, washed with 2N-sodium hydrogen carbonate and water, dried, and evaporated. The solid residue was purified from benzene, to yield α-[2-(α-*hydroxy*-2,4,6-*trimethoxystyryl*)-3,5-*dimethoxyphenoxy*]*acetic acid lactone* (XII) (0·7 g.), plates, m. p. 240° [Found: C, 64·6; H, 5·4; OMe, 32·5. $C_{16}H_8O_3(OMe)_4$ requires C, 64·5; H, 5·4; OMe, 33·3%]. This compound is insoluble in cold 2N-sodium hydroxide, has a negative ferric reaction, and does not furnish an acetate or a derivative with 2,4-dinitrophenylhydrazine sulphate. Hydrolysis with boiling aqueous-methanolic 20% potassium hydroxide during 15 min. regenerates the parent deoxybenzoin quantitatively.

4-(2,4-*Dimethoxybenzoyl*)*chroman*-3-*one* (XV; R = R′ = H).—Interaction of 2′-hydroxy-7-methoxyisoflavone [1] (7 g.) and ethyl bromoacetate (5 g.) in boiling acetone (100 ml.) containing potassium carbonate (15 g.) during 3 hr. gave 2′-*ethoxycarbonylmethoxy*-7-*methoxyisoflavone* (8·6 g.), plates m. p. 111° (from alcohol) (Found: C, 67·8; H, 5·5. $C_{20}H_{18}O_6$ requires C, 67·8; H, 5·1%). Hydrolysis of this isoflavone (5 g.) with 20% aqueous potassium hydroxide (25 ml.) in boiling methanol (5 ml.) during 1 hr. gave a quantitative yield of 2′-*carboxymethoxy*-2-*hydroxy*-4-*methoxydeoxybenzoin*, prisms, m. p. 164° (from aqueous acetone) [Found: C, 64·7; H, 5·2; OMe, 10·5. $C_{16}H_{13}O_5(OMe)$ requires C, 64·6; H, 5·1; OMe, 9·8%], that gave an intense red-brown ferric reaction in alcohol. Prepared quantitatively by using methyl sulphate–potassium carbonate in boiling acetone during 3 hr., 2,4-*dimethoxy*-2′-*methoxycarbonylmethoxydeoxybenzoin* formed stout prisms, m. p. 91°, from aqueous alcohol [Found: C, 65·6; H, 6·0; OMe, 26·8. $C_{16}H_{11}O_3(OMe)_3$ requires C, 66·3; H, 5·9; OMe, 27·0%], identical with the methylation product of 2′-carboxymethoxy-2,4-dihydroxydeoxybenzoin prepared by an alternative process.[6]

Hydrolysis of this ester gave 2′-*carboxymethoxy*-2,4-*dimethoxydeoxybenzoin*, prisms, m. p. 150° (from aqueous acetone) [Found: C, 64·9; H, 5·4; OMe, 18·5. $C_{16}H_{12}O_4(OMe)_2$ requires C, 65·4; H, 5·5; OMe, 18·2%]. A solution of this acid (1 g.) in methanol (10 ml.) containing sodium (0·3 g.) was refluxed for 1 hr. The yellow precipitate was collected and dissolved in water, the solution acidified, and the precipitate purified from aqueous methanol, to yield 4-(2,4-*dimethoxybenzoyl*)*chroman*-3-*one* (0·4 g.), yellow prisms, m. p. 109° [Found: C, 68·6; H, 5·3; OMe, 20·0. $C_{16}H_{10}O_3(OMe)_2$ requires C, 69·2; H, 5·2; OMe, 19·9%]. This ketone exhibits an intense green ferric reaction, is readily soluble in N-sodium hydroxide, and on hydrolysis with boiling 5N-potassium hydroxide during 1 hr. regenerates the parent deoxybenzoin quantitatively.

Cyclisation of 2′-carboxymethoxy-2,4-dimethoxydeoxybenzoin (2 g.) with sodium acetate (2 g.) in boiling acetic anhydride (10 ml.) during 2½ hr. gave a neutral, non-crystallisable product, devoid of a ferric reaction. Hydrolysis of this compound (1·5 g.) during 2 min. in methanol with 50% potassium hydroxide (0·5 ml.) gave 4-(2,4-dimethoxybenzoyl)chroman-3-one (1·2 g.).

