[Chem. Pharm. Bull. 33(3)1088—1096(1985)]

Structures of Three New Natural Diels–Alder Type Adducts, Kuwanons P and X, and Mulberrofuran J, from the Cultivated Mulberry Tree (*Morus lhou* KOIDZ.)[1,2)]

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(Received July 16, 1984)

Two new stilbene derivatives, named kuwanons P and X, as well as a new 2-arylbenzofuran derivative, named mulberrofuran J, were isolated from the acetone extract of the root bark of cultivated mulberry tree (Japanese name "Rosō," a variety of *Morus lhou* KOIDZ.) together with a known 2-arylbenzofuran derivative, albafuran C. The structures of the new compounds were elucidated on the basis of the spectral evidence, and the compounds can be regarded biogenetically as Diels–Alder type adducts of chalcone derivatives and dehydroprenylphenols. In view of the biogenetic route to 2-arylbenzofuran derivatives, involving oxidative cyclization of hydroxystilbenes, it is noteworthy that two stilbene derivatives, kuwanons P (**1**) and X (**2**), coexist with two 2-arylbenzofuran derivatives, albafuran C (**4**) and mulberrofuran J (**3**), in the mulberry root bark.

Keywords——*Morus lhou*; Moraceae; mulberry tree, kuwanon P; kuwanon X; mulberrofuran J; albafuran C; Diels–Alder type adduct

In the previous papers,[1,3)] we reported the structure determination of a series of natural Diels–Alder type adducts and isoprenylated flavonoids isolated from the extract of the root bark of the cultivated mulberry tree (Japanese name "Rosō," a variety of *Morus lhou* KOIDZ.).[4)] Further extensive fractionation of the extract of the root bark led to the isolation of two new stilbene derivatives, kuwanons P (**1**) and X (**2**), and a new 2-arylbenzofuran derivative, mulberrofuran J (**3**), along with a known compound, albafuran C (**4**).[5)] We report herein the structure elucidations of the new compounds.

The dried root bark of the cultivated mulberry tree (Japanese name "Rosō") was extracted successively with *n*-hexane, benzene, and acetone. The acetone extract was fractionated sequentially by column chromatography, and then by preparative thin-layer chromatography (preparative TLC), resulting in the isolation of kuwanons P (**1**) and X (**2**), mulberrofuran J (**3**), and albafuran C (**4**). The known compound **4** was identified by comparison with authentic sample.

Kuwanon P (**1**), is a colorless amorphous powder, $[\alpha]_D^{17}$ $-509°$. The field desorption mass spectrum (FD-MS) showed the molecular ion peak at m/z 582. The carbon-13 nuclear magnetic resonance (^{13}C-NMR) spectrum indicated the presence of thirty-four carbons: nine aliphatic carbons ($CH_3-\times 1$, $-CH_2-\times 1$, $>CH-\times 3$, $-CH=CH-\times 1$, $>C=CH-\times 1$), twenty-four aromatic carbons ($CH\times 11$, $C\times 5$, $C{-}O-\times 8$) and one carbonyl carbon (Table I). Treatment of **1** with dimethyl sulfate in acetone gave an octamethyl ether (**1a**, M^+ 694) as an amorphous powder which was negative to the methanolic ferric chloride test. The molecular formula of **1a** was determined to be $C_{42}H_{46}O_9$ by high-resolution MS. These results indicated the composition of kuwanon P to be $C_{34}H_{30}O_9$.

Compound **1** gave a brown color in the methanolic ferric chloride test, and was negative to the magnesium–hydrochloric acid test. The infrared (IR) spectrum of **1** disclosed absorption bands due to hydroxyl, conjugated carbonyl, conjugated double bond and benzene ring moieties. The ultraviolet (UV) spectrum of **1** exhibited maxima at 218, 284, 310 (sh), and 331 nm, and was similar to that of oxyresveratrol (**5**).[6] Comparison of the spectrum of **1** with that of **5** disclosed an extra absorption in the former at *ca.* 285 nm which can be ascribed to a conjugated carbonyl group.[7,8] In the spectrum of **1** the absorption at *ca.* 285 nm showed a bathochromic shift in the presence of aluminum chloride.[9] These results indicated the presence of an oxyresveratrol-type chromophore and a chelated carbonyl group in the structure. This assumption was further supported by examination of the ^{13}C-NMR spectrum of **1** and the proton nuclear magnetic resonance (^{1}H-NMR) spectrum of **1a**. In the ^{13}C-NMR spectrum of **1**, all the carbon atoms were assigned by the off-resonance decoupling technique as well as by comparison with the ^{13}C-NMR spectra of model compounds, **5** and other Diels–Alder type adducts obtained from *Morus* species.[10] The chemical shift values of the carbon atoms of the stilbene skeleton of **1** were similar to those of the relevant carbon atoms of **5** except for the signals of the carbon atoms at the C-4, -5, and -6 positions which are subject to an additional effect (Table I). Examination of the ^{1}H-NMR spectrum of **1a** compared with that of oxyresveratrol tetramethyl ether (**5a**)[6] suggested that **1** is an oxyresveratrol derivative having a substituent at the C-5 position: δ 6.23 (1H, s, C_3-H), 6.37 (1H, t, $J=2$ Hz, $C_{4'}$-H), 6.70 (2H, d, $J=2$ Hz, $C_{2'}$ and $C_{6'}$-H), 6.94 (1H, d, $J=16$ Hz, C_α-H), 7.35 (1H, d, $J=16$ Hz, C_β-H), 7.42 (1H, s, C_6-H). From these results, the partial structure **1′** was suggested.

