Oligomeric Isoflavonoids. Part 1. Structure and Synthesis of the First (2,3')-Isoflavone-Isoflavan Dimer

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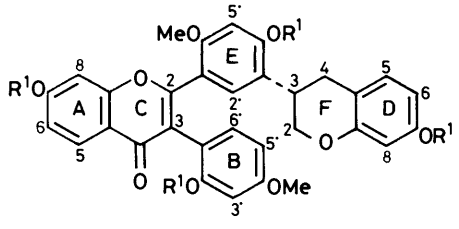
The structure and stereochemistry of a novel [2,3']-isoflavone-isoflavan oligomer, 2',7-dihydroxy-2-[(3*S*)-6',7-dihydroxy-4'-methoxyisoflavan-3'-yl]-4'-methoxyisoflavone (**1**; R = H), from *Dalbergia nitidula* are established by synthesis. The strategy of condensation of a C_{16} to C_{14} moiety, *i.e.* C-5' formylated isoflavan (**21**) to a 2-hydroxydeoxybenzoin (**23**) in a modified Baker-Venkataraman approach, should provide general access to this novel class of C-2 coupled oligomeric isoflavonoids.

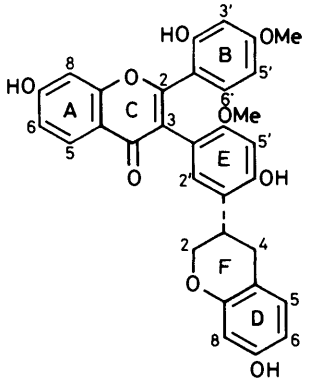
The structure and stereochemistry of the first natural bi-isoflavonoid, (3*S*,4*S*)-3,4-*trans*-4-[(3*S*)-6',7-dihydroxy-4'-methoxyisoflavan-3'-yl]-4'-methoxyisoflavan-2',7-diol were recently established by synthesis *via* acid-mediated condensation or photolysis of the appropriate pterocarpan and isoflavan precursors.[1,2] This bi-isoflavanoid is accompanied in the heartwood of *Dalbergia nitidula* Welw. *ex* Bak[3] by an analogue which has now been characterized as 2',7-dihydroxy-2[(3*S*)-6',7-dihydroxy-4'-methoxyisoflavan-3'-yl]-4'-methoxyisoflavone (**1**; R = H) by means of spectroscopic and synthetic methods.

Results and Discussion

The ^{1}H n.m.r. spectrum at 250 MHz of the novel [2,3']-isoflavone-isoflavan dimer (**1**; R = H) exhibits three ABX systems and two one-proton singlets in the aromatic regions. Besides two *O*-methyl resonances the heterocyclic region shows the presence of an ABMXY system only [δ 4.13, dd, *J* 3.3 and 10.5 Hz, 2-H (*eq.*) (F); δ 3.78, dd, *J* 9.5 and 10.5 Hz, 2-H (*ax.*) (F); δ 3.49—3.31, m, 3-H (F); δ 2.84—2.56, m, 4-CH_2 (F)], characteristic of the spin pattern of an isoflavan heterocycle. Extensive spin-spin decoupling experiments using the MXY protons as reference signals facilitated allocation of the ABX system [δ 6.86, d, *J* 8.3 Hz, 5-H (D); δ 6.35, dd, *J* 2.2 and 8.3 Hz, 6-H (D); δ 6.27, d, *J* 2.2 Hz, 8-H (D)] and the one-proton singlet [δ 7.14, 2'-H (E)] associated with the heterocyclic system. When taken in conjunction with the additional aromatic singlet (δ 6.54), the above data strongly indicate the presence of a 2',4',7-tri-oxygenated isoflavan moiety substituted at C-5' † of its B ring. The lowfield position of the aromatic *o*-doublet (δ 8.02, *J* 8.7 Hz) of the second ABX pattern is compatible with a C-4 carbonyl for the heterocyclic ring of the remaining C_{15} moiety thus indicating two possible structures ‡ for the natural product, *i.e.* [2,3']-isoflavone-isoflavan (**1**; R = H) or [3,3']-flavone-isoflavan (**2**). Mass fragmentation data similarly indicates a mono-*O*-methylated isoflavan-triol [*m/z* 272 (69%)] and mono-*O*-methylated trihydroxy-isoflavone or flavone unit [*m/z* 283 (11%)]. Since comparison of the chemical-shift values of 2'-H (E) of the isoflavan moiety and *o*-doublet (δ 6.64, *J* 8.3 Hz) of the third ABX system favours structure (**1**; R = H) for the novel isoflavonoid oligomer, confirmation for this constitution was sought by synthesis.



(**1**)

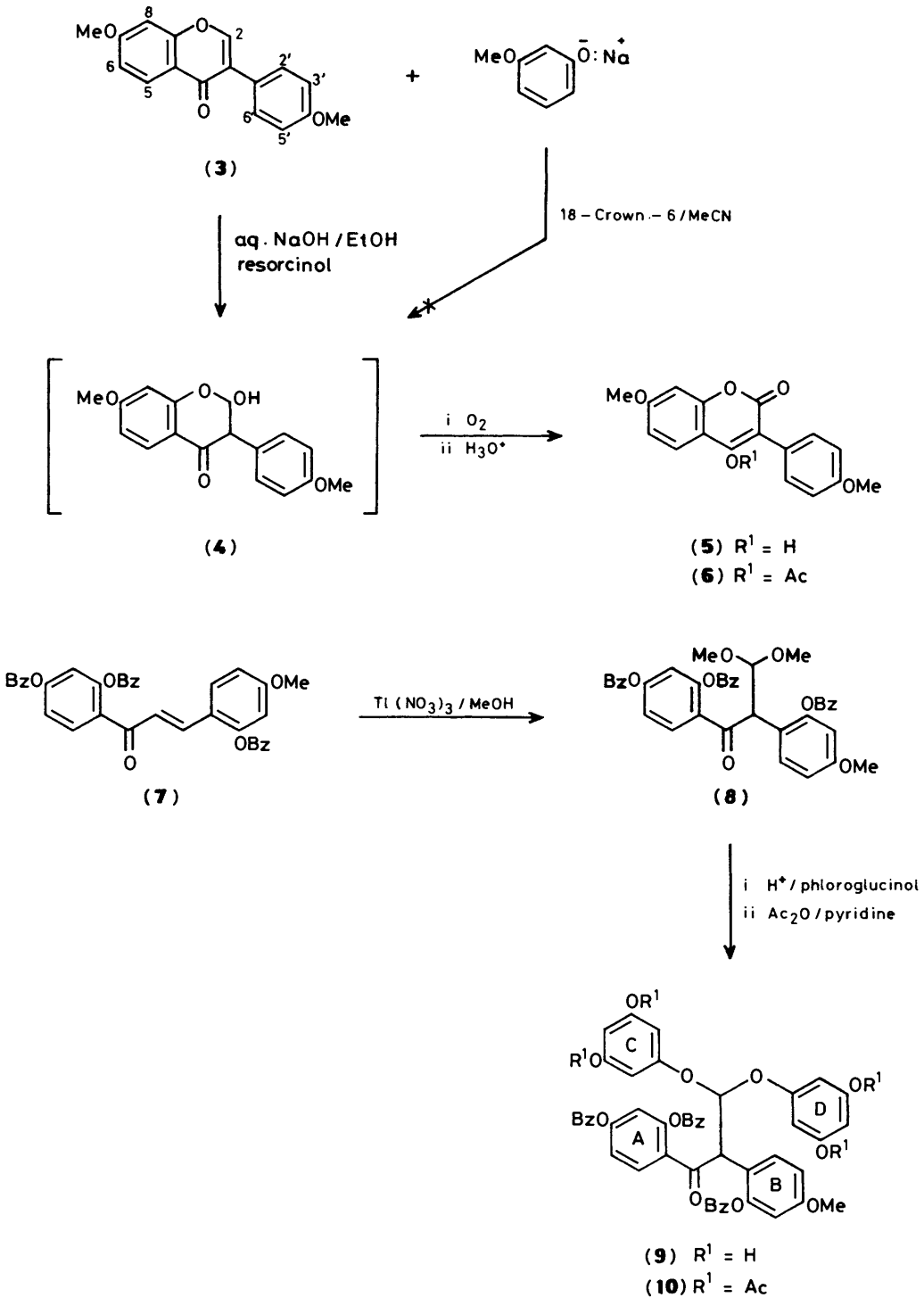


(**2**)

Conditions similar to those utilised for the biomimetic synthesis of condensed tannins,[4] but when applied to pterocarpans [*e.g.* (**12**)] as inceptive electrophiles and nucleophilic isoflavans, led to facile formation of the natural [4,3']-bi-isoflavan (*cf.* refs. 1 and 2). The unique structural differences between the natural bi-isoflavan and the isoflavone-isoflavan dimer (**1**; R = H), *e.g.* functioning of an oxygenated benzylic electrophilic centre in the former in comparison to the electron-deficient β-carbon in the α,β-unsaturated carbonyl arrangement of (**1**; R = H), necessitates development of a different approach towards its synthesis. Several possibilities were investigated. These include coupling of nucleophilic phenolic units to aromatic oxygenated isoflavone-2,3-epoxides,[5] direct coupling of phenolic nuclei to isoflavones in a 1,4-Michael fashion, linkage of phenolic units to the acetal-type electrophilic centre of the intermediate in isoflavone synthesis prior to construction of the heterocycle [thallium(III) nitrate strategy[6,7]], and, finally, by condensation of a C_{16}- and a C_{14}-unit, *i.e.* C-5' formylated isoflavan to 2-hydroxydeoxybenzoin in a modified Baker-Venkataraman synthesis.[8]

† The equivalent of C-3' (E-ring) in the dimer.

