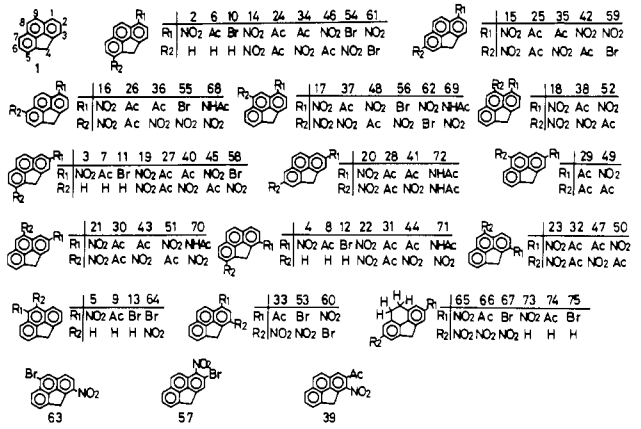

Figure 1.

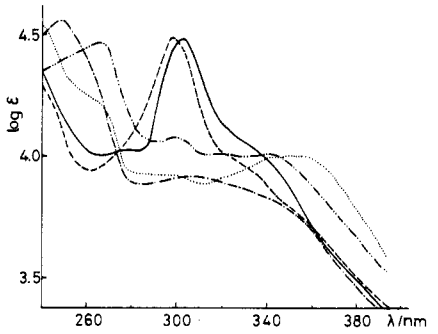

Figure 2. UV spectra of **48** (···), **49** (—), **50** (–·–·–), **51** (– – –), and **52** (–·–) in $CHCl_3$.

penta[*def*]phenanthrene (**66**) was isolated; **66** was also obtained in a 72% yield by treatment of **73** (237 mg, 1 mmol) with Ac_2O (0.12 mL, 1.3 mmol) and $AlCl_3$ (0.54 g, 4 mmol) in $PhNO_2$ (20 mL) at 20 °C for 20 h.

Nitration of 2-Bromo-8,9-dihydro-4H-cyclopenta[def]-phenanthrene (75). A mixed acid (HNO_3, d = 1.42 g cm^{-3}, 0.32 mL, and concentrated H_2SO_4, 0.55 mL) was added to a solution of **75** (542 mg, 2 mmol) in HOAc (20 mL) at 75–78 °C for 5 min. After stirring for an additional 15 min, the reaction mixture afforded 2-bromo-6-nitro-8,9-dihydro-4*H*-cyclopenta-[*def*]phenanthrene (**67**) (474 mg, 75%).

Oxidation of 2-Acetyl-6-nitro-8,9-dihydro-4H-cyclopenta[def]phenanthrene (66). To a refluxing solution of **66** (130 mg, 0.47 mmol) in HOAc (30 mL), nitric acid (d = 1.42 g cm^{-3}, 5 mL) was added over a period of 10 min, and the refluxing was maintained for an additional 1 h, yielding 21 mg (16%) of **41**.

Schmidt Reaction of 36. A mixture of **36** (180 mg, 0.65 mmol), NaN_3 (90 mg, 1.38 mmol), and Cl_3CCO_2H (3.5 g) was stirred at 90–95 °C for 6 h. To the reaction mixture, 30 mL of water was added, and the precipitate was chromatographed in benzene on a silica gel column. The eluate yielded 23 mg (13%) of **36**. Also, 88 mg (46%) of *N*-acetyl-7-nitro-4*H*-cyclopenta[*def*]phenanthren-1-amine (**68**) was obtained by extraction of the column with EtOAc.

In a similar manner, the following amines were obtained from the corresponding acetyl compounds: *N*-acetyl-8-nitro-4*H*-cyclopenta[*def*]phenanthren-1-amine (**69**, yield 65%); *N*-acetyl-9-nitro-4*H*-cyclopenta[*def*]phenanthren-2-amine (**70**, yield 66%); *N*-acetyl-5-nitro-4*H*-cyclopenta[*def*]phenanthren-3-amine (**71**, yield 66%); *N,N'*-diacetyl-4*H*-cyclopenta[*def*]-phenanthrene-2,6-diamine (**72**, yield 71%).