The electron impact (EI)-MS of the octamethyl ether (**1a**) gave fragment ions at *m/z* 529 (**6**), 366 (**7**), and 165 (**8**). The formulae of the fragment ions at *m/z* 366 and 165 were supported by the results of high-resolution MS. This result suggests that kuwanon P is a Diels–Alder type adduct which can be regarded as a cycloaddition product of a chalcone and a dehydroprenyloxyresveratrol.[10] In order to clarify the complete nature of the C-5 side chain, the ^{1}H-NMR spectrum of **1a** was analyzed and compared with the ^{1}H-NMR spectra of natural Diels–Alder type adducts obtained from *Morus* species;[10] the results suggested the presence of 2,4-dihydroxyphenyl, 2,4-dihydroxybenzoyl, and methylcyclohexene ring moieties: δ 6.16 (1H, dd, $J=2$ and 8.5 Hz, $C_{19''}$-H), 6.26 (1H, d, $J=2$ Hz, $C_{17''}$-H), 7.06 (1H, d, $J=8.5$ Hz, $C_{20''}$-H); δ 5.97 (1H, d, $J=2$ Hz, $C_{11''}$-H), 6.01 (1H, dd, $J=2$ and 9 Hz, $C_{13''}$-H), 7.09 (1H, d, $J=9$ Hz, $C_{14''}$-H). Figure 2 shows the chemical shifts and coupling constants of protons of the relevant methylcyclohexene ring. The presence of 2,4-dihydroxyphenyl and 2,4-dihydroxybenzoyl moieties was also supported by a comparison of the ^{13}C-NMR spectrum of **1** with those of sanggenon D (**9**),[11] and mulberrofuran C (**10**),[12] as shown in Table I. On the basis of these results and the biogenetic similarity of the Diels–Alder type adducts[10] obtained from *Morus* species, the structure of kuwanon P was considered to be represented by **1** or **1″**. The location of the 2,4-dihydroxyphenyl and 2,4-dihydroxybenzoyl moieties and the relative configuration of the substituents on the methylcyclohexene ring of **1** were supported by comparing the ^{1}H-NMR spectrum of **1a** with those of albafuran C heptamethyl ether (**4a**)[5] and **10**.[12] Compound **1a** resembled **4a** in the chemical shifts and coupling constants of the relevant protons of the methylcyclohexene ring except for the signal of the proton at the C-3″ position, which is affected by the substituent effect (Fig. 2). On the basis of these results, we propose formula **1** for the structure of kuwanon P.

Kuwanon X (**2**), is a colorless amorphous powder, $[\alpha]_D^{21}$ $-322°$. The FD-MS showed the molecular ion peak at *m/z* 582. Treatment of **2** with dimethyl sulfate in acetone gave an octamethyl ether (**2a**, M^+ 694) as an amorphous powder which was negative to the methanolic ferric chloride test. The molecular formula of **2a** was determined to be $C_{42}H_{46}O_9$ by the high-resolution MS. These results indicated the composition of **2** to be $C_{34}H_{30}O_9$. In

