

RESEARCH PAPER

Cu (II) Salen Complex@KCC-1: An Effective and Beneficial Catalyst for the Preparation of 1,4-Dihydropyridine Derivatives via Hantzsch Reaction

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ARTICLE INFO

Article History:

Received 10 October 2023

Accepted 17 December 2023

Published 01 January 2024

Keywords:

1,4-dihydropyridines

Hantzsch reaction

Green chemistry

ABSTRACT

Cu (II) Salen complex@KCC-1 has been synthesized and characterized via XRD, FT-IR, SEM, TEM, BET, and EDX analysis. An effective and useful Hantzsch preparation of a variety of 1,4-dihydropyridine (1,4-DHP) from a β -dicarbonyl compound, benzaldehyde (BzH), and ammonium acetate with Cu (II) Salen complex@KCC-1 in the H₂O/EtOH (with a ratio of 1:1) as the solvent and 65°C were obtained. The synthesized catalyst was determined to be a useful heterogeneous catalyst for preparing 1,4-DHP. Short reaction times, high yields of products, reusability of catalyst, ease of catalyst separation, versatility, and simple workup procedure are the main advantages of the presented method for the synthesis of 1,4-dihydropyridine derivatives. Moreover, the catalyst was stable in the reaction system and could be easily recovered from the reaction media and reused for 5 runs without significant loss in catalytic activity. In addition, the results of hot filtration studies show the lack of copper leaching from the catalyst surface.

How to cite this article

Zeinali A., Allahresani A., Nasseri M., Dehghani A. Cu (II) Salen Complex@KCC-1: An Effective and Beneficial Catalyst for the Preparation of 1,4-Dihydropyridine Derivatives via Hantzsch Reaction. J Nanostruct, 2024; 14(1):156-167. DOI: 10.22052/JNS.2024.01.016

INTRODUCTION

In recent years, heterocyclic chemistry has become one of the most significant disciplines in pharmaceutical chemistry and organic synthesis [1–3]. Also, technology and science have switched to environmentally sustainable and economical methods. In this regard, the growth of one-pot multicomponent coupling reaction approaches in green circumstances has received much attention. It is an essential tool for preparing biologically active compounds via the fast production of variety with predefined

functionality and molecular complexity. The advantages of MCRs are enhanced because they generally perform well and provide quick access to many heterocyclic compounds for various applications [4–8]. Newly, much consideration has been done to the 1,4-dihydropyridines (1,4-DHP) because these compounds have been widely used in organic chemistry, pharmaceuticals, and drugs [9–11], because of their vasodilator, antihypertensive, antitumor, antimutagenic, antidiabetic, anticonvulsant, anti-depressive, antianxiety, sedative, analgesic, anti-inflammatory,

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and bronchodilator activities [12–14]. Currently, commercial representatives like nicardipine, felodipine, amlodipine, and nifedipine are several of the best-selling drugs that are utilized in hypertension treatment.

In 1882, Arthur Hantzsch reported the first preparation of 1,4-dihydropyridines (1,4-DHP), some of these compounds have been utilized commercially as calcium channel blockers [15], and the factors that regenerate the reduction of nicotinamide adenine dinucleotide (NAD) [16]. Besides, 1,4-dihydropyridines (1,4-DHP) have likewise been utilized as a reductant [17] and intermediate in organic conversions [18]. Generally, 1,4-dihydropyridine (1,4-DHP) is prepared using the Hantzsch procedure [19], including Knoevenagel condensation and forming enamino ester. Then, Michael addition and intramolecular condensation afford the 1,4-DHP with good efficiency. Nevertheless, this conventional procedure has some difficulties like low efficiency and prolonged reaction time [20]. Therefore, developing an effective, and easy procedure for derivatives of 1,4-DHP is an area of study. The progression in the development of more diverse and more efficient procedures was significant, among ionic liquid [21], microwave radiation [22], and solid-phase organic production methods [11]. With the purpose of an extremely efficient preparation of 1,4-DHP, some catalysts have been used in the synthesis procedure, like organo-catalysts [23], solid acid [24], sulfated polyborate [25], and chitosan [26].

Though homogeneous catalysts are efficient catalysts because of high selectivity and their catalytic activity, one of their problems with homogeneous catalysts is their separation from the reaction medium. Newly, due to easy separation, the development of heterogeneous catalysts in the synthesis of the organic compound has been emphasized. In addition, improving the efficiency of the reaction was achieved by nanoscale heterogeneous catalysts because of their high surface area and very small size [27–29]. A new procedure for the preparation of 1,4-dihydropyridines (1,4-DHP) catalyzed by magnetic iron oxide nanoparticles was reported by Koukabi et al. [30].