Dinitro Compounds from Amides. The amide **68** (75 mg, 0.26 mmol) in HOEt (10 mL) was refluxed with concentrated HCl (8 mL) for 3 h and was cooled to room temperature to give the hydrochloride. The salt was stirred in HOEt (5 mL) and benzene (5 mL) with aqueous ammonia (28%, 0.1 mL) at room temperature for 1 min. After extraction with benzene, the extract was evaporated to dryness, and the residue was added dropwise to *m*-chloroperoxybenzoic acid (350 mg, 2 mmol) in $CHCl_3$ (8 mL) at 0 °C for 10 min. Then the temperature of the mixture was elevated to 30 °C for a period of 30 min. The resulting mixture was poured into water and extracted with benzene. The organic layer was evaporated to dryness, and the residue was chromatographed in benzene on silica gel to afford 35 mg (48%) of **16**. By a similar method, **17**, **20**, **21**, and **22** were obtained from **69**, **72**, **70**, and **71** in yields of 24%, 25%, 31%, and 46%, respectively.

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Synthesis of Potential Juvenogen Insecticides. 1. Tetrahydrofuran and Tetrahydropyran Ether Derivatives

Jitka Kahovcová* and Miroslav Romaňuk

Institute of Organic Chemistry and Biochemistry, Czechoslovak Academy of Sciences, Prague, Czechoslovakia

A series of new tetrahydrofuran and tetrahydropyran ethers with acyl components in the molecules was prepared.

As part of a program aimed at the synthesis of new compounds with selective juvenile hormone activity, we have prepared a series of new ethers derived from tetrahydrofuran and tetrahydropyran and their halogen derivatives (Table I).

Some of the synthesized compounds possess an appreciable juvenile hormone activity as well as proper lipophilicity, low volatility, and other physicochemical properties desirable for practical use.

Experimental Section

All of the boiling points are uncorrected. IR, mass, and ^1H NMR spectra were recorded on a UR 20 spectrophotometer (CCl_4, $CHCl_3$), an AEI MS-902 spectrometer at 70-eV ionization potential, and a Varian HA-60 or HA-100 spectrometer ($CDCl_3$, Me_4Si), respectively. The reaction course and the purity of the

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Table I. Properties of Compounds V[a]

