

## Solvent free solid support synthesis of arylmethylene bis(3-Hydroxy-2-cyclohexene-1-ones) and Xanthenediones derivatives by microwave irradiation

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**Abstract:** An efficient and effective microwave-assistant synthesis of arylmethylene bis(3-hydroxy-2-cyclohexene-1-ones) **1** and Xanthenediones **2** by using neutral alumina, followed by conc. Sulfuric acid catalyzed dehydration reaction was developed starting from dimedone and various aromatic aldehydes. This method provides several advantages such as high yields and simple purification procedure of products by non-chromatographic method, i.e., by simple recrystallization from ethanol. In addition, this process devoid of any expensive catalyst. The short reaction time and simple reaction condition offers a scope for the synthesis of biologically and medicinally interesting molecules.

**Keywords:** Neutral alumina; microwave irradiation; Xanthenedione; Dimedone.

### Introduction

Arylmethylene bis(3-hydroxy-2-cyclohexene-1-one) derivative **1** are important substrate extensively used as valuable precursor for the synthesis of Xanthenes and acridinediones for laser dye technology [Fig. 1] [1]. Xanthenes are known for possessing various biological properties including antibacterial, antiviral and anti-inflammatory activities [2]. These compounds have also shown potent activity as antioxidant [3], lipoxygenase inhibitors [3], and a new clinical class of tyrosinase inhibitors against very important dermatological disorder including hyperpigmentation and skin melanoma [4]. Some Xanthene derivatives are used in industry, such as fluorescent materials for visualization of biomolecules [5], in laser technologies due to their useful spectroscopic properties [6].

Xanthenedione derivatives **2** have attracted considerable interest in recent years because of their important biological properties including antibacterial [7], antiviral [8] and anti-inflammatory activities [9] as well as positive allosteric modulators of metabotropic receptors [10], potent non-peptide inhibitors of recombinant human calpain I [11] efficient in photodynamic therapy [12] and antagonists for the paralyzing action of zoxazolamine [13]. In particular,

Xanthenedione derivatives are valuable synthons because of the inherent reactivity of the inbuilt pyran ring [14]. They are also found as core units in several natural products [15]. Therefore, a great number of synthetic methods have been reported by the condensation of cyclic 1,3-dicarbonyl and aryl aldehydes in the presence of  $\text{HClO}_4\text{-SiO}_2$  [16],  $\text{Et}_4\text{NBr}/\text{NH}_4\text{Cl}$  [3],  $\text{FeCl}_3\cdot 6\text{H}_2\text{O}/\text{TMSCl}[\text{bmin}][\text{BF}_4]$  [17],  $\text{I}_2$  [18], or Lewis acid such as  $\text{InCl}_3\cdot 4\text{H}_2\text{O}$  [19],  $\text{NaHSO}_4$  [20] and heterogeneous catalysts for instance Dowex-50 W [21],  $\text{NaHSO}_4\cdot \text{SiO}_2$  [22], Silica Sulphuric acid [23], polyaniline-*p*-toluenesulfonate [24],  $\text{PPA-SiO}_2$  [25],  $\text{TiO}_2/\text{SO}_4$  [2, 26], and Amberlyst-15 [27], as a catalyst. Other catalyst, such as trimethylsilylchloride [28], *p*-dodecylbenzenesulfonic acid [29, 30, 27-29] and  $\text{NH}_2\text{SO}_3/\text{SDS}$  [31] have also been employed for the preparation of Xanthenedione derivatives. Additionally, the above condensation process could proceed in ionic liquid [32], or ethyleneglycol [33],  $\text{ZnO}$  and  $\text{ZnO}$ -acetyl chloride [34], Silica gel ( $\text{SiO}_2\text{-R-SO}_3\text{H}$ ) [35],  $\text{Fe}^{3+}$ -montmorillonite [36], Heteropolyacid ( $\text{H}_3\text{PW}_{12}\text{O}_{40}$ ) [37]. However, some of these methodologies have some disadvantage, such as low yields [24, 25], prolonged reaction time [19, 20], harsh reaction condition [38] and the requirement of excess catalyst [28]. Thus the development of simple, highly efficient methodologies remains desired. Herein, we reported a

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novel method of synthesis of arylmethylene bis(3-hydroxy-2-cyclohexene-1-ones) using solid support

solvent free by microwave irradiation.

