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ORIGINAL PAPER

Synthesis and evaluation of biological activity of novel chromeno[4,3-b]quinolin-6-one derivatives by SO_3H-tryptamine supported on Fe_3O_4@SiO_2@CPS as recyclable and bioactive magnetic nanocatalyst

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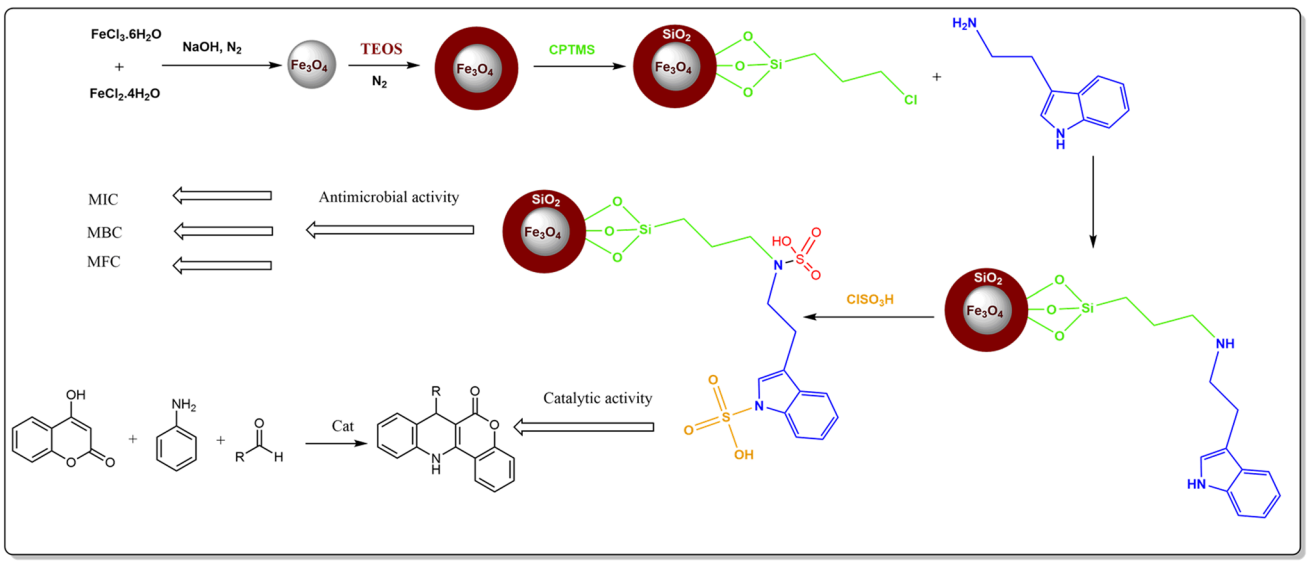
Abstract

New derivatives of chromeno[4,3-b]quinolin-6-one were synthesized using novel SO_3H-tryptamine supported on Fe_3O_4@SiO_2@CPS which could be recycled as an effective magnetic nanocatalyst. SEM, EDX, XRD, FT-IR, TGA, VSM and BET analyses were utilized to confirm the magnetic nanocatalyst structure. Evaluation of Antimicrobial (antibacterial and antifungal) function of magnetic nanocatalyst as well as derivatives undergone synthesis was carried out according to MIC, MBC and MFC values. Moreover, evaluation of the derivatives subject to synthesis was performed according to DPPH free radical besides the biological features, in order to obtain justifiable biological features.

Graphic abstract



Keywords Antimicrobial activity · Antioxidant activity · Bioactive magnetic nanocatalyst · Chromeno[4,3-b]quinolin · SO_3H supported on magnetic nanomaterials

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Extended author information available on the last page of the article

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Introduction

Multicomponent reactions are capable of synthesizing various compounds in one step with no generation of hazardous intermediates and with pro-environmental as well as green chemical features [1–6]. Multicomponent reactions can be considered of high importance in different areas of study including as medicinal chemistry as well as organic compounds synthesis [7–9].

Development of the novel nanomaterials contributing as effective catalysts to synthesize heterocyclic compounds via new methods with the use of multicomponent reactions can be really challenging [10, 11].

Currently, application of nanoparticles has attracted significant attention because of distinguished features of these materials [12–14]. Reports have shown different utilizations of nanoparticles in industrial fields including chemistry and biology [15–18]. It is also possible to use nanoparticles as magnetic nuclei to synthesize magnetic nanoparticles. Moreover, reports indicated various applications of magnetic nanoparticles in different areas, including solar cells [19], semiconductors [20], biotechnologies, biomedicine [21] and so on. In organic chemistry, their application aims at synthesis of heterogeneous magnetic catalysts [22–24]. Among the usages of magnetic nanocatalysts with the highest importance, one can refer to being easily separable and recyclable, along with having great surface area [25, 26].

The catalysts have Fe_3O_4 nanoparticles as their core coated by different compounds [27–31]. Different reports exist on SO_3H coated on magnetic nanomaterials as catalysts used to synthesize heterocyclic compounds, including pyrano[2,3-d]pyrimidines derivatives, 2,3-dihydroquinazolin-4(1H)-one derivatives and oxidizing agents, consisting of oxidizing sulfides as well as oxidative coupling of thiols [32–34].

Scholars have significantly considered quinoline in organic chemistry [35]. There is wide application of numerous natural compounds with this antibiotic property in their structures in the area of pharmaceutics and chemical industries [36–39]. Different reports have emphasized on several biological features including inhibition of tyrosine-kinase (PDGF-RTK) [40] and anti-HIV [41, 42], anticancer [43, 44], antimalarial [45], anti-inflammation [46, 47], antifungal [48] and antibacterial [49, 50] characteristics for the compounds consisting of quinoline derivatives.

Chromen having biological properties such as antimicrobial [51–53], anti-diabetic [54], anti-HIV [55] and antioxidant [56, 57] can be considered possessing bioactivity present in natural compounds consisting of flavonoids [58–61]. Chromen fused heterocycles (such as quinolone) are naturally abundant, with a variety of biological features [62–70].

Chromeno-quinoline derivatives have biological activities which are also found naturally. As an instance, nonsteroidal progesterone receptor modulators (I) and pheofungin A (II) consist of chromeno-quinoline [69] (Fig. 1).

In 2012, Mulakayala et al. performed synthesis of chromeno[4,3-b]quinolin-6-one derivatives subject to ultrasound, catalyst-free circumstances and investigated its anticancer impacts, obtaining favorable results (Fig. 2) [71].

Because of the significant role of heterocyclic compounds synthesis with biological features, development of a new SO_3H-tryptamine compound supported on Fe_3O_4 along with its application as a catalyst was performed through multicomponent reactions over the synthesis of new chromeno[4,3-b]quinolin-6-one derivatives. Next, evaluation of the antimicrobial features of the compounds undergone synthesis and the catalyst can be carried out. Eventually, the antioxidant characteristics of the compounds are investigated and admissible results are subsequently provided.

