CONCERNING METHOXY SUBSTITUENT EFFECT AND TOPOTACTIC ASSISTANCE BY METHYLENE CHAIN ON PHOTOCYCLIZATION OF n-METHYLENE DICINNAMATES

Masayuki Kuzuya*, Mitsushi Tanaka and Takachiyo Okuda Gifu College of Pharmacy, 6-1, Mitahora-Higashi 5-Chome, Gifu 502, Japan

Abstract: Methoxy substituent effect and topotactic assistance by the methylene chain of n-methylene dicinnamates upon the photocyclization to the cyclobutane derivatives was explored and the relative efficiencies were rationalized in terms of the odd electron densities of S₁ state obtained by the CNDO/S-CI excited state calculation.

There is a continued interest in photophysical and photochemical processes of cinnamic acid and its derivatives in both liquid phase¹ and solid state.²

On the other hand, there exist a wide variety of biologically active aromatic compounds including cinnamic derivatives which possess 3- and/or 4hydroxy and/or methoxy substituents. We have recently reported that the cooperative effect of 3,4-dialkoxy substitution to the aromatic ring of methyl cinnamate on determining the unique pathway of its electrophilic reaction.³

It is known that unsubstituted methylene dicinnamate esters <u>la</u>, in dilute solution, undergo two competitive photochemical pathways, i.e., the isomerization and the cyclization to cyclobutane derivatives.⁴ This can be ascribed to the concept that the pairs of cinnamoyl moieties have been compelled into close proximity, as is the case in the solid state. This type of reactions may be considered to be the micromorphic solid photochemistry, and provides the different phase to study the topochemical behavior of cinnamate derivatives.

From these points of interest, we have evaluated the substituent effect on the photodimerization of the cinnamate derivatives in acetonitrile solution based on the relative efficiencies of photocyclization (pseudo-photodimerization) of methylene dicinnamate derivatives $\frac{1}{V}$, each of which possesses various methylene chain (n=2 \sim 6 and 10).



We wish to report here the striking 3-methoxy subtituent effect and the methylene chain effect of n-methylene dicinnamate derivatives on the photolability and the stereochemical course toward the cyclization to cyclobutane derivatives. Each of the acetonitrile solutions containing the trans-trans dicinnamate derivatives (ca. 2.0×10^{-5} M) was irradiated with a grating monochromator with 2 kW xenon lamp and 3 nm bandwidth (Model CRM-FM, JASCO).⁵ The resulting solution was subjected to electronic spectral measurement at appropriate intervals. The relative efficiencies (Φ_{rel}) of the photocyclization were illustrated in Figure 1.⁶



Figure 1. Methoxy substituent effect and methylene chain effect upon photolability toward the intramolecular cycloaddition of n-methylene dicinnamates

It can be seen that the photocyclization of 3-methoxy derivative l_{C} , was exceptionally fast, while 4-methoxy derivative l_{D} , is rather slightly slow relative to the unsubstituted one la. Another noticeable point is that trimethylene chain exhibited the greatest topotactic assistance by the immobilization of the two cinnamoyl groups in favor for the photocyclization in all cases examined, and in a series of 3-methoxy derivatives l_{C} , the similar rate enhancements were observed even in tetramethylene (n=4) and pentamethylene (n=5) dicinnamates. The separate experiments on the similarly methoxy-substituted methyl cinnamates demonstrated that the rate of trans-cis isomerizations had of no marked difference from each other. Based on these results, it could be concluded that an introduction of 3-methoxy group largely accelerated the photocyclization to cyclobutane derivatives.

In order to gain further insight into the 3-methoxy substituent effect, we have performed the photolyses of l_{VV} in acetonitrile solution (ca. 2×10^{-2} M) in a preparative scale together with those of unsubstituted one l_{A} , for comparison. The photoconversions were clean and no polymer formation was observed in

all cases, indicating that the intermolecular crosslinks were negligible.⁷ The stereochemical analyses of the photoproducts were summarized in Table I.

\bigcirc	$\wedge \bigcirc$	tio ^{a)}	uct r	Prod	_	Substrate
<u>Тх</u>	ΥY	-truxinate		β-truxinate	n	
		0	:	100	2	
\cap	Х	1	:	99	3	la
\sim		72	:	28	4	
<u>δ-truxina</u>	<u>β-truxinate</u>	0		100	2	le
c the combonyla	V: nonnoconte	9	:	91	3	
s the carboxyla	moiety	27	:	73	4	

 Table I.
 3-Methoxy effect and methylene chain concentration effect upon the photoproduct composition

a) determined by the NMR integration of each photolysate

Table I shows that β -truxinate is the major product of trimethylene dicinnamates (n=3) in both cases, $\frac{1}{\sqrt{2}}$ and $\frac{1}{\sqrt{2}}$. In the case of tetramethylene derivatives (n=4), however, the major product is δ -truxinate on the unsubstituted dicinnamate $\frac{1}{\sqrt{2}}$, whereas the major product was unaltered on the 3-methoxy derivative $\frac{1}{\sqrt{2}}$. This can be interpreted as gaining an advantage of the excited state electronic structure for the formation of the transition state with the ground state cinnamoyl residue leading to the β -truxinate such as the formation of intramolecular excimer.

