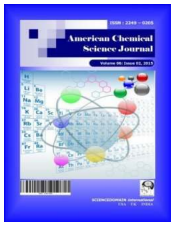

American Chemical Science Journal
13(4): 1-8, 2016, Article no.ACSJ.24655
ISSN: 2249-0205

SCIENCEDOMAIN *international*
www.sciencedomain.org

One-pot Synthesis of 1*H*-benzo[f]chromen-2-yl (phenyl)methanone Derivatives in the Presence of Copper Triflate as Catalyst Using Ultrasonic Irradiation

Tamrat Yimenu Zeleke[1], Kadir Turhan[2] and Zuhal Turgut[2*]

[1]Department of Chemistry, Faculty of Natural and Computational Sciences, Wachemo University, 667, Hossana, Ethiopia.
[2]Department of Chemistry, Faculty of Science and Art, Yildiz Technical University, 34210, Davutpasa, Esenler, İstanbul, Turkey.

Authors' contributions

This work was carried out in collaboration between all authors. Author TYZ performed the experiments. Authors ZT and KT planned the study, managed the literature searches and wrote the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ACSJ/2016/24655
Editor(s):
(1) Georgiy B. Shul'pin, Semenov Institute of Chemical Physics, Russian Academy of Sciences, Moscow, Russia.
Reviewers:
(1) S. Srinivas Rao, Vidya Jyothi Institute of Technology (Autonomous), Hyderabad, India.
(2) Hamada Mohamed Ibrahim, Kuwait University, Kuwait.
(3) F. M. A. El-Taweel, Damietta University, Egypt.
(4) S. Satyanarayana, R V College of Engineering, India.
Complete Peer review History: http://sciencedomain.org/review-history/13827

Original Research Article

Received 28th January 2016
Accepted 12th March 2016
Published 24th March 2016

ABSTRACT

A rapid, efficient and environment-friendly protocol for the synthesis of naphthopyranes has been developed by one-pot condensation of 2-naphthol, various aromatic aldehydes and benzoylacetone or 1,3-diphenyl-1,3-propandione in the presence of $Cu(OTf)_2$ as catalyst under ultrasonic irradiation. The present approach offers the advantages of clean reaction, simple methodology, short reaction time, high yield and economic availability of the catalyst.

Keywords: Copper(II)triflate; naphthopyran; one-pot reaction; ultrasound.

**Corresponding author: E-mail: zturgut@yildiz.edu.tr, zturgut61@yahoo.com;*

1. INTRODUCTION

Naphthopyranes or benzochromenes are important biologically active oxygenated heterocyclic compounds, which possess antiviral [1], antibacterial [2], antimicrobial [3], anti-proliferative [4], antitumor [5], anti-HIV [6], and antileishmanial [7] activity. The various substituted benzochromene derivatives can be mentioned for molecular modeling as potential drugs for treatment of Alzheimer's disease [8]. Furthermore, naphthopyranes are photochromic compounds [9,10]. Therefore, a number of methods have been reported for the synthesis of naphthopyrane derivatives in the literature [11-17]. However, some of these methods are not environment-friendly due to long reaction times. Thus improvements in these syntheses have been sought continuously. As a result, in the synthesis of various new naphthopyran derivatives the development of more rapid, eco-friendly and efficient method is preferred.

One-pot reaction (multi-component method) has been becoming one of the most important aspects in Organic Chemistry. One-pot synthesis is carrying out successive chemical reactions in just one reactor. One-pot offers a significant advantages over single linear step synthesis such as simple work-up, less time, less energy and less raw-material consuming. Since one-pot method avoids a lengthy separation process and purification of the intermediate chemical compounds, it would save time and resources while increasing chemical yield. Concisely, multi-component reactions provide both economic and environmental advantages [16,18-22].

Lewis acid catalysis is one of the most powerful tools in modern organic synthesis; it has to be generally carried out under strictly anhydrous conditions because of its water-labile nature. Recently, metal triflates (trifluoromethanesulfonate), a new type of Lewis acids, have been widely used in organic synthesis as catalyst due to their high stability, water tolerance, and recoverability from water [23]. This process is efficiently promoted by the copper(II)triflate [$Cu(OTf)_2$].