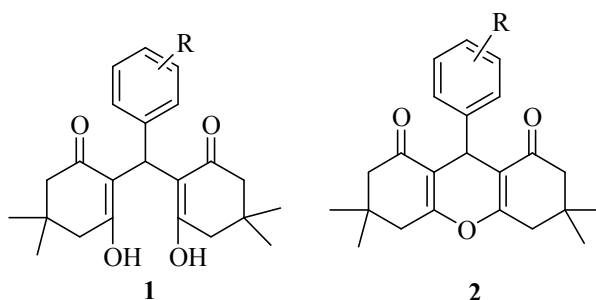
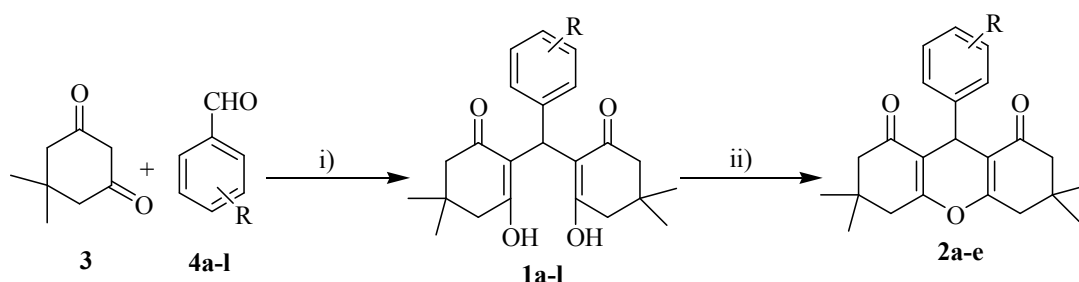


Figure 1.

### Results and Discussion

As an inexpensive, efficient and environmentally safe alumina has been used extensively in organic synthesis for a long time. In recent years, more and more organic transformations mediated by solid support have been documented. For the synthesis of **1** and **2**, we selected 5,5-dimethylcyclohexane-1,3-dione (dimedone) as a starting material and used microwave-assistant reaction condition. In an initial experiment, dimedone **3** (1.88 mmol), benzaldehyde **4a** (0.94 mmol) and neutral alumina was introduced in a microwave chamber and irradiated with 50 W at 25 °C for 5 min. It furnished a white solid product **1a** in a low yield (27%). Compound **1a** was identified by the spectral methods. The presence of two singlet at  $\delta$  11.91 and  $\delta$  5.45 in  $^1\text{H}$  NMR and peaks at  $3432\text{ cm}^{-1}$  and  $1592\text{ cm}^{-1}$  in IR spectra clearly indicate the formation of **1a**. In an attempt to improve the yield, we further optimized the reaction condition by employing various watt,

temperatures and times. This conversion was found to be even slower and yielded lower yield of the product when either we used 100 W and 50 °C temperature, 10 min and neutral alumina. Significant improvement was achieved by using 150 W, 65 °C, 7 min and neutral alumina. Compound **1a** was isolated by recrystallization from ethanol in 87% yield. This success prompted us to extend this methodology for a similar synthesis of arylmethylene bis(3-hydroxy-2-cyclohexene-1-one) derivatives **1b-l** summarized in Table 1. We have thus used "optimal" procedure for all subsequent reactions. Dimedone (1.88 mmol), aryl aldehydes (0.94 mmol), neutral alumina (200 mg) were irradiated with 150 W, at 65 °C. The progresses of the reactions were monitored by TLC; the reactions took 5-10 min to go to completion.



**Scheme 1.** Reagents and conditions: (i) Neutral alumina, MW 150 W, 65 °C, 5-10 min.

(ii) Neutral alumina, conc.  $\text{H}_2\text{SO}_4$ , MW 150 W, 70 °C, 7-12 min

All compounds were analytically pure and structures were determined by analysis of spectral data. It follows from Table 1, that electron-rich, electron-neutral and

electron-deficient aldehydes furnished corresponding products in good to excellent yields. Aromatic aldehydes carrying electron-deficient substituent react

in a shorter reaction time with excellent yields compared to the presence of electron-rich substituent in aromatic aldehydes and under similar reaction

condition aliphatic aldehydes did not give any desired products.

