

## Photochemical Cleavage of Dibenzoylmethane and Curcumin in the Presence of *N,N*-Dimethylaniline in Methanol

Sung Sik Kim\*, Yoon Jung Mah, Ae Rhan Kim and Kyung Won Cho  
Department of Chemistry, Chonbuk National University, Chonju 561-756, Korea

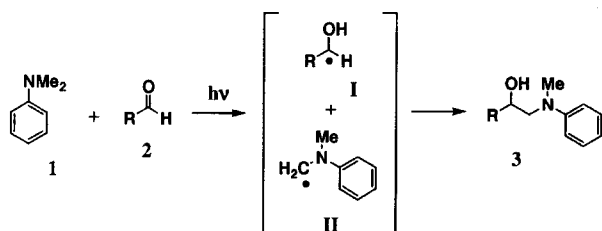
Photochemically stable dibenzoylmethane and curcumin were cleaved dramatically when they were irradiated in the presence of *N,N*-dimethylaniline in methanol with 300 nm UV light. Several products such as benzil, secondary product derived from 1,4-diphenyl-1,4-butanedione, and unidentified compound were observed from the photoreactions of dibenzoylmethane with *N,N*-dimethylaniline. It was also found that one of the primary fragments produced by irradiation of curcumin in methanol were coupled with *N,N*-dimethylaniline to give a new enone compound, *i.e.*, 1-(4-dimethylaminophenyl)-4-(4-hydroxy-3-methoxyphenyl)-but-3-en-2-one, as the major product.

**key words:** 1,3-diketone, dibenzoylmethane, curcumin, *N,N*-dimethylaniline, photochemical cleavage

### INTRODUCTION

Among a variety of compounds, *N,N*-dimethylaniline **1** affects the photochemical reactivity of carbonyl compounds, when irradiated with UV light in methanol. Regarding this fact, we previously reported the formation of reductive dimerization from the photoreactions of some carbonyl compound with *N,N*-dimethylaniline [1]. In fact, various kinds of ethanolamines are found as biologically active compounds which include adrenaline and ephedrine. Irradiation of aldehyde **2** and *N,N*-dimethylaniline **1** in methanol affords ethanolamine **3** as the major product, as shown in Scheme 1. This result was extended to the photoreactions of some aromatic aldehydes and ketones with *N,N*-dimethylaniline. The formation of **3** could be interpreted by the abstraction of hydrogen atom of the excited aldehyde from *N,N*-dimethylaniline to give radical intermediates **I** and **II**, and followed by coupling of the two radical intermediates to give the final product.

Meanwhile, dibenzoylmethane **4** is a  $\beta$ -diketone and minor



Scheme 1.

\*To whom correspondence should be addressed.

E-mail: hvssk@chonbuk.ac.kr

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constituent of sunscreens, which display anti-inflammatory and anti-tumor activity [2, 3]. Curcumin **5**, a common natural dye found in turmeric, has been used for fabric, food colorations, etc. [4, 5]. We found that *N,N*-dimethylaniline also affects the photochemical stability of  $\beta$ -diketones **4** and **5**, when irradiated them with UV light. Several photoproducts were also found and isolated from the photoreaction mixtures.

### MATERIALS AND METHODS

#### Materials

Methanol, *n*-hexane and ethyl acetate were used after distillation. *N,N*-Dimethylaniline, dibenzoylmethane and curcumin were purchased from Aldrich Chemical Co. and used as received or recrystallized prior to use. *n*-Hexane and ethyl acetate were used for column chromatography using silica gel (Kiesel Gel G, 230-400 mesh). Analytical thin layer chromatography (TLC) plates were purchased from Merck Co. as aluminum sheets (20x20 cm) precoated with 0.25 mm silica gel together with fluorescent indicator.

#### Instruments

NMR spectra were recorded on a Jeol JMN EX NMR spectrometer. Chemical shifts,  $\delta$ , were reported as parts per million (ppm) downfield from internal tetramethylsilane (TMS) standard. Ultraviolet (UV) spectra were obtained on a Hitachi 556 spectrophotometer. Infrared (IR) spectra were recorded on a Nicolet 5-DXB Fourier Transform spectro-

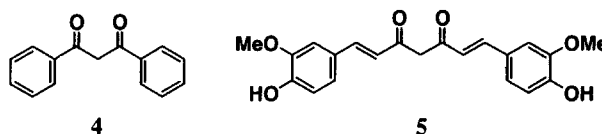


Figure 1.

photometer in KBr pellets, in which peaks are reported in reciprocal centimeters ( $\text{cm}^{-1}$ ). Mass (MS) spectra were determined on a Hewlett Packard 5985 GC/MS system using electron impact method.