‡ *The positions of the O*-methyl functions were determined by a 2D COSY experiment.



Whereas acid-catalysed coupling of simple phenols to isoflavone-2,3-epoxides leads to predominant formation of C-3 arylated products (*cf.* ref. 5), attempts at coupling of resorcinol at C-2 of 4′,7-dimethoxyisoflavone (**3**) under mild acidic conditions failed. The same reaction, but under mild basic conditions, either failed (sodium salt of 3-methoxyphenol/18-crown-6) or gave 4-hydroxy-7-methoxy-3-(4-methoxyphenyl)-coumarin (**5**) (resorcinol/aq. NaOH) following aerial oxidation of the intermediate 2-hydroxyisoflavanone (**4**) arising from 1,4-Michael addition of hydroxide ion to isoflavone (**3**).

In order to minimize the directing effect of the heterocyclic oxygen, 4-carbonyl, and 3-aryl group of isoflavanoid analogues (*e.g.* epoxides, *cf.* ref. 5) on the course of intermolecular coupling, linkage of phenolic units to the relatively isolated electrophilic centre of the 1,2-diaryl-3,3-dimethoxypropan-1-one (**8**)* was subsequently attempted. Acid-catalysed coupling of phloroglucinol to (**8**), however, gave only the acetal (**9**) which was identified as its tetra-*O*-acetyl derivative (**10**) by means of ^{1}H n.m.r. data. The observed preference of *O*- over *C*-alkylation

* Available *via* thallium(III) nitrate oxidative rearrangement of 2,2′,4′-tribenzyloxy-4-methoxy-*trans*-chalcone (**7**) in methanol.

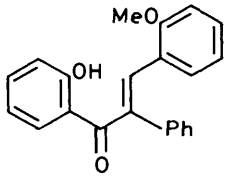
Table. ^{1}H N.m.r. peaks (p.p.m.) of the natural and synthetic [2,3′]-bi-isoflavonoid (**1**; R = H). Splitting patterns and *J* values are given in parentheses

Proton	Natural product		Synthetic product
	80 MHz (303 K)	250 MHz (297 K)	300 MHz (298 K)
5-H(A)	8.08 (d, 8.5)	8.02 (d, 8.7)	8.04 (d, 8.8)
6-H(A)	7.01 (dd, 2.1, 8.5)	7.00 (dd, 2.2, 8.7)	7.01 (dd, 2.2, 8.8)
8-H(A)	6.94 (d, 2.1)	6.90 (d, 2.2)	6.91 (d, 2.2)
3′-H(B)	6.48 (d, 2.5)	6.43 (d, 2.2)	6.44 (d, 2.5)
5′-H(B)	6.23 (dd, 2.5, 8.5)	6.18 (dd, 2.2, 8.3)	6.19 (dd, 2.5, 8.5)
6′-H(B)	6.69 (d, 8.5)	6.64 (d, 8.3)	6.66 (d, 8.5)
2-$H_{eq.}$(F)	4.13 (dd, 3.3, 10.5)	4.05—4.21 (m)*	4.08—4.17 (m)*
2-$H_{ax.}$(F)	3.78 (dd, 9.5, 10.5)	3.75—3.89 (m)*	3.74—3.85 (m)*
3-H(F)	3.31—3.49 (m)	3.33—3.50 (m)	3.34—3.48 (m)
4-CH_2(F)	2.56—2.84 (m)	†	†
5-H(D)	6.89 (d, 8.0)	6.86 (d, 8.3)	6.86 (d, 8.3)
6-H(D)	6.37 (dd, 2.5, 8.0)	6.35 (dd, 2.2, 8.3)	6.35 (dd, 2.4, 8.3)
8-H(D)	6.31 (d, 2.5)	6.27 (d, 2.2)	6.27 (d, 2.4)
2′-H(E)	7.17 (s)	7.14 (s)	7.14 (s)
5′-H(E)	6.58 (s)	6.54 (s)	6.54 (s)
OMe	3.63, 3.69 (each s)	3.62, 3.70 (each s)	3.63, 3.71 (each s)
OH	—	8.37 (s)	8.18, 8.30, 9.09, 9.74 (each br s)

* Due to rotational restrictions these signals exhibit extensive line-broadening. † Overlapped by signal due to moisture in the solvent.

under conditions which should favour the latter (polar reaction medium) is presumably explicable in terms of a decreased degree of steric compression in the transition state leading to the ether-linked compound (**9**).

α-Phenylchalcones of type (**11**) could, in principle, be utilised in a synthetic sequence leading to the novel bi-isoflavanoid (**1**; R = H). Since these chalcones are available[9] in good yields



(**11**)

from the appropriate aromatic aldehyde and deoxybenzoin, we embarked on a strategy of adding a C-5′ formylated isoflavan moiety to the α-carbon of a 2-hydroxydeoxybenzoin. Owing to problems* regarding preparation of 2-hydroxy-4-methoxyphenylacetonitrile required for synthesis of 2,2′,4-tribenzyloxy-4′-methoxydeoxybenzoin (**22**), the latter was obtained from the acetal (**8**) by perchloric acid-induced decarbonylation.[10]† Debenzylation with BF_3–diethyl ether[11] smoothly afforded the dibenzyloxydeoxybenzoin (**23**).

The C-5′ formylated (3*S*)-2′,7-dibenzyloxy-4′-methoxyisoflavan (**18**) was prepared from the readily available natural (6a*S*, 11a*S*)-9-methoxypterocarpan-3-ol [(+)-medicarpin][12] (**12**). It should be emphasised that the success of the synthetic sequence is dependent on selective protection-deprotection procedures in order to introduce differences in chemical behaviour of the very similar A and B rings. Thus, methoxymethylation of the pterocarpan (**12**) afforded the di-ether (**13**) which was smoothly hydrogenolysed to the (3*S*)-2′-hydroxyisoflavan (**14**). In order to obtain a substantial proportion of *para*-, *i.e.* C-5′ to *ortho*-formylation, the isoflavan (**14**) was subjected to a photo-Reimer-Tiemann reaction[13,14] to give, *via* coupling of a phenoxy radical or radical cation with dichloromethyl radical, the aldehyde (**16**), accompanied by its regioisomer (**15**), in low yield.‡ Facile removal of the 7-*O*-methoxymethyl group in (**16**) under mild acidic conditions and subsequent benzylation gave the 2′,7-di-*O*-protected formylated (3*S*)-vestitol (**18**). Efforts towards addition of this aldehyde to the deoxybenzoin (**22**) in an approach similar to that of Donnelly *et al.*[9] for preparation of α-phenylchalcone (**11**) led to failure under both alkaline and acidic conditions. Such failure may presumably be attributed to the combined effect of destabilization of an intermediate α-carbanion analogue by 2′,4′-dioxygenation in deoxybenzoin (**22**) and by reduced electrophilicity of the carbonyl carbon in aldehyde (**18**), again due to its 2′,4′-dioxygenated B ring.

In order to adopt the Baker-Venkataraman methodology, the isoflavan (**18**) had to be oxidized to the carboxylic acid analogue. The aldehyde group, however, exhibited resistance towards oxidation by a variety of conventional mild reagents (*e.g.* Ag_2O, Jones reagent). This problem was circumvented by application of the approach of Corey[16] whereby oxidation was effected by manganese dioxide in the presence of sodium cyanide in methanol containing acetic acid. Saponification of the resulting methyl carboxylate (**19**) afforded the acid (**20**) which was transformed into the acid chloride (**21**) and immediately treated with the 2-hydroxydeoxybenzoin (**23**) to give the ester (**24**). Base-catalysed rearrangement afforded the β-diketone (**25**)§ which was smoothly converted into the [2,3′]-isoflavone-isoflavan (**1**; R = CH_2Ph)§ *via* cyclization and dehydration under acidic conditions. Debenzylation of this dimer gave (**1**; R = H) with ^{1}H n.m.r. spectral data at 300 MHz very similar to those of the natural product at 250 MHz (*cf.* Table).

