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Three component one-pot synthesis of some 4H-benzo[b]pyran derivatives by using dual organo modified MCM-41 as nanocatalyst

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This paper presents a feasible protocol for the preparation of new nano dual organo modified MCM-41, MCM-41-*β*-CD.NH_2, and investigate its catalytic application for the synthesis of 4*H* benzo[b]pyran derivatives. The nanocomposite was succesfully characterized by FT-IR, TGA, SEM, TEM and BET techniques. These data were shown that *β*-CD and triethoxysilyl amine are grafted onto MCM-41.

Keyword: new nano MCM-41-*β*-CD.NH_2, 4*H*benzo[b]pyran derivatives, *β*-cyclodextrin(*β*-CD), triethoxysilyl amine, base catalyst.

INTRODUCTION

Pyran derivatives are an important class of natural organic compounds with several biological and pharmacological activities, such as anti-coagulant, spasmolytic, anticancer, antibacterial andantifungal, diuretic, specific IKCa channel blockers. [1] Different synthetic approaches have been reported in the literature for the synthesis of these compounds. Some of these methods including the Michael addiction reaction,[2] applying of microwave [11] and ultrasonic irradiation [12]. In addition,there are several modified procedures using a variety of reagents, including the use of hexadecyldimethylbenzylammonium bromide (HDMBAB) [13], tetrabutylammonium bromide (TBAB) [14,15] , fluoride ion [16], ionic liquids [17–20], MgO [21],nanoMgO [6,7], solid acid [8],and DBU[9,10].

A multicomponent reaction (MCR) is defined as any process in whichthree or more reactants react in one pot to form a product which contains portions of all the reactants, generating products with structural complexity in a single step. [3] The MCRs have the advantages of selectivity, simplicity and synthetic efficiency emerging as an powerful tool in modern synthetic chemistry. [4,5]However, the aim of this work is to synthesis of a some 4*H* benzo[b]pyran derivatives by using new nano MCM-41-*β*-CD.NH_2 as a catalyst via MCR method.

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EXPERIMENTAL SECTION

All chemical materials were purchased from Aldrich and Merck Chemical companies. Tetraethyl orthosilicate, (TEOS (98%, Aldrich)) was selected as a source of silica and cetyltrimethyl-ammonium bromide, (CTAB (98%, Aldrich)) was used as the structure directing agent. Deionized water was obtained from a system of two ionic interchange columns, cole–Parmer instruments. Melting points were determined on an electrothermal SI550 apparatus. FT-IR spectra were recorded from KBr discs on a Perkinelemer BX_ll. ^{1}H NMR and ^{13}C NMR spectra were recorded using a Bruker Avance 500 MHz instrument in DMSO-*d6*. All yields refer to the isolated products. Productswere characterized by comparison of their physical constants such as melting point, FT-IR and/or NMR spectroscopy with authentic samples and those reported in the literature. The purity determination of the substrate and reaction monitoring were accompanied by TLC on silicagel polygram SILG/UV 254 plates.

Preparation of nano dual organo modified MCM-41, MCM-41-*β*-CD.NH_2,

For synthesized this molecular sieve, 0.5g CTAB were added to 96 mL of deionized H_2O under stirring. After the solution turned clear, 34 mL of ethanol was added to the mixture. Then 10 mL of aqueous ammonia solution was added to mixture and it was allowed to mix for 5 min. After that, 2.0 mL of TEOS was poured into the solution immediately under stirring for 3 h at room temperature. The solid product was recovered by filtration and dried at room temperature overnight. The CTAB was removed from the composite material by calcining

the sample at 540 ˚C for 9 h. In the other step, the obtained powder (1g) was dispersed in dry DMF (30 mL) by sonication. Then solution of hexamethylene diisocyanate (HMDI) (3 mL) in 5 mL of dry DMF was added dropwise to the mixture. After mechanically agitation for 3 h, the suspended substance was seprated with filtration. For removing of unreacted HDMI, product was re-dispersed in dry DMF and isolate with filtration.The precipitate product was used in the next step to graft *β*-CD onto surface of MCM-41, product in pre step was suspended in dry DMF (15 mL) and then (2 mmol) of *β*-CD was dissolved in 15 mL of dry DMF and was added dropwise to mixture. The reaction mixture was stirred at 70 °C for 3 h. The precipitate washed with water and acetone several times. The product was dried in a vacuum for 24 h. Finally, triethoxysilyl amine (2 g) was added to this obtained powder (1 g) with 80 mL of toluene. This mixture was refluxed for 24 h at 110 °C. (Scheme 1)

General procedure for the synthesis of 4*H*benzo[b]pyran derivatives catalyzed by MCM-41-*β*-CD.NH_2

A mixture of an benzaldehyde (1 mmol), molononitrile (1 mmol), dimedone (1 mmol), and nanocomposite MCM-41-*β*-CD.NH_2(0.05g), in acetonitrile (5 mL) was stirred at reflux condition for an appropriate time. After completion of the reaction, monitored by TLC, the mixture was cooled to room temperature and the solid product was filtered, washed with cold distilledwater to obtain essentially pure products. The solid product can be recrystallized from hot ethanol.

