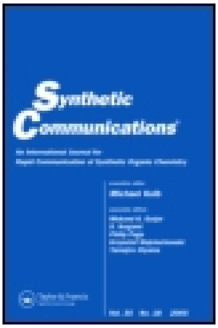

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Catalyst-Free Synthesis of α,α-bis(4-Hydroxycoumarin-3-yl)toluene in Aqueous Media Under Microwave Irradiation

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Abstract: An efficient catalyst-free synthesis of α,α-bis(4-hydroxycoumarin-3-yl)toluene was performed by the reaction of 4-hydroxycoumarin with aromatic aldehydes in aqueous media under microwave irradiation. The reaction was completed in short reaction time of 8–10 min with high yields of 76–94, was environmental benign, and had easy workup. Their structures were confirmed by IR spectra, ^{1}H NMR, ^{13}C NMR, and elemental analysis.

Keywords: Aqueous media, aromatic aldehyde, α,α-bis(4-hydroxycoumarin-3-yl)toluene, 4-hydroxycoumarin, microwave irradiation

Coumarin derivatives are widespread in nature and have various biological activities such as anticoagulant, insecticidal, antihelminthic, hypnotic, antifungal, phytoalexin, and HIV protease inhibition.[1–3] It was found that the minimum active harmacophore consisted of a coumarin dimer containing an aryl substituent on the central linker methylene.[3,4] The addition of 4- and 7-hydroxy substituents in the coumarin rings improved the potency of the compounds. Among the systems studied, the α,α-benzylidene bis(4-hydroxycoumarin-3-yl)toluene has been tested as a HIV integrase inhibitor and has shown significant activity.[3] The compound is a

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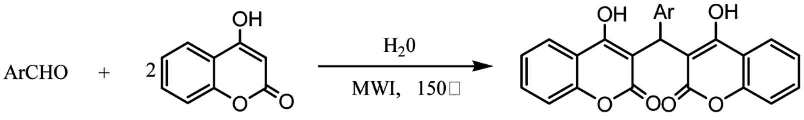
4-hydroxycoumarin (4-hc) dimer, consisting of two monomeric building blocks of 4-hc and a phenyl ring on the central methylene linker.[5] However, α,α-benzylidene bis(4-hydroxycoumarin-3-yl)toluene is usually prepared by the condensation of carbonyl compounds with 4-hydroxycoumarin in organic solvents,[3,6a–d] which employs large amounts of hazardous and toxic solvents associated with catalysts, such as piperidine,[7] ethylenediammonium diacetate,[8] glacial acetic acid, and acetic anhydride.[6a]

In today's world, synthetic chemists in both academia and industry are constantly challenged to consider more environmentally benign methods for generation of the desired target molecules. Among the 12 principles of green chemistry, the desire for to utilize "safer solvents" and to "design for energy efficiency" can be considered 2 key principles of relevance to synthetic chemists.[9] Because of the toxic and volatile nature of many organic solvents, water as a reaction medium was considered a very promising and attractive substitute for volatile organic solvents and was widely used in the green chemistry area since Breslow,[10] who showed that hydrophobic effects could strongly enhance the rate of several organic reactions, rediscovered the use of water as a solvent in organic chemistry in 1980s. There has been growing recognition that water is an attractive medium for many organic reactions, resulting in less expensive, less dangerous, and environmentally friendly reactions, such as Diels–Alder reactions,[11] Claisen rearrangement reactions,[12] Reformatsky reactions,[13] and pinacol-coupling reactions.[14] It is known that microwave irradiation has been utilized as one of the most convenient and efficient ways to promote organic reactions.[15–17] In particular, the use of microwave energy to directly heat chemical reactions has become an increasingly popular technique in the scientific community. Therefore, in recent years, the combination of these two prominent green chemistry principles, microwaves and water, has become very popular and received substantial interest due to the work of Leadbeater[18] and others who demonstrated that a great variety of synthetic organic transformations can be carried out very efficiently and rapidly under these environmentally benign conditions.