Continuing our investigation for sustainable and green nanocatalyst protocols [31–36], we support here the report of the copper Salen complex, which was later found high surface area silica

and has a unique fiber morphology (KCC-1). We found that high surface areas of KCC-1 are caused by fibers rather than pores, which significantly increment the accessibility. We believe that this unique feature will be extremely beneficial for the design of silica-supported catalysts, which can significantly increase access to active sites. This would be a perfect catalyst support candidate for the manufacture of excellent metal-based catalysts that show a high availability of active sites and superb catalytic activity. In this study, we synthesized copper (II) immobilized on Schiff base-functionalized KCC-1. In this procedure, in the beginning step, the KCC-1 was prepared and then the Salen ligand was attached to the KCC-1 and ultimately, copper was coordinated to the Salen ligand, and the corresponding catalyst was synthesized. In the next step, the efficiency of Cu (II) Salen complex@KCC-1 has been studied in the Hantzsch reaction. The presented method offers several advantages including mild reaction conditions, simple workup, heterogeneous nature, green process, low amount of catalyst, high to excellent yield of derivatives, and short reaction times. The products were obtained in excellent yields and the reaction times were significantly shorter than the available methods. Moreover, the catalyst was stable in the reaction system and could be easily recovered from the reaction media and reused for 5 runs without significant loss in catalytic activity. The prepared green catalyst could be used for other noteworthy organic reactions.

MATERIALS AND METHODS

Chemical and instrumentation

All chemicals were obtained from Sigma and Fluka suppliers and used as received without further purification. Determination of the monitoring of the progress of reactions and purity of the substrate was accomplished by thin-layer chromatography on silica gel polygram SILG/UV 254 plates. NMR spectra were recorded on a Bruker Avance DPX-300 (^1H NMR 300 MHz, ^{13}C NMR 75 MHz) spectrometer in pure deuterated chloroform (CDCl_3). Chemical shifts are given in parts per million (ppm) downfield from tetramethylsilane (TMS) as an internal reference and coupling constants (J -values) are in hertz (Hz). ^1H NMR assignment abbreviations are the following; singlet (s), doublet (d), triplet (t), quartet (q), doublet of doublets (dd), and multiplet (m). FTIR spectra were recorded using a Shimadzu FT-IR-8300

spectrophotometer. The Brunauer- Emmett-Teller (BET) surface area analysis was adopted at 77 K to obtain surface areas with Belsorp mini II apparatus (Microtrac Bel Corp, Japan) after the sample had been degassed in a flow of N_2 . X-ray diffraction (XRD) patterns of catalysts were recorded by the Bruker AXS D8-advance X-ray diffractometer using $CuK\alpha$ radiation ($\lambda=1.54178 \text{ \AA}$) with scanning range 2θ from 20° to 90° . Scanning electron micrograph (SEM) was performed using SEM instrumentation (model: VEGA3, TESCAN company, Czechia, at 20.0 kV). Transmission electron microscopy images were recorded using a Zeiss instrument with an accelerating voltage of 100 kV.

Preparation of the catalyst

Preparation of KCC-1

Dissolve 2 g of cetyltrimethylammonium bromide (CTAB) (5.48 mmol) and 2.4 g of urea (39.96 mmol) in 100 mL of water and stirred for 15 minutes. Then mix 10 mL of tetraethyl orthosilicate (TEOS) (44.78 mmol) with 10 mL of cyclohexane and drop by drop to the above solution and stirrer again for 15 minutes on a magnetic stirrer. Subsequently, 6 mL of 1-panthenol was added to it, and this time it was placed on a magnetic stirrer at room temperature for 20 minutes. Then put the solution in the microwave for 1 hours at $120^\circ C$ and then dry at room temperature to form a precipitate. The corresponding precipitate is washed and separated by centrifugation and water and ethanol solvents and placed in an oven at $80^\circ C$ for 8 hours to dry [37].

Preparation of Salen ligand

Mix 0.106 mL of salicylaldehyde (0.95 mmol) with 2 mL of ethanol Merck and transfer the mixture to a balloon and 0.218 mL of (3-Aminopropyl)trimethoxysilane (APTMS) (0.93 mmol) was added drop by drop to the balloon. The reaction mixture was then refluxed for 3 hours, after which the solvent was removed by rotary, and the corresponding ligand was obtained [38].