Experimental

General

Merck and Sigma-Aldrich were considered for the supply of reagents and solvents, and antibiotics were supplied

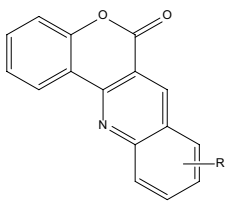
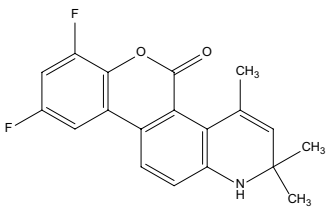
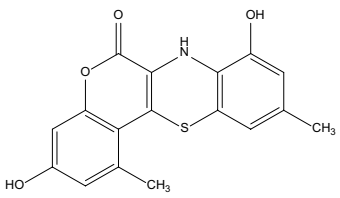


Fig. 2 Chromeno[4,3-b] quinolin-6-one synthesized chromeno[4,3-b]quinolin-6-one under ultrasound mediated and catalyst-free conditions with anticancer activity



Nonsteroidal progesterone receptor modulators (I)



Pheofungin A (II)
(Cytotoxic agent)

Fig. 1 Chromeno-quinoline derivatives are compounds with biological activity

from Sigma-Aldrich. Application of the scanning electron microscope (SEM) was carried out with the use of a Hitachi S4160 tool. A Bruker D8 X-ray diffractometer with Cu-Kα radiation ($\lambda = 1.5418$ Å) ranging at 10–70° along with the scanning rate of 1.5°/min was utilized to analyze X-ray diffraction (XRD). The records of the products' FT-IR spectra were prepared on Bruker Tensor 27 FT-IR spectrometer with the use of KBr pellets. Shimadzu DTG-60 tool was used to record the thermogravimetric analysis (TGA), while MDKFD was employed to record vibrating sample magnetometer (VSM). TLC (Silica gel, Aluminum Sheets F254, Merck) had effects on the reactions' monitoring progress as well as the products' purity. Kruss type KSP1N melting point was used to determine the material's melting points. Recording of the ^{1}H and ^{13}C-NMR spectra of the DMSO-*d*6 solutions was performed on a Bruker FT-NMR Ultra Shield-400 spectrometer (400 and 100 MHz, resp). The use of a Thermo Finnigan Flash EA microanalyzer aimed at performing elemental analyses. Jenway 6405 UV–Vis spectrophotometer was also used to determine the concentrations of bacterial and fungal suspensions along with derivatives absorption over antioxidant activities.

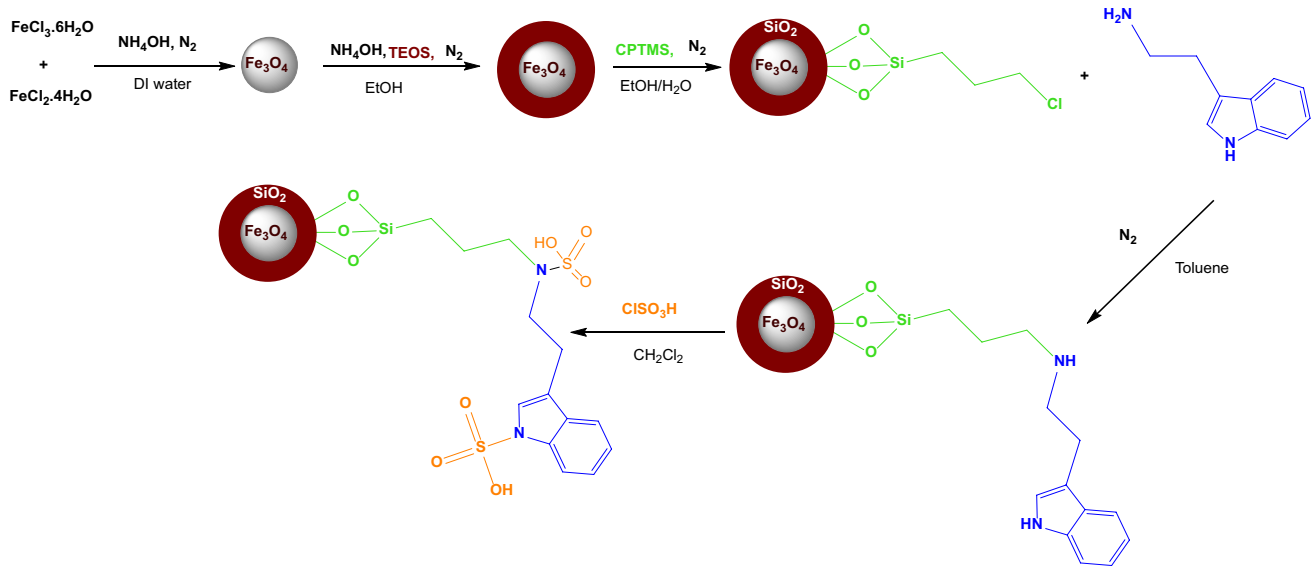
Synthesis of SO_3H-tryptamine supported on Fe_3O_4@SiO_2@ CPS

Initially, dissolution of $FeCl_3.6H_2O$ (5.838 g, 0.0216 mol) and $FeCl_2.4H_2O$ (2.147 g, 0.0108 mol) in 100 mL of deionized water was prepared subject to N_2 atmosphere. Slow addition of 10 mL of NH_4OH to the solution took place over 30 min after which stirring followed for another 30 min. Heating of the black product at a temperature of 80 °C in the next step lasted for 30 min, after which isolation was carried out with an external magnet and washing up was performed using double-distilled water to reach the neutral conditions. Further washing was then performed with DI water and EtOH for a number of times, and finally, room temperature was used for drying [34].

The next step included dispersion of 1 g of Fe_3O_4 NPs in 150 ml EtOH using sonication, along with addition of 5 ml of 25% NH_4OH and stirring for 30 min. Addition of 1 ml of tetraethyl orthosilicate (TEOS) drop-wise to the compound continued for 10 min, and stirring lasted for 24 h. Fe_3O_4@SiO_2 subject to synthesis was isolated using an external magnet, after which washing was run for a number of times with DI water and EtOH, and drying was considered subject to vacuum at a temperature of 80 °C for 24 h [27].

Dispersion of 1.5 gr Fe3O4@SiO2 nanoparticles subject to ultrasound conditions takes place in step three for 30 min in 150 ml ethanol/water (1:1), after which addition of 2.5 ml CPTMS ((3-chloropropyl)trimethoxysilane) to the combination and stirring follows at N2 atmosphere and a temperature of 40 °C for 8 h. Isolation of nanoparticles was carried out through sonication with the use of an external magnet, and washing was performed repeatedly using DI water and EtOH. Drying of Fe3O4@SiO2@CPS was conducted at room temperature [33].

Dispersion of Fe_3O_4@SiO_2@CPS (1gr) in toluene (50 ml) and addition of tryptamine (2 mmol, 0.25 g) along with stirring at reflux temperature for 12 h subject to N_2 atmosphere were considered in step four. Separation of the prepared functionalized magnetic nanoparticles was conducted using an external magnet, after which frequent washing with ethanol and drying at room temperature were carried out.