**Table 1.** Synthesis of 2, 2-arylmethylenebis(3-hydroxy-5,5-dimethyl-2-cyclohexene-1-ones)<sup>a</sup>

Entry	Aryl aldehydes	Product	Yield (%)	Time (min)
1	Benzaldehyde	1a	87	7
2	4-Methoxybenzaldehyde	1b	81	8
3	3-nitrobenzaldehyde	1c	86	6
4	4-Flurobenzaldehyde	1d	88	6
5	4-Bromobenzaldehyde	1e	85	6
6	2-methylbenzaldehyde	1f	83	7
7	4-cyanobenzaldehyde	1g	87	6
8	3-chlorobenzaldehyde	1h	81	7
9	4-dimethylaminobenzaldehyde	1i	80	10
10	4-methylbenzaldehyde	1j	84	8
11	4-nitrobenzaldehyde	1k	94	5
12	4-chlorobenzaldehyde	1l	89	6

<sup>a</sup> Reaction condition: (i) Neutral alumina, MW 150 W, 65 °C, 5-10 min.

Compound **1a** contained divenyl alcohol moiety and therefore it was very susceptible for the dehydration. Compound **1a** was subjected to microwave irradiation in presence of neutral alumina, and catalytic amount of conc. sulfuric acid furnished a white solid **2a** in 87 % yield. The appearance of a singlet at  $\delta$  4.78 and disappearance of the singlet at  $\delta$  11.91 in <sup>1</sup>H NMR and the peak 1662 cm<sup>-1</sup> in IR clearly indicate the formation of cyclized product **2a**. This result encouraged us to extend this method to synthesize other substituted Xanthenediones (Table 2). On similar treatment, compounds **1b-e** produced compounds **2b-e** in good to

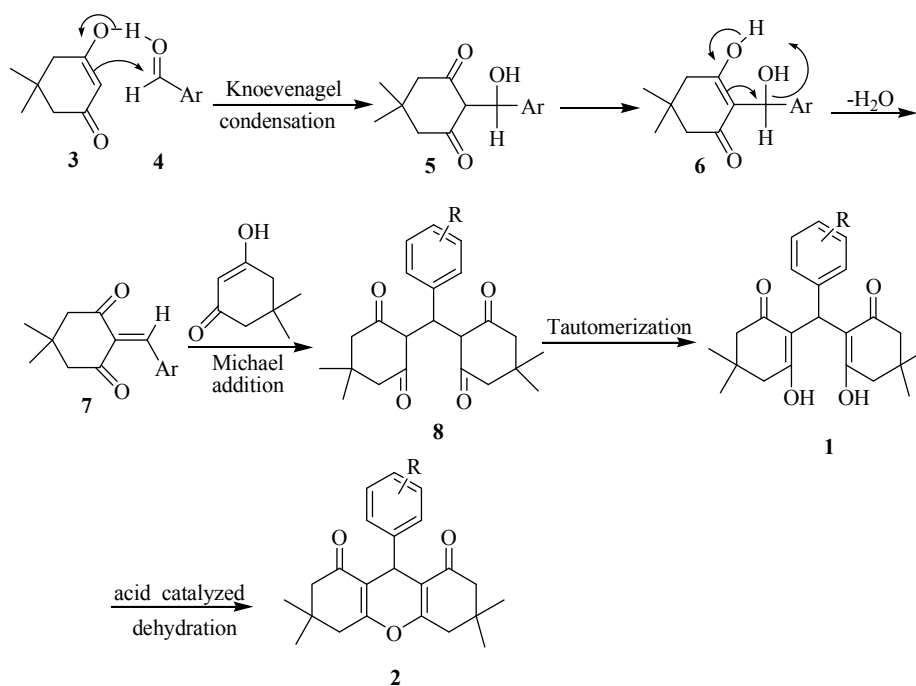
excellent yields. The structures of the products **2b-e** were confirmed from their elemental analysis and spectral data.