n	R¹	R²	R³	yield, %	NMR values,[b] δ	IR bands,[c] cm⁻¹	mass spectra[d] m/e	fragment ion	rel intens, %
1	Cl	H	CH_3	70[e]	0.83 (t), CH_3	1740, CO ester	370, 372	M, $C_{19}H_{27}ClO_5$	3.2, 1.1
					1.50–2.30 (m), CH_2	1615, 1588, 1518, benzene ring	327, 329	$C_{17}H_{24}ClO_4$	0.9, 0.3
					2.02 (s), CH_3CO	1252, C-O	311, 313	$C_{17}H_{24}ClO_3$	18.6, 5.7
					3.40–4.30 (m), CH_2O, CHCl		194	$C_{11}H_{14}O_3$	80.7
					5.08 (s), OCHO		165	$C_9H_9O_3$	14.2
					5.62 (t), CHOCO		135	$C_9H_{11}O$	100.0
					6.83, 7.26 (m), benzene ring		105, 107	C_4H_6ClO	49.3, 18.1
1	Cl	H	CH_2Cl	63	0.85 (t), CH_3	1762, 1744, CO ester	404, 406, 408	M, $C_{19}H_{26}Cl_2O_5$	2.6, 1.9, 0.3
					1.30–2.20 (m), CH_2	1615, 1586, 1517, benzene ring	375, 377, 379	$C_{17}H_{21}Cl_2O_5$	0.6, 0.4, 0.1
					3.40–4.10 (m), CH_2O, CHCl	1252, C-O	299, 301	$C_{15}H_{20}ClO_4$	4.2, 1.5
					4.02 (s), $COCH_2Cl$		283, 285	$C_{15}H_{20}ClO_3$	16.7, 6.2
					5.08 (s), OCHO		228, 230	$C_{11}H_{13}ClO_3$	70.8, 25.0
					5.68 (t), CHOCO		177, 179	$C_8H_{14}ClO_2$	14.6, 4.1
					6.85, 7.30 (m), benzene ring		135	$C_9H_{11}O$	100.0
							105, 107	C_4H_6ClO	61.3, 20.1
1	Cl	H	$(CH_2)_7CH{=}CH(CH_2)_7CH_3$, trans	44	0.83 (t), CH_3	1737, CO ester	592, 594	M, $C_{35}H_{57}ClO_5$	2.2, 0.6
					1.20–2.60 (m), CH_2, CH_2CO	1615, 1588, 1517, benzene ring	563, 565	$C_{33}H_{52}ClO_5$	6.2, 2.1
					3.40–4.20 (m), CH_2O, CHCl	1250, C-O	458	$C_{29}H_{46}O_4$	12.2
					5.08 (s), OCHO		442	$C_{29}H_{46}O_3$	10.0
					5.31 (m), CH=		387	$C_{25}H_{39}O_3$	15.5
					5.61 (t), CHOCO		135	$C_9H_{11}O$	100.0
					6.81, 7.26 (m), benzene ring		105, 107	C_4H_6ClO	90.2, 30.0
1	Cl	H	4-C_6H_4Cl	60	0.90 (t), CH_3	1723, CO ester	466, 468, 470	M, $C_{24}H_{28}Cl_2O_5$	10.7, 7.3, 1.7
					1.50–2.30 (m), CH_2	1613, 1597, 1519, benzene ring	437, 439, 441	$C_{22}H_{23}Cl_2O_5$	1.3, 0.9, 0.2
					3.40–4.30 (m), CH_2O, CHCl	1250, C-O	361, 363	$C_{20}H_{22}ClO_4$	26.7, 8.7
					5.09 (s), OCHO		345, 347	$C_{20}H_{22}ClO_3$	16.9, 5.3
					5.84 (t), CHOCO		311, 313	$C_{17}H_{24}ClO_3$	22.2, 7.0
					6.85, 7.31, 7.39, 7.99 (m), benzene ring		290, 292	$C_{16}H_{15}ClO_3$	14.2, 4.0
							261, 263	$C_{14}H_{10}ClO_3$	8.9, 2.8
							235	$C_{14}H_{19}O_3$	34.3
							139, 141	C_7H_4ClO	63.5, 23.8
							134	$C_9H_{10}O$	100.0
							105, 107	C_4H_6ClO	69.8, 20.6
1	Cl	H	2-C_6H_4COOH	55	0.88 (t), CH_3	2550, OH acid dimer	476, 478	M, $C_{25}H_{29}ClO_7$	1.3, 0.5
					1.40–2.40 (m), CH_2	1728, CO ester	371	$C_{21}H_{23}O_6$	3.6
					3.40–4.30 (m), CH_2O, CHCl	1710, CO acid dimer	300	$C_{17}H_{16}O_5$	51.9
					5.06 (s), OCHO	1615, 1600, 1584,	135	$C_9H_{11}O$	100.0
					5.85 (t), CHOCO	1521, 1517, benzene ring	105, 107	C_4H_6ClO	70.0, 25.0
					6.82, 7.30, 7.31, 7.70 (m), benzene ring	1287, 1252, C-O			
1	Cl	H	2-$C_6H_4COOCH_3$	86[f]	0.90 (t), CH_3	1736, 1731, CO ester	490, 492	M, $C_{26}H_{31}ClO_7$	8.3, 3.0
					1.40–2.40 (m), CH_2	1615, 1585, 1517, benzene ring	385	$C_{22}H_{25}O_6$	4.9
					3.40–4.30 (m), CH_2O, CHCl	1285, 1252, C-O	314	$C_{18}H_{18}O_5$	60.2
					3.63 (s), CH_3OCO		180	$C_9H_8O_4$	18.7
					5.05 (s), OCHO		163	$C_9H_7O_3$	8.0
					5.83 (t), CHOCO		135	$C_8H_7O_2$, $C_9H_{11}O$	100.0
					6.83, 7.30, 7.31, 7.63 (m), benzene ring		105, 107	C_4H_6ClO	70.0, 25.0
1	Cl	H	$(CH_2)_2COOH$	53	0.83 (t), CH_3	2600, OH acid dimer	428, 430	M, $C_{21}H_{29}ClO_7$	1.4, 0.5
					1.40–2.60 (m), CH_2, CH_2CO	1739, CO ester	311, 313	$C_{17}H_{24}ClO_3$	9.3, 3.0
					3.30–4.30 (m), CH_2O, CHCl	1719, CO acid dimer	252	$C_{13}H_{16}O_5$	2.8

Table I (*Continued*)

