J. Iran. Chem. Soc., Vol. 7, No. 4, December 2010, pp. 890-894.

JOURNAL OF THE
Iranian
Chemical Society

Synthesis of Biscoumarin and 3,4-Dihydropyrano[c]chromene Derivatives Catalysed by Sodium Dodecyl Sulfate (SDS) in Neat Water

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(Received 27 October 2009, Accepted 29 January 2010)

A simple and efficient one-pot synthesis of biscoumarin and 3,4-dihydropyrano[c]chromene derivatives using catalytic amounts of SDS in water medium is reported. The catalyst can be recovered by simple filtration and reused.

Keywords: Biscoumarin, 3,4-Dihydropyrano[c]chromene, One-pot synthesis, SDS (Sodium dodecyl sulfate)

INTRODUCTION

Biscoumarins and dihydropyrano[c]chromenes are of considerable interest as they possess a wide range of biological properties [1-7]. A number of methods have been reported for the synthesis of biscoumarins [8-11]. However, comparatively fewer methods have been described for the synthesis of 3,4-dihydropyrano[c]chromenes [11-14]. Some of these procedures require refluxing for hours in organic solvents, use of expensive catalysts and tedious work-up.

With the increasing public concern over environmental degradation, the use of environmentally benign solvents like water represent very powerful green chemical technology procedures from both the economical and synthetic points of view.

They have many advantages, such as reduced pollution, lower cost, and simplicity in processing which are beneficial to the industry as well as to the environment [15]. There is also another route to combine economic aspects with the environmental, that is, the multicomponent reaction (MCR). This process consists of two or more synthetic steps which are taken without isolation of any intermediate; thus, reducing time, saving money, energy and raw materials [16,17].

In recent years, many surfactants have been used as phase transfer catalysts in a number of organic reactions having unique capabilities to dissolve both organic and aqueous solutions to enhance the reaction rate [18-22]. In this work, we studied our reactions using SDS (Sodium dodecyl sulfate) as a surfactant, since it forms micelles in water and can both solubilize the organic compounds and catalyze the reaction. Accordingly, we herein report the synthesis of 3,4-dihydropyrano[c]chromenes (**2**) and biscoumarins (**4**) by the reaction of aromatic aldehydes, malononitrile and 4-hydroxycoumarin in the presence of 20 mol% SDS in neat water (Schemes 1 and 2).

EXPERIMENTAL

All chemicals were purchased from Aldrich and Merck chemical companies with high-grade quality, and used without any purification. All melting points were obtained by Bamslead Electrothermal 9200 apparatus and are uncorrected. The reactions were monitored by TLC and all yields refer to isolated products. ^{1}H and ^{13}C NMR spectra were recorded in DMSO on a Bruker 500 MHz spectrometer. Infrared spectra were recorded on a Bruker FT-IR Equinax-55

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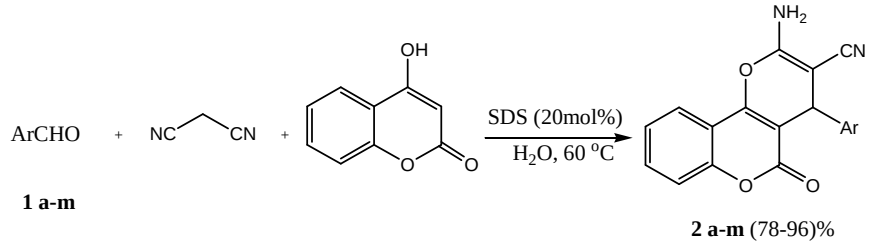
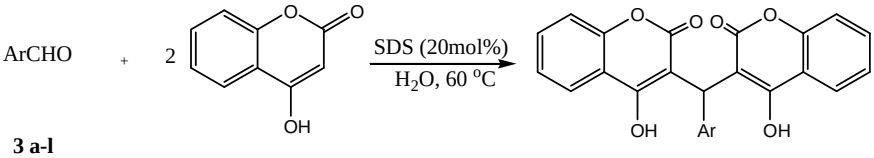


1 a-m

2 a-m (78-96)%

Scheme 1



3 a-l

4 a-l (84-98)%

Scheme 2

spectrophotometer in KBr with absorption in cm^{-1}. All products were characterized by their spectral and physical data.

General Procedure

A mixture of 4-hydroxycoumarin (1 mmol), malononitrile (1 mmol), an aromatic aldehyde (1 mmol) and SDS (0.2 mol, 57.6 mg) in H_2O (3 ml) for the synthesis of 3,4-dihydropyrano [c]chromenes and 4-hydroxycoumarin (2 mmol), an aromatic aldehyde (1 mmol) and SDS (0.2 mol, 57.6 mg) in H_2O (3 ml) for the synthesis of biscoumarins were stirred at 60 °C for the appropriate times (Tables 2, 3). Upon completion of the reaction, monitored by TLC, the reaction mixture was allowed to cool to room temperature. The solid was filtered off and washed with water (2 × 20 ml) and purified by recrystalization from ethanol.