The proposed mechanism for the formation of compound **1** and **2** is shown in the scheme 2. The formation of compounds **1a-l** in presence of neutral alumina, ethylacetate can easily be explained by self catalyzed knoevenagel condensation (**7**) followed by Michael addition (**8**) and tautomerization (**1**). Acid catalyzed dehydration of compound **1a-e** furnished cyclic products **2a-e**.

**Table 2.** Synthesis of Xanthenediones

Entry	Aryl aldehydes	Product	Yield (%)	Time(min)
1	Benzaldehyude	2a	87	8
2	4-Methoxybenzaldehyde	2b	80	12
3	3- Nitrobenzaldehyde	2c	84	7
4	4-Flurobenzaldehyde	2d	86	7
5	4- Bromobenzaldehyde	2e	91	8

Reaction condition: (i) Neutral alumina, conc. H<sub>2</sub>SO<sub>4</sub>, MW 150 W, 70 °C, 7-12 min



Scheme 2.

## Experimental

All the experiment was carried out in MATTHEWS, NC- MADE IN USA. MODEL-DISCOVER-S. MODEL NO-NP-1009, Microwaves Digester in closed vessel. Melting points were determined in open capillaries and are uncorrected. IR spectra were recorded on Spectrum BX FT-IR, Perkin Elmer ( $\nu_{\max}$  in  $\text{cm}^{-1}$ ) on KBr disks.  $^1\text{H}$  NMR and  $^{13}\text{C}$  NMR (400 MHz and 100 MHz respectively) spectra were recorded on Bruker Avance II-400 spectrometer in  $\text{CDCl}_3$  (chemical shifts in  $\delta$  with TMS as internal standard). Mass spectra were recorded on Waters 2695. CHN were recorded on CHN-OS analyzer (Perkin Elmer 2400, Series II). Silica gel G (E-mark, India) was used for TLC. Hexane refers to the fraction boiling between  $60^\circ\text{C}$  and  $80^\circ\text{C}$ .

*2,2'-arylmethylene bis(3-hydroxy-5,5-dimethyl-2-cyclohexene-1-one) (1a):*

mp  $198\text{--}200^\circ\text{C}$ . White solid. IR (KBr): 3432, 2962,  $1592\text{ cm}^{-1}$ .  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta = 11.91$  (s, 1H), 7.28-7.08 (m, 5H), 5.54 (s, 1H), 2.48-2.29 (m, 8H), 1.23 (s, 6H), 1.10 (s, 6H).  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta = 190.5, 189.4, 138.0, 128.2, 126.7, 125.8, 115.5, 47.0, 46.4, 32.7, 31.4, 29.6, 27.3$ ; FAB- MS:  $m/z$  369  $[\text{M} + \text{H}]^+$ . Anal. Calcd for  $\text{C}_{23}\text{H}_{28}\text{O}_4$ : C, 74.97; H, 7.66. Found: C, 74.92; H, 7.73.

*4-Methoxy-2,2'-arylmethylene bis(3-hydroxy-5,5-dimethyl-2-cyclohexene-1-one) (1b):*

*General procedure for the synthesis of Compound 1a-l.*

Dimedone **3** (200 mg, 1.88 mmol), aryl aldehydes **4a-l** (0.94 mmol), neutral alumina 200 were thoroughly mixed. The resulting mixture was subjected to microwave irradiation (CEM Discover Bench Microwaves Digester) for 5-10 min, 150 W and  $65^\circ\text{C}$  temperature. The reaction was monitored by TLC. After completion, the reaction mixture was cooled to room temperature. Then it was dissolved in 10 mL ethylacetate and filtered, removal of the solvent under vacuo furnished solid compounds, which were then recrystallized from ethanol to get pure crystalline products **1a-l**.

mp  $230\text{--}231^\circ\text{C}$ . White solid. IR (KBr): 3447, 2959,  $1604\text{ cm}^{-1}$ .  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta = 11.93$  (s, 1H), 7.01 (d,  $J = 8.4$  Hz, 2H), 6.82 (d,  $J = 8.8$  Hz, 2H), 5.49 (s, 1H), 3.78 (s, 3H), 2.48-2.29 (m, 8H), 1.23 (s, 6H), 1.10 (s, 6H).  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta = 190.4, 189.3, 157.5, 129.8, 127.7, 115.7, 113.6, 55.2, 47.0, 46.4, 32.0, 31.3, 29.6, 27.3$ ; FAB- MS:  $m/z$  399  $[\text{M} + \text{H}]^+$ . Anal. Calcd for  $\text{C}_{24}\text{H}_{30}\text{O}_5$ : C, 72.34; H, 7.59. Found: C, 72.13; H, 7.65.