The significance of environmental friendly chemical processes is becoming more and more prevalent due to increasing pollution rates during the last decades. Ultrasonic-assisted organic synthesis (UAOS) as a green synthetic approach is an efficient method that is widely used in the acceleration of many organic reactions. This approach enhances reaction rates and helps the formation of purer products in high yields. The manipulation of this process is easier; it helps the conservation of energy and waste minimization in comparison to traditional methods. Thus, ultrasound method has become so popular and received substantial interest. However, the use of ultrasound method in heterocyclic systems needs some further investigation due to a few applications found in literature on the synthesis of naphthopyran derivatives [13,24]. Therefore, developing a general, more efficient and eco-friendly method for the synthesis of hydrobenzo[f]chromen-2-yl phenyl methanone is being considered in order to deploy the application of ultrasound method in the synthesis of heterocyclic compounds.

In this work, naphthopyran derivatives were obtained by one-pot reaction of 2-naphthol, aromatic aldehydes and acyclic 1,3-dicarbonyl compound in the presences of $Cu(OTf)_2$ as a catalyst in dichloroethane assisted with ultrasound irradiation method. In comparison with other routes, the one that employs one-pot reaction of 2-naphthol, 1,3-dicarbonyl compounds and aromatic aldehydes under various conditions has been chosen as the most efficient.

2. EXPERIMENTAL

2.1 General Information

Sonication was performed in an Intersonik ultrasound cleaner (model: MIN4) with a frequency of 25 kHz, an US output power of 100 W, a heating 200 W. The temperature of the water bath was controlled by a controlled automatic constant temperature cooling circulatory system. TLC was carried out on silica gel 60 F_{254} pre-coated plates and visualized with "Camag UV light" (254/366 nm). Column chromatography was performed on silica gel 60 (70–230 mesh). FTIR spectra were recorded on a Philips PU 9714 ATR spectrophotometer using "Perkin-Elmer Spectrum One" program. ^{1}H NMR (500MHz) and ^{13}C NMR (100 MHz) spectra were recorded on a "Inova 500"and "Bruker 500" spectrometers using TMS as an internal standard in $CDCl_3$ or DMSO. Mass Spectra were obtained using "Agilent 6890 N GC System-5973 IMSD" instrument. CHN analyses were performed on "Thermo Finnigan Flash Ea 1112 Series". Melting points were determined with Gallenkamp melting point apparatus and were uncorrected. All

chemical reagents were purchased from Merck, Fluka, Aldrich and were used without purification.

2.2 General Procedure for Synthesis of Hydrobenzo[f]chromen-2-yl Phenyl Methanone

Copper triflate (0.1 mmol) in 1,2-dichloroetane (2 mL) was added to a mixture of β-naphthol (1.0 mmol), aromatic aldehyde (1.0 mmol), and acyclic 1,3-dicarbonyl compound (1.0 mmol). The reaction mixture was stirred at 80℃ for a given time (Table 1). The progress of the reaction was monitored by TLC. After completion of the reaction, mixture was diluted by 10 mL of ethyl acetate and water (8:2). Organic phase was separated and aqueous phase extracted with 10 mL ethyl acetate three times. The collected organic phase was dried over $MgSO_4$ and the solvent was evaporated, and the crude product was purified by column chromatography on silica gel with dichloromethane: n-hexane as eluents.

2.3 Ultrasound-assisted Synthesis of Hydrobenzo[f]chromen-2-yl Phenyl Methanone

$Cu(OTf)_2$ (0.1 mmol) in 1,2-dichloroetane (2 mL) was added to a mixture of β-naphthol (1.0 mmol), aromatic aldehyde (1.0 mmol), and acyclic 1,3-dicarbonyl compounds (1.0 mmol). The reaction mixture was sonicated at 50℃ in an ultrasound cleaner bath according to the given times in Table 1. The maximum energy area in the ultrasound cleaner is the center of the bath, so the flask was suspended there. The progress of the reaction was monitored by TLC and then stopped by the addition of water. The product was extracted with 10 mL of EtOAc three times. The organic layer was dried over $MgSO_4$ and evaporated, and the crude product was purified by column chromatography (n-hexane/ dichloromethane) to obtain pure products (**5a-d, 6a-d**).