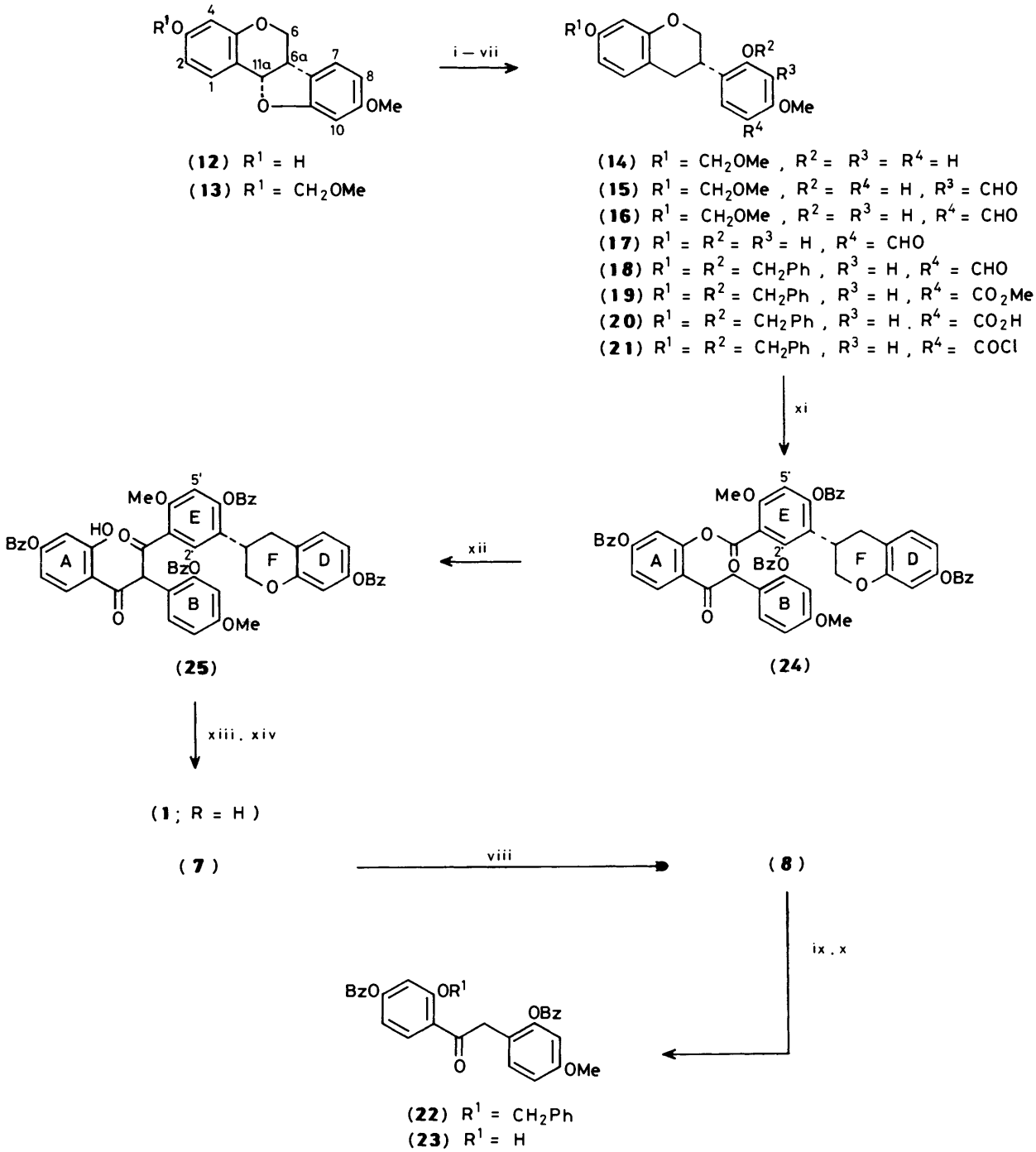
Since the isoflavan moiety containing the single chiral centre

* Presumably due to instability of the intermediate benzyl bromide.

† This reaction also leads to considerable conversion into both 2′,7-dibenzyloxy-4′-methoxyisoflavone and the dibenzyloxydeoxybenzoin (**23**).

‡ Although the 7-*O*-methyl ether of (3*R*)-vestitol[15] could be formylated at C-5′ in 75% yield by $HC(OMe)_3/BF_3$, sensitivity of the 7-OCH_2OMe group in (**14**) towards Lewis-acid discriminates against a similar approach for (**14**).

§ Owing to rotational restrictions the ^{1}H n.m.r. spectra at 300 MHz of these compounds exhibit extensive line-broadening and duplication of signals.



Scheme. Synthesis of the [2,3′]-isoflavone-isoflavan (**1**; R = H). *Reagents:* i. H_2–10% Pd/C; ii, $CHCl_3$–Et_2NH, 300 nm; iii, 3M HCl; iv, $PhCH_2Cl$–Me_2CO–K_2CO_3; v, MnO_2–NaCN–AcOH–MeOH; vi, 25% KOH–MeOH; vii, $(COCl)_2$–pyridine; viii, $Tl(NO_3)_3$–MeOH–dioxane; ix, 60% $HClO_4$–MeOH; x, BF_3–Et_2O; xi, (**23**)–pyridine; xii, K_2CO_3–Me_2CO–18-Crown-6; xiii, H_2SO_4; xiv, H_2–10% Pd/C

may have 3*S* or 3*R* absolute configuration, distinction between these possibilities was obtained by comparison of circular dichroic (c.d.) data. In the 260—400 nm region,* the c.d. curves of the natural and synthetic products are virtually superimposable except for the amplitude of the Cotton effects at 280 nm (*cf.* Figure). Notable also is the mirror-image relationship between the curves of the natural/synthetic products and that of the enantiomeric analogue (**27**) derived by similar pathway than for (**1**; R = H) but starting from the (3*R*)-vestitol equivalent. This unambiguously defined the (3*S*)-absolute configuration of the isoflavanyl unit in the natural product.

* For reasons that cannot be explained at present, results in the 220—260 nm region were inconsistent. Similar inconsistency was observed for the synthetic 2-arylisoflavone [(**26**), *cf.* Experimental section].

Experimental

T.l.c. was performed on DC-Plastikfolin Kieselgel 60 PF_{254} (0.25 mm) and the plates sprayed with H_2SO_4–HCHO (40:1, v/v) after development. Preparative plates (p.l.c.) [Kieselgel

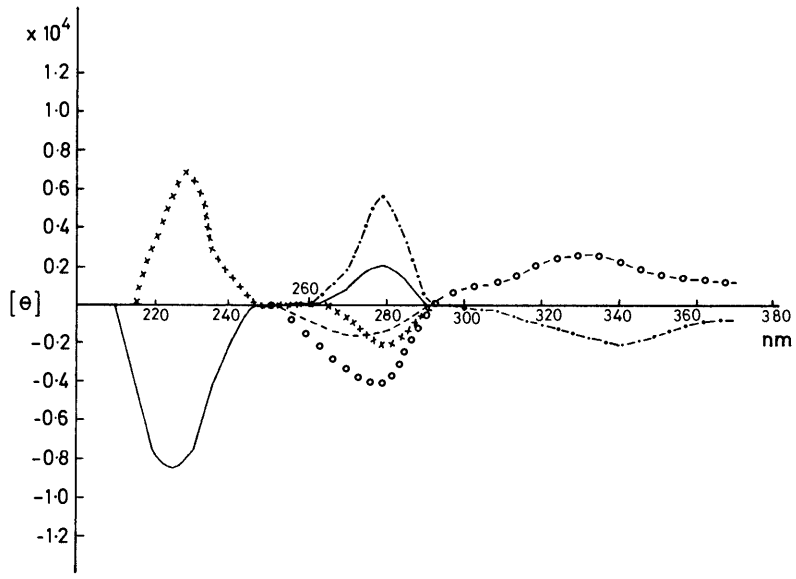
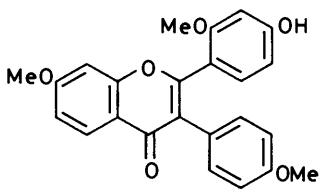
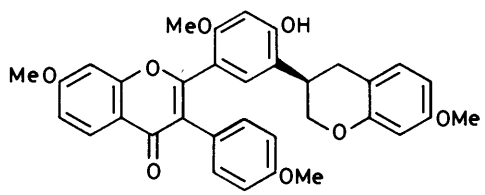


Figure. C.d. spectra of (3*R*)-7-*O*-methylvestitol (–), (3*S*)-7-*O*-methoxymethylvestitol (**14**) (× × × ×), [2,3′]-(3*R*)-isoflavone-isoflavan dimer (**27**) (–·–·–), [2,3′]-(3*S*)-isoflavone-isoflavan natural (– – –) and synthetic (o–o–o–o–o) products (**1**; R = H)



(**26**)



(**27**)

PF_{254} (1.0 mm)] were air-dried and used without prior activation. Methylations and benzylations were performed with methyl iodide or benzyl chloride respectively and anhydrous K_2CO_3 in dry acetone at 60 °C whilst acetylations were carried out with acetic anhydride–anhydrous pyridine. ^1H N.m.r. spectra were, unless specified to the contrary, recorded on a Bruker AM-300 spectrometer for solutions in $CDCl_3$ at 25 °C with the solvent as internal standard. Mass spectral data were recorded on a Varian CH-5 instrument, m.p.s (uncorrected) on a Reichert hot-stage apparatus and c.d. data on a JASCO J-20 spectropolarimeter. Optical rotations were measured with a Bendix-NPL automatic polarimeter. Owing to insufficient material $[\alpha]_D$ values for (**14**) and (**25**) lack accuracy. Analyses (C & H) were performed by Analytische Laboratorien, Fritz-Pregl-Strasse 24, 5270 Gummbersbach 1 Elbach, West Germany.