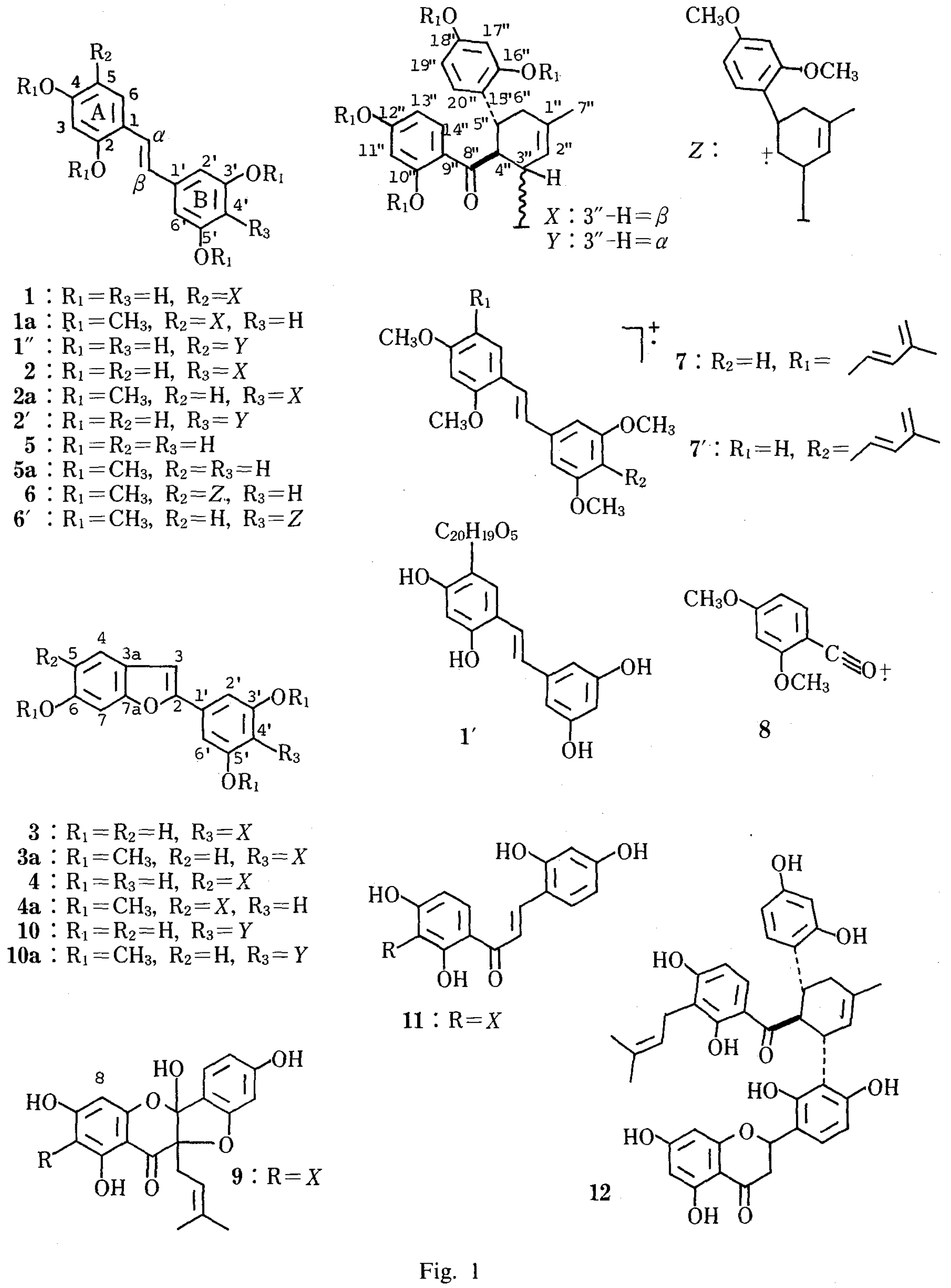
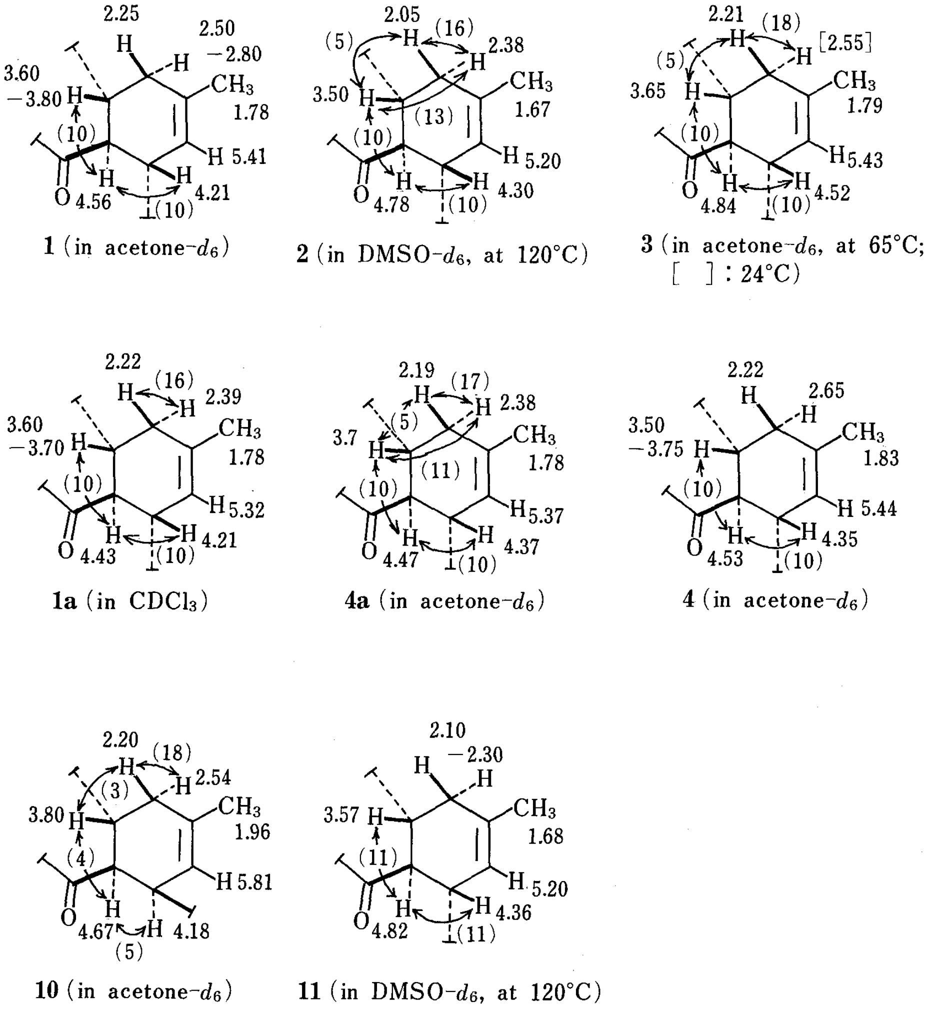


Fig. 1

accordance with this formula, the ^{13}C-NMR spectrum of **2** indicated the presence of thirty-four carbon atoms: nine aliphatic carbons, twenty-four aromatic carbons, and one carbonyl carbon (Table I). Compound **2** gave a dark brown color in the methanolic ferric chloride test. The IR spectrum of **2** showed absorption bands due to hydroxyl, conjugated carbonyl, conjugated double bond, and benzene ring moieties. The UV spectrum of **2** exhibited maxima at 216 (infl.), 283, 304, 328, and 343 (infl.) nm, and showed a bathochromic shift in the presence of aluminum chloride. These UV characteristics were similar to those of **1**, suggesting the presence of an oxyresveratrol moiety and a chelated carbonyl group. The ^{13}C-NMR spectrum of **2** was analyzed and compared with those of oxyresveratrol (**5**) and kuwanon P (**1**). The chemical shift values of the carbon atoms of the A ring of **2** were similar to those of the relevant carbon atoms of **5**, while the carbon atoms of the B ring of **2** showed different chemical shift values from the relevant carbon atoms of **5**. Moreover, the chemical



1 (in acetone-d_6) 2 (in DMSO-d_6, at 120°C) 3 (in acetone-d_6, at 65°C; [ ] : 24°C)

1a (in $CDCl_3$) 4a (in acetone-d_6) 4 (in acetone-d_6)

10 (in acetone-d_6) 11 (in DMSO-d_6, at 120°C)

Fig. 2. ^{1}H-NMR Chemical Shifts and Coupling Constants (Hz) of Cyclohexene Rign Protons of **1**, **1a**, **2**, **3**, **4**, **4a**, **10**, and **11**

shift values of the carbon atoms at the C-2′ and -6′ positions were equivalent, and the chemical shift value of the carbon atom at the C-4′ was markedly shifted downfield as compared with that of the relevant carbon atom of **5** (Table I). These results indicate that **2** is a 4′-substituted oxyresveratrol derivative. This assumption was further supported by examination of the ^{1}H-NMR spectrum of **2**: δ 6.23 (1H, dd, J=2.6 and 8.5 Hz, C_5-H), 6.27 (2H, s, $C_{2'}$ and $C_{6'}$-H), 6.31 (1H, d, J=2.6 Hz, C_3-H), 6.56 (1H, d, J=16 Hz, C_α-H), 6.99 (1H, d, J=16 Hz, C_β-H), 7.21 (1H, d, J=8.5 Hz, C_6-H).

