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PHOTOCYCLOADDITION OF 5,7-DIMETHOXYCOUMARIN TO TETRAMETHYLETHYLENE

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The photocycloaddition reaction of DMC to TME is studied as a model for skin-sensitizing DMC-thymine C_4-cycloaddition reaction. The DMC-TME 1:1 C_4-cycloadduct is obtained with a quantum yield of 0.16. The fluorescence of DMC is quenched by TME giving a linear Stern-Volmer plot and k_q of 4×10^9 ℓ $mole^{-1}$ sec^{-1} and singlet exciplex formation mechanism is proposed for the cycloaddition of DMC to TME.

Furocoumarins are known to photoreact with pyrimidine bases in DNA upon irradiation with near UV light, producing skin erythema, and lethal and mutagenic effects in Bacteria.(1) The formation of interstrand crosslinking through C_4-photocycloaddition of 3,4- and 4',5'-double bonds to the 5,6-double bond of the pyrimidines, especially thymine, in DNA has been suggested as the cause of the photosensitization, but without firm chemical evidence. The pyrone 3,4- and furan 4',5'-double bonds are both necessary for the photosensitizing activity of furocoumarins but 5,7-dimethoxycoumarin (DMC), without the furan ring in the molecule, intercalates strongly with DNA and photobinds covalently to DNA bases causing the same photosensitization activities as furocoumarins, unlike most other coumarins.(2)

The isolation and characterization of furocoumarin-thymine photoadducts have been unsuccessful because of the complexities of the photoreactions of these compounds. The lack of bifunctionality in DMC warrants a lesser number of photoproducts upon irradiation with thymine compared to those of furocoumarins. The photocycloaddition reaction of DMC to tetramethylethylene(TME) is studied as a model for the DMC-thymine C_4-cycloaddition reaction.

A solution of DMC (2.42×10^{-3} mole) and TME (0.0337 mole) in 500 ml methanol was irradiated through a Pyrex glass filter with 350 nm light in a Rayonet reactor for 9 h. A TLC analysis (silica gel, cyclohexane-acetone 45:55 v/v) shows DMC-TME 1:1 adduct at R_f 0.95, DMC at 0.90, DMC cyclodimer at 0.85 along with several other minor products. The DMC-TME 1:1 adduct, m.p. 89.5°C, formed with a quantum yield of 0.16 is isolated by column chromatography (Wako gel C-200; cyclohexane-acetone solvent 45:55 v/v).

Elemental analysis data (C, 70.3 and H, 7.76) agreed with the molecular formula $C_{17}H_{22}O_4$ (DMC + TME). Calc. C, 70.3 and H, 7.64. The infrared spectrum shows a large blue shift of the strong carbonyl stretching band from 1,710 cm^{-1} in DMC to 1,755 cm^{-1} and a geminal methyl doublet at 1,380 cm^{-1}. The UV absorption spectrum shows λ_{max} at 283 nm but no DMC absorption maximum at 325 nm. These observations are consistent with the C_4 – photocycloaddition of the pyrone double bond in DMC to TME, as the conjugated enone chromophore is deconjugated leaving only a simple substituted benzene chromophore to absorb light as shown in DMC dimerization.(3) The NMR spectra shows four methyl groups at δ 1.27, 1.22, 1.02, and 0.75 (singlets) which are exactly the same as those of the photosensitized C_4-cycloaddition product of coumarin to TME.(4) Two aromatic protons (δ 6.2, s), six methoxy protons (δ 3.78, s) and two cyclobutyl protons in an AB pattern at δ 3.47 and 3.18 with a coupling constant of J=10 Hz unequivocally prove the structure of the product to be C_4-cycloadduct of DMC to TME.

When the photoadduct in methanol is irradiated with 254-nm light, photosplitting of the DMC-TME adduct resulted, further substantiating the cyclobutane structure of the product.

To elucidate the mechanism of this reaction, the fluorescence quenching of DMC is studied. DMC has strong fluorescence and very weak phosphorescence (Φ_F, 0.65; τ_F, 7.2 ns at 298K; Φ_P/Φ_F, 0.05 at 77K) unlike other coumarins and furocoumarins(2) and its photochemical reactivity is expected to be different from that of other coumarins. Coumarin itself, for example, reacts with TME photochemically only in the presence of sensitizers such as benzophenone to form a C_4-cycloadduct. TME quenches the fluorescence of DMC very efficiently with the quenching constant, k_q, of 4.0×10^9 ℓ $mole^{-1}$ sec^{-1} obtained from the linear Stern-Volmer plot. It is, therefore, very likely that an exciplex is formed between the DMC excited singlet state and the ground state of TME prior to cycloaddition and no triplet sensitizer is necessary for DMC to add to TME photochemically. Triplet sensitization and quenching studies are in progress.

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REFERENCES

1. L. Musajo, G. Rodighiero, G. Coporale, F. Dall'Acqua, S. Marciani, F. Bordin, F. Baccichetti and R. Bevilacqua, in Sunlight and Man, T.B. Fitzpatrick ed., University of Tokyo Press, Tokyo, 1974, pp 369.
2. C.-N. Ou, P.-S. Song, M.L. Harter, and I.C. Felkner, Photochem. Photobiol., 24, 487(1977).
3. S.C. Shim, K.Y. Choi, and P.-S. Song, ibid., 27, 25(1978).
4. J. Hanifin and E. Cohen, Tetrahedron Letters, No. 13, 1419(1966).

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