*3-Nitro-2,2'-arylmethylene bis(3-hydroxy-5,5-dimethyl-2-cyclohexene-1-one) (1c):*

mp 158-160 °C. Off White solid. IR (KBr): 3410, 2960, 1593  $\text{cm}^{-1}$ .  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 11.87 (s, 1H), 8.05-8.00 (m, 2H), 7.46-7.40 (m, 2H), 5.54 (s, 1H) 2.52-2.31 (m, 8H), 1.27 (s, 6H), 1.12 (s, 6H).  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 191.1, 189.6, 148.3, 140.6, 132.8, 129.0, 122.2, 121.0, 114.7, 46.9, 46.4, 32.8, 31.4, 29.6, 27.2; FAB-MS:  $m/z$  414  $[\text{M} + \text{H}]^+$ . Anal. Calcd for  $\text{C}_{23}\text{H}_{27}\text{NO}_6$ : C, 66.81; H, 6.58; N, 3.39 Found: C, 66.97; H, 6.37; N, 3.62.

*4-Fluoro-2,2'-arylmethylene bis(3-hydroxy-5,5-dimethyl-2-cyclohexene-1-one (1d):*

mp 119-120°C. White solid. IR (KBr): 3432, 2962, 1592  $\text{cm}^{-1}$ .  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 11.92 (s, 1H), 7.08-6.96 (m, 4H), 5.51 (s, 1H), 2.51-2.32 (m, 8H), 1.25 (s, 6H), 1.13 (s, 6H).  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 190.5, 189.4, 162.2, 159.8, 133.6, 128.2, 115.5, 115.1, 114.9, 47.0, 46.4, 32.2, 31.4, 29.6, 27.3; FAB- MS:  $m/z$  387  $[\text{M} + \text{H}]^+$ . Anal. Calcd for  $\text{C}_{23}\text{H}_{27}\text{FO}_4$ : C, 71.48; H, 7.04. Found: C, 71.56; H, 7.16.

*4-Bromo-2,2'-arylmethylene bis(3-hydroxy-5,5-dimethyl-2-cyclohexene-1-one (1e):*

mp 220-222 °C. White solid. IR (KBr): 3435, 2957, 1596  $\text{cm}^{-1}$ .  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 11.88 (s, 1H), 7.38 (d,  $J$  = 8.0 Hz, 2H), 6.96 (d,  $J$  = 8.4 Hz, 2H), 5.44 (s, 1H), 2.48-2.28 (m, 8H), 1.21 (s, 6H), 1.10 (s, 6H).  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 190.6, 189.4, 137.2, 131.2, 128.6, 119.6, 115.2, 47.0, 46.4, 32.4, 31.4, 29.6, 27.4; FAB-MS:  $m/z$  447, 449  $[\text{M} + \text{H}]^+$ . Anal. Calcd for  $\text{C}_{23}\text{H}_{27}\text{BrO}_4$ : C, 61.75; H, 6.08. Found: C, 61.65; H, 6.34.

*2-Methyl-2,2'-arylmethylene bis(3-hydroxy-5,5-dimethyl-2-cyclohexene-1-one (1f):*

mp 156-158°C. White solid. IR (KBr): 3384, 2956, 1608  $\text{cm}^{-1}$ .  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 11.62 (s, 1H), 7.56-7.24 (m, 4H), 6.04 (s, 1H), 2.52-2.02 (m, 8H), 2.18 (s, 3H), 1.16 (s, 6H), 1.02 (s, 6H).  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 190.6, 189.4, 136.7, 131.5, 128.3, 128.2, 115.3, 47.0, 46.4, 32.3, 31.4, 29.6, 27.4; FAB- MS:  $m/z$  383  $[\text{M} + \text{H}]^+$ . Anal. Calcd for  $\text{C}_{24}\text{H}_{30}\text{O}_4$ : C, 75.36; H, 7.91. Found: C, 75.61; H, 8.13.