2.3.1 (1-(3,5-dichlorophenyl)-3-methyl-1*H*-benzo[f]chromen-2-yl) phenyl methanone (5a)

White solid, m.p.249-50℃; FTIR (near) $\gamma_{max/cm}^{-1}$: 3058, 2921, 1671, 1619, 1592, 1514, 1468, 1403, 1220, 995, 807, 735; ^{1}H NMR (500MHz, $CDCl_3$): δ (ppm) 1.51 (s, 3H), 5.80 (s,1H), 6.89-6.93 (d, *J*=8.79 Hz, 2H), 7.22-7.31 (m, 2H), 7.42-7.51 (m, 4H), 7.59-7.63 (m,3H), 7.79-7.87 (3H, m, Ar-H); ^{13}C NMR (100MHz, $CDCl_3$): δ (ppm)17.61, 35.87, 112.37, 114.17, 116.23, 122.00, 123.73, 126.22, 127.04, 127.52, 127.68, 128.02, 128.18, 128.34, 130.09, 130.11, 130.85, 131.48, 131.88, 131.96, 137.30, 139.89, 147.90, 150.18, 195.81; Anal. Calcd. for $C_{27}H_{18}Cl_2O_2$ C: 72.82; H: 4.07. Found C: 72.77; H: 4.28; M^+ (m/z) = 445.

2.3.2 (1-(4-chlorophenyl)-3-methyl-1*H*-benzo[f]chromen-2-yl) phenyl methanone (5b)

White solid, m.p.281-82℃; FTIR (near) $\gamma_{max/cm}^{-1}$: 3067, 2919, 1644, 1592, 1486, 1228, 1083, 807, 741; ^{1}H NMR (500MHz, $CDCl_3$): δ (ppm) 1.47 (s, 3H), 5.68 (s,1H), 7.07-7.11(d *J*= 9.20 Hz, 2H), 7.39-7.48 (m, 5H), 7.54-7.60 (m, 3H), 7.73-7.85 (m, 4H), 8.28-8.31 (d, *J* = 8.59 Hz,1 H); ^{13}C NMR (100MHz, $CDCl_3$): δ (ppm) 21.05, 37.34, 116.71, 117.99, 122.37, 123.37, 124.34, 124.69, 126.65, 126.88, 127.35, 128.35, 128.49, 128.61, 128.88, 128.96, 128.99, 129.06, 129.46, 131.01, 131.21, 132.05, 143.43, 148.65, 182.02; Anal. Calcd. for $C_{27}H_{19}ClO_2$ C: 78.92; H: 4.66. Found C: 78.89; H: 4.72; M^+ (m/z) = 410.

Table 1. Synthesis of hydrobenzo[f]chromen-2-yl phenyl) one in the presence of $Cu(OTf)_2$

Entry	R	Product	Conventional method		Ultrasound method	
			Time (h)	Yield (%)[a]	Time (h)	Yield (%)[a]
1	3,5-(Cl_2) C_6H_3	5a	5	87	1	93
2	p-(Cl) C_6H_4	5b	5	89	0.5	94
3	p-(NO_2) C_6H_4	5c	5	74	1	83
4	p-(Br) C_6H_4	5d	5	79	0.5	87
5	C_6H_5	6a	5	73	2	82
6	p-(Cl) C_6H_4	6b	5	76	2	85
7	p-(CH_3) C_6H_4	6c	5	75	2	83
8	3,5-(OCH_3) C_6H_3	6d	5	81	2	87

[a]*Yields after column chromatography*

2.3.3 (1-(4-nitrophenyl)-3-methyl-1H-benzo[f]chromen-2-yl) phenyl methanone (5c)

Yellow solid, m.p. 317.5-18.5℃; FTIR (near) $\gamma_{max/cm}^{-1}$: 3064, 2927, 1642, 1590, 1507, 1399, 1302, 1236, 1106, 825, 740; ^{1}H NMR (500MHz, $CDCl_3$): δ (ppm) 1.47 (s, 3H), 5.48 (s, 1H), 7.41-7.48 (m, 3H), 7.50-7.52 (d, *J* = 8.90 Hz, 2 H), 7.58-7.62 (m, 3H), 7.67-7.71 (d, *J*= 8.80 Hz, 2H), 7.82-7.88 (m, 3H), 7.98-8.02 (d, *J* = 8.80 Hz, 2H); ^{13}C NMR (100MHz, $CDCl_3$): δ (ppm) 19.80, 38.04, 111.78, 114.72, 116.72, 117.04, 120.98, 122.83, 123.25, 123.77, 126.16, 127.35, 127.88, 128.04, 128.52, 128.56, 130.02, 130.04, 130.22, 132.41, 145.26, 146.68, 147.74, 148.57, 150.95, 152.34, 189.71; Anal. Calcd. for $C_{27}H_{19}NO_4$ C: 76.95; H: 4.54; N:3.32. Found C: 76.92; H: 4.58; N: 3.30; M^+ (m/z) = 421.