Preparation of Cu (II) Salen complex

Then, to synthesize the Cu (II) Salen complex, add 20 mL of ethanol to the 1 mmol of the Salen ligand, and then 0.66 grams of NaOH (1.65 mmol) and 0.199 grams of copper (II) acetate (1.095 mmol) was added respectively and refluxed for 2 hours at $80^\circ C$. After purification, the product was dried at $80^\circ C$ in a vacuum oven for 8 hours [31,39].

Preparation of Cu (II) Salen complex@KCC-1

Dissolve 0.5 g of KCC-1 in 50 mL of dry toluene and the mixture mentioned was sonicated for 30 min. Then, 0.25 g of Cu (II) Salen complex was added and the mixture was stirred under reflux for 48 hours. After purifying the precipitate, it was placed in a vacuum oven at $70^\circ C$ for 8 hours.

RESULTS AND DISCUSSION

Fourier transform infrared (FT-IR), energy dispersive X-ray (EDX), powder X-ray diffractometric (XRD), Brunauer-Emmett-Teller (BET), Scanning electron microscopy (SEM) and Transmission electron microscopy (TEM) were

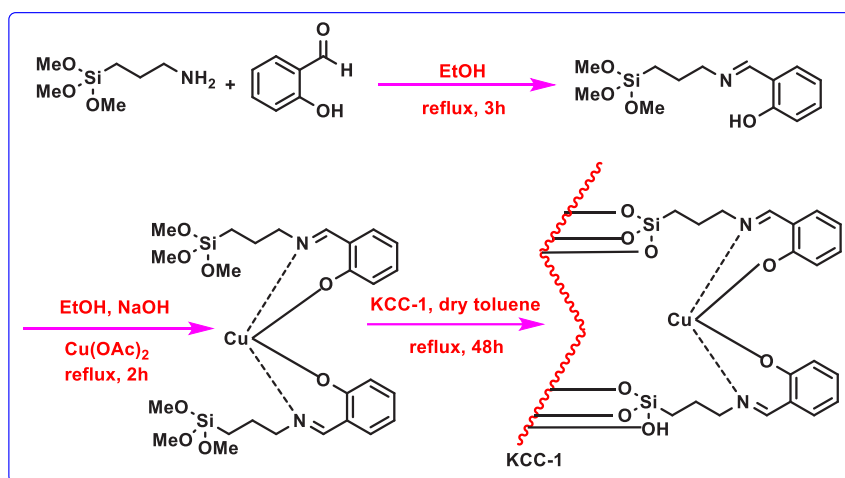


Fig . 1. Preparation of catalyst (Cu (II) Salen complex@KCC-1)