Recently, several methods of synthesis using 4-hydroxycoumarin for preparation of α,α-bis(4-hydroxycoumarin-3-yl)toluene in aqueous media have been reported. Despite effectiveness and ecofriendliness of these methods, they use catalysts such as TEBA[19] and I_2[20] and have long reaction times. Thus, the introduction of efficient new methods based on green methodology is still in great demand. In our laboratory, continuing our interest in the synthesis of organic compounds by microwave irradiation,[21–24] we report an efficient, simple, and practical method for the catalyst-free synthesis of α,α-bis (4-hydroxycoumarin-3-yl)toluene **3** using aromatic aldehydes **1** and 4-hydroxy-coumarin **2** in aqueous media under microwave irradiation (Scheme 1). The reactions were completed



1 2 3

Scheme 1. a: Ar = C_6H_5, b: Ar = 4-ClC_6H_4, c: Ar = 4-$NO_2C_6H_4$, d: Ar = 4-$CH_3C_6H_4$, e: Ar = 4-$CH_3OC_6H_4$, f: Ar = 3,4-$(CH_3O)_2C_6H_3$, g: Ar = 3,4-$OCH_2OC_6H_3$, h: Ar = 4-$N(CH_3)_2C_6H_4$, and i: Ar = 4-$OHCC_6H_4$.

in short reaction times of 8–10 min with high yields of 76–94%, were environmental benign, and had easy workup.

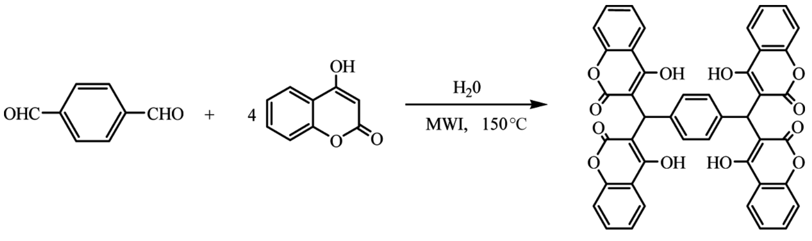
RESULTS AND DISCUSSION

As is shown in Table 1, the catalyst-free reaction of aromatic aldehyde and 4-hydroxycoumarin needs only 8–10 min in aqueous media under microwave irradiation at 150 W and 150°C. It had other advantages such as only filteration, easy operation, high yield, and less pollution. Furthermore, the reaction has been found to be applicable to dialdehyde as exemplified by using 1,4-benzenedialdehyde. Two carbonyl groups from the dialdehyde were reacted with four molecules of 4-hydroxycoumarin to afford the product **4** in 86% yield (Scheme 2). The structures of these compounds were established by spectroscopic and analytical data. The

Table 1. Catslyst-free synthesis of **3a–h**, and **4** in aqueous media under microwave irradiation

Compounds	Ar	Time (min)[a]	Yield (%)[b]	Mp (°C)	lit. mp[19,20,25,6a]
3a	C_6H_5	9	85	233–234	228–230
3b	4-ClC_6H_4	9	92	258–259	259–261
3c	4-$NO_2C_6H_4$	8	91	238–239	232–234
3d	4-$CH_3C_6H_4$	9	94	269–270	271–272
3e	4-$CH_3OC_6H_4$	8	76	249–250	245–247
3f	3,4-$(CH_3O)_2C_6H_3$	8	84	269–270	265–267
3g	3,4-$OCH_2OC_6H_3$	9	85	264–265	255–257
3h	4-$N(CH_3)_2C_6H_4$	9	95	216–217	210
4	4-$OHCC_6H_4$	10	86	307–309	313–315

[a] Microwave power: 150 W; reactive temperature: 150 °C.
[b] Yields of the isolated products.



1i **2** **4**

Scheme 2. Catalyst-free synthesis of 1,4($\alpha,\alpha',\alpha'',\alpha'''$)teter (4-hydroxycoumarin-3-yl)toluene in aqueous media under microwave irradiation.

IR spectra of compounds show the OH stretching at 3400 cm^{-1} region and a strong absorption at 1670 cm^{-1}, due to the C=O group. The ^1H NMR spectra of compound **3a**–**3g** show the OH proton absorption at 11.30 and 11.50 ppm in $CDCl_3$. However, because of the OH and aqueous DMSO-d_6 in exchange, the OH proton absorption of **3h** and **4** disappeared in DMSO-d_6.