#### *Irradiation of Dibenzoylmethane and Curcumin in the presence of *N,N*-Dimethylaniline*

Preparative photoreactions were conducted in a photoreactor composed of a water-cooled inner condenser and a Pyrex reaction vessel with 300 nm UV lamps (Rayonet Photochemical Reactor, Model RPR-208), after purging with nitrogen gas (purity: 99.9%) for 30 min. A solution of dibenzoylmethane (224 mg, 1 mmol) and *N,N*-dimethylaniline (10 mL) in methanol (100 mL) was irradiated with 300 nm UV light for 48 h. The photoreaction mixture was concentrated in vacuo and chromatographed over silica gel with *n*-hexane and ethyl acetate (10:1 to 4:1, v/v) as the eluent to give benzil **6**, secondary product **8** derived from 1,4-diphenyl-1,4-butanedione **7**, and unidentified product **9**. Benzil was characterized by comparison with authentic sample. 1,4-Diphenyl-1,4-butanedione was not found, as determined by flash column chromatography and NMR.

Spectral data of **8**: UV(MeOH)  $\lambda_{\text{max}}$  285, 249 nm; IR(KBr) 3075, 2940, 1695, 1591, 1449, 1265, 1191, 1000, 951, 840, 760, 692  $\text{cm}^{-1}$ ;  $^1\text{H-NMR}$ (400 MHz,  $\text{CDCl}_3$ )  $\delta$  8.14 (8H), 7.59 (4H), 7.49 (8H), 5.74 (t, 2x1H), 2.75 (d, 2x2H);  $^{13}\text{C-NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  196.4, 135.3, 133.8, 129.0, 128.8, 53.98, 28.96; Mass (EI) *m/e* 474 (M), 105.

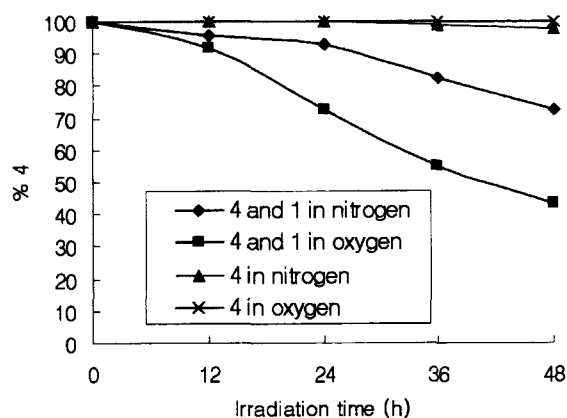
A solution of curcumin (368 mg, 1 mmol) and *N,N*-dimethylaniline (10 mL) in methanol (200 mL) was irradiated with 300 nm UV light for 24 h. The photoreaction mixture was concentrated in vacuo and chromatographed over silica gel with *n*-hexane and ethyl acetate (10:1 to 4:1, v/v) as the eluent to give 1-(4-dimethylaminophenyl)-4-(4-hydroxy-3-methoxyphenyl)-but-3-en-2-one **10** in 12 % yield.

Spectral date of **10**: UV(MeOH)  $\lambda_{\text{max}}$  322, 290, 230 nm;  $^1\text{H NMR}$ ( $\text{CDCl}_3$ )  $\delta$  8.4 (1H, s), 7.6 (1H, d), 7.4-6.8 (7H), 6.2 (1H, d), 3.7 (2H, s), 3.2 (3H, s), 2.8 (6H); Mass(EI) *m/e* 311 (M).