SELECTED SPECTRA DATA

2-Amino-7,7-dimethyl-5-oxo-4-phenyl-5,6,7,8-tetrahydro-4*H*-chromene-3-carbonitrile (2a)

IR (KBr) v: 3392, 3331, 2182, 1681, 1216 cm^{-1}

1H NMR (400 MHz, CDCl3): δ 1.07 (s, 3H), 1.14 (s, 3H), 2.22(d, 1H, J = 16.4 Hz), 2.28 (d, 1H, J = 16.4 Hz), 2.45–2.53 (m, 2H),4.43 (s, 1H), 4.54 (s, 2H, NH2), 7.20–7.33 (m, 5H). 13C NMR (100MHz, CDCl3): δ ppm:27.71, 28.91, 32.22, 35.53, 40.70, 50.68, 114.09,118.61, 127.18, 127.56, 128.62, 143.15, 157.44, 161.49, 195.83.

2-Amino-4-(3-chlorophenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4*H*-chromene-3-carbonitrile (2h)

IR (KBr) v: 3321, 3184, 2965, 2191, 1682, 1659,1372, 1213 cm^{-1};

1H NMR (400 MHz, CDCl3): δppm = 0.96 (s, 3H—CH3), 1.04 (s, 3H,—CH3), 2.15 (d,2H, J = 8.0 Hz, —CH2), 2.28 (d, 2H, J = 8.4 Hz, —CH2), 2.53 (s, 2H, —NH2), 4.22 (s, 1H,—CHaliphatic), 7.13 (d, 1H, J = 7.6 Hz, ArH), 7.17 (s, 1H, ArH), 7.27 (d, 1H, J = 8.0 Hz, ArH), 7.36 (t, 1H, J= 7.6 Hz, ArH); 13C NMR (100 MHz, CDCl3): δppm : 26.8, 28.2, 31.8, 35.3, 49.9, 57.6, 112.0, 119.4,125.9, 126.6, 127.0, 130.3, 132.9, 147.2, 158.4, 158.5, 162.8, 195.7.

2-Amino-4-(3-methoxyphenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitril (2e)

IR (KBr) v: 3392, 3328, 2178, 1681, 1213 cm-1. white solid. 1H NMR (400MHz, CDCl3): δ7.21-7.25(m, 1H, Ph), 6.84(d, J=7.6Hz, 1H, Ph), 6.75-6.79(m, 2H, Ph), 4.61(s, 2H, NH2), 4.39(s, 1H, CH), 3.81(s, 3H, OCH3), 2.47(s, 2H, CH2), 2.25(d, J=2.4Hz, 2H, CH2), 1.13(s, 3H, CH3), 1.07(s, 3H, CH3); 13C NMR (100MHz, CDCl3): δ ppm: 196.2, 164.1, 159.5, 142.1, 133.1, 130.8, 128.6, 120.6, 112.8, 57.6, 50.5, 40.5, 34.2, 32.2, 29.3, 27.5

2-Amino-4-(2-chlorophenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile (2i)