2.3.4 (1-(4-bromophenyl)-3-methyl-1H-benzo[f]chromen-2-yl) phenyl methanone (5d)

White solid, m.p. 186℃; FTIR (near) $\gamma_{max/cm}^{-1}$: 3067, 2968, 1646, 1591, 1482, 1399, 1288, 1008, 824, 739; ^{1}H NMR (500MHz, $CDCl_3$): δ (ppm) 1.83 (s, 3H), 5.75 (s, 1H), 7.03-7.08 (d, *J*=8.45 Hz, 2H), 7.24-7.28 (m, 2H), 7.29-7.32 (d, *J*=8.91 Hz, 1H), 7.35-7.42 (m, 3H), 7.47-7.58 (m, 4H), 7.71-7.84 (m, 3H); ^{13}C NMR (100MHz, $CDCl_3$): δ (ppm) 19.39, 39.95, 111.78, 114.65, 115.16, 117.18, 120.49, 123.83, 123.32, 124.70, 127.02, 128.56, 128.68, 128.77, 129.23, 129.55, 131.05, 131.27, 131.80, 132.65, 139.56, 143.88, 148.28, 152.95, 197.90; Anal. Calcd. for $C_{27}H_{19}BrO_2$ C: 71.22; H: 4.21. Found C: 71.18; H: 4.25; M^+ (m/z) = 455.

2.3.5 (1,3-diphenyl-1H-benzo[f]chromen-2-yl) phenyl methanone (6a)

White solid, m.p. 191℃; FTIR (near) $\gamma_{max/cm}^{-1}$: 3055, 2874, 1664, 1596, 1445, 1330, 1224, 813, 728; ^{1}H NMR (500MHz, $CDCl_3$): δ (ppm) 5.82 (1H, s, CH), 6.90-6.97 (m, 2H), 6.99-7.10 (m, 4H), 7.12-7.15 (m, 4H), 7.28-7.33 (m, 4H), 7.33-7.39**,** (m, 5H), 7.73-7.75 (d, j = 8.3 Hz, 1H), 7.84-7.88 (d, j = 8.30Hz, 1H); ^{13}C NMR**;** (100MHz, $CDCl_3$): δ (ppm) 40.32, 114.40, 115.34, 116.33, 122.52, 123.64, 125.64, 125.94, 126.15, 126.62, 126.85, 127.05, 127.45, 127.61, 127.66, 127.97, 128.05, 128.18, 128.63, 130.17, 130.37, 130.72, 131.43, 132.79, 137.58, 143.53, 147.71, 153.25, 196.99; Anal. Calcd. for $C_{32}H_{22}O_2$ C: 87.65; H: 5.06. Found C:87.71; H: 5.10; M^+ (m/z) = 438.

2.3.6 (1-(4-chlorophenyl)-3-phenyl-1H-benzo[f]chromen-2-yl) phenyl methanone (6b)

White solid, m.p. 208℃; FTIR (near) $\gamma_{max/cm}^{-1}$: 3055, 2958, 1649, 1590, 1486, 1270, 1222, 1073, 729; ^{1}H NMR (500MHz, $CDCl_3$): δ (ppm) 5.80 (s,1H), 6.98-7.04 (m, 2H), 7.08-7.18 (m, 5H), 7.29-7.35 (d, *J* = 8. 45 Hz, 2H), 7.37-7.51 (m, 7H), 7.81-7.85 (d, *J* = 8.75 Hz, 2H), 7.87-7.91 (d, *J*= 8.35 Hz, 2H); ^{3}C NMR (100MHz, $CDCl_3$): δ (ppm) 40.52, 114.70, 116.09, 117.33, 123.25, 124.84, 127.11, 127.16, 127.75, 127.92, 128.22, 128.60, 128.68, 128.78, 129.05, 129.23, 129.45, 129.90, 130.94, 131.41, 131.85, 132.37, 132.46, 133.60, 135.51, 138.49, 143.22, 148.63, 155.43, 185.76; Anal. Calcd. for $C_{32}H_{21}ClO_2$ C: 81.26; H: 4.48. Found C: 81.32; H: 4.42; M^+ (m/z) = 472.