The EI-MS of the octamethyl ether (**2a**) showed significant fragment ions at m/z 529 (**6′**), 366 (**7′**) and 165 (**8**), as did **1a**, suggesting that **2** is a Diels–Alder type adduct like **1**, possibly a structural isomer of **1**. The ^{1}H-NMR spectrum of **2** indicated the presence of 2,4-dihydroxyphenyl and 2,4-dihydroxybenzoyl, and methylcyclohexene ring moieties: δ 5.94 (1H, dd, J=2.1 and 8.3 Hz, $C_{19''}$-H), 6.11 (1H, d, J=2.1 Hz, $C_{17''}$-H), 6.71 (1H, d, J=8.3 Hz, $C_{20''}$-H); δ 5.90 (1H, d, J=2.5 Hz, $C_{11''}$-H), 6.00 (1H, dd, J=2.5 and 8.8 Hz, $C_{13''}$-H), 7.59 (1H, d, J=8.8 Hz, $C_{14''}$-H). The chemical shifts and coupling constants of the methylcyclohexene ring moiety are shown in Fig. 2. From these results and the biogenetic similarity of the Diels–Alder type adducts,[10] the structure of kuwanon X may be represented by **2** or **2′**. The relative configuration of the substituents on the methylcyclohexene ring of **2** was supported by a comparison of the ^{1}H-NMR spectrum of **2** with those of **1a**, **4a**,[5] **10**,[12] and kuwanon I

Table I. ^{13}C-NMR Chemical Shifts (ppm) of **1**, **2**, **3**, **5**, **9**, **10**, and **12**

C. No.		**1**[a]	**2**[b]	**5**[c]		**9**[c]	**12**[a]	C. No.	**10**[a]	**3**[a]
C-1		117.3	116.2	117.8				C-2	156.5[e]	156.5[e]
C-2		154.9[e]	156.0[e]	156.8				C-3	103.6	102.8
C-3		102.2	120.0	102.2				C-3a	121.9	122.0
C-4		157.1[e]	158.1[e]	158.6				C-4	121.9	121.8
C-5		124.7	107.0	108.5				C-5	113.1	113.1
C-6		122.7	123.1	124.6				C-6	155.3[e]	155.3[e]
C-α		126.2	125.2	126.4				C-7	98.4	98.4
C-β		130.5	127.1	128.5				C-7a	157.8[e]	158.2[e]
C-1′		141.7	137.2	142.0				C-1′	130.9	130.5
C-2′		105.4	103.4	105.7				C-2′	104.8	103.9
C-3′		159.4	155.6	159.0				C-3′	156.5	156.5
C-4′		103.7	114.9	103.4				C-4′	113.6	115.9
C-5′		159.4	155.6	159.0				C-5′	156.5	156.5
C-6′		105.4	103.4	105.7				C-6′	104.8	103.9
C-1″	(9)	134.0	131.2		(16)	133.7, 133.5	133.2		134.1	134.3
C-2″	(8)	126.2	125.1		(15)	124.9	126.2		124.2	125.1
C-3″	(7)	42.7	39.0		(14)	37.5	38.9		33.2	38.8
C-4″	(13)	50.1	46.1		(20)	45.7[d]	46.6		47.9	46.8
C-5″	(12)	42.3	37.7		(19)	37.5	38.9		33.2	38.8
C-6″	(11)	37.7	37.4		(18)	38.2	38.9		32.4	37.7
C-7″	(10)	23.4	22.7		(17)	23.4	23.5		23.8	23.4
C-8″	(14)	209.7	208.9		(21)	210.7 br	208.5		209.5	209.3
C-9″	(15)	115.8	115.2		(22)	116.0	116.7		116.4	117.2
C-10″	(16)	164.8[e]	164.2[e]		(23)	165.6	162.3		166.0	166.0
C-11″	(17)	103.5	105.0		(24)	103.8	115.7		102.0	101.7
C-12″	(18)	166.0[e]	163.9[e]		(25)	165.6	163.7		167.0	164.8
C-13″	(19)	107.7	107.6		(26)	107.5	107.4		108.8	107.7
C-14″	(20)	127.9	128.7		(27)	130.9 br	131.2		128.8	130.3
C-15″	(21)	121.6	121.1		(28)	121.4	123.9		122.5	122.5
C-16″	(22)	156.1[e]	155.9[e]		(29)	156.8	156.6[e]		157.8[e]	157.1[e]
C-17″	(23)	102.8	105.0		(30)	103.2	103.1		103.6	104.6
C-18″	(24)	156.4[e]	156.4[e]		(31)	156.8	157.4[e]		157.8[e]	157.1[e]
C-19″	(25)	107.4	106.4		(32)	108.4	108.4		107.5	107.5
C-20″	(26)	134.3	132.9		(33)	134.3 br	132.8		135.0	133.9

a) In acetone-d_6. *b*) In DMSO-d_6 at 120 °C. *c*) In CD_3OD. *d*) In DMSO-d_6. *e*) Interchangeable. ( ): The numbers are those of the corresponding carbons of **1**[2] and **9**.[11]

(**11**).[13] Compound **2** was similar to **1a**, **4a**, and **11** rather than **10** in the chemical shifts and coupling constants of the relevant protons of the methylcyclohexene ring (Fig. 2). Furthermore, comparative examination of the ^{13}C-NMR spectra of **2**, **10**,[12] and kuwanon O (**12**)[3] suggests that **2** possesses the same relative configuration as **12** as regards the substituents on the methylcyclohexene ring (Table I). From these results, the structure of kuwanon X was concluded to be represented by the formula **2**.