Scheme 1 Synthesis of SO_3H-tryptamine supported on Fe_3O_4@SiO_2@CPS

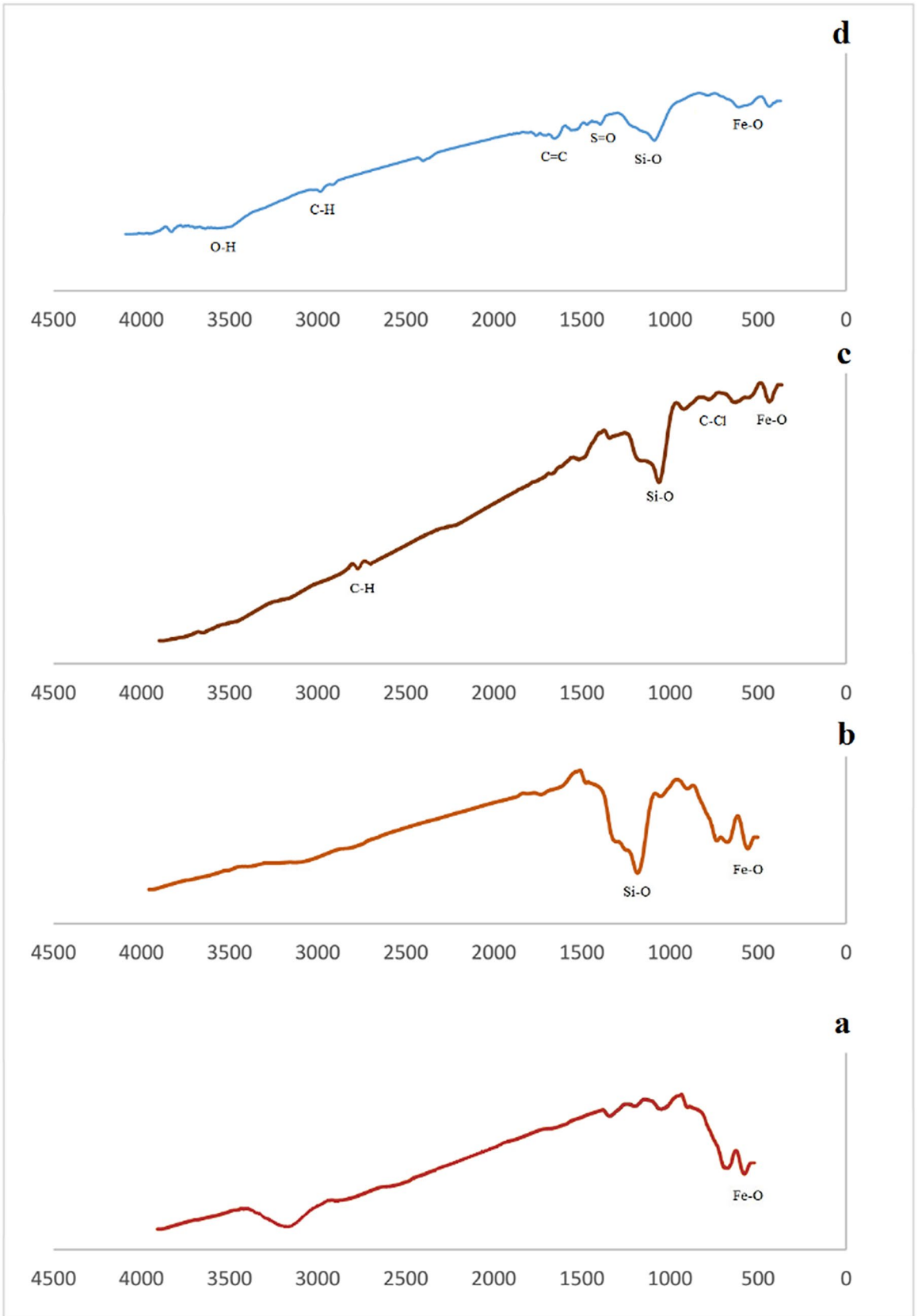


Fig. 3 IR spectrum of **a** Fe_3O_4; **b** Fe_3O_4@SiO_2; **c** Fe_3O_4@SiO_2@CPS; **d** SO_3H-tryptamine supported on Fe_3O_4@SiO_2@CPS

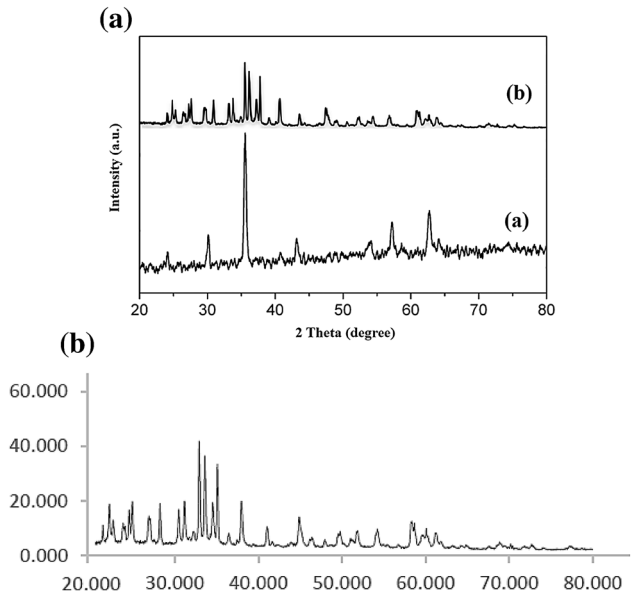


Fig. 4 XRD patterns of **a** Fe_3O_4; **b** SO_3H-tryptamine supported on Fe_3O_4@SiO_2@CPS

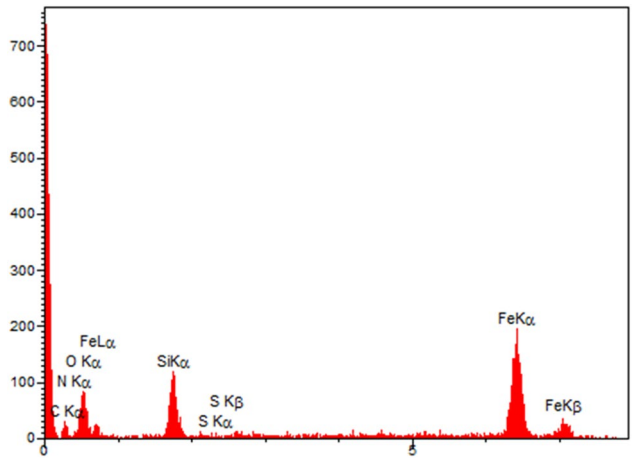


Fig. 5 EDX spectrum of SO_3H-tryptamine supported on Fe_3O_4@SiO_2@CPS

Dispersion of what results from the prior step (0.5 g) was done through sonication for 20 min in 10 ml CH_2Cl_2, after which addition of 1.5 ml chlorosulfonic to the combination in a drop-wise manner continued over 20 min, and stirring lasted 6 h at room temperature. Separation of SO_3H-tryptamine supported on Fe_3O_4@SiO_2@CPS was performed using magnetic decantation, and again frequent washing with ethanol and drying subject to vacuum at room temperature were performed.

General procedure for the preparation chromeno[4,3-b]quinolin-6-one derivatives

The temperature of 60 °C was used to stir the mixture of 4-hydroxy coumarin (1 mmol), aniline (1 mmol), aromatic aldehyde (1 mmol) as well as 4 mg cat in 2 ml of EtOH. When the reaction was completed (controlling through TLC), addition of 10 ml EtOH, separation of catalyst using external magnet, frequent washing with EtOH, and afterward, filtration of the precipitate along with the purification were carried out using recrystal in EtOH.