2.3.7 (1-(4-methylphenyl)-3-phenyl-1H-benzo[f]chromen-2-yl) phenyl methanone (6c)

White solid, m.p: 171.5℃, FTIR (near) $\gamma_{max/cm}^{-1}$: 3022, 2940, 1631, 1589, 1508, 1343, 1222, 903, 803; ^{1}H NMR (500MHz, $CDCl_3$): δ (ppm) 2.11 (3H, s, CH), 5.81 (1H, s, CH), 6.89-6.95 (m, 5H), 7.02-7.11 (m, 4H), 7.15-7.20 (m, 2H), 7.29-7.38 (m, 5H), 7.71-7.74 (m, 4H); ^{13}C NMR (100MHz, $CDCl_3$): δ (ppm) 19.97, 39.86, 114.51, 115.66, 116.33, 122.48, 123.61, 125.91, 126.15, 126.63, 26.83, 126.91, 127.44, 127.66, 127.84,128.11, 128.23, 128.31, 128.61, 130.17, 130.37, 130.68, 132.84, 135.11, 137.62, 140.67, 147.61, 153.42, 196.92; Anal. Calcd. for $C_{33}H_{24}O_2$ C: 87.58; H: 5.35. Found C: 87.32; H: 5.27; M^+ (m/z) = 452.

2.3.8 (1-(3,5-dimethoxyphenyl)-3-phenyl-1H-benzo[f]chromen-2-yl) phenyl methanone (6d)

White solid, m.p: 213℃; FTIR (near) $\gamma_{max/cm}^{-1}$: 3058, 2928, 1702, 1592, 1516, 1334, 1202, 811; ^{1}H NMR (500MHz, $CDCl_3$): δ (ppm) 3.71 (s, 3H,), 3.77 (s, 3H), 5.78 (s, 1H), 6.92-6.98 (m, 4H), 7.01-7.18 (m, 5H), 7.29-7.39 (m, 5H), 7.72-7.75 (m, 3H), 7.86-7.91 (d, *J*= 8.30 Hz,2H); ^{13}C NMR (100MHz, $CDCl_3$): δ (ppm) 40.50, 54.18, 97.26, 114.20, 114.85, 116.35, 122.51, 123.64, 125.93, 126.15, 126.67, 126.85, 127.44, 128.03, 128.09, 128.56, 130.29, 130.33, 130.80, 132.81, 137.55, 145.75, 147.80, 152.86, 159.80, 197.04; Anal. Calcd. for $C_{34}H_{26}O_4$ C: 81.91; H: 5.26. Found C: 81.82; H: 4.98; M^+ (m/z) = 498.

3. RESULTS AND DISCUSSION

The condensation of β-naphthol, 1,3-diones (benzoylacetone or 1,3-diphenyl-1,3-propandione) with substituted benzaldehydes was carried out in 1,2-dichloroethane for 5h in reflux conditions in presence of $Cu(OTf)_2$ at the commencement phase of our research. The mixture was stirred at 80℃. The synthesis of naphthopyran compounds were compared with the conventional heating ones in order to show the effect of using ultrasonic irradiation method in these reactions. The experimental results show that the reaction times are reducing when ultrasound method was used. The ultrasound-assisted reaction was carried out at 50℃ and took shorter time than the conventional methods.

Benzoylacetone and 1,3-diphenyl-1,3-propandione were also tried out as 1,3-dicarbonylacyclic compounds. The reactions proceeded steadily to afford series of 1-aryl-3-phenyl-1H-benzo[f]chromen-2-yl phenyl methanones (5a-d) and 1-aryl-3-phenyl-1H-benzo[f]chromen-2-yl phenyl methanones (6a-d) under similar conditions. Aromatic aldehydes substituted with either electron-donating or electron-withdrawing group underwent the reaction smoothly and gave the products in moderate yields in all cases. However, the yields of **5a-d** series were slightly lower than the yields of **6a-d** the series.

As part of this green concept, “ultrasound” has become so popular and received substantial interest. Then, in the second step; we investigated the condensation reaction of β-naphthol, aldehydes and acyclic-1,3-diones using $Cu(OTf)_2$ catalyst with ultrasonic irradiation in 1,2-dichloroethane and the results are listed in Table 1. Copper(II) trifluoromethane sulphonate) has been received as an inexpensive, water tolerant and potentially useful metal triflate.