The reaction may proceed via addition, elimination, and addition[19] (*i.e.*, benzylidene is formed by nucleophilic addition of 4-hydroxycoumarin to the benzaldehyde followed by dehydration, in the Michael addition fashion, to give α,α-bis(4-hydroxycoumarin-3-yl)toluene).[20]

In conclusion, an efficient, simple, and practical method for the catalyst-free synthesis of α,α-bis(4-hydroxycoumarin-3-yl)toluene from the corresponding aromatic aldehydes and 4-hydroxycoumarin in aqueous media under microwave irradiation has been developed.

EXPERIMENTAL

Melting points were determined with an WRS-1B digital melting-point apparatus and are uncorrected. IR spectra were recorded on a Nicolet Avatar 360 FT-IR instrument. ^1H NMR spectra were measured on a Burke 400-MHz spectrometer in $CDCl_3$ or DMSO-d_6 using TMS as an internal standard. Elemental analyses were determined using a Perkin-Elmer 240 C elemental analyzer. Reactions under microwaves were performed in a CEM Discover® monomode microwave reactor. All the reagents are commercially available.

General Procedure for the α,α-bis(4-Hydroxycoumarin-3-yl)toluene (3a–h, 4)

Aromatic aldehyde (1 mmol) and 4-hydroxycoumarin (2 mmol) were mixed in 2 mL water and sealed with a cap containing a septum. The loaded vial was then placed into the cavity of the microwave reactor and heated at 150 W, 150 °C, for 8–10 min (as indicated by thin-layer chromatography, (TLC). After completion of the reaction, the reaction mixture was then allowed to cool to room temperature, resulting in the precipitation of the solid product. The product was filtered off and dried. The isolated products were subjected to crystallization (mixture of $CHCl_3$ and EtOH) to afford the pure product.

Data

Compound **3a**

IR (KBr) ν: 3427, 3035, 1675, 1611, 1562, 1493, 1445, 1349, 759 cm^{-1}; ^1H NMR ($CDCl_3$) δ: 6.12 (s, 1H, CH), 7.24–8.10 (m, 13H, 13 × CH), 11.33 (s, 1H, OH), 11.56 (s, 1H, OH); ^{13}C NMR ($CDCl_3$) δ: 36.21, 105.68, 116.64, 124.41, 124.87, 126.49, 126.88, 128.64, 132.84, 135.22, 152.54. Anal. calcd. for $C_{25}H_{16}O_6$: C, 72.81; H, 3.91. Found: C, 72.61; H, 3.79.

Compound **3b**

IR (KBr) ν: 3427, 3075, 1675, 1615, 1561, 1492, 1444, 1349, 1270, 1212 cm^{-1}; ^1H NMR ($CDCl_3$) δ: 6.06 (s, 1H, CH), 7.17–8.10 (m, 12H, 12 × CH), 11.34 (s, 1H, OH), 11.56 (s, 1H, OH); ^{13}C NMR ($CDCl_3$) δ: 35.85, 103.74, 105.30, 116.64, 124.42, 124.97, 127.98, 128.77, 132.75, 133.90, 152.57, 164.62, 166.84, 169.19. Anal. calcd. for $C_{25}H_{15}ClO_6$: C, 67.20; H, 3.38. Found: C, 66.98; H, 3.27.

Compound **3c**

IR (KBr) ν: 3450, 3078, 1657, 1611, 1560, 14517, 1465, 1345, 761 cm^{-1}; ^1H NMR ($CDCl_3$) δ: 6.14 (s, 1H, CH), 7.28–8.22 (m, 12H, 12 × CH), 11.40 (s, 1H, OH), 11.59 (s, 1H, OH); ^{13}C NMR ($CDCl_3$) δ: 36.55, 103.30, 104.80, 116.26, 123.87, 124.52, 125.15, 127.58, 133.35, 143.36, 146.93, 152.40, 164.84, 166.42, 169.10. Anal. calcd. for $C_{25}H_{15}NO_8$: C, 65.65; H, 3.31; N, 3.06. Found: C, 65.73; H, 3.24; N, 2.89.