Extraction of the Heartwood of Dalbergia nitidula *Welw. ex. Bak.*—Drillings (1 129 g) of the heartwood of *D. nitidula* were extracted with diethyl ether (6 × 2 l, 24 h each) producing, on evaporation of the solvent, a tan resin (23.4 g).

Isolation of 2′,7-Dihydroxy-2-[(3S)-6′,7-dihydroxy-4′-methoxyisoflavan-3′-yl]-4′-methoxyisoflavone (**1**; R = H).—The ether extract (20 g) of the heartwood of *D. nitidula* was fractionated by column chromatography [Merck Kieselgel 60; benzene–MeOH (9:1)] to yield a fraction at R_F 0.12 (600 mg) in the same solvent system on t.l.c. This fraction was rechromatographed by column chromatography (Merck Kieselgel 60) using 1,2-dichloroethane–ethyl acetate (65:35) as eluant to give the crude isoflavan-isoflavone (**1**; R = H) (R_F 0.20 on t.l.c., 46 mg) which was purified by p.l.c. [benzene–acetone–MeOH (80:15:5, ×2), R_F 0.20] yielding (**1**; R = H) (5 mg) as a *brownish solid*, ^1H n.m.r. data (Table). (Found: M^+, 554.1554; $C_{32}H_{26}O_9$ requires *M*, 554.1556); 2D n.m.r. (250 MHz; [$^2H_6$]acetone; 297 K; ^1H–^1H shift correlations) 5(A)—6(A), 2′(E)—5′(E), 6(A)—8(A), 5(D)—6(D), 3′(B)—5′(B), 6′(B)—5′(B), 6(D)—8(D), 5′(E)—4′OMe(E), 3′(B)—4′OMe(B), and 2′(E)—3(F); *m/z* 554 (M^+, 65%), 552 (28), 538 (20), 432 (17), 431 (30), 418 (37), 415 (27), 296 (43), 283 (11), 282 (29), 281 (35), 273 (31), 272 (69), 270 (30), 267 (44), 257 (27), 256 (67), 255 (35), 242 (24), 241 (68), 161 (21), 151 (58), 150 (100), 149 (60), 148 (21), 147 (28), 138 (63), 137 (76), 136 (34), 135 (62), 134 (26), 128 (24), 123 (58), 121 (35), 110 (63), and 107 (52); c.d. (*c* 0.1420 in MeOH) $[\theta]_{370}$ 0.13 × 10^4, $[\theta]_{350}$ 0.16 × 10^4, $[\theta]_{330}$ 0.26 × 10^4, $[\theta]_{310}$ 0.12 × 10^4, $[\theta]_{291}$ 0, $[\theta]_{270}$ −0.17 × 10^4, $[\theta]_{250}$ 0; $\nu_{max.}$ 1 630 cm^{-1} (C=O).

4-Acetoxy-7-methoxy-3-(4′-methoxyphenyl)coumarin (**6**).—aq. NaOH (5 ml of a 2.5% solution, m/v) was added to an ethanolic solution (20 ml) of 4′,7-dimethoxyisoflavone[5] (100 mg) and resorcinol (100 mg) and the mixture stirred at room temp. for 24 h. Acidification (3M HCl), extraction with ethyl acetate (3 × 30 ml), neutralization ($NaHCO_3$), work-up, and p.l.c. [benzene–acetone (8:2); R_F 0.63] followed by acetylation gave the coumarin (**6**) as a *colourless solid* (12 mg); δ_H(80 MHz, TMS as internal standard) 7.95 (d, *J* 8.5 Hz, 5-H), 7.89 (d, *J* 8.8 Hz, 2′-, 6′-H), 6.97 (d, *J* 8.8 Hz, 3′-, 5′-H), 6.86 (dd, *J* 2.5 and 8.5 Hz, 6-H), 6.66 (d, *J* 2.5 Hz, 8-H), 3.86 (s, OMe), 3.83 (s, OMe), and 1.97 (s, OAc); *m/z* 340 (M^+, 0.7%), 284 (8.7), 192 (70), 168 (30), 165 (17), 152 (37), 151 (100), 150 (62), 149 (13), 140 (10), 137 (11), 136 (16), 135 (87), 122 (14), 108 (15), 107 (16), 95 (11), and 92 (30).

2,2′,4′-*Tribenzyloxy*-4-*methoxy*-trans-*chalcone* (**7**).—Condensation[5] of 2,4-dibenzyloxyacetophenone (3.0 g) with 2-benzyloxy-4-methoxybenzaldehyde (3.5 g) yielded the chalcone (**7**) as *yellow cubes* (4.0 g) from ethanol; m.p. 132 °C (Found: C, 79.8; H, 5.8. $C_{37}H_{32}O_5$ requires C, 79.8; H, 5.8%); δ_H(80 MHz, TMS as internal standard) 8.06 (d, *J* 16.0 Hz, β-H), 7.75 (d, *J* 9.0 Hz, 6-H), 7.50 (d, *J* 16.0 Hz, α-H), 7.50—7.16 (m, 6′-H, 3 × OCH_2Ph), 6.61 (dd, *J* 2.3 and 9.0 Hz, 5-H), 6.61 (d, *J* 2.3 Hz, 3-H), 6.44 (d, *J* 2.3 Hz, 3′-H), 6.38 (dd, *J* 2.3 and 9.0 Hz, 5′-H), 5.05, 5.00 and 4.97 (each s, 3 × OCH_2Ph), and 3.73 (s, OMe); *m*/*z* 556 (M^+, 2.2%), 465 (2.6), 449 (8.0), 317 (2.8), 255 (3.6), 239 (5.6), 227 (7.1), 181 (3.7), 148 (3.9), and 91 (100).

2-(2-*Benzyloxy*-4-*methoxyphenyl*)-1-(2,4-*dibenzyloxyphenyl*)-3,3-*dimethoxypropan*-1-*one* (**8**).—2,2′,4′-Tribenzyloxy-4-methoxychalcone (**7**) (3.0 g) and $Tl(NO_3)_3$ (3.6 g) were dissolved in methanol–dioxane (1:1, 300 ml) and the mixture was stirred at room temperature (2 h). After addition of water (100 ml) and neutralization (1% NaOH solution) the acetal (**8**) was extracted with chloroform (3 × 60 ml), washed free of base (H_2O), and purified by p.l.c. [hexane–benzene–acetone (5:4:1), R_F 0.33] to give (**8**) as a *colourless oil* (2.1 g); δ_H(80 MHz, TMS as internal standard) 7.59 (d, *J* 9.0 Hz, 6-H), 7.38 (d, *J* 8.8 Hz, 6′-H), 7.31, 7.25, and 7.22 (each s, 3 × OCH_2Ph), 6.56—6.28 (m, 3-, 3′-, 5-, 5′-H), 5.63 (d, *J* 8.8 Hz, β-H), 5.19 (d, *J* 8.8 Hz, α-H), 4.94 and 4.88 (× 2) (each s, 3 × OCH_2Ph), 3.69 (s, 4′-OMe), 3.38 (s, β-OMe), and 3.09 (s, β-OMe); *m*/*z* 618 (M^+, 4.7%), 586 (15), 558 (100), 544 (24), 317 (19), 270 (30), and 91 (16).