This study report is a rapid procedure for the preparation of naphthopyrans by using $Cu(OTf)_2$ as a green catalyst under ultrasound irradiation. To the best of our knowledge, only a few reported on the synthesis of hydrobenzo[f]chromen-2-yl phenyl)one derivatives, and no reports are available using ultrasound. The structures of the obtained new compounds have been clarified by spectroscopic methods (FTIR, ^{1}H NMR, ^{13}C NMR, EA and GC/MS) after the purification processes.

A tentative mechanism for the formation of of hydrobenzo[f]chromen-2-yl phenyl methanone derivatives is proposed in Fig. 2. By following the literature [12,15], we suppose that the reaction might have proceeded via ortho-quinone methides intermediate, which was formed by the nucleophilic addition of 2-naphthol to aldehydes catalyzed by $Cu(OTf)_2$. Subsequent substitution of the oxygen atom, coordinated by $Cu(OTf)_2$ with acyclic 1,3-dicarbonyl compounds. After one molecule of water eliminated, the new products **5** and **6** were obtained.

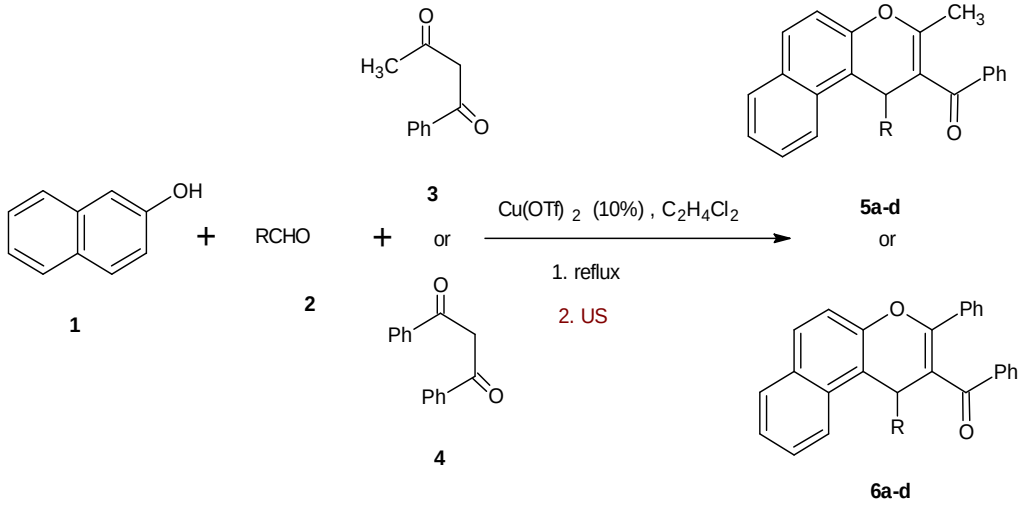

Fig. 1. $Cu(OTf)_2$ catalyzed condensation of β-naphthol, aromatic aldehydes, 1,3- dicarbonyl compounds