Compound **3d**

IR (KBr) ν: 3450, 3075, 1670, 1614, 1563, 1510, 1413, 1350, 1308, 764 cm^{-1}; ^1H NMR ($CDCl_3$) δ: 2.36 (s, 3H, CH_3), 6.09 (s, 1H, CH), 7.11–8.08 (m, 12H, 12 × CH), 11.32 (s, 1H, OH), 11.55 (s, 1H, OH);

^{13}C NMR ($CDCl_3$) δ: 20.96, 35.90, 104.15, 116.62, 124.39, 124.83, 126.38, 129.34, 132.77, 136.42, 152.31. Anal. calcd. for $C_{26}H_{18}O_6$: C, 73.23; H, 4.25. Found: C, 73.15; H, 4.43.

Compound **3e**

IR (KBr) ν: 3452, 3073, 1671, 1611, 1562, 1507, 1452, 1351, 1306, 1257, 768 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ: 3.82 (s, 3H, CH_3O), 6.07 (s, 1H, CH), 6.87–8.08 (m, 12H, 12 × CH), 11.32 (s, 1H, OH), 11.54 (s, 1H, OH); ^{13}C NMR ($CDCl_3$) δ: 35.54, 55.27, 114.05, 116.62, 124.38, 124.84, 126.96, 127.63, 132.79, 158.46. Anal. calcd. for $C_{26}H_{18}O_7$: C, 70.58; H, 4.10. Found: C, 70.82; H, 3.94.

Compound **3f**

IR (KBr) ν: 3435, 3073, 1670, 1614, 1562, 1512, 1451, 1351, 1308, 1259, 765 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ: 3.76 (s, 3H, CH_3O), 3.89 (s, 3H, CH_3O), 6.10 (s, 1H, CH), 6.73–8.09 (m, 11H, 11 × CH), 11.32 (s, 1H, OH), 11.55 (s, 1H, OH); ^{13}C NMR ($CDCl_3$) δ: 35.78, 55.90, 56.13, 110.48, 111.32, 116.64, 118.95, 124.36, 124.89, 127.57, 132.83, 148.10, 149.17, 152.41. Anal. calcd. for $C_{27}H_{20}O_8$: C, 68.43; H, 4.25. Found: C, 68.21; H, 4.12.

Compound **3g**

IR (KBr) ν: 3425, 3078, 1670, 1563, 1494, 1440, 1343, 1308, 1234, 763 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ: 5.97 (s, 2H, OCH_2O), 6.04 (s, 1H, CH), 6.69–8.07 (m, 11H, 11 × CH), 11.29 (s, 1H, OH), 11.62 (s, 1H, OH); ^{13}C NMR ($CDCl_3$) δ: 35.93, 101.18, 107.22, 108.23, 116.62, 119.61, 124.40, 124.87, 128.97, 132.86, 146.86, 148.09. Anal. calcd. for $C_{26}H_{16}O_8$: C, 68.25; H, 3.77. Found: C, 68.48; H, 3.68.

Compound **3h**

IR (KBr) ν: 3428, 3083, 1662, 1610, 1563, 1523, 1448, 1349, 1309, 765 cm^{-1}; ^{1}H NMR (DMSO-d_6) δ: 3.2 (s, 6H, $2CH_3$), 6.31 (s, 1H, CH), 7.23–7.84 (m, 12H, 12 × CH); ^{13}C NMR (DMSO-d_6) δ: 36.45, 103.56, 116.05, 120.10, 123.49, 124.58, 128.68, 131.62, 141.21, 153.00, 164.94, 168.00. Anal. calcd. for $C_{27}H_{21}NO_8$: C, 66.53; H, 4.34; N, 2.87. Found: C, 65.29; H, 3.24; N, 2.98.

Compound **4**

IR (KBr) ν: 3436, 3074, 1662, 1603, 1564, 1502, 1449, 1347, 1309, 762 cm^{-1}; ^{1}H NMR (DMSO-d_6) δ: 6.35 (s, 2H, 2CH), 7.05–7.92 (m, 20H, 20 × CH); ^{13}C NMR (DMSO-d$_6$) δ: 36.12, 104.70, 116.43, 118.13, 124.27, 124.35, 127.05, 132.42, 137.27, 152.61, 165.29, 165.32. Anal. calcd. for $C_{44}H_{26}O_{12}$: C, 70.60; H, 3.75. Found: C, 70.35; H, 3.66.