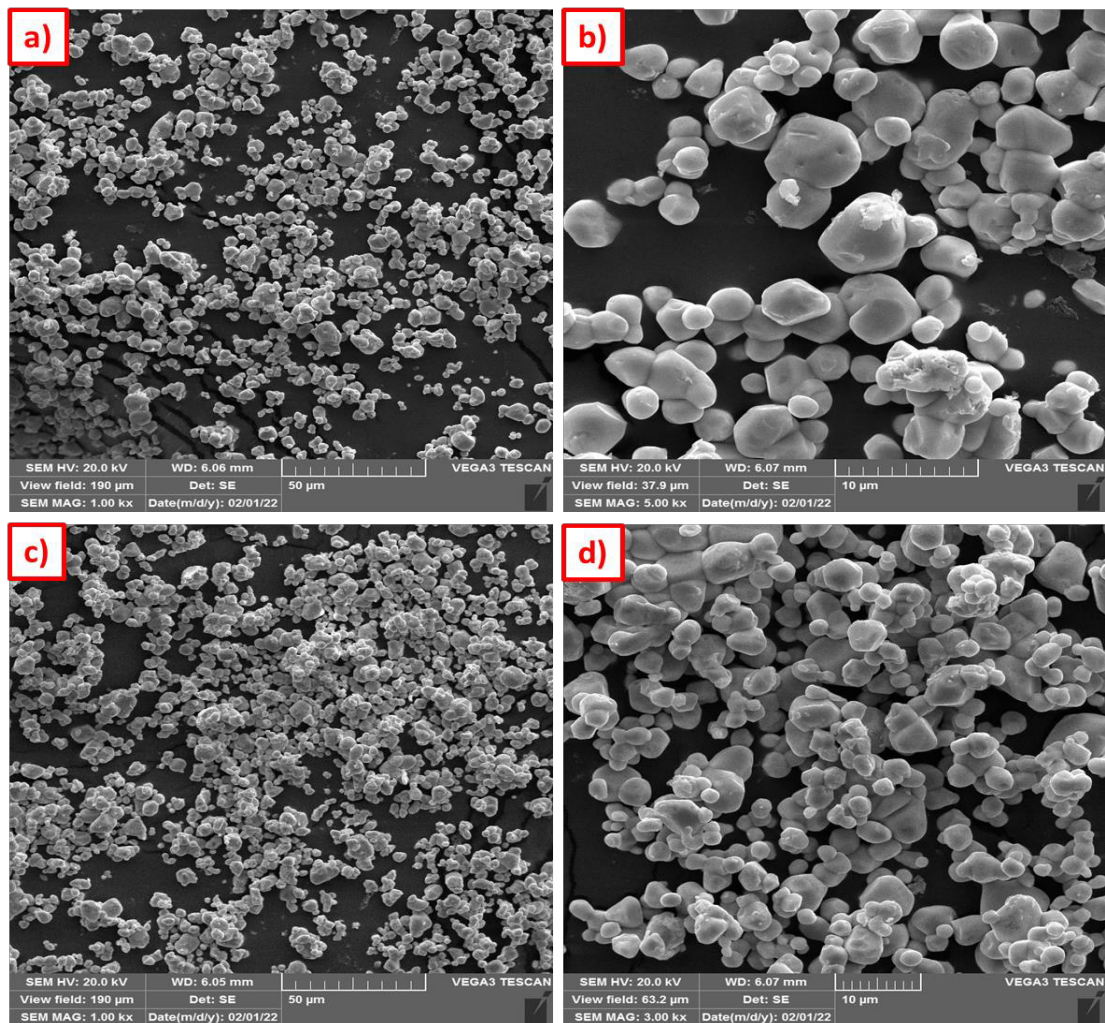


Fig. 2. The low and high magnification SEM of KCC-1 (a-b) and Cu(II) Salen complex@KCC-1 (c-d)

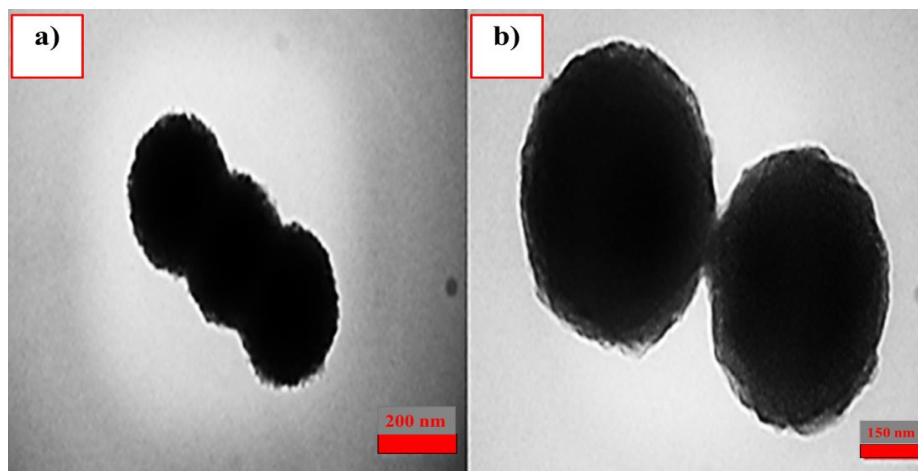


Fig. 3. TEM images of KCC-1 (a) Cu(II) Salen complex@KCC-1 (b)

utilized to characterize the Cu (II) Salen complex loaded on KCC-1.

Scanning Electron Microscopy (SEM)

The low and high magnification SEM images of the KCC-1 and Cu (II) Salen complex@KCC-1 were recorded for investigation of their morphology

(Fig. 2 a-d). As shown in these Figures, the KCC-1 and Cu (II) Salen complex@KCC-1 show nearly spherical shapes. Moreover, the particle size distribution (PSD) of the as-synthesized Cu (II) Salen complex@KCC-1 was investigated by SEM imaging. The results are shown in Fig. 2 d, indicating a size distribution over 2.20-7.29 μm

