OXIDATION OF FURANS WITH 2,3-DICHLORO-5,6-DICYANO-1,4-BENZOQUINONE (DDQ)

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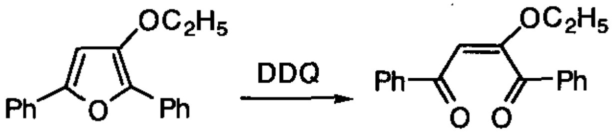
Abstract — 2,5-Disubstituted furans were oxidatively cleaved to 2-butene-1,4-diones with DDQ in CH_2Cl_2-DMSO. In particular, 3-alkoxy-2,5-diphenylfurans were selectively converted into *cis*-2-alkoxy-1,4-diphenyl-2-butene-1,4-diones with DDQ in CH_2Cl_2.

Although 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (DDQ) has been known to be a powerful dehydrogenating reagent for organic compounds such as steroids and ketones and widely used in organic syntheses,[1-3] its ability in the oxidation of furans has not been studied in detail. Furthermore, DDQ has been more convenient and easier to work up in comparison with other oxidizing reagents. Though pyridinium chlorochromate (PCC)[4] and *m*-chloroperbenzoic acid (*m*CPBA)[5,6] are useful reagents for oxidation of furans to enediones, they are not chemoselective.[7] Therefore, there has been much interest in other reagents such as DDQ and phenyltrimethylammmonium tribromide (PTAB)[8] for the oxidizing of furans instead of PCC and *m*CPBA . In our studies of the utility of DDQ, we have found that 3-alkoxyfurans could be converted into alkoxyenediones chemoselectively in CH_2Cl_2.

The oxidation of 2,5-diphenyl-3-ethoxyfuran (**1a**), chosen as a representative 3-alkoxyfuran for this study, was carried out. The results are summarized in Table 1. At the 1:0.5 or 1:0.9 molar ratio of **1a** and DDQ in CH_2Cl_2, *cis*-1,4-diphenyl-2-ethoxy-2-butene-1,4-dione (**2a**) was obtained, accompanied by **1a** (Runs 2, 3). At the 1:1.8 molar ratio of **1a** and DDQ, **1a** was converted to **2a** in good yield (Run 1). To make the oxidizing power of DDQ for the ring opening of furans clearer, the oxidation of **1a** was examined with both 1,4-hydroquinone and 1,4-benzoquinone as typical quinones (Runs 5, 6). **1a** was not affected under

Table 1. Oxidation of 2,5-diphenyl-3-ethoxyfuran (**1a**) with 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (DDQ)[a]



1a **2a**

	Molar ratio					
Run	1a	DDQ	Solvent[b]	Products ,	Yield / %[c]	
1	1	1.8	A		**2a**	85
2	1	0.9	A		**2a**	78
				Recovered	**1a**	21
3	1	0.5	A		**2a**	49
				Recovered	**1a**	50
4	1	2.0	B		**2a**	98
5	1	2.0[d]	B	Recovered	**1a**	82
6	1	2.0[e]	B	Recovered	**1a**	97

a) **1a**; 0.25 mmol. Temperature; 0-22°C. Reaction time; 15-28 h.

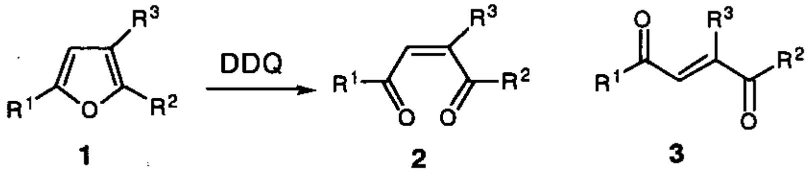
b) A; CH_2Cl_2 15 ml. B; CH_2Cl_2-DMSO (2/1 v/v) 15 ml.

c) Yield is based on **1a** used. d) 1,4-Hydroquinone was used.

e) 1,4-Benzoquinone was used.

the above-mentioned conditions. DDQ is essential for effecting the ring opening of furans (Run 4). The results of DDQ oxidation of other 3-alkoxy and 2,5-disubstituted furans are shown in Table 2. 3-Alkoxy-2,5-diphenylfurans (**1b**-**1f**) also afforded corresponding *cis*-alkoxyenediones (**2b**-**2f**) in CH_2Cl_2 (Runs 2-6). On the other hand, 2,3,5-triphenylfuran (**1g**) and 2,5-diphenylfuran (**1h**) were recovered unchanged (Runs 7, 8). In addition, 2-methyl-5-pentylfuran (**1i**) and 2,3,5-triphenylfuran (**1g**) were converted to corresponding enediones (**3i**) and (**2g**) in CH_2Cl_2-DMSO (Runs 9, 11), while 2,5-diphenylfuran (**1h**) was not affected (Run 12). It was suggested that DMSO promoted the ring opening of furans. The following experiments were carried out to examine the chemoselectivity and the effect of 3-alkoxy substituent for the oxidation of furans with DDQ. The selective oxidation of 3-butoxy-2,5-diphenylfuran