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REFERENCES

1. Lee, J. H.; Bang, H. B.; Han, S. Y.; Jun, J. G. An efficient synthesis of (+)-decursinol from umbelliferone. *Tetrahedron Lett.* **2007**, *48*, 2889–2892.
2. Manian, R. D. R. S.; Jayashankaran, J.; Raghunathan, R. A rapid access to indolo[2,1-*a*]pyrrolo[4′,3′:4,5]pyrano[5,6-*c*]coumarin/[6,5-*c*]chromone derivatives by domino Knoevenagal intramolecular hetero Diels–Alder reactions. *Tetrahedron Lett.* **2007**, *48*, 1385–1389.
3. Zhao, H.; Neamati, N.; Hong, H.; Mazumder, A.; Wang, S.; Sunder, S.; Milne, G. W. A.; Pommier, Y.; Burke, T. R. Coumarin-based inhibitors of HIV integrase. *J. Med. Chem.* **1997**, *40*, 242–249.
4. Maria, G. K.; Marian, E. The anticoagulant action of some derivatives of 3,3′-(arylidene)-bis-4-hydroxycoumarin. *J. Med. Pharm. Chem.* **1961**, *3*, 583–595.
5. Kostova, I.; Trendafilova, N.; Momekov, G. Theoretical and spectroscopic evidence for coordination ability of 3,3-benzylidenedi-4-hydroxycoumarin: New neodymium(III) complex and its cytotoxic effect. *J. Inorg. Biochem.* **2005**, *99*, 477–487.
6. (a) Ilia, M.; Caecilia, M. M.; Nicolay, D. Synthesis, structure, toxicological and pharmacological investigations of 4-hydroxycoumarin derivatives. *Eur. J. Med. Chem.* **2006**, *41*, 882–890; (b) Manolov, I. I. Aldehyde condensation products of 4-hydroxycoumarin and Schiff bases. *Tetrahedron Lett.* **1998**, *39*, 3041–3042; (c) Mao, P. C. M.; Mouscadet, J. F.; Leh, H.; Auclair, C.; Hsu, L. Y. Chemical modification of coumarin dimer and HIV-1 integrase inhibitory activity. *Chem. Pharm. Bull.* **2002**, 1634–1637; (d) Su, C. X.; Mouscadet, J. F.; Chiang, C. C.; Tsai, H. J.; Hsu, L. Y. HIV-1 integrase inhibition of biscoumarin analogues. *Chem. Pharm. Bull.* **2006**, 682–686.
7. Khan, K. M.; Iqbal, S.; Lodhi, M. A.; Maharvi, G. M.; Zia-Ullah; Choudhary, M. I.; Atta-ur-Rahman; Perveen, S. Biscoumarin: New class of urease inhibitors: Economical synthesis and activity. *Bioorg. Med. Chem.* **2004**, *12*, 1963–1968.