Antimicrobial properties

Persian Type Culture Collection (PTCC from the Persian Type Culture Collection (PTCC), Tehran, Iran, was referred to prepare Gram-negative pathogenic bacteria consisting of *Escherichia coli* (PTCC 1399), *Acinetobacter baumannii* (PTCC 1855) and *Klebsiella pneumoniae* (PTCC 1290), Gram-positive strains consisting of *Bacillus cereus* (PTCC 1665), *Streptococcus pyogenes* (PTCC 1447), as well as fungi involving *Aspergillus fumigatus* (PTCC 5009).

The CLSI guidelines M07-A9, M27-A2 and M26-A were followed prior procedures to investigate if broth microdilution was susceptible and also to carryout time–kill test [72–74]. Repetition of all tests was performed three times while reporting the mean values of the obtained results.

Antioxidant properties

Antioxidant impacts of the compounds subject to synthesis on the DPPH radical were assessed based on prior procedures [73, 75]. In this regard, addition of 1 ml of different compound concentrations (25, 50, 75, as well as 100 µg/mL) in methanol to 4 ml of 0.004% (w/v) methanol solution of DPPH, incubating for 30 min at room temperature, and reading the absorbance versus blank at 517 nm were all performed in order. The percentage (I%) of inhibiting generation of free radicals from DPPH could be then estimated using this equation:

$$\%\ \text{of scavenging} = (\text{A control} - \text{A sample})/(\text{A control}) \times 100$$

In which, A control shows all the reagents except the test compound; A sample indicates the test compound absorbance; and three repetitions were considered for the tests while reporting the average of the results.

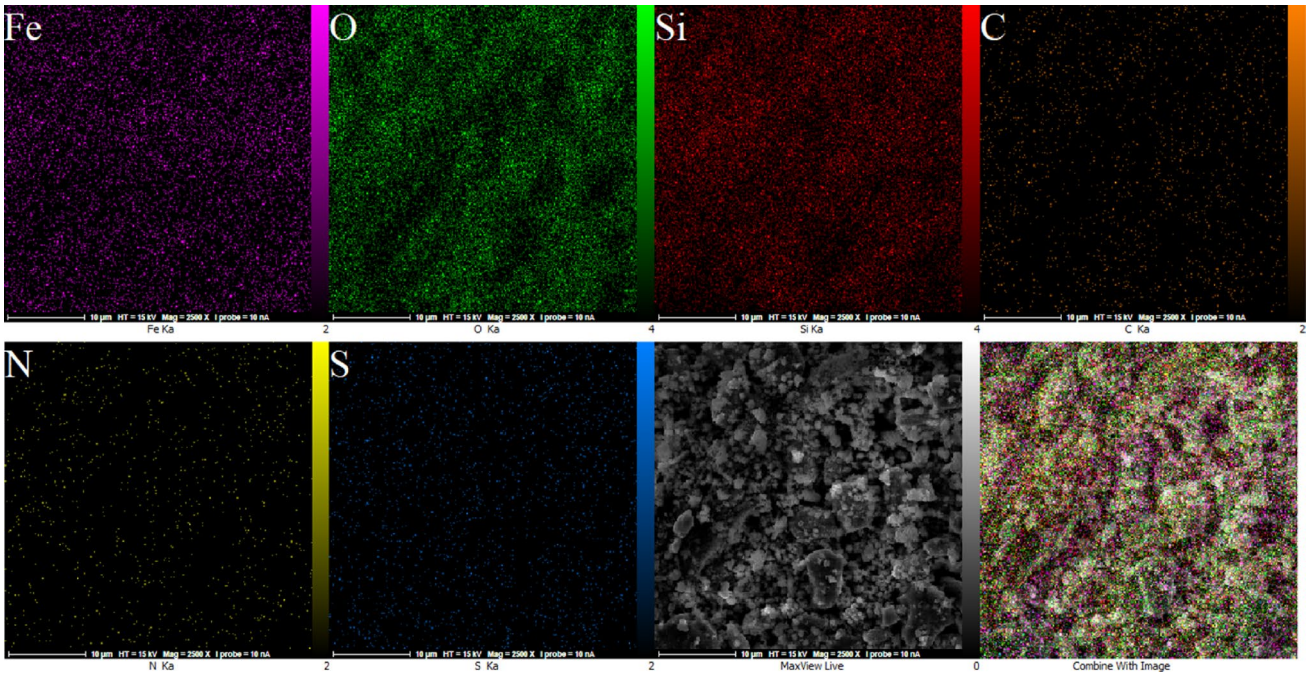


Fig. 6 EDX mapping of SO_3H-tryptamine supported on Fe_3O_4@SiO_2@CPS

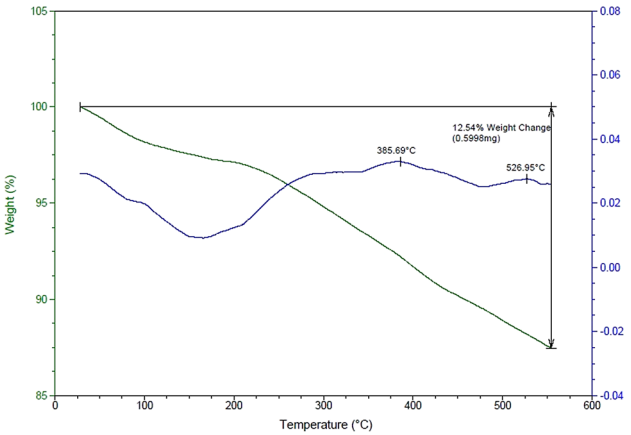


Fig. 7 TGA/DTG analysis spectrum of SO_3H-tryptamine supported on Fe_3O_4@SiO_2@CPS

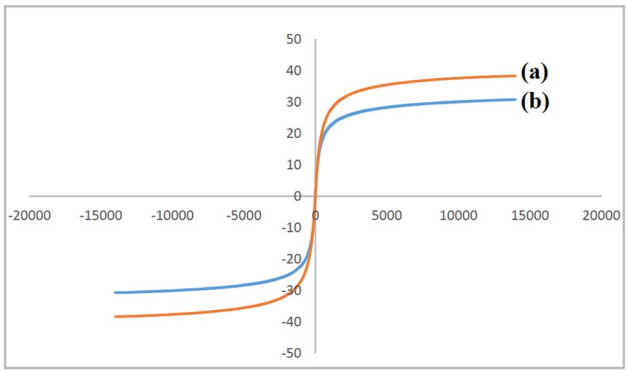


Fig. 8 VSM curve of **a** tryptamine supported on Fe_3O_4@SiO_2@CPS and **b** SO_3H-tryptamine supported on Fe_3O_4@SiO_2@CPS

Results and discussion

Catalysis synthesis

Synthesizing Fe_3O_4 nanoparticles, coating with tetraethyl orthosilicate (TEOS) and generating Fe_3O_4@SiO_2@CPS were performed in steps one through three, respectively, following the procedures already suggested. Synthesis of tryptamine supported on Fe_3O_4@SiO_2@CPS was carried out considering tryptamine and the precursor substance reaction. Eventually, synthesis of MNPs-SO_3H was conducted with the tryptamine supported on Fe_3O_4@SiO_2@CPS and chlorosulfonic acid reaction (Scheme 1).