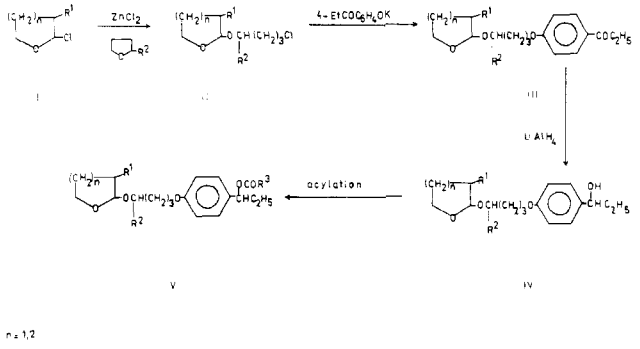
n	R¹	R²	R³	yield, %	NMR values,[b] δ	IR bands,[c] cm⁻¹	mass spectra[d] m/e	fragment ion	rel intens, %
					5.10 (s), OCHO	1615, 1587, 1516, benzene ring	223	$C_{11}H_{11}O_5$	8.3
					5.65 (t), CHOCO	1250, C-O	189	$C_{13}H_{17}O$	17.6
					6.86, 7.28 (m), benzene ring		135	$C_9H_{11}O$	100.0
							105, 107	C_4H_6ClO	51.0, 20.0
1	Cl	H	$(CH_2)_2COOCH_3$	90[f]	0.83 (t), CH_3	1743, CO ester	442, 444	M, $C_{22}H_{31}ClO_7$	9.0, 3.1
					1.40–2.60 (m), CH_2, CH_2CO	1614, 1587, 1516, benzene ring	413, 415	$C_{20}H_{26}ClO_7$	0.5, 0.2
					3.40–4.30 (m), CH_2O, CHCl	1249, C-O	337	$C_{16}H_{25}O_6$	3.6
					3.63 (s), CH_3OCO		321	$C_{15}H_{25}O_5$	10.8
					5.08 (s), OCHO		311, 313	$C_{17}H_{24}ClO_3$	10.8, 3.5
					5.63 (t), CHOCO		266	$C_{14}H_{18}O_5$	12.6
					6.85, 7.27 (m), benzene ring		205	$C_{13}H_{17}O_2$	12.6
							134	$C_9H_{10}O$	61.1
							115	$C_5H_7O_3$	100.0
							105, 107	C_4H_6ClO	73.6, 27.0
1	Cl	H	$CH_2C(=CH_2)COOH$	34	0.83 (t), CH_3	2600, OH acid dimer	328, 330	$C_{17}H_{25}ClO_4$	2.8, 0.9
					1.4–2.7 (m), CH_2	1739, CO ester	311, 313	$C_{17}H_{24}ClO_3$	8.0, 2.6
					3.40–4.30 (m), CH_2O, CHCl	1709, CO acid dimer	294	$C_{17}H_{26}O_4$	1.6
					5.07 (s), OCHO	1656, C=C gem disubst	234	$C_{12}H_{10}O_5$	1.5
					5.63 (t), CHOCO	1614, 1585, 1516, benzene ring	223	$C_{13}H_{19}O_3$	1.6
					6.26 (m), CH_2=	1248, C-O	195	$C_{11}H_{15}O_3$	22.5
					6.83, 7.25 (m), benzene ring		134	$C_9H_{10}O$	100.0
							105, 107	C_4H_6ClO	89.2, 33.1
2	Cl	H	$(CH_2)_4CH_3$	55	0.85 (t), CH_3	1738, CO ester	324, 326	$C_{18}H_{25}ClO_3$	3.6, 1.0
					1.10–2.60 (m), CH_2, CH_2CO	1608, 1579, 1514, benzene ring	304	$C_{19}H_{28}O_3$	4.5
					3.30–4.10 (m), CH_2O, CHCl	1247, C-O	290	$C_{18}H_{26}O_3$	4.5
					4.53 (m), OCHO		234	$C_{14}H_{18}O_3$	1.8
					5.63 (t), CHOCO		189	$C_{13}H_{17}O$	16.4
					6.87, 7.25 (m), benzene ring		147	$C_{10}H_{11}O$	11.8
							134	$C_9H_{10}O$	100.0
							119, 121	C_5H_8ClO	11.8, 4.0
2	H	CH_3	$(CH_2)_2COOH$	57	0.83 (t), CH_3	2600, OH acid dimer	422	M, $C_{23}H_{34}O_7$	2.2
					1.10 (d), CH_3	1739, CO ester	338	$C_{18}H_{26}O_6$	3.3
					1.30–2.60 (m), CH_2, CH_2CO	1719, CO acid dimer	304	$C_{19}H_{28}O_3$	5.5
					3.20–4.10 (m), CH_2O, CHO	1615, 1587, 1516, benzene ring	252	$C_{13}H_{16}O_5$	12.2
					4.68 (m), OCHO	1250, C-O	203	$C_{14}H_{19}O$	20.0
					5.63 (t), CHOCO		134	$C_9H_{10}O$	100.0
					6.83, 7.25 (m), benzene ring		85	C_5H_9O	50.9
2	H	CH_3	$(CH_2)_2COOCH_3$	88[f]	0.83 (t), CH_3	1743, CO ester	436	M, $C_{24}H_{36}O_7$	2.6
					1.09 (d), CH_3	1614, 1587, 1516, benzene ring	352	$C_{19}H_{28}O_6$	7.3
					1.30–2.60 (m), CH_2, CH_2CO	1250, C-O	305	$C_{19}H_{29}O_3$	5.3
					3.20–4.10 (m), CH_2O, CHO		266	$C_{14}H_{18}O_5$	20.0
					3.65 (s), CH_3OCO		203	$C_{14}H_{19}O$	28.0
					4.68 (m), OCHO		134	$C_9H_{10}O$	100.0
					5.63 (t), CHOCO		85	C_5H_9O	61.3
					6.85, 7.27 (m), benzene ring				