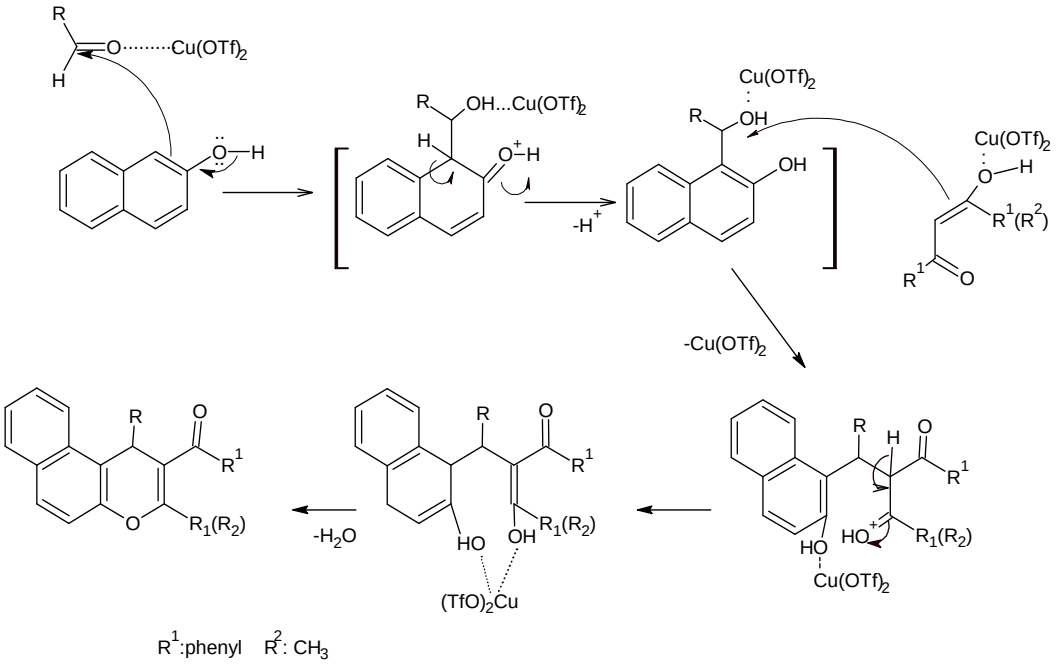

Fig. 2. A tentative mechanism for the formation of hydrobenzo[*f*]chromen-2-yl phenyl methanone derivatives

4. CONCLUSION

We have demonstrated an efficient and simple one-pot method for the synthesis of 1H-benzo[f]chromen-2-yl)-one derivatives via cyclocondensation reaction of 2-napthol, aromatic aldehydes, and 1,3-dicarbonyl compounds catalyzed by $Cu(OTf)_2$ in dichloroethane. This is the first report of one-pot synthesis of 1H-benzo[f]chromen-2-yl)(phenyl)one compounds catalyzed by cupper(II) triflate under ultrasonic irradiation. The process has several advantages such as easy workup, fast reaction rates, mild reaction conditions, and good yields.

ACKNOWLEDGEMENT

This study was financially supported by Yildiz Technical University, the project number of BAPK 2012-01-02-KAP05.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Khaligh NG. Poly(4-vinylpyridinium) hydrogensulfate catalyzed synthesis of 12-aryl-12H-indeno[1,2-b]naphtho[3,2-e]pyran-5,11,13-triones. Tetrahedron Letters. 2012;53:1637-1640.
2. Wang X, Lu G, Yan F, Ma W, Wu L. $Zr(HSO_4)_4$-catalyzed one-pot three-component synthesis of 7-alkyl-6H,7H-naphtho[10,20:5,6]pyrano[3,2-c]chromen-6-ones. J. Heterocyclic Chem. 2011;48: 1379-1382.
3. Abd El-Wahab AHF. Synthesis, reactions and evaluation of the antimicrobial activity of some 4-(p-halophenyl)-4H-naphthopyran, pyranopyrimidine and pyranotriazolopyrimidine derivatives. Pharmaceuticals. 2012;5:745-757.
4. Rafinejad A, Fallah-Tafti A, Tiwari R, Shirazi AN, Mandal D, Shafiee A, Parang K, Foroumadi A, Akbarzadeh T. 4-Aryl-4H-naphthopyrans derivatives: One-pot synthesis, evaluation of Src kinase inhibitory and anti-proliferative activities. Journal of Pharmaceutical Sciences. 2012;20(100):2-10.
5. Yin SQ, Shi M, Kong TT, Zhang CM, Han K, Cao B, Zhang Z, Du X, Tang LQ, Mao X, Liu ZP. Preparation of S14161 and its analogues and the discovery of 6-bromo-8-ethoxy-3-nitro-2H-chromene as a more potent antitumor agent in vitro. Bioorganic & Medicinal Chemistry Letters. 2013;23: 3314-3319.