2-(2-*Benzyloxy*-4-*methoxyphenyl*)-3,3-*bis*-(3,5-*diacetoxyphenoxy*)-1-(2,4-*dibenzyloxyphenyl*)*propan*-1-*one* (**10**).—Phloroglucinol (13 mg) and 3M HCl (5 ml) were added to an ethanolic solution of the acetal (**8**) (50 mg in 5 ml) and the mixture stirred at room temperature for 24 h. After neutralization ($NaHCO_3$) the reaction mixture was extracted with ethyl acetate (3 × 10 ml) and the combined extracts were dried (Na_2SO_4), evaporated to dryness, and separated by p.l.c. [hexane–chloroform–methanol (2:7:1)] to give a single product (R_F 0.33) which was acetylated and crystallized from ethanol to yield the acetal (**10**) as *white needles* (39 mg), m.p. 214 °C (Found: C, 70.1; H, 5.2. $C_{57}H_{50}O_{15}$ requires C, 70.2; H, 5.2%); δ_H(292 K) 7.69 [d, *J* 8.8 Hz, 6-H(A)], 7.40—6.94 [m, 3 × OCH_2Ph, 4-H(C + D)], 6.89 [d, *J* 9.0 Hz, 6-H(B)], 6.87 [d, *J* 2.3 Hz, 3-H(A)], 6.51, 6.47, 6.43, and 6.40 [each d, *J* 2.3, 2-, 6-H (C + D)], 6.50 [dd, *J* 2.5 and 8.8 Hz, 5-H(A)], 6.14 [d, *J* 2.3 Hz, 3-H(B)], 6.12 [dd, *J* 2.3 and 9.0 Hz, 5-H(B)], 4.98 (s, OCH_2Ph), 4.92 (d, *J* 2.3 Hz, β-H), 4.83, 4.74, 4.64, and 4.59 (each d, *J* 13.0, 12.0, 13.0, and 12.0 Hz, 2 × OCH_2Ph), 4.37 (d, *J* 2.3 Hz, α-H), 3.56 (s, OMe), and 2.24, 2.22, 2.15, and 2.08 (each s, OAc); *m*/*z* 974 (M^+, 0%), 956 (4.4), 914 (4.0), 863 (6.1), 748 (7.0), 704 (25), 655 (7.7), 526 (8.9), 436 (6.7), 318 (20), 317 (71), 300 (6.8), 276 (9.0), 252 (26), 234 (16), 211 (22), 210 (96), 169 (21), 168 (99), 127 (18), and 126 (100).

Decarbonylation of the Acetal (**8**).—The acetal (**8**) (1.7 g) was dissolved in MeOH (200 ml) containing 60% $HClO_4$ (30 ml) and the mixture refluxed for 1.5 h. Following neutralization ($NaHCO_3$) the mixture was extracted with EtOAc (3 × 100 ml) and the combined organic phases were washed with water (2 × 50 ml), dried (Na_2SO_4), and worked up to provide a residue which was separated by p.l.c. [hexane–benzene–acetone (5:4:1)] to produce three products, R_F 0.57 (290 mg), 0.39 (480 mg), and 0.28 (706 mg).

2′,4-*Dibenzyloxy*-2-*hydroxy*-4′-*methoxydeoxybenzoin* (**23**). The R_F 0.57 fraction afforded the deoxybenzoin (**23**) which was crystallized from EtOH–acetone (minimum of acetone) as *white needles* (150 mg), m.p. 101 °C (Found: C, 76.5; H, 5.8. $C_{29}H_{26}O_5$ requires C, 76.6; H, 5.8%); δ_H 9.53 (s, 2-OH), 7.77 (d, *J* 9.1 Hz, 6-H), 7.25—7.43 (m, 2 × OCH_2Ph), 7.12 (d, *J* 8.3 Hz, 6′-H), 6.53 (d, *J* 2.5 Hz, 3′-H), 6.48 (dd, *J* 2.5 and 8.3 Hz, 5′-H), 6.47 (d, *J* 2.5 Hz, 3-H), 6.38 (dd, *J* 2.5 and 9.1 Hz, 5-H), 5.07 (s, 4-OCH_2Ph), 5.01 (s, 2′-OCH_2Ph), 4.16 (s, α-CH_2), and 3.77 (s, 4′-OMe); *m*/*z* 454 (M^+, 34%), 376 (19), 363 (10), 317 (38), 290 (10), 228 (40), 227 (57), 181 (19), 163 (38), 137 (22), and 91 (100).

2,2′,4-*Tribenzyloxy*-4′-*methoxydeoxybenzoin* (**22**). Following crystallization from ethanol the R_F 0.39 band gave the tribenzyloxydeoxybenzoin (**22**) as *white needles* (320 mg), m.p. 111 °C (Found: C, 79.4; H, 5.9. $C_{36}H_{32}O_5$ requires C, 79.5; H, 5.9%); δ_H (TMS as internal standard) 7.71 (d, *J* 9.5 Hz, 6-H), 7.20—7.43 (m, 3 × OCH_2Ph), 7.00 (d, *J* 8.1 Hz, 6′-H), 6.55 (d, *J* 2.1 Hz, 3-H), 6.54 (dd, *J* 2.1 and 9.5 Hz, 5-H), 6.47 (d, *J* 2.5 Hz, 3′-H), 6.44 (dd, *J* 2.5 and 8.1 Hz, 5′-H), 5.07, 5.06, and 4.95 (each s, 3 × OCH_2Ph), 4.22 (s, α-CH_2), and 3.76 (s, 4′-OMe); *m*/*z* 544 (M^+, 2.1%), 318 (11), 317 (43), 227 (3.1), 181 (7.3), 137 (2.6), and 91 (100).

2′,7-*Dibenzyloxy*-4′-*methoxyisoflavone*. The R_F 0.28 fraction afforded 2′,7-dibenzyloxy-4′-methoxyisoflavone as *white needles* (350 mg) (from MeOH–water), m.p. 133 °C (Found: C, 77.6; H, 5.2. $C_{30}H_{24}O_5$ requires C, 77.6; H, 5.3%); δ_H(80 MHz, TMS as internal standard, 303 K) 8.19 (d, *J* 8.8 Hz, 5-H), 7.84 (s, 2-H), 7.36 and 7.25 (each s, 2 × OCH_2Ph), 7.25 (d, *J* 9.0 Hz, 6′-H), 7.00 (dd, *J* 2.5 and 8.8 Hz, 6-H), 6.86 (d, *J* 2.5 Hz, 8-H), 6.56 (d, *J* 2.5 Hz, 3′-H), 6.52 (dd, *J* 2.5 and 9.0 Hz, 5′-H), 5.08 and 5.00 (each s, 2 × OCH_2Ph), and 3.73 (s, 4′-OMe); *m*/*z* 464 (M^+, 12%), 373 (23), 282 (4.0), 238 (3.5), 227 (3.6), 119 (6.5), and 91 (100).

Selective Debenzylation of 2,2′,4-*Tribenzyloxy*-4′-*methoxydeoxybenzoin* (**22**).—BF_3–diethyl ether (30 drops) was added to a stirred solution of the deoxybenzoin (**22**) (300 mg) and NaI (90 mg) in dry MeCN (30 ml) and the mixture stirred at room temperature until all starting material had disappeared (t.l.c.). Ice-cold water (20 ml) and 15% aqueous $Na_2S_2O_3$ (10 ml) were added and the mixture extracted with EtOAc (3 × 20 ml). Evaporation of the dried (Na_2SO_4) solvent followed by p.l.c. [hexane–benzene–acetone (5:4:1)] afforded the 2-hydroxydeoxybenzoin (**23**) (220 mg) which proved to be identical with that obtained from the $HClO_4$ decarbonylation reaction.

(6aS,11aS)-(+)-3-O-*Methoxymethylmedicarpin* (**13**).—K_2CO_3 (20 g) and chloromethylmethyl ether (20 ml) were added to a solution of (+)-medicarpin[12] (5.0 g) in dry acetone (300 ml) and the suspension was stirred at room temperature for 1.5 h. The mixture was filtered and the mixture evaporated to a small volume. P.l.c. [hexane–benzene–acetone (5:4:1)] yielded the methoxymethylpterocarpan (**13**) (R_F 0.58) as *white needles* (5.0 g) from ethanol, m.p. 73 °C; $[\alpha]_D^{18}$ + 163° (*c* 0.44 in $CHCl_3$) (Found: C, 68.8; H, 5.8. $C_{18}H_{18}O_5$ requires C, 68.7; H, 5.9%); δ_H (TMS as internal standard) 7.43 (d, *J* 8.5 Hz, 1-H), 7.13 (d, *J* 8.8 Hz, 7-H), 6.75 (dd, *J* 2.1 and 8.5 Hz, 2-H), 6.64 (d, *J* 2.1 Hz, 4-H), 6.45 (dd, *J* 2.1 and 8.8 Hz, 8-H), 6.45 (d, *J* 2.1 Hz, 10-H), 5.51 (d, *J* 6.5 Hz, 11a-H), 5.17 and 5.15 (each d, *J* 6.5 Hz, OCH_2OMe), 4.25 (dd, *J* 4.6 and 10.5 Hz, 6-$H_{eq.}$), 3.77 (s, OMe), 3.63 (dd, *J* 10.5 and 10.8 Hz, 6-$H_{ax.}$), 3.54 (ddd, *J* 4.6, 6.5, and 10.8 Hz, 6a-H), and 3.46 (s, OCH_2OMe); *m*/*z* 314 (M^+, 100%), 283 (12), 269 (64), 253 (5.0), 241 (5.4), 192 (1.7), 181 (3.2), 161 (10), 151 (10), 148 (12), 137 (3.2), 133 (3.8), 123 (1.3), 121 (1.8), 115 (4.0), and 105 (2.3).