[a] Elemental analyses were in agreement with theoretical values. [b] 60 MHz. [c] Only major IR bands are reported. [d] Only characteristic ions in mass spectra are reported. [e] Compound was prepared by stirring of IV with Ac_2O in Py. [f] Compound was prepared by reaction of acid with CH_2N_2.

substances were checked by thin-layer chromatography (silica gel G, Merck and Silufol with a luminiscent indicator, Kavalier Glassworks) and gas–liquid chromatography (5% of SE-30-1F on Chromosorb W). All of the new compounds were prepared according to Scheme I. Typical examples of this synthesis are described below.

2-(1-Methyl-4-chlorobutoxy)-3-chlorotetrahydrofuran (II, R^1 = Cl, R^2 = CH_3, n = 1). 2,3-Dichlorotetrahydrofuran (1.4 g, 10 mmol) was added to a solution of the freshly fused zinc chloride (0.2 g) in the 2-methyltetrahydrofuran (2.6 g, 30 mmol), and the mixture was heated at 80 °C under nitrogen for 15 min. The reaction mixture was shaken with a mixture of diethyl ether

Scheme I



and water. The ethereal layer was then dried over anhydrous magnesium sulfate and evaporated under reduced pressure. Fraction distillation gave 1.2 g (50% yield) of the product (*1*) (bp 136–137 °C/2 kPa). Anal. Calcd for $C_9H_{16}Cl_2O_2$: C, 47.58; H, 7.10; Cl, 31.22. Found: C, 47.39; H, 7.38; Cl, 30.79. The mass spectrum showed the following main *m/e* values: 149, 151 ($M^+ - (CH_2)_3Cl$), 122, 124 ($C_4H_7ClO_2$), 105, 107 (C_4H_6ClO).

4-[4-(3-Chloro-2-tetrahydrofuryloxy)butoxy]-propiophenone (III, R^1 = Cl, R^2 = H, n = 1). Powdered potassium hydroxide (1.8 g, 32 mmol) was dissolved in a mixture of 4-hydroxypropiophenone (4.8 g, 32 mmol) and anhydrous dimethylformamide (20 mL). Finally, a solution of 2-(4-chlorobutoxy)-3-chlorotetrahydrofuran (6.8 g, 32 mmol) in anhydrous dimethylformamide (5 mL) was added, and the mixture heated under nitrogen at 60–70 °C for 2 h and then allowed to stand at room temperature overnight. The reaction mixture was then diluted with water and shaken with diethyl ether and a 10% aqueous solution of potassium hydroxide. The ethereal layer was dried over anhydrous magnesium sulfate and evaporated under reduced pressure. The residue was purified by column chromatography on a 100-fold amount of silica gel M (0.05–0.1 mm). Elution with light petroleum (40–60 °C) containing up to 20 vol% of diethyl ether gave 6.3 g (60% yield) of the product (*1*) (bp 163–164 °C/13 Pa. Anal. Calcd for $C_{17}H_{23}ClO_4$: C, 62.47; H, 7.09; Cl, 10.85. Found: C, 62.57; H, 7.20; Cl, 10.55. The NMR spectrum (100 MHz) showed signals at δ 1.21 (t, CH_3, 3 H, J = 7.5 Hz), 1.60–2.25 (m, CH_2, 6 H), 2.47 (m, CHCl, H), 2.94 (q, $COCH_2$, 2 H, J = 7.5 Hz), 3.40–4.30 (m, OCH_2, 6 H), 5.09 (s, OCHO, H), 6.90 (d, benzene ring, 2 H, J = 8.5 Hz), 7.93 (d, benzene ring, 2 H, J = 8.5 Hz). The mass spectrum had the following main *m/e* values: 326, 328 (M^+), 297, 299 ($M^+ - C_2H_5$), 121 ($C_7H_5O_2$), 105, 107 (C_4H_6ClO).