6. Rawat M, Prutyanov V, Wulff WD. Chromene chromium carbene complexes in the syntheses of naphthopyran and naphthopyrandione units present in photochromic materials and biologically active natural products. J. Am. Chem. Soc. 2006;128:11044-11053.
7. Verma RK, Prajapati VK, Verma GK, Chakraborty D, Sundar S, Rai M, Dubey VK, Singh MS. Molecular Docking and in Vitro Antileishmanial Evaluation of Chromene-2-thione Analogues. ACS Med. Chem. Lett. 2012;3:243-247.
8. Maalej E, Chabchoub F, Oset-Gasque, MJ, Esquivias-Pérez M, González MP, Monjas, L, Pérez C, Ríos C, Rodríguez-Franco MI, Iriepa I, Moraleda I, Chioua M, Romero A, J. Marco-Contelles J, Samadi A. Synthesis, biological assessment, and molecular modeling of racemic 7-aryl-9,10,11,12-tetrahydro-7H-benzo[7,8]chromeno[2,3-b]quinolin-8-amines as potential drugs for the treatment of Alzheimer's disease. European Journal of Medicinal Chemistry. 2012;54:750-763.
9. Katritzky AR, Sakhuja R, Khelashvili L, Shanab K. Gelation behavior of 2H-chromene N-acylamino acid conjugates. J. Org. Chem. 2009;74:3062-3065.
10. Jockusch S, Turro NJ, Blackburn FR. Photochromism of 2H-naphtho[1,2-b]pyrans: A spectroscopic investigation. J. Phys. Chem. A. 2002;106:9236-9241.
11. Shaterian HR, Kangani M. Mild brønsted basic ionic liquids catalyzed three component synthesis of pyrazolo[1,2-a][1,2,4]triazole-1,3-dione and 2-amino-3-cyano-5,10-dioxo-4-phenyl-5,10-dihydro-4H-benzo[g]chromene derivatives. Scientia Iranica C. 2013;20(3):571-579.
12. Kidwai M, Jahan A, Mishra NK, A novel method for the synthesis of tetrahydrobenzo[a]-xanthen-11-one derivatives using cerium(III) chloride as a highly efficient catalyst. C. R. Chimie. 2012;15:324-330.
13. Datta B, Pasha MA. Glycine catalyzed convenient synthesis of 2-amino-4H-chromenes in aqueous medium under sonic condition. Ultrasonics Sonochemistry. 2012;19:725-728.
14. Srihari P, Ganganna B, Rajendraprasad K, Bhunia C, Yadav JS. Bronsted acid catalyzed one-pot condensation of β-naphthol, aldehyde and active methylene substrate: Synthesis of naphthopyrans, Indian Journal of Chemistry. 2011;50B: 1755-1761.
15. Li J, Tang W, Lu L, Su W. Strontium triflate catalyzed one-pot condensation of β-naphthol, aldehydes, cyclic 1,3-dicarbonyl compounds, Tetrahedron Letter. 2008;49:7117-7120.
16. Chaskar A, Shaikh H, Padalkar V, Phatangare K Deokar H. IBX promoted one-pot condensation of β-naphthol, aldehydes, and 1,3-dicarbonyl compounds, Green Chemistry Letters and Reviews. 2011;4(2):171-175.
17. Karami B, Hoseini SJ, Eskandari K, Ghasemi A, Nasrabadi H., Synthesis of xanthene derivatives by employing Fe_3O_4 nanoparticles as an effective and magnetically recoverable catalyst in water. Catal. Sci. Technol. 2012;2:2331-338.
18. Shaabani A, Ghadari R, Sarvary A, Rezayan AH. Synthesis of highly functionalized bis(4H-chromene) and 4H-benzo[g]chromene derivatives via an isocyanide-based pseudo-five-component reaction. J. Org. Chem. 2009;74:4372–4374.
19. Pradhan K, Paul S, Das AR. $Fe(DS)_3$, an efficient Lewis acid-surfactant-combined catalyst (LASC) for the one pot synthesis of chromeno[4,3-b]chromene derivatives by assembling the basic building blocks. Tetrahedron Letters. 2013;54:3105-3110.
20. Jin TS, Zhang JS, Liu LB, Wang AQ, Li TS. Clean, one-pot synthesis of naphthopyran derivatives in aqueous media. Synthetic Communications. 2006;36:2009-2015.
21. Zeng LY, Lv MF, Cai C. Iodine catalyzed synthesis of the chromene derivatives in one-pot. Chinese Chemical Letters. 2012;23:1347-1351.
22. Essamlali Y, Amadine O, Maati H, Abdelouahdi K, Fihri A, Zahouily M, Varma RS Solhy A. Highly efficient one-pot three-component synthesis of naphthopyran derivatives in water catalyzed by phosphates. ACS Sustainable Chem. Eng. 2013;1:1154−1159.
23. Kobayashi S, Sugiura M, Kitagawa H, Lam WWL. Rare-earth metal triflates in organic synthesis. Chemical Reviews. 2002;102(6):2227-2302.

24. Patil R, Bhoir P, Deshpande P, Wattamwar T, Shirude M, Chaskar P. Relevance of sonochemistry or ultrasound (US) as a proficient means for the synthesis of fused heterocycles. Ultrasonics Sonochemistry. 2013;20: 1327-1336.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/13827