Selected Spectroscopic Data

2-Amino-4-(4-fluorophenyl)-4,5-dihydro-5-oxopyrano [3,2-c]chromene-3-carbonitrile (2d). M.p.: 260-262 °C; IR (KBr): υ_{max} = 3378, 3292, 2194, 1716, 1677, 1605, 1507, 1379 cm^{-1}, ^{1}H NMR (500 MHz, DMSO-d_6): δ = 4.47 (1H, s, CH), 7.07 (2H, t, J = 8.7 Hz, H_{Ar}), 7.31 (2H, t, J = 6.8 Hz, H_{Ar}), 7.38 (2H, br s, NH_2), 7.41 (1H, d, J = 8.3 Hz, H_{Ar}), 7.46 (1H, t, J = 7.6 Hz, H_{Ar}), 7.67 (1H, t, J = 7.5 Hz, H_{Ar}), 7.88 (1H, d, J = 7.5 Hz, H_{Ar}) ppm. ^{13}C NMR (125 MHz, DMSO-d_6): δ = 36.26, 57.89, 103.76, 112.92, 115.11, 116.47, 119.02, 123.50, 129.59, 132.85, 139.45, 152.12, 153.36, 157.93, 159.45, 160.23, 162.16 ppm

2-Amino-4,5-dihydro-4-(3,4-dimethoxyphenyl)-5-oxopyrano[3,2-c]chromene-3-carbonitrile (2l). M.p.: 228-230 °C; IR (KBr): υ_{max} = 3406, 3326, 2196, 1710, 1672, 1609, 1517, 1378 cm^{-1}, ^{1}H NMR (500 MHz, DMSO-d_6): δ = 3.70 (6H, s, $2OCH_3$), 4.40 (1H, s, CH), 6.75 (1H, d, J = 8.15 Hz, H_{Ar}), 6.86 (2H, d, J = 8 Hz, H_{Ar}),7.31 (2H, br s, NH_2), 7.38 (1H, d, J = 8.25 Hz, H_{Ar}), 7.43 (1H, t, J = 7.5 Hz, H_{Ar}), 7.64 (1H, t, J = 7.65 Hz, H_{Ar}), 7.88 (1H, d, J = 7.65 Hz, H_{Ar}) ppm. ^{13}C NMR (125 MHz, DMSO-d_6): δ = 36.51, 55.50, 55.56, 58.27, 104.08, 111.78, 111.96, 112.97, 116.40, 119.22, 119.67, 122.38, 124.47, 132.68, 135.82, 148.02, 148.58, 152.05, 153.11, 157.93, 159.49 ppm.

3-((3-Chlorophenyl)(4-hydroxy-2-oxo-2H-chromen-3-yl)methyl)-4-hydroxy-2H-chromen-2-one (4e). M.p.: 228-230 °C; IR (KBr): υ_{max} = 3445, 3073, 1667, 1616, 1567, 1351, 764 cm^{-1}, ^{1}H NMR (500 MHz, DMSO-d_6): δ = 6.32 (1H, s, CH), 7.10-7.92 (12H, m, H_{Ar}), 12.37 (2H, br s, OH) ppm. ^{13}C NMR (125 MHz, DMSO-d_6): δ = 36.04, 103.58, 115.89, 118.26, 123.58, 123.97, 125.49, 125.62, 126.48, 129.80, 131.78, 132.81, 143.51, 152.32, 164.56, 165.85 ppm.

4-Hydroxy-3-((4-hydroxy-2-oxo-2H-chromen-3-yl)(p-

tolyl)methyl)-2H-chromen-2-one (4i). M.p.: 266-268 °C; IR (KBr): υ_{max} = 3445, 3073, 1671, 1618, 1606, 1565, 1351, 763 cm^{-1}, ^1H NMR (500 MHz, DMSO-d_6): δ = 2.23 (3H, s, CH_3), 6.20 (1H, s, CH), 7.01-7.89 (12H, m, H_{Ar}), 11.86 (2H, brs, OH) ppm. ^{13}C NMR (125 MHz, DMSO-d_6): δ = 20.45, 35.60, 104.16, 115.83, 118.05. 123.59, 123.84, 126.57, 128.57, 131.71, 134.29, 136.88, 152.17, 164.74, 165.32 ppm.

RESULTS AND DISCUSSION

In order to optimize the reaction conditions, we studied the synthesis of 2-amino-5-oxo-4-phenyl-4H,5H-pyrano[3,2-c]chromene-3-carbonitrile **2a** from the condensation of 4-hydroxycoumarin, benzaldehyde and malononitrile in the presence of a variety of catalysts (Table 1).