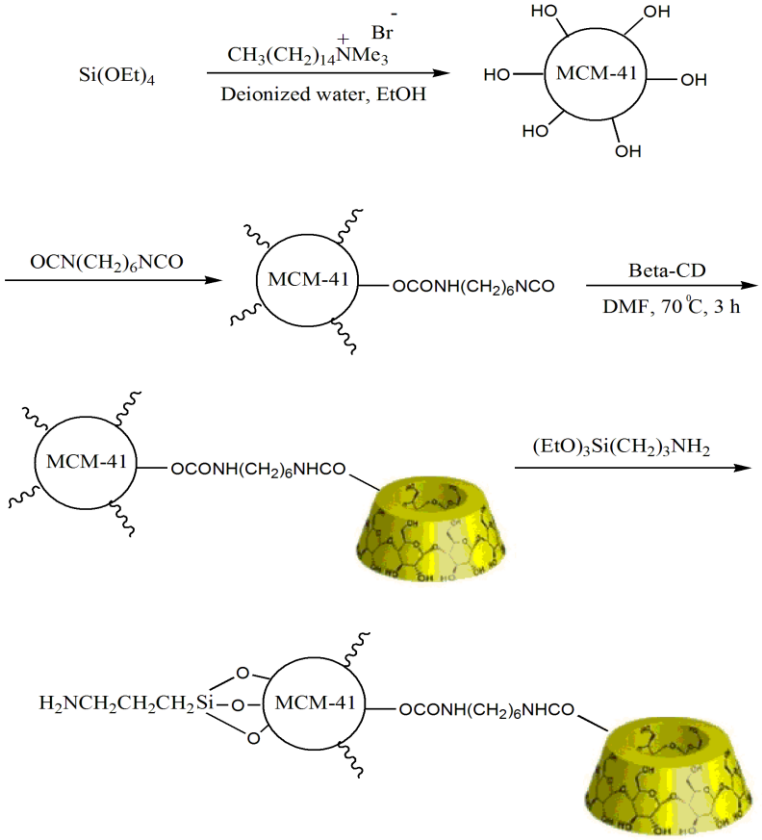
IR (KBr) v: 3394, 3323, 2187, 1681, 1216 cm-1. 1H NMR (400MHz, CDCl3): δ7.34(d, J=7.6Hz, 1H, Ph), 7.21-7.23(m, 2H, Ph), 7.14-7.18(m, 1H, Ph), 4.87(s, 1H, CH), 4.64(s, 2H, NH2), 2.47(s, 2H, CH2), 2.18-2.28(m, 2H, CH2), 1.14(s, 3H, CH3), 1.09(s, 3H, CH3);13C NMR (100MHz, CDCl3): δ 196.2, 164.2, 159.6, 142.1, 133.1, 131.2, 130.8, 128.8, 128.5, 120.6, 112.8, 57.8, 50.8, 40.5, 34.2, 32.2, 29.3, 27.9

2-Amino-7,7-dimethyl-4-(4-nitrophenyl)-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile (2m)

IR (KBr) v: 3394, 3325, 2176, 1681, 1222cm-1.1H NMR (400MHz, CDCl3): δ8.19(d, J=8.8Hz, 2H, Ph), 7.44(d, J=8.4Hz, 2H, Ph), 4.69(s, 2H, NH2), 4.54(s, 1H, CH), 2.51(s, 2H, CH2), 2.24-2.27(m, 2H, CH2), 1.15(s, 3H, CH3), 1.06(s, 3H, CH3); 13C NMR (100MHz, CDCl3): δ 195.8, 162.9, 158.6, 146.2, 128.9, 128.7, 124.2, 124.0, 119.8, 119.6, 112.1, 57.6, 49.8, 39.8, 35.9, 32.2, 28.5, 28.2.

RESULTS AND DISCUSSION

The systematic steps of aminopropyl and *β*-cyclodextrin grafted mesoporous MCM-41, MCM-41-*β*-CD.NH_2, preparation was shown in Scheme 1.



Scheme 1. Synthetic procedure of MCM-41-β-CD.NH_2

The structures of MCM-41-*β*-CD.NH_2 was confirmed by FT-IR spectra. As shown in Fig. 1, the typical Si–O–Si bands around 1228, 1063, 794 and 462 cm^{-1} associated with the formation of a condensed silica network are present in the spectra. The strong peak around 1630 cm^{-1} is mainly from the bending vibration of adsorbed H_2O. The peaks at 2800-3400 cm^{-1} region are attributed to amino groups which are covered by O–H vibration located in silica surface and also physically adsorbed water. The bands in the range of 2800–3000 cm^{-1} corresponded to the stretching vibration of C–H bonds of the methylene groups that indicates successful grafting of organic groups to MCM-41 (Fig. 1).