Mulberrofuran J (**3**), is a colorless amorphous powder, $[\alpha]_D^{18}$ -341 °. The FD-MS showed the molecular ion peak at m/z 580. Treatment of **3** with dimethyl sulfate in acetone gave a heptamethyl ether (**3a**) as an amorphous powder which was negative to the methanolic ferric chloride test. The molecular formula of **3a** was determined to be $C_{41}H_{42}O_9$ by high-resolution MS. These results indicated the composition of mulberrofuran J to be $C_{34}H_{28}O_9$. In accordance with this formula, the ^{13}C-NMR spectrum indicated the presence of thirty-four carbon atoms: nine aliphatic carbons, twenty-four aromatic carbons, and one carbonyl carbon (Table I). Compound **3** gave a brown color in the methanolic ferric chloride test. The

IR spectrum of **3** showed absorption bands due to hydroxyl, conjugated carbonyl, conjugated double bond, and benzene ring moieties. The UV spectrum of **3** exhibited maxima at 209, 283, 293 (sh), 310 (infl.), 321, and 337 nm, and showed a bathochromic shift in the presence of aluminum chloride. The UV characteristics were similar to those of **4**[5] and **10**.[12] These results suggested that **3** has a 2-arylbenzofuran skeletal structure along with a hydrogen-bonded carbonyl group. The ^{13}C-NMR spectrum of **3** was analyzed and compared with that of **10**.[12] The chemical shift values of the carbon atoms of the 2-arylbenzofuran skeleton were similar to those of the relevant carbon atoms of **10** except for the signal of the carbon atom at the C-4′ position (Table I). The results indicate that **3** is a 4′-substituted 3′,5′,6-trihydroxy-2-arylbenzofuran derivative. The EI-MS of **3** and **3a** showed almost the same fragments as **10**[12] and its heptamethyl ether (**10a**),[12] indicating that **3** is a Diels–Alder type adduct such as **4** and **10**. The ^{1}H-NMR spectrum (24 °C, 400 MHz, acetone-d_6) of **3** showed a complex pattern with broad signals. This implies that **3** exists as an equilibrium mixture of conformational isomers in the solution.[11] Supporting this, at higher temperature (65 °C), all the signals appeared more clearly except for four proton signals [δ 6.60—6.85 (2H, br, C$_{2'}$ and C$_{6'}$-H), δ 3.65 (1H, br, C$_{5''}$-H), and one of the protons at C$_{6''}$-H (not observed)]. Careful analysis of the spectrum (65 °C) by sequential decoupling and a comparison with the spectra of **4**,[5] **10**,[12] and kuwanon I (**11**)[13] revealed the presence of 2,4-dihydroxyphenyl, 2,4-dihydroxybenzoyl, 2-arylbenzofuran, and methylcyclohexene ring moieties: δ 6.13 (1H, dd, $J=2.4$ and 8.3 Hz, C$_{19''}$-H), 6.23 (1H, d, $J=2.4$ Hz, C$_{17''}$-H), 6.91 (1H, d, $J=8.3$ Hz, C$_{20''}$-H); δ 5.97 (1H, d, $J=2.4$ Hz, C$_{11''}$-H), 6.02 (1H, dd, $J=2.4$ and 8.7 Hz, C$_{13''}$-H), 7.64 (1H, d, $J=8.7$ Hz, C$_{14''}$-H); δ 6.77 (1H, dd, $J=2.2$ and 8.3 Hz, C$_{5}$-H), 6.60—6.85 (2H, br, C$_{2'}$ and C$_{6'}$-H), 6.82 (1H, d, $J=1$ Hz, C$_{3}$-H), 6.92 (1H, br d, C$_{7}$-H), 7.33 (1H, d, $J=8.3$ Hz, C$_{4}$-H). Figure 2 shows the chemical shifts and coupling constants of protons of the relevant methylcyclohexene ring. The existence of the 2,4-dihydroxyphenyl and 2,4-dihydroxybenzoyl moieties was also supported by comparison of the ^{13}C-NMR spectrum of **3** with those of **10**[12] and other Diels–Alder type adducts (Table I).[10] These results, together with the similarity of the biogenetic pathway of the Diels–Alder type adducts obtained from *Morus* species,[10,12] suggest that mulberrofuran J is a C-3″ stereoisomer on the methylcyclohexene ring of **10**. The presumption that **3** has the same relative configuration as **4** and **11** as regards the substituents on the methylcyclohexene ring was based on a comparison of the ^{1}H-NMR spectrum of **3** with those of **4**,[5] **10**,[12] and **11**[13] (Fig. 2), and of the ^{13}C-NMR spectrum of **3** with those of **10**[12] and kuwanon O (**12**)[3] (Table I). In the ^{1}H-NMR spectra, the chemical shifts and coupling constants of protons of the relevant methylcyclohexene ring of **3** resembled those of **4** and **11** more than those of **10**. The chemical shifts of carbon atoms of the methylcyclohexene ring of **3** resembled those of **12** more than those of **10**. The location of the methylcyclohexene ring on the C-ring was also supported by the examination of the ^{1}H-NMR spectra of **3**: at low temperature (24 °C, 400 MHz, in acetone-d_6) the C-ring protons appeared as separate signals at δ 6.67 (1H, br s) and 6.83 (1H, br s), while at higher temperature (65 °C), these two protons were observed as a broad signal at δ 6.60—6.85, indicating equivalence of these two protons. Irradiation of the signal at δ 6.67 resulted in the disappearance of the signal at δ 6.83, and irradiation of the signal at δ 6.83 caused the disappearance of the signal at δ 6.67. Similar phenomena had been observed in a double irradiation experiment on the proton at the C-8 position of sanggenon D (**9**).[14] The ^{1}H-NMR spectrum of **9** (24 °C, 400 MHz, CD$_3$CN) showed signals at δ 5.60 (0.4H, br s, C$_8$-H) and δ 5.78 (0.6H, br s, C$_8$-H). When the signal at δ 5.60 was irradiated, the signal at δ 5.78 disappeared. It follows, therefore, that the protons at the C-2′ and -6′ positions of **3** are equivalent, and hence the methylcyclohexene ring in question must be located at the C-4′ position. All these results indicate that mulberrofuran J is a C-3″ stereoisomer of mulberrofuran C (**10**), and the structure is therefore represented by the formula **3**.