The electronic structures of hydroxy ring-substituted cinnamic acids were also theoretically evaluated by the CNDO/S-CI excited state calculation to assess the nature of the substituent perturbations. Details of the computed spectral and other electronic features will be presented elsewhere. However, the sense of the results pertinent to the present discussion is briefly mentioned here: the CI state of the lowest excited triplet state (T_1) consisted of nearly single HOMO-LUMO transition in all cases, while that of the lowest excited singlet state (S_1) consisted of an admixture of many configurations. 4-Hydroxy substituent enhanced the mixing of HOMO-NLUMO excitation and reduced that of NHOMO-LUMO excitation, whereas 3-hydroxy substituent enhanced the mixing of HOMO-LUMO excitation. Also, the HOMO and LUMO are largely polarized to the olefinic double bond. These characteristics of the CI states of S1 reflects strongly on the odd electron densities of the olefinic double bond. The calculated odd electron densities were listed in Table Π together with the relative efficiencies for the photocyclization (Φ_{rel}) . In fact, the observed $\Phi_{\texttt{rel}}$ were considerably well correlated with the odd electron densities at C_{α} of S_1 states as being indicated by the correlation coefficient (r) of the least square treatment between the odd electron densities (Q_{odd}) and the relative efficiencies of trimethylene derivatives of la-d (log \$rel).*

Substrate	Δ.	Q	odd
	^Φ rel	Cα	C _β
R₁=R₂≈H	1.00	0.1951	0.1462
R₁=H, R₂=OH	0.84	0.1836	0.1118
R ₁ =OH, R ₂ =H	40.69	0.2405	0.1832
R₁=R₂≈OH	5.42	0.2162	0.1525

Table II. Relative efficiencies (Φ_{rel}) and odd electron densities (Q_{odd}) of olefinic carbons on S_1 of cinnamic derivatives computed by the CNDO/S-CI method

We are elaborating the further precise nature of alkoxy substituent effect upon the intramolecular photocyclization of dicinnamates and it will be the subject of the forthcoming paper.

REFERENCES AND FOOTNOTES

1.	a) B.K.Vaidya, Proc. Roy. Soc., Ser. A, 129, 299 (1930)
	a) B.K.Vaidya, <u>Proc. Roy. Soc., Ser. A</u> , 129, 299 (1930) b) H.G.Curme, C.C.Natale, and D.J.Kelley, <u>J. Phys. Chem.</u> , <u>71</u> , 767 (1967);
	See also for the substituent effect of cinnamates; T. Ishigami, K.Nakazato,
	M. Uehara and T. Endo, <u>Tetrahedron Lett.</u> , 863 (1979)

- a) H.I.Bernstein and W.C.Quimby, J. Am. Chem. Soc., 65, 1845 (1943) b) M.D.Cohen and G.M.J.Schmidt, J. Chem. Soc., 1996 (1964) and the paper 2. following. c) J.M.Thomas, S.E.Morsi and J.P.Desvergne, "Advances in Physical Organic Chemistry" Vol. 15, edited by V.Gold and D.Bethell, Academic Press, New York, 1977, pp63-151
 - d) L.Addadi and M.Lahav, J. Am. Chem. Soc., 101, 2152 (1979)
 - e) Y.Shindo, N.Fujitani, K.Horie and I.Mita, Polymer Preprints, Japan, 31, 417 (1982)
- 3. M.Kuzuya, M.Hosoda, A.Noguchi and T.Okuda, Chem. Pharm. Bull., 30, 3838 (1982)
- a) M.Freedman, Y.Mohadger, J.Rennert, S.Soloway and I.Waltcher, Org. Prep. 4. Proceed., 1, 267 (1969) b) J.Rennert, Phot. Sci. Eng., 15, 60 (1971)
 - c) J.Rennert, S.Soloway, I.Waltcher and B.Leong, J. Am. Chem. Soc., 24, 7242 (1972)

d) P.L.Egerton, E.M.Hyde, J.Trigg, A.Payne, P.Beyon, M.V.Mijovic and A. Reiser, J. Am. Chem. Soc., 103, 3859 (1981); See also, J.Damer and D.C. Neckers, J. Am. Chem. Soc., 102, 3265 (1980) The irradiation wavelength where the UV absorption of the photoproduct is

- 5. negligible was selected in each run.
- The relative efficiencies were approximated with $\Phi_{rel} = (p \times \epsilon)^{-1}$ where p is 6. the irradiated photon number for the one-half decrease in concentration of the total dicinnamate and ε is the molar absorptivity at the irradiating wavelength.
- The isolated yields of the photoproducts were more than 90 % in all cases, 7. and each mass spectrum of the photolysates showed the molecular ion to be the same as the starting dicinnamate.
- Examinations of the similar correlation with the odd electron densities of 8. T_1 state were shown to be poor indicating that T_1 state is of minor importance for the cyclizations of these compounds.

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