(3S)-7-O-*Methoxymethylvestitol* (**14**).—Catalytic hydrogenation [10% Pd–C (1 g), EtOH (400 ml)] of the pterocarpan (**13**) (5.0 g) followed by crystallization of the product from ethanol yielded the isoflavan (**14**) as *white needles* (4.9 g), m.p. 148 °C; $[\alpha]_D^{18}$ +9.3° (*c* 0.86 in $CHCl_3$) (Found: C, 68.3; H, 6.4. $C_{18}H_{20}O_5$ requires C, 68.3; H, 6.5%); δ_H 6.99 (d, *J* 8.8 Hz, 6′-H), 6.97 (d, *J* 9.0 Hz, 5-H), 6.58 (dd, *J* 2.5 and 9.0 Hz, 6-H), 6.57 (d, *J* 2.5 Hz, 8-H), 6.45 (dd, *J* 2.5 and 8.8 Hz, 5′-H), 6.33 (d, *J* 2.5 Hz,

3′-H), 5.41—5.47 (br s, OH), 5.13 (s, OCH_2OMe), 4.32 (ddd, *J* 1.9, 3.5 and 10.5 Hz, 2-$H_{eq.}$), 4.02 (dd, *J* 10.3 and 10.5 Hz, 2-$H_{ax.}$), 3.74 (s, 4′-OMe), 3.47 (s, OCH_2OMe), 3.44—3.55 (m, 3-H), 3.00 (dd, *J* 10.5 and 16.0 Hz, 4-$H_{ax.}$), and 2.89 (ddd, *J* 1.9, 5.5, and 16.0 Hz, 4-$H_{eq.}$); *m/z* 316 (M^+, 56%), 269 (5.5), 178 (8.0), 167 (45), 150 (100), 137 (59), 121 (15), and 107 (5.7); c.d. (*c* 0.0644 in MeOH) $[\theta]_{290}$ 0, $[\theta]_{280}$ -0.22×10^4, $[\theta]_{270}$ -0.08×10^4, $[\theta]_{255}$ 0, $[\theta]_{240}$ 0.24×10^4, $[\theta]_{228}$ 0.69×10^4, $[\theta]_{215}$ 0; $\lambda_{max.}$(MeOH) 225 (log ε 4.26) and 282 nm (3.88).

Formylation of (3S)-7-O-*Methoxymethylvestitol* (**14**).—A solution of the isoflavan (**14**) (500 mg) in 50% aqueous MeCN (500 ml) containing chloroform (12 ml) and diethylamine (25 ml) was irradiated (300 nm) for 1.5 h. The mixture was acidified (3M HCl, pH = 1) and extracted with EtOAc (3 × 150 ml) to give a pale yellow extract which was washed free of acid (1 × 10% aqueous $NaHCO_3$, 3 × 50 ml water), dried (Na_2SO_4), evaporated to dryness, and the residue separated on p.l.c. [hexane–benzene–acetone (4:4:2)] to give, in addition to unchanged starting material (R_F 0.51, 160 mg), two products at R_F 0.58 (22 mg) and 0.30 (175 mg). Repetition (×10) of the above procedure afforded 220 mg of the first and 1.75 g of the second product.

(3S)-3′-*Formyl*-7-O-*methoxymethylvestitol* (**15**). The R_F 0.58 fraction consisted of 3′-formylisoflavan (**15**) which crystallised from EtOH as *pale yellow needles* (100 mg), m.p. 99 °C (Found: C, 66.1; H, 5.9. $C_{19}H_{20}O_6$ requires C, 66.3; H, 5.9%); δ_H 10.32 (s, CHO), 7.25 (d, *J* 8.8 Hz, 6′-H), 6.97 (d, *J* 8.0 Hz, 5-H), 6.57 (dd, *J* 2.5 and 8.0 Hz, 6-H), 6.55 (d, *J* 2.5 Hz, 8-H), 6.31 (d, *J* 8.8 Hz, 5′-H), 5.12 (s, OCH_2OMe), 4.30 (dd, *J* 3.5 and 10.5 Hz, 2-$H_{eq.}$), 4.08 (dd, *J* 8.6 and 10.5 Hz, 2-$H_{ax.}$), 3.85 (s, OMe), 3.51—3.63 (m, 3-H), 3.46 (s, OCH_2OMe), and 2.92—2.97 (m, 4-CH_2); *m/z* 344 (M^+, 71%) 179 (25), 178 (100), 177 (47), 168 (12), 167 (60), 166 (22), 165 (39), 163 (37), 149 (17), 137 (26), 135 (12), and 121 (13).

(3S)-5′-*Formyl*-7-O-*methoxymethylvestitol* (**16**).—The compound at R_F 0.30 was identified as the 5′-formylisoflavan (**16**) and crystallised as *cream needles* (920 mg) from EtOH, m.p. 86 °C; $[\alpha]_D^{18}$ +34° (*c* 0.11 in $CHCl_3$) (Found: C, 66.2; H, 5.9. $C_{19}H_{20}O_6$ requires C, 66.3; H, 5.9%); δ_H 10.16 (s, CHO), 7.95—8.45 (br s, OH), 7.58 (s, 6′-H), 6.94 (d, *J* 8.0 Hz, 5-H), 6.56 (dd, *J* 2.5 and 8.0 Hz, 6-H), 6.54 (d, *J* 2.5 Hz, 8-H), 6.42 (s, 3′-H), 5.11 (s, OCH_2OMe), 4.31 (ddd, *J* 2.0, 3.5 and 10.7 Hz, 2-$H_{eq.}$), 3.96 (dd, *J* 10.3 and 10.7 Hz, 2-$H_{ax.}$), 3.78 (s, OMe), 3.40—3.54 (m, 3-H), 3.46 (s, OCH_2OMe), 2.99 (dd, *J* 10.8 and 16.0 Hz, 4-$H_{ax.}$), and 2.85 (ddd, *J* 2.0, 5.2 and 16.0 Hz, 4-$H_{eq.}$); *m/z* 344 (M^+, 67%), 178 (22), 177 (24), 168 (12), 167 (100), 166 (18), 165 (23), 161 (11), 151 (15), 149 (15), 147 (12), 137 (49), 135 (10), and 121 (8.4).

(3S)-2′,7-*Di*-O-*benzyl*-5′-*formylvestitol* (**18**).—The isoflavan (**16**) (1.55 g) was boiled for 15 min in MeOH (200 ml) containing 3M HCl (10 ml). The mixture was extracted with EtOAc and the solvent evaporated. Benzylation [PhCl (2 ml), K_2CO_3 (5 g), acetone (200 ml)] followed by p.l.c. [hexane–benzene–acetone (4:5:1)] afforded the title compound (**18**) (R_F 0.39) as a *white amorphous solid* (730 mg); $[\alpha]_D^{18}$ +30° (*c* 0.34 in $CHCl_3$) (Found: C, 77.5; H, 5.9. $C_{31}H_{28}O_5$ requires C, 77.3; H, 5.7%); δ_H(TMS as internal standard) 10.28 (s, CHO), 7.63 (s, 6′-H), 7.26—7.44 (m, 2 × OCH_2Ph), 6.97 (d, *J* 8.3 Hz, 5-H), 6.54 (dd, *J* 2.6 and 8.3 Hz, 6-H), 6.50 (s, 3′-H), 6.48 (d, *J* 2.6 Hz, 8-H), 5.19 and 5.00 (each s, 2 × OCH_2Ph), 4.32 (ddd, *J* 2.1, 3.5, and 10.5 Hz, 2-$H_{eq.}$), 3.95 (dd, *J* 10.5 and 10.5 Hz, 2-$H_{ax.}$), 3.86 (s, OMe), 3.56—3.68 (m, 3-H), 3.02 (dd, *J* 11.0 and 15.9 Hz, 4-$H_{ax.}$), and 2.85 (ddd, *J* 2.1, 5.1, and 15.9 Hz, 4-$H_{eq.}$); *m/z* 480 (M^+, 3.5%), 389 (0.8), 298 (0.7), 268 (0.9), 213 (1.2), 177 (4.0), 176 (1.0), 165 (3.9), 147 (1.2), 131 (1.2), 128 (1.0), 126 (3.8), 121 (1.4), 119 (1.2), 106 (20), 105 (26), 103 (14), and 91 (100).