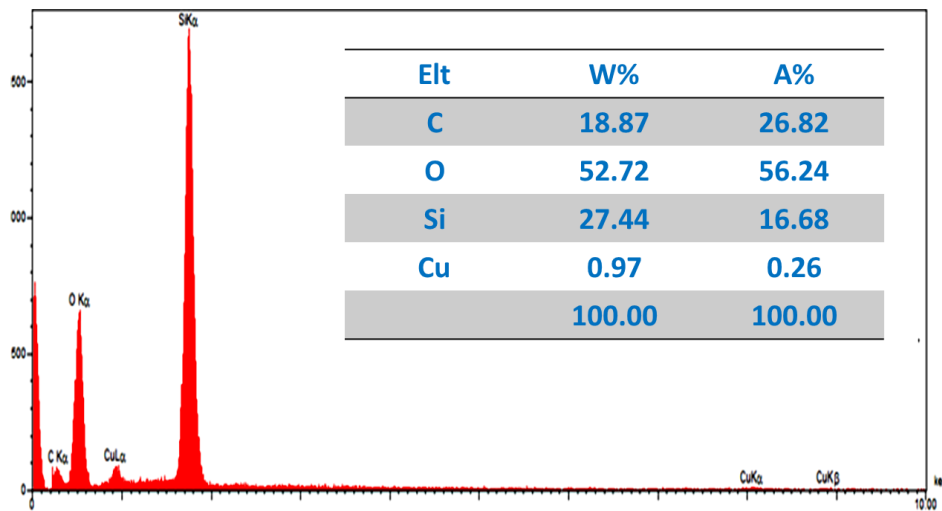


Fig. 4. EDX of Cu(II) Salen complex@KCC-1

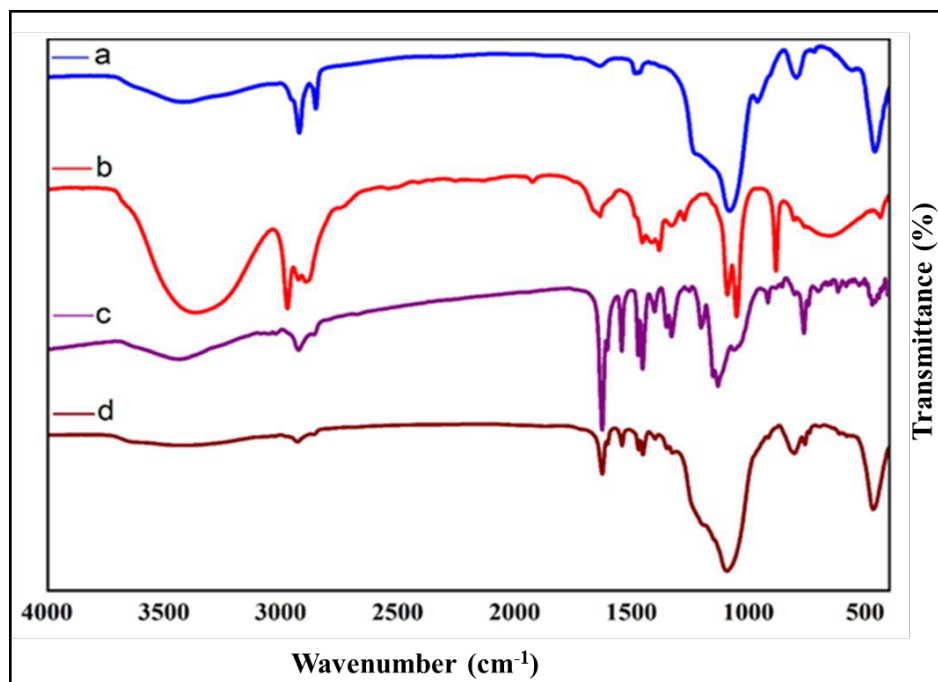


Fig. 5. FT-IR spectra of: KCC-1(a), Salen ligand (b), Cu(II) Salen complex (c), Cu(II) Salen complex@KCC-1(d)

with an average size of 4.37 μm .

Transmission Electron Microscopy (TEM)

The TEM images of KCC-1 (a) and Cu (II) Salen complex@KCC-1 (b) were shown in Fig. 3a-b and exhibit the nearly spherical shapes of all synthesized NPs. As can be seen, the approximate size range for the Cu (II) Salen complex@KCC-1 has

measured about 452 nm.

Energy dispersive X-ray (EDX)

The elemental analysis of freshly synthesized Cu (II) Salen complex@ KCC-1 was investigated by energy dispersive spectroscopy (EDX) analyses. Based on the EDX spectra (Fig. 4), Cu (II) Salen complex@ KCC-1 consisted of C, O, Si, and Cu.