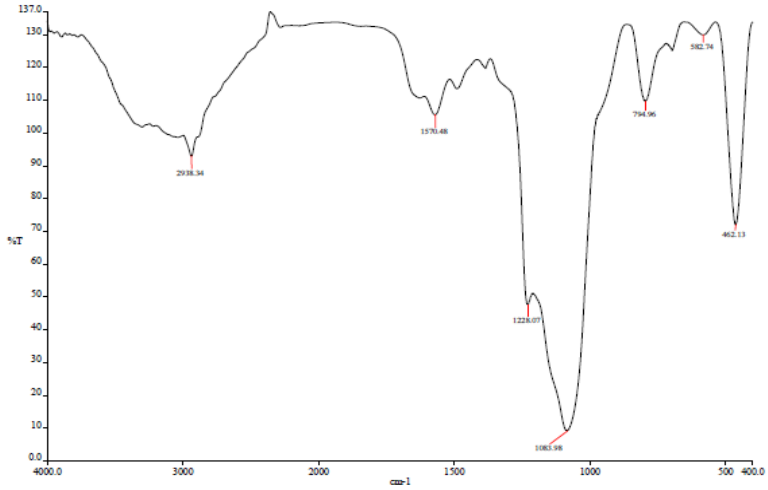


Fig. 1. FT-IR spectra of MCM-41-β-CD/NH_2

TGA and DTA analysis of the organic- inorganic nanocomposite was also used to determine the content of organic functional groups of the sample and their thermal stability. As shown in Fig. 2, the emission mass fraction of water was about 10 % when the temperature was less than 200 °C and the

other decrease in weight was 26% in the temperature range from ca. 200 to 680 °C should be ascribed to the decomposition of groups grafed to the silica surface during hydrothermal treatment.

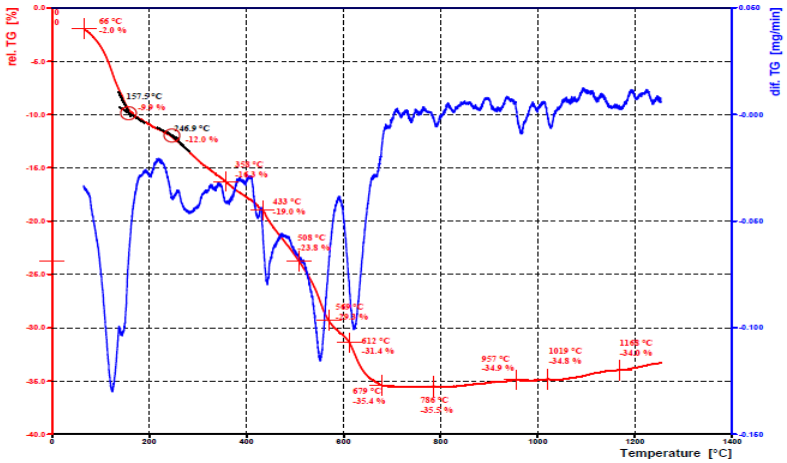


Fig. 2. TGA and DTA analysis of MCM-41-β-CD.NH_2

The morphology and particle size distribution ofMCM-41-β-CD.NH_2 was performed by measuring SEM and TEM using. Fig. 3 reveals that nanocomposite has spherical shape with nano dimension ranging under 300 nm

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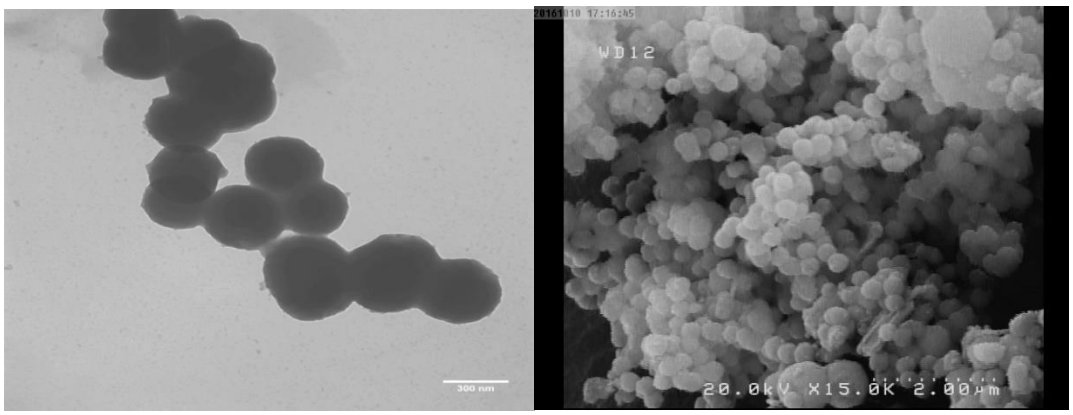


Fig. 3. The SEM (Left) & TEM (Right) images of MCM-41-β-CD.NH_2.