Catalysis characterization

FT-IR (infrared spectroscopy), XRD (X-ray diffraction), EDX (energy-dispersive X-ray spectroscopy), TGA (thermogravimetric analysis), VSM (vibrating sample magnetometer) and SEM (scanning electron microscopy) analyses were used to investigate and verify nanoparticles structure.

As shown in Fig. 3, in the IR spectrum, broad peak at 3486 cm^{-1} associated with OH, C–H stretching vibration

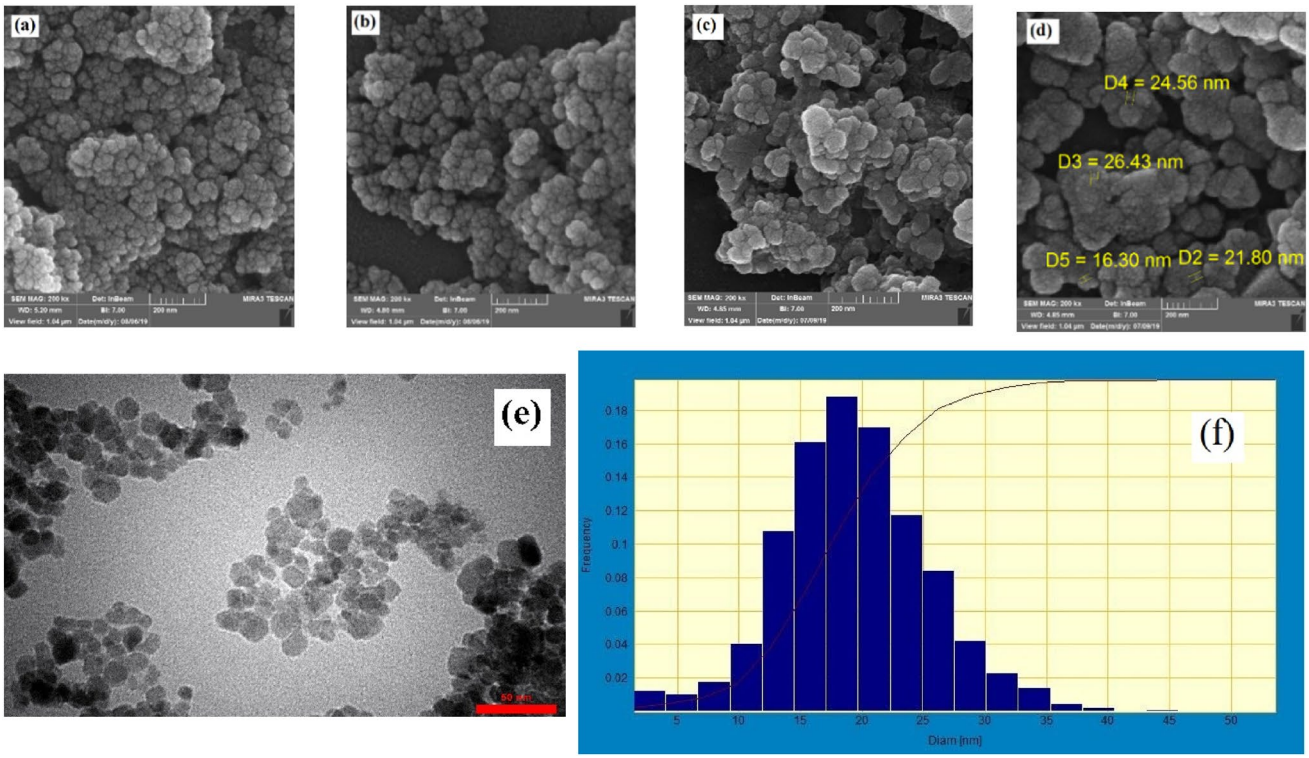


Fig. 9 SEM images of **a** Fe_3O_4; **b** Fe_3O_4@SiO_2; **c** tryptamine supported on Fe_3O_4@SiO_2@CPS; **d** SO_3H-tryptamine supported on Fe_3O_4@SiO_2@CPS; **e** TEM images of SO_3H-tryptamine supported on Fe_3O_4@SiO_2@CPS and **f** the size histogram of SO_3H-tryptamine supported on Fe_3O_4@SiO_2@CPS

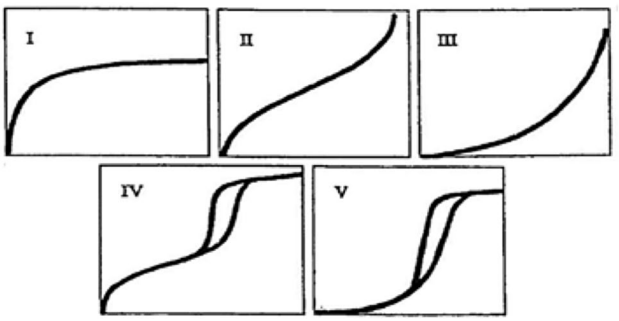


Fig. 10 General nitrogen uptake/absorption isotherms

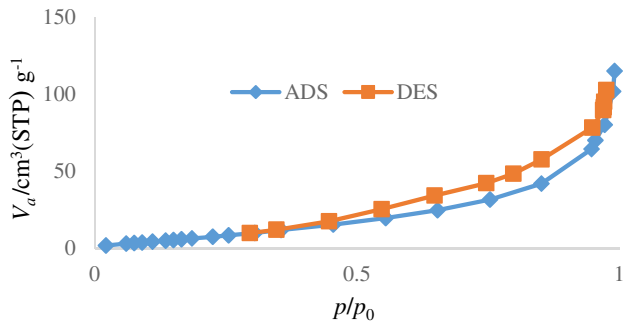


Fig. 11 Sample absorption and absorption isotherms

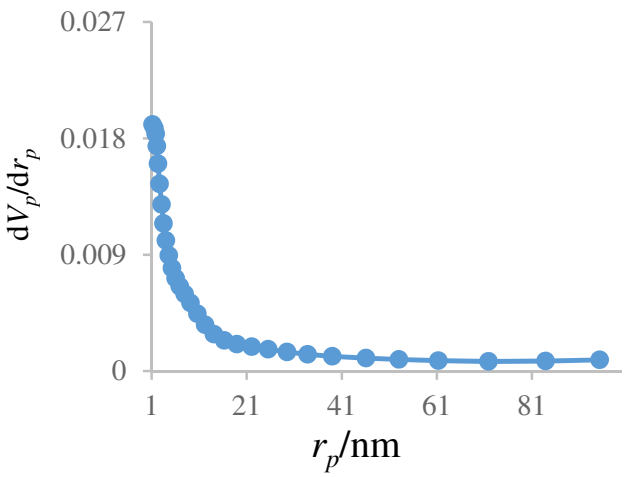
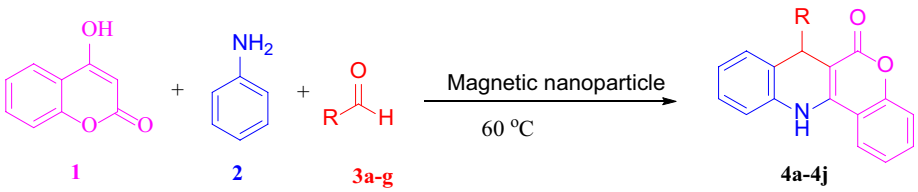


Fig. 12 Distribution of nanostructured cavity sizes based on BJH method

of alkyl chain was observed in 2869 cm^{-1} and 2935 cm^{-1}, in regions 1625 cm^{-1} C=C, 1350 cm^{-1} S=O, Si–O in 1124 cm^{-1} and eventually in 542 cm^{-1} Fe–O.