*4-Cyano-2-Methyl-2,2'-arylmethylene bis(3-hydroxy-5,5-dimethyl-2-cyclohexene-1-one (1g):*

mp 210-212 °C. White solid. IR (KBr): 3439, 2963, 1594  $\text{cm}^{-1}$ .  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 11.80 (s, 1H), 7.57 (d,  $J$  = 8.4 Hz, 2H), 7.20 (d,  $J$  = 8.4 Hz, 2H), 5.52 (s, 1H) 2.50-2.30 (m, 8H), 1.22 (s, 6H), 1.11 (s,

6H).  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  190.9, 190.6, 189.5, 144.3, 132.9, 132.0, 129.8, 127.6, 118.9, 114.8, 109.6, 46.9, 46.4, 33.2, 31.4, 29.5, 27.4; FAB- MS:  $m/z$  394  $[\text{M} + \text{H}]^+$ . Anal. Calcd for  $\text{C}_{24}\text{H}_{27}\text{NO}_4$ : C, 73.26; H, 6.92; N, 3.56. Found: C, 73.14; H, 6.93; N, 3.69.

*3-Chloro-2,2'-arylmethylene bis(3-hydroxy-5,5-dimethyl-2-cyclohexene-1-one (1h):*

mp 175-176 °C. White solid. IR (KBr): 3431, 2952, 1596  $\text{cm}^{-1}$ .  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 11.92 (s, 1H), 7.22-6.96 (m, 4H), 5.49 (s, 1H), 2.50-2.30 (m, 8H), 1.23 (s, 6H), 1.10 (s, 6H).  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 190.6, 189.4, 140.4, 134.1, 129.4, 127.1, 126.0, 124.9, 115.1, 47.0, 46.3, 32.6, 31.4, 29.5, 27.3; FAB- MS:  $m/z$  403, 405  $[\text{M} + \text{H}]^+$ . Anal. Calcd for  $\text{C}_{23}\text{H}_{27}\text{ClO}_4$ : C, 68.56; H, 6.75. Found: C, 68.43; H, 6.66.

*4-Aminodimethyl-2,2'-arylmethylene bis(3-hydroxy-5,5-dimethyl-2-cyclohexene-1-one (1i):*

mp 227-228 °C. Orange solid. IR (KBr): 3434, 2959, 1601  $\text{cm}^{-1}$ .  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 11.95 (s, 1H), 6.95 (d,  $J$  = 8.4 Hz, 2H), 6.67 (d,  $J$  = 8.4 Hz, 2H), 5.47 (s, 1H), 2.89 (s, 6H), 2.46-2.28 (m, 8H), 1.22 (s, 6H), 1.09 (s, 6H).  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 190.2, 189.3, 148.7, 127.4, 125.5, 115.9, 112.6, 47.0, 46.4, 40.7, 31.8, 31.3, 29.7, 27.3; FAB- MS:  $m/z$  412  $[\text{M} + \text{H}]^+$ . Anal. Calcd for  $\text{C}_{25}\text{H}_{33}\text{NO}_4$ : C, 72.96; H, 8.08; N, 3.40. Found: C, 73.20; H, 8.36; N, 3.36.

*4-Methyl-2,2'-arylmethylene bis(3-hydroxy-5,5-dimethyl-2-cyclohexene-1-one (1j):*

mp 208-210°C. White solid. IR (KBr): 3430, 2960, 1602  $\text{cm}^{-1}$ .  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 11.91 (s, 1H), 7.08 (d,  $J$  = 8.0 Hz, 2H), 6.98 (d,  $J$  = 8.0 Hz, 2H), 5.49 (s, 1H), 2.47-2.32 (m, 8H), 2.29 (s, 3H), 1.22 (s, 6H), 1.09 (s, 6H).  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 190.4, 189.3, 135.2, 134.9, 128.9, 126.6, 115.7, 47.0, 46.4, 32.4, 31.4, 29.6, 27.3, 20.9; FAB- MS:  $m/z$  383  $[\text{M} + \text{H}]^+$ . Anal. Calcd for  $\text{C}_{24}\text{H}_{30}\text{O}_4$ : C, 75.36; H, 7.91. Found: C, 75.41; H, 7.93.