Kuwanons P (**1**) and X (**2**) are optically active, as is mulberrofuran J (**3**), and are the first examples of natural products which are considered to be formed by a Diels–Alder type of enzymatic process from a chalcone derivative and dehydroprenylstilbene derivatives. On the other hand, Takasugi *et al.*[5] isolated albafuran C (**4**) from the mulberry shoot, and suggested that **4** is a Diels–Alder adduct of a chalcone and a dehydromoracin N with a 2-arylbenzofuran skeleton. Considering the biogenetic route to 2-arylbenzofuran derivatives, involving oxidative cyclization of hydroxystilbenes,[15] kuwanons P (**1**) and X (**2**) might be regarded as possible intermediates in the biosynthesis of albafuran C (**4**) and mulberrofuran J (**3**). It noteworthy that two stilbene derivatives, kuwanons P (**1**) and X (**2**), coexist with two 2-arylbenzofuran derivatives, albafuran C (**4**) and mulberrofuran J (**3**), in mulberry root bark.

Experimental

^{1}H-NMR and ^{13}C-NMR spectra were measured with tetramethylsilane (TMS) as an internal reference. Chemical shifts were expressed in ppm downfield from TMS, and coupling constants (J) in Hz. Abbreviations: s = singlet, d = doublet, t = triplet, m = multiplet, br = broad, sh = shoulder, infl. = inflection. The following instruments were used: UV spectra, Hitachi 340 UV spectrometer; IR spectra, Hitachi 260-30 IR spectrometer; ^{1}H-NMR spectra, JEOL GX-400 and GX-270 FT NMR spectrometers and a JEOL JNM 4H-100 NMR spectrometer; ^{13}C-NMR spectra, JEOL GX-270 and Hitachi R-900 FT NMR spectrometers; optical rotation, JASCO DIP-4; mass spectra, JEOL JMS 0ISG-2 and Hitachi RMU-7M mass spectrometers; high-performance liquid chromatography (HPLC), Toyo Soda HLC-803; centrifugal thin-layer chromatography (TLC), Harrison 2924 centrifugal TLC. Wakogel B-5FM was used for TLC, Wakogel B-5F and Merck Kieselgel 60 PF_{254} for preparative TLC, Wakogel C-200 and Polyamide C-200 for column chromatography, Merck Kieselgel 60 GF_{254} for centrifugal TLC, and TSK-GEL (LS-410AK) for the HPLC system.

Isolation of Kuwanons P (1) and X (2), and Mulberrofuran J (3)——The dried root bark of the cultivated mulberry tree (4 kg, Japanese name "Rosō," a variety of *Morus lhou* Koidz.), collected in the neighborhood of Takasaki, Gunma Prefecture, Japan, in December 1981, was extracted successively with *n*-hexane, benzene, and acetone. Evaporation of the *n*-hexane, benzene, and acetone solutions to dryness yielded 48, 27, and 220 g of residue, respectively. The acetone extract (200 g) was chromatographed on silica gel (400 g) using benzene–MeOH as an eluent, each fraction being monitored by TLC. The fractions eluted with benzene containing 5% MeOH were evaporated to give the residue (34 g). This residue (2 g) was fractionated by preparative TLC (solvent system, *n*-hexane : $(CH_3)_2CO$ = 1 : 2; $CHCl_3$: MeOH = 4 : 1) to give kuwanon P (**1**, 178 mg),[16] while a portion of the residue (2 g) was also fractionated by preparative TLC ($CHCl_3$: MeOH = 4 : 1; $CHCl_3$: EtOAc = 1 : 3; C_6H_6 : $(CH_3)_2CO$ = 1 : 3) to give kuwanon X (**2**, 67 mg) as well as albafuran C (**4**, 27 mg). Another portion of the same residue (2 g) was also fractionated by preparative TLC (EtOAc : $CHCl_3$ = 3 : 2; $CHCl_3$: MeOH = 8 : 1; ether only) to give mulberrofuran J (**3**, 30 mg).[16] A known compound (**4**) was identified by comparison of the IR and ^{1}H-NMR spectra with those of an authentic specimen.

Kuwanon P (1)——Compound **1** was obtained as an amorphous powder. One spot and one peak was detected on TLC (*n*-hexane : $(CH_3)_2CO$ = 1 : 2, $CHCl_3$: MeOH = 4 : 1) and on HPLC (solvent system, MeOH : H_2O = 7 : 3), respectively. FD-MS *m/z*: 582 (M^+). $[\alpha]_D^{17}$ $-509°$ (c = 0.11 in MeOH). $FeCl_3$ test: brown. IR ν_{max}^{Nujol} cm^{-1}: 3300, 1630 (sh), 1618 (sh), 1600, 1590. UV λ_{max}^{EtOH} nm (log ε): 218 (4.42), 284 (4.19), 310 (sh 4.12), 331 (4.16); $\lambda_{max}^{EtOH+AlCl_3}$: 221 (4.43), 299 (sh 4.25), 305 (4.23), 331 (sh 4.15). ^{1}H-NMR ($(CD_3)_2CO$, 100 MHz) δ: 1.78 (3H, s, $C_{1''}$-CH_3), 2.25 (1H, m, $C_{6''}$-H), 2.50—2.80 (1H, m, $C_{6''}$-H), 3.60—3.80 (1H, m, $C_{5''}$-H), 4.21 (1H, br d, J = 10 Hz, $C_{3''}$-H), 4.56 (1H, br t, J = 10 Hz, $C_{4''}$-H), 5.41 (1H, br s, $C_{2''}$-H), 6.03 (1H, d, J = 2 Hz, $C_{11''}$-H), 6.14 (1H, dd, J = 2 and 9 Hz, $C_{13''}$-H), 6.17 (1H, dd, J = 2 and 9 Hz, $C_{19''}$-H), 6.20—6.30 (3H, m, C_3, $C_{4'}$, and $C_{17''}$-H), 6.56 (2H, d, J = 2 Hz, $C_{2'}$ and $C_{6'}$-H), 6.86 (1H, d, J = 16 Hz, C_α-H), 6.97 (1H, d, J = 9 Hz, $C_{20''}$-H), 7.29 (1H, d, J = 16 Hz, C_β-H), 7.45 (1H, s, C_6-H), 7.82 (1H, d, J = 9 Hz, $C_{14''}$-H), 13.38 (1H, s, $C_{10''}$-OH).