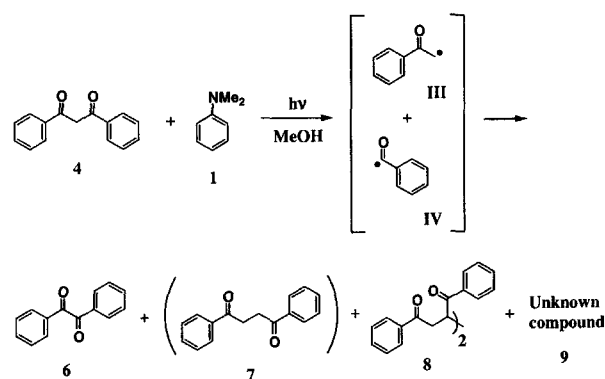
## RESULTS AND DISCUSSION

As described before,  $\beta$ -diketones, such as dibenzoylmethane **4** and curcumin **5**, are known to be photochemically stable and used to protect harmful UV light, scavenge free-radical, and suppress the growth of cancer cells [2-7, 8-10].

Recently, we found that *N,N*-dimethylaniline affects the photochemical stabilities of  $\beta$ -diketones under various conditions. To investigate the photochemical reactivity, dibenzoylmethane **4** and curcumin **5** were irradiated with 300 nm UV light in the presence of *N,N*-dimethylaniline **1** in methanol. In fact, irradiation of a solution of **4** in methanol for 24 h did not yield any noticeable products, as shown in Figure 2. In contrast, photochemical cleavage of **4** increased dramatically



**Figure 2.** % Conversion of dibenzoylmethane **4** observed in methanol in the presence and absence of *N,N*-dimethylaniline **1** after irradiation with 300 nm UV light.



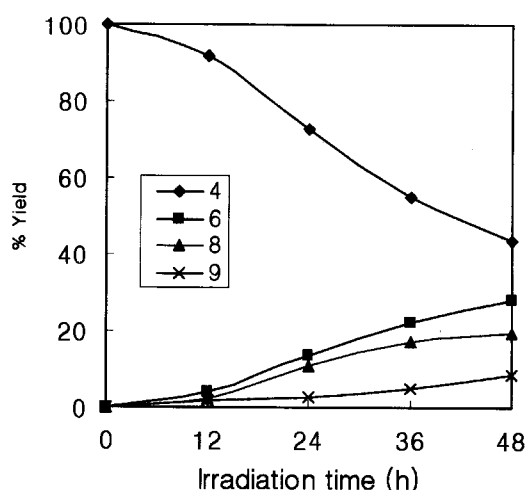
**Scheme 2.**

in the presence of **1**.

When a solution of **4** (1 mmol) and **1** (10 mL) in methanol (100 mL) was irradiated for 48 h, **4** was decomposed to give various kinds of products, as shown in Scheme 2. It was suggested that  $\alpha$ -cleavage of **4** may result in the formation of two intermediates **III** and **IV**, as suggested in Scheme 2. Homocoupling of **III** and **IV** may lead to the formation of  $\alpha$ -diketone **6** and  $\gamma$ -diketone **7**, respectively. It is noteworthy that **7** are not found from the photoreaction mixture. Based on this results, it may be suggested that  $\alpha$ -hydrogens of **7** are too active to be alive under the reaction condition. In fact, some secondary photoproducts such as **8** and **9** were found and isolated by TLC and flash column chromatography.

As for the photoreactions of **4** with **1** in methanol, % yields of the photoproducts were determined according to irradiation time, 12 h, 24 h, 36 h, and 48 h, as shown in Figure 3. % Conversion of **4** determined after irradiation for 12 h, 24 h, 36 h, and 48 h was 8%, 17%, 45%, and 56%, respectively. It was observed that the amount of benzil **6**, secondary product **8** derived from  $\gamma$ -diketone **7**, and unidentified compound **9** increases as the irradiation time increases.

The  $\gamma$ -diketone **7** was not found from the reaction mixture,

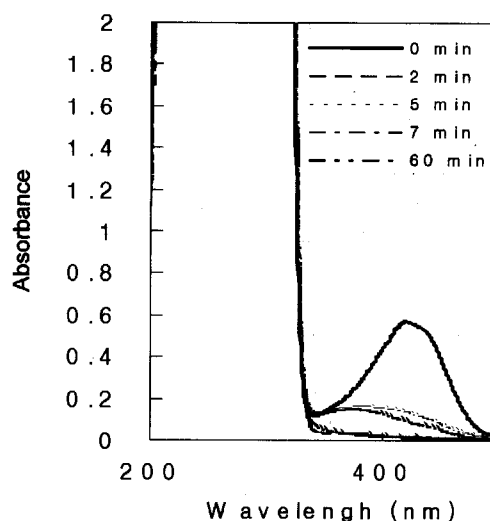


**Figure 3.** % Yields of photoproducts determined after irradiated **4** and **1** in methanol for 12 h, 24 h, 36 h, and 48 h, respectively.