Table 2. Oxidation of furans (**1a**-**1i**) with 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (DDQ)[a]



	Substrate							
Run	(S)	R^1	R^2	R^3	Solvent[b]	Products ,		Yield / %[c]
1	(**1a**)	Ph	Ph	OC_2H_5	A		**2a**	98
2	(**1b**)	Ph	Ph	OCH_3	A		**2b**	98
3	(**1c**)	Ph	Ph	OC_3H_7	A		**2c**	98
4	(**1d**)	Ph	Ph	OiC_3H_7	A		**2d**	80
5	(**1e**)	Ph	Ph	OC_4H_9	A		**2e**	87
6	(**1f**)	Ph	Ph	OiC_4H_9	A		**2f**	90
7	(**1g**)	Ph	Ph	Ph	A	Recovered	**1g**	81
8	(**1h**)	Ph	Ph	H	A	Recovered	**1h**	97
9	(**1i**)	CH_3	C_5H_{11}	H	B		**3i**	57
10	**1a**				B		**2a**	98
11	**1g**				B		**2g**	83
12	**1h**				B	Recovered	**1h**	95
13	**1e**				A		**2e**	80
	1g					Recovered	**1g**	96

a) **1a**-**1i**; 0.04-0.25 mmol. Reaction time; 15-28 h. Molar ratio; 1 : 2 (**1a**-**1i** / DDQ) Temperature; 0-22°C. b) A; CH_2Cl_2 15 ml. B; CH_2Cl_2-DMSO (2/1 v/v) 15 ml.
c) Yield is based on **1a**-**1i** used.

(**1e**) in the presence of 2,3,5-triphenylfuran (**1g**) with DDQ in CH_2Cl_2 was examined in the competition experiments. Equimolar amounts of **1e** and **1g** were allowed to compete for the oxidation with two molar equivalents of DDQ in CH_2Cl_2. **1e** was selectively oxidized to **2e** in 80% yield but **1g** was recovered unchanged (Run 13). This result sufficiently accounted for the chemoselective oxidation of 2,5-

disubstituted 3-alkoxyfuran with DDQ. In addition, the oxidation of 2-methoxyfuran, 4-(2-furoyl)-2-butanone, and 3-(2-furoyl)propanenitrile with DDQ was carried out to ascertain an effect of 3-alkoxy substituent and 2,5-diphenyl moiety on the ring opening of furans. 2-Methoxyfuran gave no corresponding enediones with DDQ. 4-(2-Furoyl)-2-butanone and 3-(2-furoyl)propanenitrile were also recovered unchanged. In the present experiments, it was assumed that both 3-alkoxy substituent and 2,5-diphenyl moiety were required for the selective oxidation of alkoxyfurans with DDQ.

A typical procedure is described for the oxidation of **1a**. To a solution of DDQ (126 mg, 0.5 mmol) in CH_2Cl_2 (13 ml) at 0 ^{o}C was added alkoxyfuran (**1a**) (66 mg, 0.25 mmol) in CH_2Cl_2 (2 ml). After stirring for 18 h at 0-22 ^{o}C, the reaction mixture was treated with 8 % $NaHCO_3$ and extracted with ethyl acetate. The organic layer was washed by saturated aq NaCl and dried by $MgSO_4$. After removal of solvent *in vacuo*, the residue was purified by column chromatography on silica gel (Wakogel C-200) with CCl_4 and $CHCl_3$ (1:1, v/v). Alkoxyenedione (**2a**) (71 mg) was obtained quantitatively. The structures of alkoxyenediones (**2a**-**2f**) were determined on the basis of spectral data and NOE experiments. The stereochemistries of **2a**-**2f** were confirmed by the values of NOEs (11-18 %) observed between olefin proton and adjacent proton of oxygen atom of alkoxyl group.

In conclusion, we demonstrated that DDQ in CH_2Cl_2 or CH_2Cl_2-DMSO provided a chemoselective and simple alternative procedure for the ring opening of furans.

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7. Furans (**1a**, **1g**, **1h**, and **1i**) were oxidized to corresponding enediones with PCC or *m*CPBA.
8. PTAB was also found to be chemoselective for ring opening of alkoxyfurans in THF-DMSO.

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