8. Appendino, G.; Cravotto, G.; Tagliapietra, S.; Ferraro, S.; Nano, G. M.; Palmisano, G. The chemistry of coumarin derivatives, part 3: Synthesis of 3-alkyl-4-hydroxycoumarins by reductive fragmentation of 3,3′-alkyiidene-4,4′-dihydroxybis [coumarins]. *Helv. Chim. Acta.* **1991**, 1451–1452.
9. Dallinger, D.; Kappe, C. O. Microwave-assisted synthesis in water as solvent. *Chem. Rev.* **2007**, *107*, 2563–2591.
10. (a) Breslow, R.; Rideout, D. C. Hydrophobic acceleration of Diels–Alder reactions. *J. Am. Chem. Soc.* **1980**, *102*, 7816–7817; (b) Breslow, R. Hydrophobic effects on simple organic reactions in water. *Acc. Chem. Res.* **1991**, *24*, 159–164.
11. (a) Breslow, R.; Maitra, U.; Rideout, D. C. Selective Diels–Alder reactions in aqueous solutions and suspensions. *Tetrahedron Lett.* **1983**, *24*, 1901–1904; (b) Breslow, R.; Maitra, U. On the origin of product selectivity in aqueous Diels–Alder reactions. *Tetrahedron Lett.* **1984**, *25*, 1239–1240.
12. (a) Ponaras, A. A. A new variant of the Claisen rearrangement capable of creating the bond between two quaternary centers. *J. Org. Chem.* **1983**, *48*, 3866–3868; (b) Coates, R. M.; Rogers, B. D.; Hobbs, S. J.; Peck, D. R.; Curran, D. P. Synthesis and Claisen rearrangement of alkoxyallyl enol ethers: Evidence for a dipolar transition state. *J. Am. Chem. Soc.* **1987**, *109*, 1160–1170.
13. (a) Mattes, H.; Benezra, C. Reformatsky-type reactions in aqueous media use of bromomethyl-acrylic acid for the synthesis of α-methylene-γ-butyrolactones. *Tetrahedron Lett.* **1985**, *26*, 5697–5698; (b) Zhou, J. Y.; Lu, G. D.; Wu, S. H. A new approach for the synthesis of α-methylene-g-buty-rolactones from α-bromomethylacrylic acid (or esters). *Synth. Commun.* **1992**, *22*, 481–487.
14. Delair, P.; Luche, J. L. A new sonochemical carbonyl cross-coupling reaction. *J. Chem. Soc., Chem. Commun.* **1989**, *7*, 398.
15. Kappe, C. O. Controlled microwave heating in modern organic synthesis. *Angew. Chem. Inter. Ed.* **2004**, *43*, 6250–6284.
16. Loupy, A.; Petti, A.; Hamelin, J.; Texier-Boullet, F.; Jacquault, P.; Mathe, D. New solvent-free organic synthesis using focused microwaves. *Synthesis* **1998**, 1213-1234.
17. Valizadeh, H.; Mamaghani, M.; Badrian, A. Effect of microwave irradiation on reaction of arylaldehyde derivatives with some active methylene compounds in aqueous media. *Synth. Commun.* **2005**, *35*, 785–790.
18. Leadbeater, N. E. *Chem. Commun.* **2005**, 2881.
19. Wang, J.; Shi, D. Q.; Zhuang, Q. Y.; Wang, X. S.; Tu, S. J. Clean synthesis of α,α-bis(4-hydroxycoumarin-3-yl)toluene in aqueous media. *Chin. J. Org. Chem.* **2005**, *25*, 926–929.
20. Mazaahir, K.; Bansal, V.; Mothsra, P.; Saxena, S.; Somvanshi, R. K.; Dey, S.; Singh, T. P. Molecular iodine: A versatile catalyst for the synthesis of bis(4-hydroxycoumarin) methanes in water. *J. Mol. Catal. A—Chem.* **2007**, *268*, 76–81.
21. Zhou, J. F. One-step synthesis of pyridine and 4h-pyran derivatives from bisarylidenecyclohexanone and malononitrile under microwave irradiation. *Synth. Commun.* **2003**, *33*(1), 99–103.

22. Zhou, J. F.; Tu, S. J.; Zhu, H. Q.; Zhi, S. J. A facile one pot synthesis of pyrano[2,3-c]pyrazole derivatives under microwave irradiation. *Synth. Commun.* **2002**, *32*, 3363–3366.
23. Zhou, J. F. α,α′-*bis*(benzylidene)cycloalkanones by aldol condensation in water under PTC catalysis and microwave irradiation. *Org. Prep. Proc. Inter.* **2005**, *37*, 75–79.
24. Tu, S. J.; Li, C. M.; Li, G. G..; Cao, L. J.; Shao, Q. Q.; Zhou, D. X.; Jiang, B; Zhou, J. F.; Xia, M. Microwave-assisted combinatorial synthesis of polysubstituent imidazo[1,2-a]quinoline, pyrimido[1,2-a]quinoline and quinolino[1, 2-a]quinazoline derivatives. *J. Comb. Chem.* **2007**, *9*, 1144–1148.
25. Sullivan, W. R.; Huebner, C. F.; Stahmann, M. A.; Link K. P. Studies on 4-hydroxycoumarins, II: The condensation of aldehydes with 4-hydroxycoumarns. *J. Am. Chem. Soc.* **1943**, *65*, 2288–2291.