*4-Nitro-2,2'-arylmethylene bis(3-hydroxy-5,5-dimethyl-2-cyclohexene-1-one (1k):*

mp 229-231°C. Yellow solid. IR (KBr): 3447, 2959, 1593  $\text{cm}^{-1}$ .  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 11.85 (s, 1H), 8.18 (d,  $J$  = 8.8 Hz, 2H), 7.28 (d,  $J$  = 8.0 Hz, 2H), 5.57 (s, 1H), 2.54-2.34 (m, 8H), 1.26 (s, 6H), 1.14 (s, 6H).  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 190.9, 189.5, 146.5, 146.0, 127.6, 123.5, 114.9, 46.9, 46.4, 33.2, 31.4, 29.5, 27.4; FAB- MS:  $m/z$  414  $[\text{M} + \text{H}]^+$ . Anal.

Calcd for  $C_{23}H_{27}NO_6$ : C, 66.81; H, 6.58; N, 3.39. Found: C, 66.58; H, 6.44; N, 3.60.

*4-Chloro-2,2'-arylmethylene bis(3-hydroxy-5,5-dimethyl-2-cyclohexene-1-one (11))*:

mp 210-212 °C. White solid. IR (KBr): 3446, 2957, 1594  $cm^{-1}$ .  $^1H$  NMR (400 MHz,  $CDCl_3$ ):  $\delta$  = 11.87 (s, 1H), 7.23 (d,  $J$  = 8.4 Hz, 2H), 7.02 (d,  $J$  = 8.0 Hz, 2H), 5.47 (s, 1H), 2.48-2.28 (m, 8H), 1.21 (s, 6H), 1.09 (s, 6H).  $^{13}C$  NMR (100 MHz,  $CDCl_3$ ):  $\delta$  = 190.6, 189.4, 136.7, 131.5, 128.3, 128.2, 115.3, 47.0, 46.4, 32.3, 31.4, 29.6, 27.4; FAB-MS:  $m/z$  403, 405  $[M + H]^+$ . Anal. Calcd for  $C_{23}H_{27}ClO_4$ : C, 68.56; H, 6.75. Found: C, 68.81; H, 6.97.

*General procedure for the synthesis of Compound 2a-e*:

A mixture of arylmethylene bis(3-hydroxy-2-cyclohexene-1-ones) **1a-e** (50 mg, 0.13 mmol), neutral alumina 50 mg, and catalytic amount of conc.  $H_2SO_4$  were placed inside a microwave oven (CEM Discover Bench Microwaves Digester). After irradiation with 150 W, for 7-12 min at 70 °C, the mixture was then cooled to room temperature and small volume of ethylacetate (5 mL) was added. After filtration, the filtrate was washed with 10 % NaOH (2  $\times$  10 mL) solution,  $H_2O$  (3  $\times$  10 mL) and brine (10 mL) and dried over anhy.  $Na_2SO_4$ . Solvent was removed under vacuo and solid products were obtained, which was further recrystallized from ethanol.

*9-Aryl-3,3,6,6-tetramethyltetrahydroanthene-1,8-dione (2a)*:

mp 198-199 °C. White solid. IR (KBr): 2959, 1662  $cm^{-1}$ .  $^1H$  NMR (400 MHz,  $CDCl_3$ ):  $\delta$  = 7.29-7.05 (m, 5H), 4.78 (s, 1H), 2.46 (s, 4H), 2.25-2.14 (m, 4H), 1.09 (s, 6H), 0.98 (s, 6H).  $^{13}C$  NMR (100 MHz,  $CDCl_3$ ):  $\delta$  = 196.4, 162.2, 144.0, 128.3, 128.0, 126.3, 115.6, 50.7, 40.8, 32.1, 32.0, 29.2, 27.1; FAB-MS:  $m/z$  351  $[M + H]^+$ . Anal. Calcd for  $C_{23}H_{26}O_3$ : C, 78.83; H, 7.48. Found: C, 78.90; H, 7.46.