We examined this reaction in the absence and presence of several catalysts. It was found that when the reaction occurred without any catalysts, it resulted in poor yield (Table 1, entry 1). However, catalysts such as $Al(HSO_4)_3$, surfactants $Zn(DS)_2$ (Zinc dodecyl sulfate), and $Cu(DS)_2$ (Cupper dodecyl sulfate) could push the reaction forward with moderate yields(Table 1, entries 7-9). But, when surfactant SDS was used in this reaction system, the yields of the products improved (Table 1, entries 2-5).

We also evaluated the amount of surfactant required for this transformation. It was found that when we increased the amount of the SDS from 5 to 20 mol%, the yields increased from 70 to 85%. Using 20 mol% SDS in water was sufficient to push the reaction forward. Extra amounts of the surfactant did not improve the yields. Under the optimized reaction conditions, a series of 3,4-dihyropyrano[c]chromene derivatives **2** were synthesized (Scheme 1, Table 2).

All the aforementioned reactions (Table 2) delivered excellent product yields and accommodated a wide range of aromatic aldehydes bearing both electro-donating and electro-withdrawing substituents.

Subsequently, the condensation of aldehydes with 4-hydroxycoumarin was carried out using SDS as the catalyst under the above optimized reaction condition. All aldehydes reacted almost equally well to afford biscoumarins in excellent yields (Scheme 2, Table 3).

Furthermore, we decided to study the catalytic activity of the recycled SDS in the synthesis of **2a**. After the separation of products, the catalyst-containing aqueous medium was reused in the next run without further purification. As shown in Table 4, the reaction medium can be recycled at least four times without significant decrease of the yields. The obtained yields ranged from 80% to 85%.

In conclusion, we have demonstrated a simple, efficient and green protocol for the synthesis of biscoumarins and 3,4-dihydropyrano[c]chromenes in neat water. Particularly, the use of SDS, as a green, non-toxic, inexpensive and reusable catalyst, makes this method very efficient.

Table 1. Optimization of the Reaction Conditions in Neat Water

Entry	Catalyst	Mol (%)	Time (h)	Yield (%)[a]
1	Non	-	24	25
2	SDS	5	3	70
3	SDS	10	3	72
4	SDS	15	2	74
5	SDS	20	2	85
6	SDS	25	2	85
7	$Cu(DS)_2$	20	5	62
8	$Zn(DS)_2$	20	6	57
9	$Al(HSO_4)_3$	20	8	51

[a]Yields are related to the isolated pure products.

Table 2. Synthesis of 3,4-Dihyropyrano[c]chromenes by Condensation of Aldehydes, 4-Hydroxycoumarin and Malononitrile Using SDS (20 mol%) as Catalyst in Neat Water at 60 °C Temperature

Entry	Ar	Product	Time (h)	Yield (%)[a]	Melting point (°C)/(lit.)
1	C_6H_5	**2a**	2.0	85	256-258(258-260)[12]
2	4-$O_2NC_6H_4$	**2b**	3.0	96	258-260(255-256)[12]
3	3-$O_2NC_6H_4$	**2c**	2.15	95	258-260(262-264)[13]
4	4-FC_6H_4	**2d**	2.45	96	260-262
5	3-ClC_6H_4	**2e**	2.15	86	246-248(245-247)[11]
6	4-ClC_6H_4	**2f**	2.30	88	256-258(258-260)[12]
7	4-BrC_6H_4	**2g**	2.0	80	247-249(249-251)[14]
8	2-$CH_3C_6H_4$	**2h**	2.0	87	264-266
9	4- $CH_3C_6H_4$	**2i**	1.30	78	251-253(250-252)[11]
10	2,4-$Cl_2C_6H_3$	**2j**	2.45	83	258-259(257-259)[13]
11	4- $CH_3OC_6H_4$	**2k**	2.30	95	238-240(232-234)[12]
12	3,4-$(CH_3O)_2C_6H_3$	**2l**	2.30	90	228-230
13	4-$(CH_3)_2NC_6H_4$	**2m**	3.0	89	265-267(266-268)[11]

[a]Yields are related to the isolated pure products.