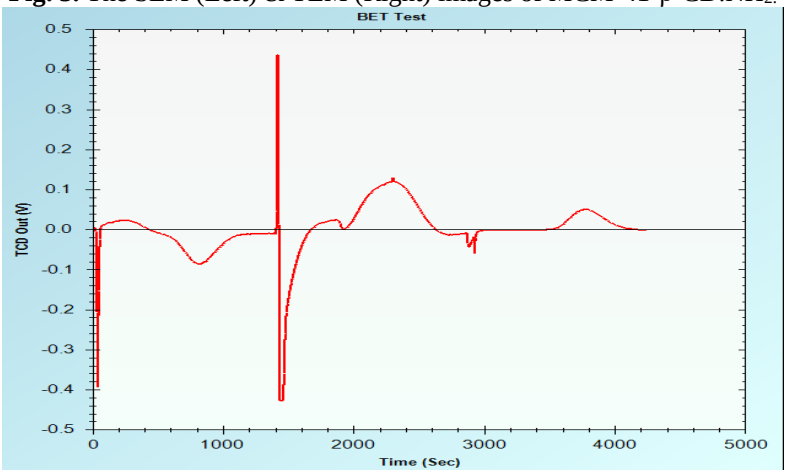


Fig.4. BET analysis of MCM-41-β-CD.NH_2.

The specific surface area and the pore size distribution were calculated by Brunauer-Emmett-Teller (BET) method. The pore size distribution was calculated using desorption branches of nitrogen isotherms. The total surface of new nano MCM-41-β-CD.NH_2 is 39.9 m^2/g and the BET surface is 6.981 m^2 (Fig. 4).

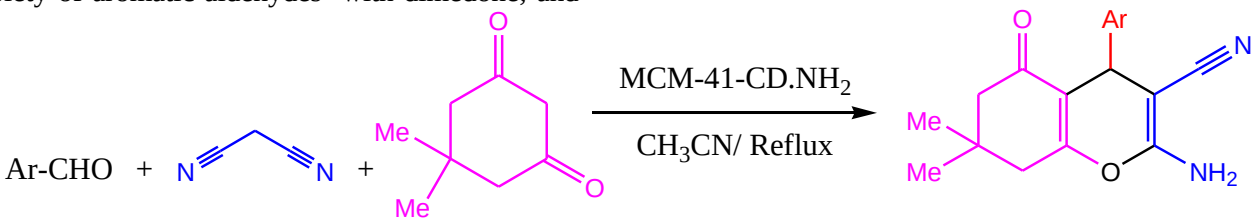
After characterization, the catalytic performance of this heterogeneous organocatalyst has been studied as stationary micro-vessel basic heterogeneous catalystin the synthesis of cyclic pyranes.

At first, one pot multicomponents condensation of dimedone, benzaldehyde and malononitril was investigated in the presence of nanocomposite (Table 1). TLC analysis of the reaction mixture interestingly showed that this catalyst acted very efficiently in CH_3CN, and that 0.0 5 g of the catalyst was enough to convert 1 mmol of benzaldehyde to 2-Amino-7,7-dimethyl-5-oxo-4-phenyl-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile in 85% isolated yield.

Table 1. The one-pot three component reaction of benzaldehyde (1mmol), malononitrile (1 mmol) and dimedone (1mmol) under different conditions

Entry	Solvent	T °C	Catalytic amount (g)	Time (min)	Yield (%) [a]
1	CH_2Cl_2	r.t	0.05	60	52
2	Toluene	r.t	0.05	85	45
3	CH_3CN	r.t	0.05	60	68
4	EtOH	r.t	0.05	90	44
5	H_2O	r.t	0.05	120	37
6	Solvent free	r.t	0.05	185	35
7	CH_3CN	reflux	0.05	45	85
8	CH_3CN	reflux	0.1	40	58
9	CH_3CN	reflux	0.025	65	47

Using the optimized reaction conditions, the activity and the scope of the catalyst was explored in the one pot multicomponents condensation of variety of aromatic aldehydes with dimedone, and malononitril (Scheme 2). As shown in Table 2, electron withdrawing/donating groups have a very small influence on the reaction times and yields.



1a-1s 2a-2s

Scheme 2. MCM-41-β-CD.NH_2 catalyzed facile synthesis of 4H benzo[b]pyran derivatives

Table 2. Three-component synthesis of some 4*H* benzo[b]pyran derivatives via condensation of various aldehydes, malononitrile and dimedone in the presence of MCM-41-*β*-CD.NH_2.