Methyl (3S)-2′,7-*Di*-O-*benzylvestitol*-5′-*carboxylate* (**19**).—The 5′-formylisoflavan (**18**) (730 mg), NaCN (700 mg) and acetic acid (0.4 ml) were dissolved in MeOH (300 ml) and stirred at room temperature. After 1 h MnO_2 (5.0 g) was added and stirring continued for a further 6 h. The black slurry was filtered off and the filtrate concentrated to *ca.* 20 ml. After addition of water (100 ml) the filtrate was extracted with ethyl acetate (4 × 50 ml) and the extract washed with water (3 × 50 ml), dried (Na_2SO_4), evaporated, and the residue subjected to p.l.c. [hexane–benzene–acetone (4:5:1)] to yield the ester (**19**) (210 mg; R_F 0.30) together with unchanged starting material (471 mg). Repetition of the reaction on recovered starting material produced a further batch (138 mg) of product which was combined and recrystallized from EtOH to afford *white needles*, m.p. 147 °C (Found: C, 75.2; H, 6.0. $C_{32}H_{30}O_6$ requires C, 75.3; H, 5.9%); δ_H (TMS as internal standard) 7.69 (s, 6′-H), 7.28—7.45 (m, 2 × OCH_2Ph), 6.98 (d, *J* 8.5 Hz, 5-H), 6.54 (dd, *J* 2.5 and 8.5 Hz, 6-H), 6.54 (s, 3′-H), 6.49 (d, *J* 2.5 Hz, 8-H), 5.18 and 5.02 (each s, 2 × OCH_2Ph), 4.33 (ddd, *J* 2.0, 3.5, and 10.3 Hz, 2-$H_{eq.}$), 3.99 (dd, *J* 10.3 and 10.3 Hz, 2-$H_{ax.}$), 3.86 and 3.84 (each s, 2 × OMe), 3.58—3.70 (m, 3-H), 3.04 (dd, *J* 11.2 and 16.0 Hz, 4-$H_{ax.}$), and 2.87 (ddd, *J* 2.0, 5.5, and 16.0 Hz, 4-$H_{eq.}$); *m/z* 510 (M^+, 3.2%), 419 (0.9), 327 (1.4), 298 (2.5), 213 (2.2), 207 (4.3), 195 (5.6), 181 (1.4), 177 (1.1), 175 (1.7), 147 (1.5), 135 (1.4), 123 (1.1), 105 (2.9), 103 (1.4), and 91 (100).

(3S)-2′,7-*Di*-O-*benzylvestitol*-5′-*carboxylic Acid* (**20**).—The ester (**19**), (348 mg) was dissolved in MeOH (150 ml) containing 25% aqueous KOH (30 ml). The mixture was refluxed for 1.5 h, neutralized (HOAc), and extracted with EtOAc. The extract was evaporated and residue recrystallized from EtOH to provide carboxylic acid (**20**) as *white needles* (260 mg), m.p. 158 °C (Found: C, 74.8; H, 5.8. $C_{31}H_{28}O_6$ requires C, 75.0; H, 5.7%); δ_H 7.94 (s, 6′-H), 7.26—7.44 (m, 2 × OCH_2Ph), 6.97 (d, *J* 8.5 Hz, 5-H), 6.56 (s, 3′-H), 6.53 (dd, *J* 2.6 and 8.5 Hz, 6-H), 6.47 (d, *J* 2.6 Hz, 8-H), 5.20 and 5.00 (each s, 2 × OCH_2Ph), 4.31 (ddd, *J* 2.3, 3.5, and 10.5 Hz, 2-$H_{eq.}$), 3.99 (s, OMe), 3.97 (dd, *J* 10.3 and 10.5 Hz, 2-$H_{ax.}$), 3.57—3.69 (m, 3-H), 3.05 (dd, *J* 11.3 and 16.0 Hz, 4-$H_{ax.}$), and 2.86 (ddd, *J* 2.3, 5.0 and 16.0 Hz, 4-$H_{eq.}$); *m/z* 496 (M^+, 4.2%), 452 (1.5), 362 (1.2), 298 (1.1), 284 (1.4), 279 (1.0), 272 (1.1), 255 (1.3), 240 (2.5), 238 (7.6), 227 (2.6), 213 (2.9), 209 (1.1), 207 (1.5), 200 (1.9), 195 (1.8), 182 (3.9), 181 (4.2), 180 (3.1), 178 (1.5), 167 (2.7), 165 (2.8), 163 (3.1), 152 (1.6), 150 (2.6), 149 (5.4), 147 (2.0), 137 (4.0), 135 (2.0), 129 (1.4), 123 (3.5), 121 (3.8), 119 (4.4), 117 (2.4), 107 (22), 105 (33), 93 (73), and 91 (100).

5-*Benzyloxy*-2-[2-(2-*benzyloxy*-4-*methoxyphenyl*)*acetyl*]-*phenyl*-(3S)-6′,7-*dibenzyloxy*-4′-*methoxyisoflavan*-3′-*carboxylate* (**24**).—A solution of the carboxylic acid (**20**) (225 mg) in dry CH_2Cl_2 (4 ml) was added over a period of 2 h at room temperature with continuous stirring, to a solution of oxalyl chloride (290 mg) in CH_2Cl_2 containing pyridine (1 drop in 4 ml). After addition of the acid, stirring was continued for a further 20 min. Removal of the solvent and unchanged oxalyl chloride under reduced pressure gave the crude acid chloride (**21**), which was immediately subjected to esterification (1.5 h) with 2-hydroxydeoxybenzoin (**23**) (300 mg) dissolved in pyridine (4 ml). Crushed ice was added, the mixture extracted with EtOAc (4 × 20 ml), and the extract washed with 3M HCl (3 × 10 ml), aqueous $NaHCO_3$ (1 × 20 ml), and water (3 × 10 ml). The extract was dried (Na_2SO_4) and evaporated to give the ester (**24**) as an amorphous solid (R_F 0.24; 169 mg) following p.l.c. in hexane–benzene-acetone (5:4:1), ×2 (Found: C, 77.2; H, 5.6. $C_{60}H_{52}O_{10}$ requires C, 76.9; H, 5.5%); δ_H 7.89 [s, 2′-H(E)], 7.80 [d, *J* 8.8 Hz, 6-H(A)], 7.17—7.46 (m, 4 × OCH_2Ph), 7.00 [d, *J* 8.3 Hz, 6′-H(B)], 6.89 [d, *J* 8.5 Hz, 5-H(D)], 6.80 [d, *J* 2.5 Hz, 3-H(A)], 6.76 [dd, *J* 2.5 and 8.8 Hz, 5-H(A)], 6.51 [s, 5′-H(E)], 6.51 [dd, *J* 2.6 and 8.5 Hz, 6-H(D)], 6.46 [d, *J* 2.6 Hz, 8-

H(D)], 6.42 [d, 2.5 Hz, 3'-H(B)], 6.39 [dd, *J* 2.5 and 8.3 Hz, 5'-H(B)], 5.17, 5.06, 5.00, and 4.90 (each s, 4 × OCH_2Ph), 4.27 [ddd, *J* 2.0, 3.5, and 10.3 Hz, 2-$H_{eq.}$(F)], 4.11 (s, α-CH_2), 3.87 [dd, *J* 10.3 and 10.5 Hz, 2-$H_{ax.}$(F)], 3.81 and 3.71 (each s, 2 × OMe), 3.54—3.71 [m, 3-H(F)], 2.95 [dd, *J* 11.3 and 15.5 Hz, 4-$H_{ax.}$(F)], and 2.80 [ddd, *J* 2.0, 5.1, and 15.5 Hz, 4-$H_{eq.}$(F)]; *m/z* 932 (M^+, 0%), 916 (22), 914 (6.9), 497 (2.5), 479 (5.2), 454 (11), 437 (8.6), 346 (11), 291 (5.9), 269 (5.0), 267 (3.6), 255 (22), 245 (29), 241 (23), 239 (15), 227 (23), 214 (17), 201 (29), 181 (30), 165 (23), 153 (18), 151 (16), 149 (17), 137 (39), 125 (47), 123 (52), 119 (26), 111 (34), 107 (74), 105 (76), 101 (78), and 91 (100).

3-(4-*Benzyloxy*-2-*hydroxyphenyl*)-2-(2-*benzyloxy*-4-*methoxyphenyl*)-1-[(3S)-6',7-*dibenzyloxy*-4'-*methoxyisoflavan*-3'-*yl*]-*propane*-1,3-*dione* (**25**).—A solution of the ester (**24**) (150 mg) in dry acetone (40 ml) was treated with K_2CO_3 (2 g) and 18-crown-6 (20 mg) and the suspension stirred at room temperature for 3 h. The K_2CO_3 was filtered off, the filtrate evaporated, and the mixture separated by p.l.c. [hexane–benzene–acetone (5:4:1)] to give the β-diketone (**25**) as an amorphous solid (R_F 0.29, 135 mg); $[\alpha]_D^{18}$ +5° (*c* 0.42 in $CHCl_3$) δ_H*; *m/z* 932 (M^+, 0%), 914 (20), 823 (1.0), 454 (6.5), 239 (15), 213 (17), 201 (33), 125 (21), 108 (44), and 91 (100).