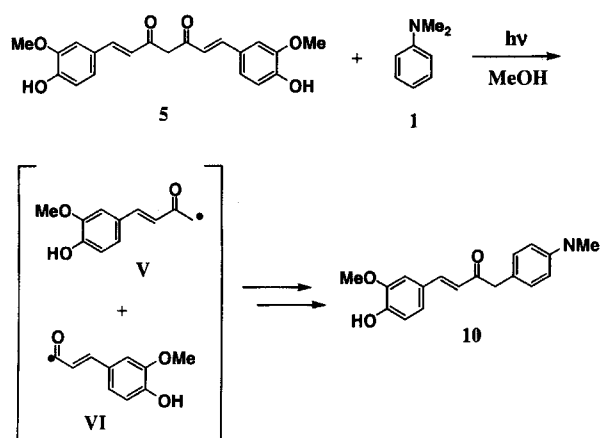
as determined by NMR and flash column chromatography. Benzil **6** was characterized by comparison with authentic sample. UV spectrum of **8** taken in methanol shows two absorption bands at 285 nm and 249 nm. IR spectrum of **8** shows aromatic CH, C=O, and aliphatic CH stretching bands at 3075, 1695, and 1449  $\text{cm}^{-1}$ .  $^1\text{H-NMR}$  spectrum shows two proton signals at  $\delta$  5.74 and  $\delta$  2.75 ppm, along with phenyl protons at  $\delta$  8.14–7.49. Two proton signals at  $\delta$  5.74 and  $\delta$  2.75 were correlated with carbon signals at  $\delta$  53.98 and  $\delta$  28.96. Mass spectrum of **8** shows two distinct peaks at  $m/e$  474 (M) and  $m/e$  105, in which the latter may be correspond to benzoyl (PhCO) group. It was found that the unknown compound **9** has carbonyl and *N,N*-dimethylamino groups, as determined by IR and NMR spectra.

Curcumin **5** was also very stable toward UV irradiation in methanol, as shown in Figure 4. The absorption band of **5** at 422 nm did not particularly decrease, as the absorption values were compared in methanol according to the irradiation time [11]. In fact, irradiation of a solution of **5** in methanol did not give any noticeable photoproducts, except for its geometric isomers. In contrast, the absorption band decreased remarkably with an increase of irradiation time, when irradiated **5** in the presence of *N,N*-dimethylaniline **1** in methanol.

Irradiation of a solution of **5** (1 mmol) and **1** (10 mL) in methanol (200 mL) was carried out in the atmosphere of nitrogen for 24 h. A new photoadduct **10** produced from **5** and **1** was isolated by flash column chromatography and characterized by spectral data. The formation of such a new enone compound could also be rationalized by  $\alpha$ -cleavage which give radical intermediates **V** and **VI**, formation of charge transfer complex between **V** and **1**, and finally aromatic substitution reaction *via* photoinduced electron transfer process to give 1-(4-dimethylaminophenyl)-4-(4-hydroxy-3-methoxyphenyl)-but-3-en-2-one **10**. Other types of products were also found in this reaction. In fact, photochemical



**Figure 4.** Visible spectral change of the photoreaction mixture after irradiation of curcumin **5** ( $10^{-5}\text{M}$ ) in methanol in the presence of **1** in the atmosphere of nitrogen for 2, 5, 7, and 60 min.



**Scheme 3.**

electron transfer from electron rich compound such as *N,N*-dimethylaniline **1** to organic molecule is possible and a variety of reactions has been published [12].

In conclusion, it is interesting to note that photochemically stable  $\beta$ -diketones **4** and **5** are decomposed easily by UV irradiation in the presence of *N,N*-dimethylaniline to give various photoproducts via  $\alpha$ -cleavage of the diketones and photoinduced electron transfer process. New types of photoproducts were isolated in these reactions. Characterization of the unknown compounds and synthetic applications of these photoreactions, as well as mechanistic investigation of this aniline-mediated photoreaction are under progress.

## ACKNOWLEDGEMENT

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