Table 3. Synthesis of Biscoumarins by Condensation of Aldehydes and 4-Hydroxycoumarin Using SDS (20 mol%) as Catalyst in Neat Water at 60 °C Temperature

Entry	Ar	Product	Time (h)	Yield (%)[a]	Melting point (°C)/(lit.)
1	C_6H_5	**4a**	2.30	90	230-232(228-230)[10]
2	4-$O_2NC_6H_4$	**4b**	3.00	98	232-234(232-234)[10]
3	3-$O_2NC_6H_4$	**4c**	2.45	95	234-236(220-224)[10]
4	4-FC_6H_4	**4d**	3.00	94	213-215
5	3-ClC_6H_4	**4e**	2.45	92	228-230
6	4-ClC_6H_4	**4f**	2.30	93	256-258(252-254)[10]
7	4-BrC_6H_4	**4g**	2.45	91	265-267(266-268)[11]
8	2-$CH_3C_6H_4$	**4h**	2.45	84	221-223(218-220)[10]
9	4- $CH_3C_6H_4$	**4i**	2.45	97	266-268
10	4- $CH_3OC_6H_4$	**4j**	3.00	97	246-248(242-244)[10]
11	3,4-$(CH_3O)_2C_6H_3$	**4k**	3.00	98	263-265(264-266)[11]
12	4-$(CH_3)_2NC_6H_4$	**4l**	3.00	94	222-224

[a]Yields are related to the isolated pure products.

Table 4. Reusability of the Catalyst in the Model Reaction

Entry	Number of recycle	Yield (%)[a]
1	First	85
2	1	85
3	2	83
4	3	82
5	4	80

[a]Yields are related to the isolated pure products.

ACKNOWLEDGMENTS

We are thankful to the Office of Graduate Studies, Rafsanjan Vali-e-Asr University, for partial support of this work.

REFERENCES

[1] G.R. Green, J.M. Evans, A.K. Vong, in: A.R.

Katritzky, C.W. Rees, E.F.V. Scriven (Eds.), Comprehensive Heterocyclic Chemistry II, Pergamon Press, Oxford, 1995, p. 469.

[2] W.O. Foye, Principi Di Chemico Farmaceutica, Piccin: Padova, Italy, 1991, p. 416.

[3] L. Bonsignore, G. Loy, D. Secci, A. Calignano, Eur. J. Med. Chem. 28 (1993) 517.

[4] C.S. Konkoy, D.B. Fick, S.X. Cai, N.C. Lan, J.F.W. Keana, PCT Int. Appl. WO 0075123, 2000; Chem. Abstr. 134 (2001) 29313a.

[5] I. Kostava, I. Manolov, I. Nicolova, S. Konstantonov, M. Karaivanova, Eur. J. Med. Chem. 36 (2001) 339.

[6] Z.H. Chohan, A.U. Shaikh, A. Rauf, C.T.J. Supuran, Enzym. Inhib. Med. Chem. 21 (2006) 741.

[7] H. Zhao, N. Neamati, H. Hong, A. Mazumdar, S. Wang, S. Sunder, G.W.A. Milne, Y. Pommier, T.R. Burke, J. Med. Chem. 40 (1997) 242.

[8] I. Manolov, C.M. Moessmer, N. Danchev, Eur. J. Med. Chem. 41 (2006) 882.

[9] S. Kadir, A.A. Dar, K.Z. Khan, Synth. Commun. 38 (2008) 3490.

[10] M. Kidwai, V. Bansal, P. Mothsra, S. Saxena, R.K. Somvanshi, S. Dey, T.P.J. Singh, Mol. Catal. 268 (2007) 76.

[11] J.M. Khurana, S. Kumar, Tetrahedron Lett. 50 (2009) 4125.

[12] R.M. Shaker, Pharmazie 51 (1996) 148.

[13] S. Abdolmohammadi, S. Balalaie, Tetrahedron Lett. 48 (2007) 3299.

[14] M.M. Heravi, B.A. Jani, F. Derikvand, F.F. Bamoharram, H.A. Oskooie, Catal. Commun. 10 (2008) 272.

[15] R.A. Sheldon. J. Mol. Catal. A 107 (1996) 75.

[16] C.J. Li, Chem. Rev. 105 (2005) 3095.

[17] S. Narayan, J. Muldoon, M.G. Finn, V.V. Fokin, H.C. Kolb, K.B. Sharpless, Angew. Chem., Int. Ed. 44 (2005) 3275.

[18] D.O. Jang, Tetrahedron Lett. 37 (1996) 5367.

[19] H. Yorimitsu, H. Shinokubo, K. Oshima, Chem. Lett. (2000) 104.

[20] Y. Kita, H. Nambu, N.G. Ramesh, G. Anilkumar, M. Matsugi, Org. Lett. 3 (2001) 1157.

[21] T.A. Khan, R. Tripoli, J.J. Crawford, C.G. Martin, J.A. Murphy, Org. Lett. 5 (2003) 2971.

[22] S. Lang, M. Corr, N. Muir, T.A. Khan, F. Schonebeck, J.A. Murphy, A.H. Payne, A.C. Williams, Tetrahedron Lett. 46 (2005) 4027.