2',7-*Dibenzyloxy*-2-[(3S)-6',7-*dibenzyloxy*-4'-*methoxyisoflavan*-3'-*yl*]-4'-*methoxyisoflavone* (**1**; R = $PhCH_2$).—The β-diketone (**25**) (100 mg) was dissolved in dry THF (20 ml), H_2SO_4 (8 drops) added, and the mixture stirred at room temperature. After 24 h, water (10 ml) was added and the mixture extracted with EtOAc (3 × 20 ml). The organic phase was neutralized ($NaHCO_3$), washed with water (3 × 10 ml), evaporated, and subjected to p.l.c. [hexane–benzene–acetone (5:4:1), R_F 0.16] to give the dimer (**1**; R = $PhCH_2$) as *white needles* (70 mg) from EtOH–acetone (minimum acetone), m.p. 168 °C $[\alpha]_D^{18}$ +12° (*c* 0.36 in $CHCl_3$) (Found: C, 79.0; H, 5.7; $C_{60}H_{50}O_9$ requires C, 78.8; H, 5.5%); δ_H [$(CD_3)_2SO$; 453 K], 8.02 [d, *J* 8.8 Hz, 5-H(A)], 7.15—7.50 (m, 4 × OCH_2Ph), 7.11 [dd, *J* 2.3 and 8.8 Hz, 6-H(A)], 7.07 [d, *J* 2.3 Hz, 8-H(A)], 6.94 [s, 2'-H(E)], 6.87 [d, *J* 8.5 Hz, 5-H(D)], 6.85 [d, *J* 8.3 Hz, 6'-H(B)], 6.74 [s, 5'-H(E)], 6.53 [d, *J* 2.3 Hz, 3'-H(B)], 6.51 [dd, *J* 2.2 and 8.5 Hz, 6-H(D)], 6.42 [dd, *J* 2.2 and 8.3 Hz, 5'-H(B)], 6.41 [d, *J* 2.2 Hz, 8-H(D)], 5.27, 5.20, 5.04, and 4.93 (each s, 4 × OCH_2Ph), 4.00—4.10 [m, 2-$H_{eq.}$(F)], 3.69—3.77 [m, 2-$H_{ax.}$(F)], 3.72 and 3.68 (each s, 2 × OMe), 3.30—3.45 [m, 3-H(F)], and 2.55—2.75 [4-CH_2(F)] †; *m/z* 914 (M^+, 13%), 823 (1.5), 688 (0.5), 505 (0.5), 461 (0.3), 227 (0.5), 137 (0.8), 121 (3.1), 107 (21), 105 (17), and 91 (100).

2',7-*Dihydroxy*-2-[(3S)-6',7-*dihydroxy*-4'-*methoxyisoflavan*-3'-*yl*]-4'-*methoxyisoflavone* (**1**; R = H).—Catalytic debenzylation [H_2, 10% Pd–C (20 mg), acetone (15 ml), 2.5 h] of the benzyloxyisoflavone analogue (**1**; R = $PhCH_2$) (30 mg) afforded the title compound (**1**; R = H) as a *white amorphous solid* (5 mg), c.d. (*c* 0.1410 in MeOH) $[\theta]_{370}$ 0.13 × 10^4, $[\theta]_{350}$ 0.16 × 10^4, $[\theta]_{330}$ 0.26 × 10^4, $[\theta]_{310}$ 0.12 × 10^4, $[\theta]_{292}$ 0, $[\theta]_{278}$ −0.20 × 10^4, $[\theta]_{250}$ 0; $\lambda_{max.}$(MeOH) 230 (log ε 4.60), 249 (4.42), 287 (4.28), 307 (4.21), and 337 nm (3.99).

2-(4-*Hydroxy*-2-*methoxyphenyl*)-4',7-*dimethoxyisoflavone* (**26**).—In a procedure similar to that for the isoflavan-isoflavone dimer (**1**; R = H) reaction of 4-benzyloxy-2-methoxybenzaldehyde (300 mg), obtained by selective benzylation followed by methylation of 2,4-dihydroxybenzaldehyde (1 g), with 2-hydroxy-4,4'-dimethoxydeoxybenzoin[17] (110 mg) gave the 2-arylisoflavone (**26**) as a *colourless solid*‡ (12 mg); δ_H 8.17 (d, *J* 8.5 Hz, 5-H), 7.08 (d, *J* 8.0 Hz, 6''-H), 7.08 (br s, 4''-OH), 7.07 (d, *J* 8.3 Hz, 2'- and 6'-H), 6.98 (dd, *J* 2.3 and 8.5 Hz, 6-H), 6.88 (d, *J* 2.3 Hz, 8-H), 6.71 (d, *J* 8.3 Hz, 3'- and 5'-H), 6.34 (dd, *J* 2.1 and 8.0 Hz, 5''-H), 6.29 (d, *J* 2.1 Hz, 3''-H), and 3.90, 3.71, and 3.44 (each s, 3 × OMe); *m/z* 404 (M^+, 100%) 403 (65), 389 (34), 373 (25), 346 (4.4), 254 (19), 239 (8.4), 211 (8.1), 202 (13), 194 (15), 151 (25), and 121 (5.8); $\lambda_{max.}$(MeOH) 238 (log ε 4.38), 248 (4.34), 260 (4.20), 309 (4.10), and 336 nm (3.86).

2-[3*R*-6'-*Hydroxy*-4',7-*dimethoxyisoflavan*-3'-*yl*]-4',7-*dimethoxyisoflavone* (**27**).—Reaction of (3*R*)-7-*O*-methylvestitol[15] (1.0 g) with 2-hydroxy-4,4'-dimethoxydeoxybenzoin[17] (105 mg) in a procedure similar to that for (**1**; R = H) gave the isoflavan-isoflavone dimer (**27**) as *white needles* (21 mg) from EtOH–acetone (minimum of acetone), m.p. 291 °C (Found: C, 71.8; H, 5.4. $C_{34}H_{30}O_8$ requires C, 72.1; H, 5.3%); δ_H[$(CD_3)_2CO$] 9.00 [s, 6'-OH(E)], 8.06 [d, *J* 8.9 Hz, 5-H(A)], 7.07 [s, 2'-H(E)], 7.05 [d, *J* 8.5 Hz, 2'- and 6'-H(B)], 7.04 [dd, *J* 2.3 and 8.9 Hz, 6-H(A)], 6.99 [d, *J* 2.3 Hz, 8-H(A)], 6.95 [d, *J* 8.3 Hz, 5-H(D)], 6.77 [d, *J* 8.5 Hz, 3'- and 5'-H(B)], 6.55 [s, H-5'(E)], 6.45 [dd, *J* 2.3 and 8.3 Hz, 6-H(D)], 6.34 [d, *J* 2.3 Hz, 8-H(D)], 4.15 [ddd, *J* 1.8, 3.5, and 10.0 Hz, 2-$H_{eq.}$(F)], 3.86 [dd, *J* 10.0 and 10.0 Hz, 2-$H_{ax.}$(F)], 3.96, 3.76, 3.73, and 3.62 (each s, 4 × OMe), 3.37—3.49 [m, 3-H(F)], and 2.73—2.81 [m, 4-CH_2(F)]; *m/z* 566 (M^+, 60%), 535 (3.6), 430 (64), 429 (100), 417 (4.2), 416 (7.6), 413 (9.4), 403 (8.8), 280 (4.9), 279 (5.5), 264 (7.4), 249 (4.3), 221 (7.7), 165 (4.7), 151 (23), 137 (20), and 121 (11); c.d. (*c* 0.1510 in MeOH) $[\theta]_{370}$ −0.08 × 10^4, $[\theta]_{360}$ −0.1 × 10^4, $[\theta]_{340}$ −0.21 × 10^4, $[\theta]_{320}$ −0.1 × 10^4, $[\theta]_{295}$ 0, $[\theta]_{290}$ 0.07 × 10^4, $[\theta]_{279}$ 0.56 × 10^4, $[\theta]_{270}$ 0.18 × 10^4, and $[\theta]_{259}$ 0; $\lambda_{max.}$(MeOH) 228 (log ε 4.63), 249 (4.49), 275 (4.36), 308 (4.21), and 338 nm (4.04).

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* Owing to severe restrictions on rotation, the ^1H n.m.r. spectrum exhibited extensive broadening and duplication of signals over the temperature range 25—180 °C.

† Overlapped by signal due to moisture in the solvent.

‡ Satisfactory microanalysis (Found: C, 75.1; H, 5.5. $C_{31}H_{26}O_6$ requires C, 75.3; H, 5.3%) was obtained for the 4''-*O*-benzyl ether of (**26**).

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