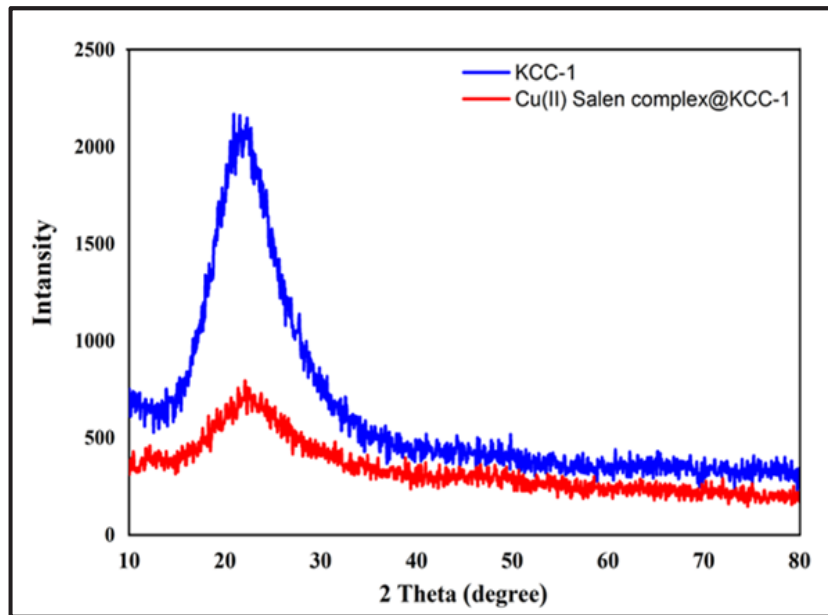


Fig. 6. XRD pattern of KCC-1 (a) Cu(II) Salen complex@KCC-1 (b)

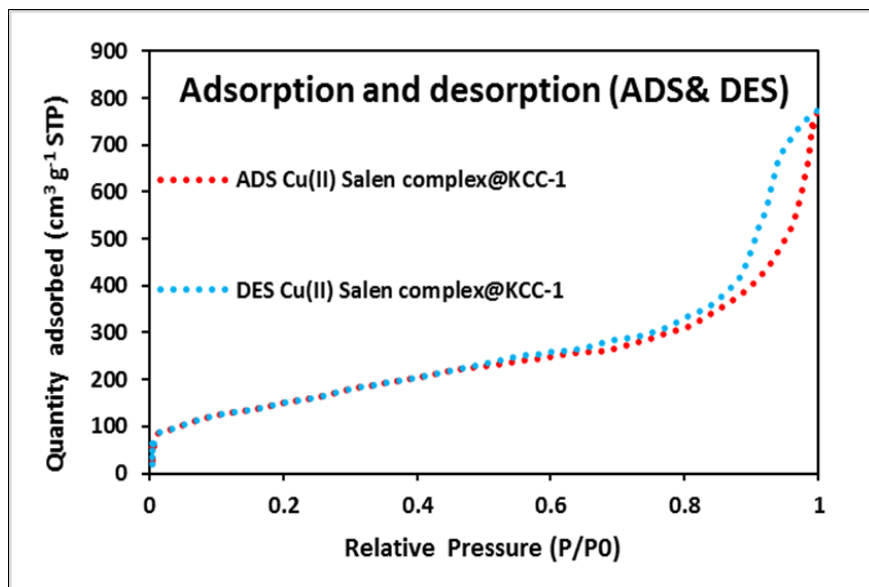


Fig. 7. Nitrogen adsorption-desorption isotherms of Cu(II) Salen complex@KCC-1

FT-IR spectroscopy

The FT-IR was studied at 4000 to 400 cm^{-1} for KCC-1, ligand, Cu(II) Salen complex, and Cu(II) Salen complex@KCC-1 via FT-IR spectroscopy. The infrared spectra of all stages of Cu Salen complex @ KCC-1 synthesis are shown in the figure below (Fig. 5). In Fig. 2a spectrum shows the KCC-1 infrared spectrum, with vibrations in the 808, 915, and 3300 cm^{-1} regions, which are Si and OH, respectively. The above vibrations emphasize KCC-

1 synthesis. Spectrum 5b represents the infrared spectrum of Salen ligand that vibrations at about 1100, 1690, 3323 cm^{-1} correspond to Si, C=N, and OH respectively [40, 41]. The 5c spectrum, the infrared spectrum of the Cu(II) Salen, shows that the stretching band vibrations in the region of 1115 and 2889 cm^{-1} are related to Si and methylene rings, respectively, and also the stretching band vibration of the C=N bond is observed in 1626 cm^{-1} [40, 41]. The spectrum 5d represents the infrared