Kuwanon P Octamethyl Ether (1a)——A mixture of kuwanon P (**1**, 10 mg), $(CH_3)_2SO_4$ (0.5 ml), and K_2CO_3 (5 g) in dry $(CH_3)_2CO$ (30 ml) was refluxed for 23 h, and treated as usual. The products were purified by preparative TLC ($CHCl_3$: C_6H_6 : Et_2O = 1 : 4 : 0.5) to give an amorphous powder (**1a**, 4 mg). $FeCl_3$ test: negative. IR ν_{max}^{Nujol} cm^{-1}: 1670, 1600 (sh), 1585 (sh). UV λ_{max}^{EtOH} nm (log ε): 218 (sh 4.55), 283 (sh 4.23), 279 (infl. 4.28), 304 (4.29), 330 (4.28); $\lambda_{max}^{EtOH+AlCl_3}$: 220 (sh 4.55), 283 (sh 4.23), 279 (infl. 4.29), 304 (4.30), 330 (4.29). ^{1}H-NMR ($CDCl_3$, 270 MHz) δ: 1.78 (3H, s, $C_{1''}$-CH_3), 2.22 (1H, br d, J = 16 Hz, $C_{6''}$-H), 2.39 (1H, m, $C_{6''}$-H), 3.60—3.70 (1H, $C_{5''}$-H, overlapping with methoxyl groups), 3.52, 3.62, 3.69, 3.70, 3.72, 3.76 (each 3H, s, OCH_3), 3.85 (6H, s, $OCH_3 \times 2$), 4.21 (1H, br d, J = 10 Hz, $C_{3''}$-H), 4.43 (1H, br t, J = 10 Hz, $C_{4''}$-H), 5.32 (1H, br s, $C_{2''}$-H), 5.97 (1H, d, J = 2 Hz, $C_{11''}$-H), 6.01 (1H, dd, J = 2 and 9 Hz, $C_{13''}$-H), 6.16 (1H, dd, J = 2 and 8.5 Hz, $C_{19''}$-H), 6.23 (1H, s, C_3-H), 6.26 (1H, d, J = 2 Hz, $C_{17''}$-H), 6.37 (1H, t, J = 2 Hz, $C_{4'}$-H), 6.70 (2H, d, J = 2 Hz, $C_{2'}$ and $C_{6'}$-H), 6.94 (1H, d, J = 16 Hz, C_α-H), 7.06 (1H, d, J = 8.5 Hz, $C_{20''}$-H), 7.09 (1H, d, J = 9 Hz, $C_{14''}$-H), 7.35 (1H, d, J = 16 Hz, C_β-H), 7.42 (1H, s, C_6-H). EI-MS *m/z*: 694

(M^+), 529 (**6**), 366 (**7**), 313, 300, 165 (**8**), 151. High-resolution MS, Calcd for $C_{42}H_{46}O_9$ (M^+), *m/z* 694.3142. Found: *m/z* 694.3147; Calcd for $C_{23}H_{26}O_4$, *m/z* 366.1830. Found: *m/z* 366.1785; Calcd for $C_9H_9O_3$, *m/z* 165.0550. Found: *m/z* 165.0542.

Kuwanon X (2)——Compound **2** was obtained as an amorphous powder. One spot was detected on TLC ($CHCl_3$: MeOH = 4 : 1, $CHCl_3$: EtOAc = 1 : 3, C_6H_6 : $(CH_3)_2CO$ = 1 : 3). $[\alpha]_D^{21}$ $-322°$ (c = 0.049 in MeOH). $FeCl_3$ test: dark brown. IR ν_{max}^{KBr} cm^{-1}: 3350, 1620 (sh), 1605. UV λ_{max}^{EtOH} nm (log ε): 216 (infl. 4.60), 283 (4.38), 304 (4.05), 328 (4.45), 343 (infl. 4.39); $\lambda_{max}^{EtOH+AlCl_3}$: 220 (sh 4.57), 293 (infl. 4.43), 304 (4.49), 312 (sh 4.48), 330 (4.45). ^{1}H-NMR (DMSO-d_6, 120 °C, 270 MHz) δ: 1.67 (3H, s, $C_{1''}$-CH_3), 2.05 (1H, dd, J = 5 and 16 Hz, $C_{6''}$-H), 2.38 (1H, dd, J = 13 and 16 Hz, $C_{6''}$-H), 3.50 (1H, ddd, J = 5, 10, and 13 Hz, $C_{5''}$-H), 4.30 (1H, br d, J = 10 Hz, $C_{3''}$-H), 4.78 (1H, br t, J = 10 Hz, $C_{4''}$-H), 5.20 (1H, br s, $C_{2''}$-H), 5.90 (1H, d, J = 2.5 Hz, $C_{11''}$-H), 5.94 (1H, dd, J = 2.1 and 8.3 Hz, $C_{19''}$-H), 6.00 (1H, dd, J = 2.5 and 8.8 Hz, $C_{13''}$-H), 6.11 (1H, d, J = 2.1 Hz, $C_{17''}$-H), 6.23 (1H, dd, J = 2.6 and 8.5 Hz, C_5-H), 6.27 (2H, s, $C_{2'}$ and $C_{6'}$-H), 6.31 (1H, d, J = 2.6 Hz, C_3-H), 6.56 (1H, d, J = 16 Hz, C_α-H), 6.71 (1H, d, J = 8.3 Hz, $C_{20''}$-H), 6.99 (1H, d, J = 16 Hz, C_β-H), 7.21 (1H, d, J = 8.5 Hz, C_6-H), 7.59 (1H, d, J = 8.8 Hz, $C_{14''}$-H), 13.11 (1H, s, OH, at 21 °C).