1-[4-[4-Methyl-4-(2-tetrahydropyranyloxy)butoxy]-phenyl]propanol (IV, R^1 = H, R^2 = CH_3, n = 2). A solution of 4-[4-methyl-4-(2-tetrahydropyranyloxy)butoxy]propiophenone (1.1 g, 3.6 mmol) in anhydrous diethyl ether (10 mL) was gradually added to a stirred suspension of lithium aluminum hydride (80 mg, 1.8 mmol, 20% excess) in anhydrous diethyl ether (10 mL) at 10–20 °C. The reaction mixture was then refluxed for 30 min. After cooling and dilution with diethyl ether, the unreacted hydride was decomposed with ice water and with dilute sulfuric acid. The ethereal layer was washed with the saturated sodium chloride solution, dried over anhydrous magnesium sulfate, and evaporated under reduced pressure. The residue was then chromatographed on a silica gel column with light petroleum containing up to 50 vol % of diethyl ether as eluent, affording 0.93 g (80% yield) of the product (*2*) (bp 197–199 °C/13 Pa). Anal. Calcd for $C_{19}H_{30}O_4$: C, 70.77; H, 9.38. Found: C, 71.01; H, 9.58. The IR spectrum showed the major bands at 3609 (OH), 1612, 1585, and 1515 cm^{-1} (benzene ring). The mass spectrum had the main peaks at the following *m/e* values: 322 (M^+), 293 ($M^+ - C_2H_5$), 220 ($C_{14}H_{20}O_2$), 134 ($C_9H_{10}O$), 85 (C_5H_9O).

1-[4-[4-(3-Chloro-2-tetrahydrofuryloxy)butoxy]phenyl]-propyl ester of 4-Chlorobenzoic Acid (V, R^1 = Cl, R^2 = H, R^3 = 4-C_4H_6Cl, n = 1). 4-Chlorobenzoyl chloride (0.5 g, 3 mmol) was added gradually to a stirred equimolar solution of 1-[4-[4-(3-chloro-2-tetrahydrofuryloxy)butoxy]phenyl]propanol and dry pyridine in 10 mL of anhydrous dimethylformamide at room temperature. The reaction mixture was then allowed to stand overnight. After dilution with water, extraction with diethyl ether, drying, and taking down under diminished pressure, the residue was chromatographed on silica gel (light petroleum containing up to 20 vol % of diethyl ether) giving 0.84 g (60% yield) of the product (*2*). Anal. Calcd for $C_{24}H_{28}Cl_2O_5$: C, 61.67; H, 6.03; Cl, 15.17. Found: C, 61.95; H, 5.84; Cl, 15.59. The NMR spectrum (100 MHz) showed signals at δ 0.93 (t, CH_3, 3 H, J = 7.0 Hz), 1.50–2.30 (m, CH_2, 8 H), 3.40–4.30 (m, OCH_2 and CHCl, 7 H), 5.09 (s, OCHO, H), 5.84 (t, CHO, H, J = 7.0 Hz), 6.85 (m, benzene ring, 2 H, J = 9.0 Hz), 7.39 (m, benzene ring, 2 H, J = 8.5 Hz), 7.31 (m, benzene ring, 2 H, J = 9.0 Hz), 7.99 (m, benzene ring, 2 H, J = 8.5 Hz). Dicarboxylic acid esters were prepared by heating an equimolar mixture of IV, the corresponding anhydride, and dry pyridine at 60 °C for 10 h (in the case of maleic anhydride, for 2 h only) and then letting the mixture stand at room temperature overnight. The reaction product was isolated in the same manner as described above.

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