Table 1. The effect of different amounts of Cu (II) Salen complex@KCC-1 catalysts on the Hantzsch reaction^a

Entry	Catalyst (g)	Time (min)	Yield (%) ^b
1	0.03	120	65
2	0.05	120	65
3	0.08	120	90
4	0.10	120	90
5	0.12	120	88

^aReaction conditions: benzaldehyde (1 mmol), ammonium acetate (1 mmol), ethyl acetoacetate (2 mmol), H₂O/EtOH (2 mL), 65 °C. ^bIsolated yield

Table 2. The effect of different of solvents on the Hantzsch reaction^a

Entry	Solvent	Time (min)	Yield (%) ^b
1	Solvent free	120	75
2	n-hexane	120	67
3	CH ₃ CN	120	80
4	H ₂ O	120	60
5	EtOH	120	85
6	H ₂ O/EtOH	120	90

^aReaction conditions: benzaldehyde (1 mmol), ammonium acetate (1 mmol), ethyl acetoacetate (2 mmol), Cu (II) Salen complex@KCC-1 (0.08 grams), 65 °C. ^bIsolated yield.

Table 3. The effect of diverse temperatures in the Hantzsch reaction by Cu (II) Salen complex@KCC-1

Entry	Temperature	Time (min)	Yield (%)
1	r.t.	120	20
2	50	120	30
3	65	120	90
4	80	120	92
5	100	120	92

^aReaction conditions: benzaldehyde (1 mmol), ammonium acetate (1 mmol), ethyl acetoacetate (2 mmol), H₂O/EtOH (1:1), Cu (II) Salen complex@KCC-1 (0.08 grams)

Table 4. Control tests for the synthesis of 1,4-DHP under different catalyst^a

Entry	Catalyst	Time (min)	Yield (%)
1	-	120	-
2	KCC-1	120	30
3	Cu (II) Salen complex	120	94
4	Cu (II) Salen complex@KCC-1	120	90

^aReaction conditions: benzaldehyde, ammonium acetate, ethyl acetoacetate, H₂O/EtOH (1:1), 65 °C.

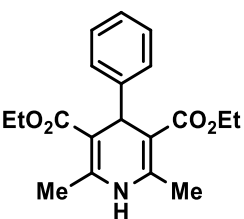
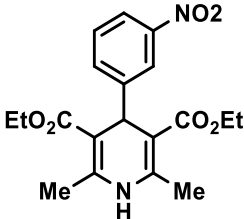
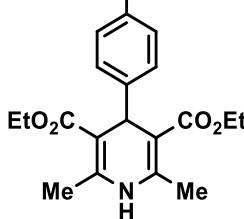
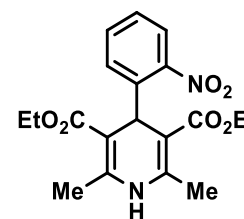
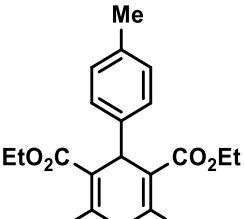
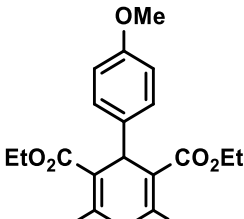
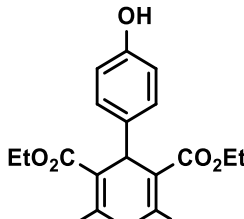
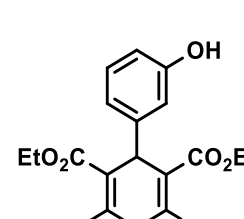
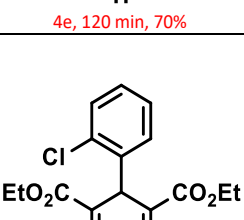
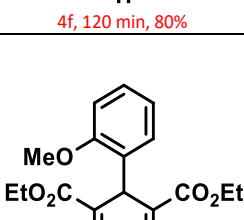
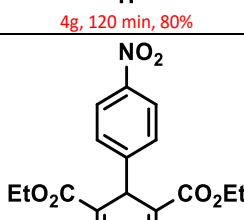
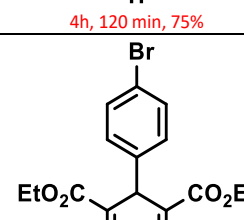
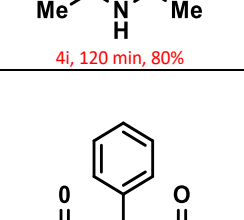
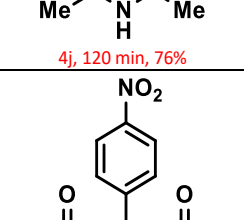
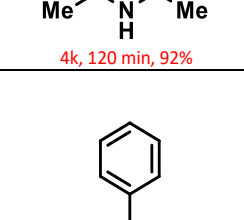
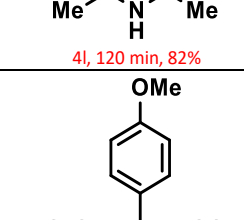
spectrum of the heterogeneous catalyst (Cu (II) Salen complex @ KCC-1). The new band at 1585 cm^{-1} has appeared in the heterogeneous catalyst, which together with the 1099 cm^{-1} band related to Si-O-Si indicates the successful immobilization of the homogeneous Cu (II) Salen complex on the surface of KCC-1.