Comp	Ar	Time (min)	Yield%	observed M.P (˚C)	reported M.P (˚C)
2a	C_6H_5-	45	85	219-221	223–224 [40]
2b	3-CH_3-C_6H_4-	40	97	197-199	198-200 [51]
2c	2-CH_3-C_6H_4-	45	98	176-178	176-179 [51]
2d	4-CH_3O-C_6H_4-	50	83	197-200	198-200 [40]
2e	3-CH_3O-C_6H_4-	45	95	188-191	188-190 [48]
2f	2-CH_3O-C_6H_4-	45	86	203-206	203-205 [48]
2g	4-Cl-C_6H_4-	55	86	208-210	208-209 [40]
2h	3-Cl-C_6H_4-	45	86	228-231	230-232

					[46]
2i	2-Cl-C_6H_4-	60	88	209-211	208-210 [45]
2j	4-Br-C_6H_4-	45	80	204-207	205-208 [42]
2k	3-Br-C_6H_4-	45	82	227-230	229-230 [50]
2l	2-Br-C_6H_4-	55	80	151-154	150-152 [47]
2m	4-NO_2-C_6H_4-	50	80	179-181	180-181 [41]
2n	3-NO2-C_6H_4-	45	82	213-215	214-216 [43]
2o	3-OH--C_6H_4-	55	83	204-206	204-205 [42]
2p	4-OH--C_6H_4-	60	80	207-209	208-210 [44]
2q	$C_5H_4O_2$	60	75	221-224	223-225
2r	C_9H_7NO	55	78	185-187	185-186 [49]
2s	C_5H_4OS	45	81	221-224	222-224 [41]

The reusability of the catalyst was also tested. For this gold, after completion of the reatcion, the MCM-41-*β*-CD.NH_2 was easily separated from the reaction mixture by filteration and washed with water and ethanol and then dried and reused for four times under one constant set of operating conditions. As shown in Fig. 5, the average chemical yield for four consecutive runs was equal, which clearly demonstrates the practical recyclability of this catalyst.

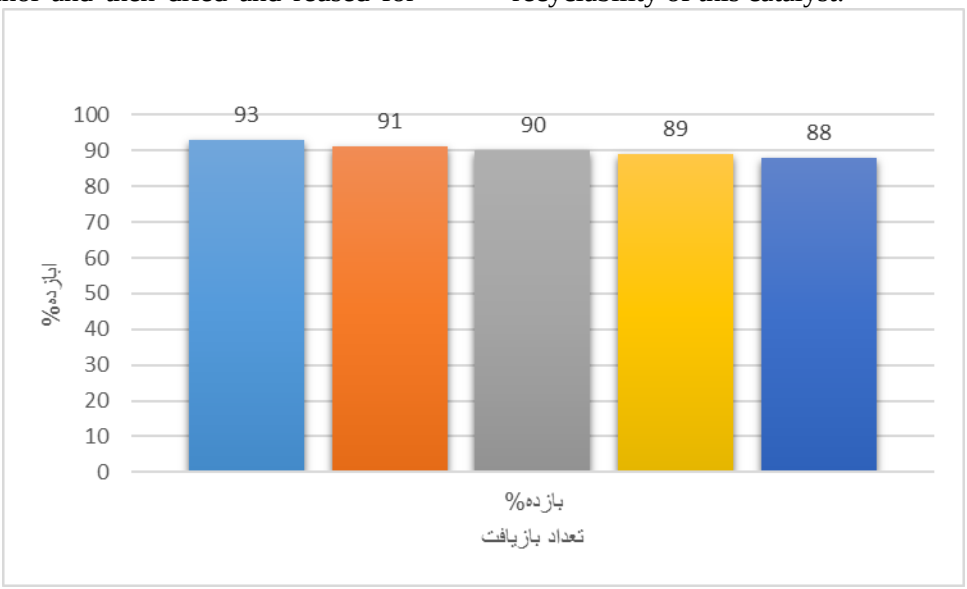


Fig. 5. Recyclability of MCM-41- β-CD.NH_2

CONCLUSION

In the present study, a mesoporous MCM-41 having *β*-CD and Brønsted basic units was synthesized via a surfactant-templated sol–gel methodology and a post modification process. The catalytic activity of the basic nanocomposite has been successfully applied for the one-pot three-components reaction dimedone, aromatic aldehyde and malononitril under in CH_3CN. This catalytic system certainly contributes to better environmental and green technology for the facile preparation of the 4*H* benzo[b]pyran derivatives. The current methodology has the advantages of operational simplicity, short reaction times, good yields and the desired products can be separated directly from the reaction mixture with high purity.

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