*9-(4-Methoxy-phenyl)-3,3,6,6-tetramethyltetrahydroanthene-1,8-dione (2b)*:

mp 230-232 °C. White solid. IR (KBr): 2958, 1677  $cm^{-1}$ .  $^1H$  NMR (400 MHz,  $CDCl_3$ ):  $\delta$  = 7.21 (d,  $J$  = 8.8 Hz, 2H), 6.76 (d,  $J$  = 8.8 Hz, 2H), 4.69 (s, 1H), 3.72 (s, 3H), 2.45 (s, 4H), 2.25-2.14 (m, 4H), 1.09 (s, 6H), 0.99 (s, 6H).  $^{13}C$  NMR (100 MHz,  $CDCl_3$ ):  $\delta$  = 196.5, 162.0, 157.9, 136.4, 129.3, 115.7, 113.4, 55.0, 50.7, 40.8, 32.1, 30.9, 29.2, 27.3; FAB-MS:  $m/z$  381  $[M + H]^+$ .

Anal. Calcd for  $C_{24}H_{28}O_4$ : C, 75.76; H, 7.42. Found: C, 75.92; H, 7.22.

*9-(3-Nitro-phenyl)-3,3,6,6-tetramethyltetrahydroanthene-1,8-dione (2c)*:

mp 165-166 °C. White solid. IR (KBr): 2959, 1659  $cm^{-1}$ ;  $^1H$  NMR (400 MHz,  $CDCl_3$ ):  $\delta$  = 8.03-7.27 (m, 4H), 4.84 (s, 1H), 2.51 (s, 4H), 2.27-2.15 (m, 4H), 1.11 (s, 6H), 1.00 (s, 6H).  $^{13}C$  NMR (100 MHz,  $CDCl_3$ ):  $\delta$  = 196.4, 163.0, 148.2, 146.2, 135.7, 128.8, 122.5, 121.6, 114.5, 50.6, 40.7, 32.2, 32.0, 29.1, 27.2; FAB-MS:  $m/z$  396  $[M + H]^+$ . Anal. Calcd for  $C_{23}H_{25}NO_5$ : C, 69.86; H, 6.37; N, 3.54. Found: C, 70.03; H, 6.49; N, 3.77.

*9-(4-Fluro-phenyl)-3,3,6,6-tetramethyltetrahydroanthene-1,8-dione (2d)*:

mp 188-190 °C. White solid. IR (KBr): 2957, 1661  $cm^{-1}$ .  $^1H$  NMR (400 MHz,  $CDCl_3$ ):  $\delta$  = 7.19-7.16 (m, 2H), 6.84-6.80 (m, 2H), 4.65 (s, 1H), 2.39 (s, 4H), 2.18-2.07 (m, 4H), 1.03 (s, 6H), 0.91 (s, 6H).  $^{13}C$  NMR (100 MHz,  $CDCl_3$ ):  $\delta$  = 196.4, 162.5, 162.3, 160.1, 139.9, 129.7, 115.4, 114.9, 114.7, 50.7, 40.8, 32.2, 31.2, 29.2, 27.2; FAB-MS:  $m/z$  369  $[M + H]^+$ . Anal. Calcd for  $C_{23}H_{25}FO_3$ : C, 74.98; H, 6.84. Found: C, 74.95; H, 7.05.

*9-(4-Bromo-phenyl)-3,3,6,6-tetramethyltetrahydroanthene-1,8-dione (2e)*:

mp 208-210 °C. White solid. IR (KBr): 2951, 1661  $cm^{-1}$ .  $^1H$  NMR (400MHz,  $CDCl_3$ )  $\delta$  = 7.35 (d,  $J$  = 8.0 Hz, 2H), 7.19 (d,  $J$  = 8.4Hz, 2H), 4.70 (s,1H), 2.46 (s, 4H), 2.26-2.15 (m, 4H), 1.11 (s, 6H), 0.99 (s, 6H). MS:  $m/z$  429, 431  $[M + H]^+$ . Anal. Calcd for  $C_{23}H_{25}BrO_3$ : C, 64.34, H, 5.87. Found: C, 64.52; H, 6.12.

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