7-*Methoxy*-4-(2,4,6-*trimethoxybenzoyl*)*chroman*-3-*one* (XV; R = R′ = OMe).—Prepared by the condensation during 4 days of 4-methoxy-2-methoxycarbonylmethoxyphenylacetonitrile [5] (5 g.) with phloroglucinol (10 g.) in ether (250 ml.) containing zinc chloride (5 g.) and saturated with hydrogen chloride at 0°, followed by isolation in the usual manner, 2′-*carboxymethoxy*-2,4,6-*trihydroxy*-4′-*methoxybenzoin* separated from aqueous acetone in pale yellow prisms (4·6 g.), m. p. 213°, giving an intense plum-coloured ferric reaction in alcohol (Found: C, 58·2; H, 5·0; OMe, 8·6. $C_{16}H_{13}O_7$·OMe requires C, 58·6; H, 4·6; OMe, 8·9%). Methylation of this deoxybenzoin by methyl sulphate–potassium carbonate gave quantitatively 2,4,6,4′-*tetramethoxy*-2′-*methoxycarbonylmethoxydeoxybenzoin*, prisms, m. p. 124° (from methanol) [Found: C, 62·4; H, 6·3; OMe, 39·3. $C_{16}H_9O_3(OMe)_5$ requires C, 62·4; H, 6·0; OMe, 38·4%]. Prepared quantitatively, the *acid* formed needles, m. p. 127°, from benzene or aqueous acetone [Found: C, 61·8; H, 5·6; OMe, 31·6. $C_{16}H_{10}O_4(OMe)_4$ requires C, 61·5; H, 5·7; OMe, 31·8%]. Cyclisation of this acid (1 g.) in boiling methanol (10 ml.) containing sodium (0·3 g.) during ½ hr. gave 7-*methoxy*-4-(2,4,6-*trimethoxybenzoyl*)*chroman*-3-*one* (0·4 g.), yellow plates, m. p. 128° (from methanol) [Found: C, 64·7; H, 5·5; OMe, 33·2. $C_{16}H_8O_3(OMe)_4$ requires C, 64·5; H, 5·4; OMe, 33·3%]. This diketone is readily soluble in N-sodium hydroxide, gives an intense green ferric reaction, and is hydrolysed quantitatively to the parent deoxybenzoin during 1 hr. in boiling 5N-potassium hydroxide solution.

Cyclisation of this acid (3·5 g.) with sodium acetate (5 g.) in boiling acetic anhydride (15 ml.) during 2 hr. gave a *monoacetate* of the chroman-3-one which formed pale yellow prisms (0·5 g.), m. p. 168°, from methanol [Found: C, 63·2; H, 5·5; OMe, 26·5. $C_{18}H_{10}O_4(OMe)_4$ requires

C, 63·8; H, 5·4; OMe, 30·0%]. This compound gives no ferric colour and is insoluble in N-sodium hydroxide, but it is quantitatively converted during 2 min. into the diketone when a suspension of the acetate (0·5 g.) in methanol (10 ml.) is treated with 50% potassium hydroxide (0·5 ml.).

Acetylation by pyridine–acetic anhydride or sodium acetate–acetic anhydride gave a quantitative yield of an isomeric *monoacetate* in pale yellow needles, m. p. 158° (Found: C, 63·6; H, 5·5. $C_{22}H_{22}O_8$ requires C, 63·8; H, 5·4%). A mixed m. p. of the two acetates was *ca.* 140°. Deacetylation furnished the parent diketone.

Spectra.—Infrared spectra were determined in a paraffin mull using a Perkin-Elmer model 21 spectrophotometer. Ultraviolet absorption spectra were determined for alcohol solutions by using a Perkin-Elmer 137 U.V. spectrophotometer.

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Department of Organic Chemistry, The University, Liverpool.
The School of Pharmacy, The University, London. [*Received, May 20th,* 1963.]