Kuwanon X Octamethyl Ether (2a)——A mixture of kuwanon X (**2**, 4 mg), $(CH_3)_2SO_4$ (0.05 ml), K_2CO_3 (5 g), and crown ether (18-crown-6-ether, catalytic amount) in dry $(CH_3)_2CO$ (30 ml) was refluxed for 5 h, and treated as usual. The products were purified by preparative TLC (C_6H_6 only; Et_2O: *n*-hexane = 2 : 1) to give an amorphous powder (**2a**, 1 mg). $FeCl_3$ test: negative. EI-MS *m/z*: 694 (M^+), 529 (**6′**), 366 (**7′**), 313, 300, 165 (**8**), 151. High-resolution MS, Calcd for $C_{42}H_{46}O_9$, *m/z* 694.3139. Found: *m/z* 694.3137; Calcd for $C_{23}H_{26}O_4$, *m/z* 366.1830. Found: *m/z* 366.1836; Calcd for $C_{18}H_{20}O_4$, *m/z* 300.1361. Found: *m/z* 300.1372; Calcd for $C_9H_9O_3$, *m/z* 165.0551. Found: *m/z* 165.0556.

Mulberrofuran J (3)——Compound **3** was obtained as an amorphous powder. One spot was detected on TLC (*n*-hexane : EtOAc = 3 : 2, $CHCl_3$: MeOH = 8 : 1, Et_2O only). FD-MS *m/z*: 580 (M^+). EI-MS *m/z*: 293, 242, 110. $[\alpha]_D^{18}$ $-341°$ (c = 0.079 in MeOH). $FeCl_3$ test: dark brown. IR ν_{max}^{KBr} cm^{-1}: 3350 (br), 1640 (sh), 1620, 1600. UV λ_{max}^{EtOH} nm (log ε): 209 (4.97), 283 (4.51), 293 (sh 4.46), 310 (infl. 4.57), 321 (4.67), 337 (4.56); $\lambda_{max}^{EtOH+AlCl_3}$: 210 (4.78), 222 (sh 4.68), 288 (sh 4.39), 310 (sh 4.63), 320 (4.65), 335 (sh 4.52), 370 (sh 3.52). ^{1}H-NMR ($(CD_3)_2CO$, 65 °C, 400 MHz), δ: 1.79 (3H, s, $C_{1''}$-CH_3), 2.21 (1H, dd, J = 5 and 18 Hz, $C_{6''}$-H), 2.55 (1H, m, $C_{6''}$-H, observed at 24 °C, 100 MHz; not observed at 65 °C, 400 MHz, overlapping with signals of H_2O), 3.65 (1H, br, $C_{5''}$-H), 4.52 (1H, br d, J = 10 Hz, $C_{3''}$-H), 4.84 (1H, br t, J = 10 Hz, $C_{4''}$-H), 5.43 (1H, br s, $C_{2''}$-H), 5.97 (1H, d, J = 2.4 Hz, $C_{11''}$-H), 6.02 (1H, dd, J = 2.4 and 8.7 Hz, $C_{13''}$-H), 6.13 (1H, dd, J = 2.4 and 8.3 Hz, $C_{19''}$-H), 6.23 (1H, d, J = 2.4 Hz, $C_{17''}$-H), 6.60—6.85 (2H, br, $C_{2'}$ and $C_{6'}$-H), 6.77 (1H, dd, J = 2.2 and 8.3 Hz, C_5-H), 6.82 (1H, d, J = 1 Hz, C_3-H), 6.91 (1H, d, J = 8.3 Hz, $C_{20''}$-H), 6.92 (1H, br d, C_7-H, overlapping with the signal at δ 6.91) 7.33 (1H, d, J = 8.3 Hz, C_4-H), 7.64 (1H, d, J = 8.7 Hz, $C_{14''}$-H), 13.13 (1H, s, C_{10}-OH, observed at 24 °C).

Mulberrofuran J Heptamethyl Ether (3a)——A mixture of mulberrofuran J (**3**, 5 mg), $(CH_3)_2SO_4$ (0.02 ml), and K_2CO_3 (5 g) in dry $(CH_3)_2CO$ (30 ml) was refluxed for 5 h, and treated as usual. The products were purified by preparative TLC (C_6H_6 : $(CH_3)_2CO$ = 7 : 1) to give an amorphous powder (**3a**, 3.2 mg). $FeCl_3$ test: negative. IR ν_{max}^{KBr} cm^{-1}: 1660, 1610, 1565. UV λ_{max}^{EtOH} nm (log ε): 230 (infl. 4.57), 280 (sh 4.27), 288 (sh 4.29), 297 (infl. 4.33), 313 (sh 4.51), 323 (4.58), 339 (4.47). High-resolution MS, Calcd for $C_{41}H_{42}O_9$ (M^+), *m/z* 678.2826. Found: *m/z* 678.2831; Calcd for $C_{33}H_{32}O_7$, *m/z* 540.2145. Found: *m/z* 540.2141; Calcd for $C_{22}H_{22}O_4$, *m/z* 350.1516. Found: *m/z* 350.1535; Calcd for $C_{19}H_{20}O_5$, *m/z* 328.1308. Found: *m/z* 328.1285; Calcd for $C_{18}H_{17}O_4$, *m/z* 297.1126. Found: *m/z* 297.1131; Calcd for $C_{17}H_{16}O_4$, *m/z* 284.1047. Found: *m/z* 284.1059; Calcd for $C_9H_9O_3$, *m/z* 165.0552. Found: *m/z* 165.0556.

Acknowledgement We are grateful to Dr. M. Takasugi, Hokkaido University, providing spectral data and an authentic specimen of albafuran C, and to Prof. S. Sakai, Chiba University, for high-resolution MS measurements.

References and Notes

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