As shown in Fig. 4 and based on the patterns of X-ray, compounds going under synthesis indicate similarities in their standard crystalline cubic spinel X-ray spectra of Fe_3O_4

Scheme 2 Synthesis of chromeno[4,3-b]quinolin-6-one derivatives



Magnetic nanoparticle: SO_3H-tryptamine supported on Fe_3O_4@SiO_2@CPS

Table 1 Optimization of reaction conditions in synthesis 4a

Entry	solvent	MNPs (mg)	Temperature (°C)	Time (min)	Yield (%)
1	Solvent free	10	50	90	38
1	EtOH	10	50	35	65
2	H_2O	10	50	90	47
3	EtOH:H_2O	10	50	50	52
4	DMF	10	50	60	56
5	EtOH	0	50	75	10
6	EtOH	5	50	45	58
8	EtOH	15	50	30	81
9	EtOH	20	50	25	87
10	EtOH	25	50	25	84
11	EtOH	20	25	60	37
12	**EtOH**	**20**	**60**	**15**	**92**
13	EtOH	20	70	15	90
14	EtOH	20	80	15	86

Reaction conditions: EtOH solvent, 20 mg cat, 60 °C temperature

nanoparticles [12] in locations of 2θ angles at 30.4, 35.7, 43.4, 53.9, 57.3, 61.1.

Based on Figs. 5 and 6, all elements taken into account in the suggested nanoparticle structure, consisting of Fe, O, Si, C, N and S could be detected in the EDX spectrum as well as mapping of magnetic nanoparticle subject to synthesis.

Moreover, measurement of the TGA analysis in compounds undergoing synthesis was carried out at a temperature of up to 550 °C. As Fig. 7 shows, losing weight to a temperature up to 150 °C is dependent on the vaporization of water confined at the surface and the temperature reduction from 200 to 550 °C which seems related to the organic product groups decomposition. As shown in Fig. 7 and based on the DTG curve, the organic structure decomposition took place primarily at a temperature of 385 °C. Therefore, the magnetic nanoparticles undergoing synthesis showed stability under this value.

The amount of sulfamic acid loaded on magnetic nanoparticles was measured using back titration analysis, and the results show that the loaded amount was mmol.g^{-1}.

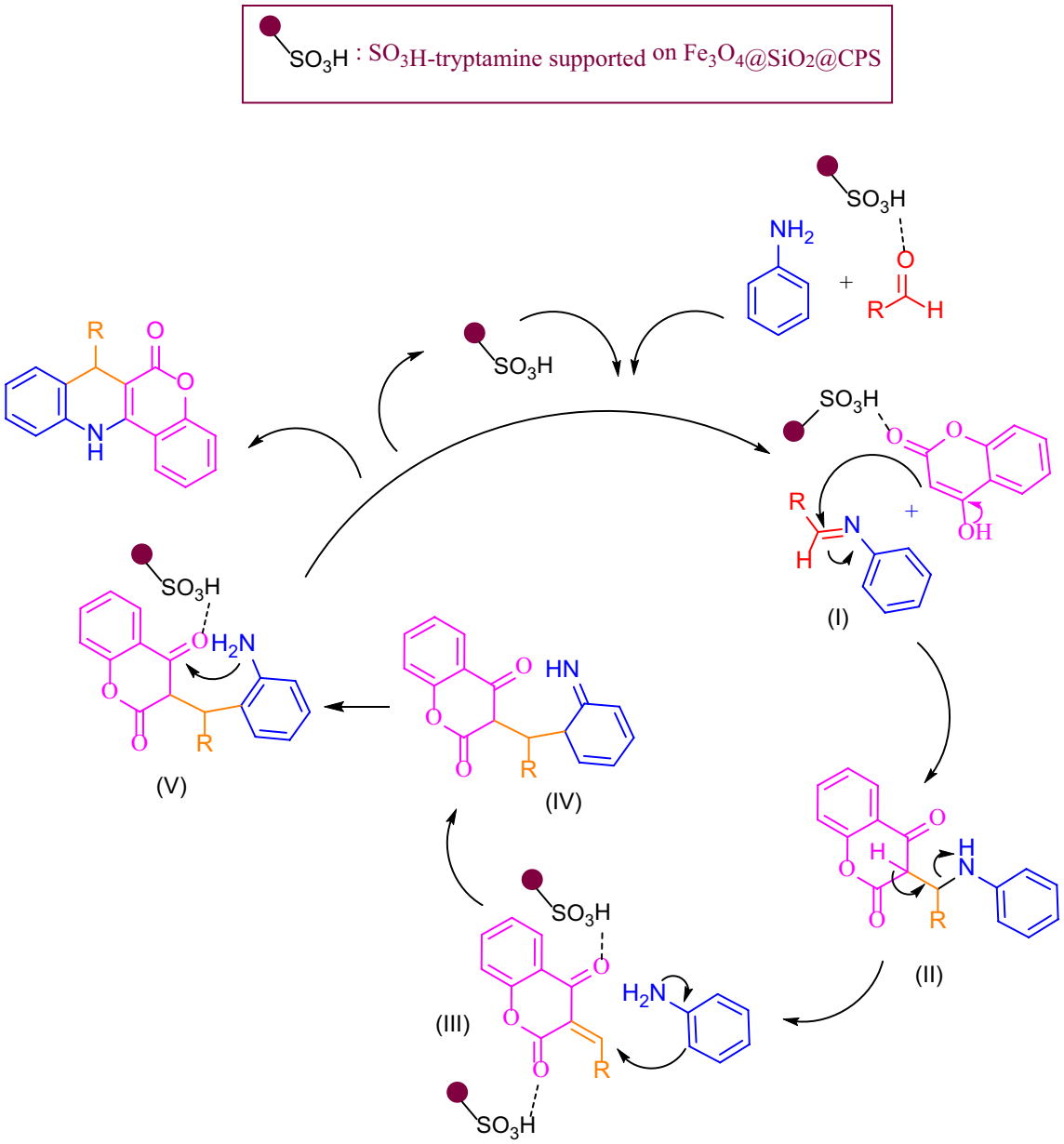
As reported previously, the value of VMS for Fe_3O_4 nanoparticles 55.1 emu g^{-1} was documented [34]. VMS value for Fe_3O_4@SiO_2@CPS 40.3 emu g^{-1} was reported [12]. According to Fig. 8, vibrating sample magnetometer for the tryptamine supported on Fe_3O_4@SiO_2@CPS (a) and SO_3H-tryptamine supported on Fe_3O_4@SiO_2@CPS (b), 38.37 emu g^{-1} and 30.76 emu g^{-1} were obtained, respectively.

Based on the SEM and TEM images, the nanoparticles are at the scope of nanoscale having the mean size of 19.2

Table 2 Multicomponent synthesis chromeno[4,3-b]quinolin-6-one derivatives

Entry	R	Time (min)	Yield (%)	MP (°C)	
				Found	Reported
4a	C_6H_5	15	92	>300	>300[53]
4b	2,6-Cl_2-C_6H_3	15	81	161–163	New
4c	4-$N(CH_3)_2$-C_6H_4	15	89	201–203	New
4d	2,5-$(OCH_3)_2$-C_6H_3	15	84	289 dec	New
4e	3,4-$(OCH_3)_2$-C_6H_3	10	86	265–267	New
4f	3,4,5-$(OCH_3)_2$-C_6H_2	10	95	>300	337–339[54]
4g	4-OCH_3-C_6H_4	15	93	224–22	227–229[51]
4h	2-CH_3-C_6H_4	30	83	231–234	233–234
4i	3-Cl-C_6H_4	25	88	248–250	249–252
4j	4-Br-C_6H_4	25	88	295–297	293–295

Reaction conditions: EtOH solvent, 20 mg cat, 60 °C temperature



Scheme 3 Proposed mechanism for the synthesis of chromeno[4,3-b]quinolin-6-one derivatives

along with uniform configuration and spherical shape which can be observed in Fig. 9.

It is important to study the specific surface area of the sample as well as its porosity for optimal sample performance. Absorbent/adsorbent isotherms were used for this purpose [76, 77].

Isotherms of total nitrogen uptake are shown in Fig. 10, and absorption isotherms related to the sample are shown in Fig. 11.

Comparing these isotherms, the behavior of the sample was similar to that of the third type of series of adsorbent/adsorbent isotherms.

Based on the results of BJH (Fig. 12), the porosity of the sample in accordance with isotherms is the third type (average hole size is 22.7 nm). Also, based on the results of the BET technique, the specific surface area of the sample was about 30 m^2/g. It seems that the optimal effect of synthesis method parameters has affected the level of surface area.

As a result, the high permeability and the desired surface area of these specimens have developed them as new compounds for use in catalytic field.

Based on Scheme 2, 4-hydroxy coumarin, aniline and aldehyde derivatives were used for the synthesis of chromeno[4,3-b] quinolin-6-ons.

Table 3 Comparison of different methods in the synthesis chromeno[4,3-b]quinolin-6-ons derivatives

Entry	Cat	Time (min)	Temperature (°C)	Yield (%)
4a	$[HYSBPI].HSO_4$	13	150	94[78]
4a	$Bi(OTf)_3$	15	130	86[80]
4a	This work	20	50	92
4f	LDHs-*g*-POEGMA	7	60	96[79]
4f	This work	10	50	95
4g	I_2	30	165	91[69]
4g	$Bi(OTf)_3$	10	130	89[80]
4g	This work	15	50	93

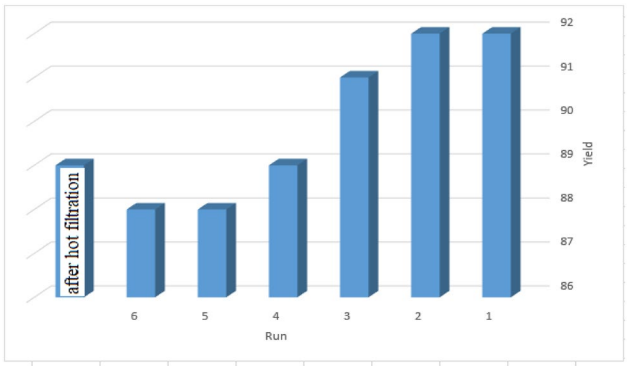


Fig. 13 Reusability of SO_3H-tryptamine supported on Fe_3O_4@SiO_2@CPS in synthesis 4a

Initially, optimization of the catalysts, solvents and temperature was performed based on Table 1. Evaluation of the optimized solvent was primarily done. Solvent free, ethanol, water, combinations of water and ethanol, DMF were used to investigate the reaction, according to which the highest output could be achieved when using ethanol as the solvent. Next, the amount of catalyst had to be examined. Different amounts of 5, 10, 15, 20 and 25 mg catalysts were present to test the reaction, indicating that considerable output could be obtained with 20 mg of catalysts. Eventually, evaluation of the reaction took place at temperatures of 25, 50, 60, 70 and 80 °C, indicating that the most considerable output was achievable at a temperature of 60 °C.

Totally, the most favorable outcomes and the shortest time were found with the use of 20 mg of catalyst and ethanol as solvent in 60 °C.

Out of seven chromeno[4,3-b]quinolin-6-ons derivatives, four new compounds could be observed, which had gone under synthesis in optimum circumstances as shown in Table 2.

Scheme 3 indicates the suggested mechanisms in acidic circumstances.

Formation of Schiff base (I) was observed from the amine condensation with aldehyde, while a catalyst was present. Considering the nucleophilic attack, 4-hydroxycoumarin with Schiff base (I) intermediate (II) could be obtained, leading to a combination (III). Regarding Michael's reaction of combination (III) with aniline, combination (IV) was generated, capable of being changed into a combination (V) and eventually, considering intermolecular cyclization (V), synthesis of the target products was performed when the catalyst was present.

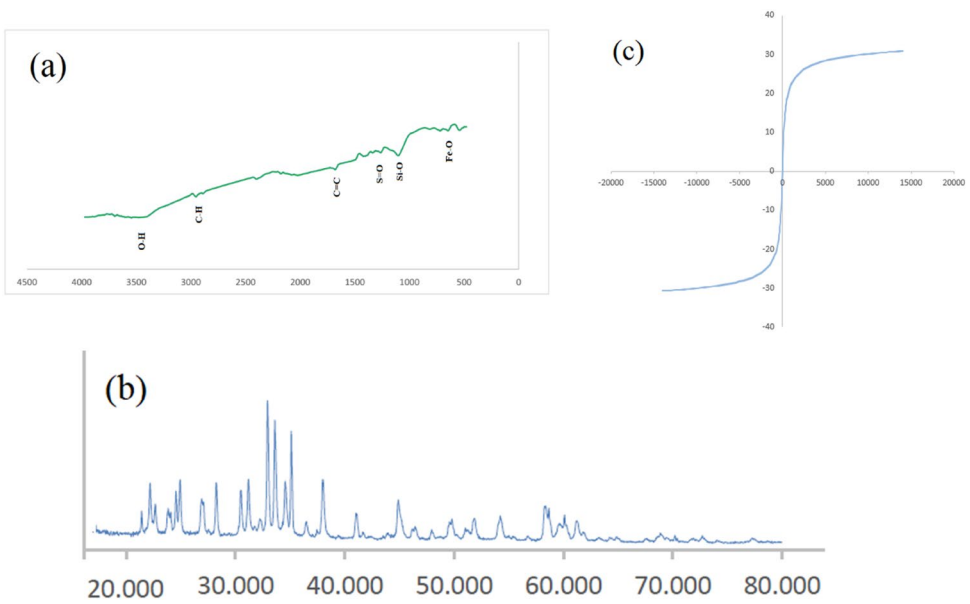


Fig. 14 FT-IR (**a**), XRD pattern (**b**) and VSM analysis (**c**) of catalyst after recycling

Table 4 Antimicrobial activity of chromeno[4,3-b]quinolin-6-ons derivatives and SO_3H-tryptamine supported on Fe_3O_4@SiO_2@CPS (MNP)

Product/Antibiotics	Gram-negative bacteria						Gram-positive bacteria				Fungi	
	1399		1855		1290		1665		1447		5009	
	MIC	MBC	MIC	MBC	MIC	MBC	MIC	MBC	MIC	MBC	MIC	MFC
4a	–	–	1024	2048	–	–	–	–	2048	4096	–	–
4b	64	128	64	128	128	256	256	256	128	256	128	256
4c	–	–	128	256	512	1024	1024	2048	512	1024	–	–
4d	512	1024	512	1024	–	–	–	–	1024	2048	1024	2048
4e	512	1024	512	512	–	–	–	–	1024	1024	1024	1024
4f	256	512	256	512	–	–	–	–	512	1024	1024	1024
4g	–	–	1024	2048	–	–	–	–	1024	2048	1024	2048
MNP	–	–	256	512	–	–	512	1024	256	512	512	1024
a	8	16	16	32	4	8	2	4	4	4	32	64
b	4	16	–	–	0.5	1	–	–	8	16	–	–

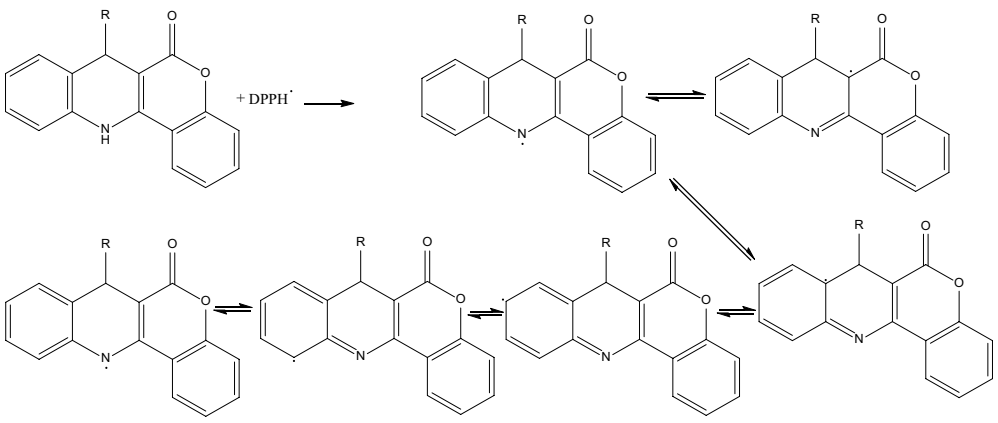
Table 5 Antioxidant activity of chromeno[4,3-b]quinolin-6-ons derivatives

Compounds	(%) Scavenging concentrations (µg/ml)				IC_{50} (µg/ml)
	5	10	15	20	
4a	35	42	51	62	13.88
4b	31	39	49	60	15.21
4c	28	46	56	67	12.79
4d	31	48	54	68	12.39
4e	29	45	52	66	13.34
4f	27	46	55	67	12.98
4g	33	42	54	65	13.19
Ascorbic acid	42	59	67	75	5.61

Reports of the reaction were prepared considering the employment of sulfonic acid functionalized ionic liquid *L*-2-(hydroxymethyl)-1-(4-sulfobutyl)pyrrolidinium hydrogen sulfate ([HYSBPI].HSO_4) [78], poly(oligoethylene glycol methacrylate)-*g*-layered double hydroxides (LDHs-*g*POEGMA) [79], bismuth(lll) trifluoromethanesulfonate [80], as well as iodine [69] as catalysts. Table 3 shows the results obtained from comparing the current and prior works. Accordingly, the nanocatalyst has performed the reactions in a shorter time and lower temperatures, while much more considerable effectiveness has been obtained.

Subsequent to the reaction, frequent washing of the catalyst SO_3H-tamine supported on Fe_3O_4@SiO_2@CPS took place using water and ethanol which were used again following the drying. The catalyst reuse was repeated for six times, with no considerable reduction in its effectiveness. In addition, the recycled catalyst was subject to the hot filtration test, showing 86% effectiveness when synthesizing 4a (Fig. 13).

Subsequent to the recycling, examination of the FT-IR, XRD pattern and VSM analysis from catalyst was carried out, the results of which indicated similarities with the primary results (Fig. 14).



Scheme 4 Proposed mechanism for radical stability of DPPH

Antimicrobial activity

The following order of antimicrobial activities could be found for the chromium derivatives: 4b > 4c > 4f > 4e > 4d > 4g > 4a (Table 4), which was dependent on the aldehyde derivative. Overall, the 4b with chlorine in its structure showed the most considerable effectiveness. Next, 4c with amine and eventually depending on the number and location of the methoxy groups in the derivative structure, the order of effectiveness could be observed.

Antimicrobial examination was also carried out for nanoparticles undergoing synthesis. Accordingly, sufficient effectiveness was found on the 1855, 1665 and 1447 (bacterial strains) with relative values of MIC 256 µg/mL, 512 µg/mL and 256 µg/mL, and 5009 (fungi) with MIC 512 µg/mL.

A comparison of the antimicrobial impacts of derivatives and nanoparticles subject to synthesis was performed with the impacts of several commercial medicine including gentamicin and Cefazolin (for bacterial strains) and Terbinafine and Tolnaftate (for fungi).

Accordingly, the derivatives and nanoparticles showed more significant effectiveness in several instances compared to their commercial counterparts. As an instance, no effects were found by Cefazolin on 1855 and 1665, while MIC for 4b could be achieved up to 64 µg/m and 256 µg/m, correspondingly.

Antioxidant activity

The derivatives' antioxidant impacts for 4a-g can be observed in Table 5.

Based on the obtained results, considerably close features of the derivatives antioxidant features could be found which showed independence from their structure. Thus, the mechanism represented in Scheme 4 was suggested for DPPH extreme stability.

Conclusion

Totally, synthesis of novel SO_3H-tryptamine supported on Fe_3O_4@SiO2@CPS magnetic nanoparticles possessing biological features was performed and they were then employed to synthesize derivatives of chromeno[4,3-b] quinolin-6-ons. Comparing the synthetic catalysts and previously applied procedures indicated a shorter reaction time along with lower temperatures, while higher productivity could be obtained. Moreover, synthesis of magnetic nanocatalyst was possible from cheap and conveniently accessible materials following simple stages. Furthermore, in comparison with the other procedures and considering hazardous catalysts, green catalysts were used to synthesize the derivatives. The chromeno[4,3-b] quinolin-6-ons derivatives indicated favorable antibacterial as well as antioxidant impacts. In several instances, they showed even higher effectiveness compared to their commercial counterparts.

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Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

Human and animal rights This article does not contain descriptions of studies performed by the authors with participation of humans or using animals as object.

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