X-ray diffraction (XRD) analysis

Fig. 6 presents the XRD patterns of synthesized KCC-1 (a) Cu(II) Salen complex@KCC-1 (b)

nanoparticles. The presence of a broad peak between $2\theta=15-30^\circ$ for the KCC-1 sample signifies the existence of the amorphous nature of silica (JCPDS No. 29-0085). In the Cu (II) Salen complex @ KCC-1 X-ray diffraction pattern, the peak intensity decrease relative to the KCC-1 X-ray diffraction pattern could indicate the presence of a Salen complex immobilized on KCC-1. Also, a decrease in broad peak intensity of $2\theta = 15-30^\circ$ can be evidence of Salen complex coating on a KCC-1 substrate [31,37-40].

Table 5. Synthesis of 1,4-dihydropyridine derivatives catalyzed by Cu (II) Salen complex@KCC-1.

 4a, 120 min, 90%	 4b, 120 min, 90%	 4c, 120 min, 85%	 4d, 120 min, 87%
 4e, 120 min, 70%	 4f, 120 min, 80%	 4g, 120 min, 80%	 4h, 120 min, 75%
 4i, 120 min, 80%	 4j, 120 min, 76%	 4k, 120 min, 92%	 4l, 120 min, 82%
 4m, 120 min, 95%	 4n, 120 min, 97%	 4o, 120 min, 80%	 4p, 120 min, 70%

Amount of materials in all reactions: benzaldehyde (1 mmol), ammonium acetate (1 mmol), 1,3-dicarbonyl (2 mmol), $\text{H}_2\text{O}/\text{EtOH}$ (1:1(v/v)), Cu (II) Salen complex@KCC-1 (0.08 grams), 65 °C.

BET surface area

The Brunauer-Emmett-Teller analysis was used to study the porous structure and surface area of freshly synthesized Cu(II) Salen complex@KCC-1 and the obtained results were summarized in Fig. 7. The N₂ adsorption-desorption isotherm of Cu(II) Salen complex@KCC-1 revealed a characteristic type IV curve with a typical H3 hysteresis loop (Fig. 6). The measured specific surface area was 698 m²/g and a mean pore diameter of 3.41 nm.

General procedure for the synthesis of 1,4-dihydropyridine (1,4-DHP) derivatives in the presence of Cu (II) Salen complex@KCC-1 as a recyclable and reusable catalyst

To the same vessel containing 2 mL EtOH/H₂O (1:1), there were added all ingredients including benzaldehyde (1 mmol), ammonium acetate (1mmol), ethyl acetoacetate (2mmol), and 0.08 g of Cu (II) Salen complex@KCC-1. This multicomponent one-pot reaction was heated at 65°C in appropriate times and the progress of the reaction was monitored by TLC. After the reaction was completed, the products were separated and purified, the best reaction efficiency was reported to be 90% after 2 hours. Structural assignments of the products are according to their ¹HNMR, ¹³CNMR spectra.

Analytical Data

Diethyl 2,6-dimethyl-4-phenyl-1,4-dihydropyridine-3,5-dicarboxylate

FT-IR (KBr, cm⁻¹) u: 3443, 2802, 1600, 1465,

1115; ¹H-NMR (300 MHz, CDCl₃, 25 °C) δ (ppm)= 1.13-1.16 (t, 6H), 2.39 (s, 6H), 3.94-4.02 (q, 4H), 4.88 (s, 1H), 7.10-7.21 (m, 4H), 8.82 (s, 1H); ¹³C-NMR (75 MHz, CDCl₃, 25 °C) δ (ppm)= 14.4, 18.4, 39.9, 58.4, 102.3, 125.3, 127.4, 128.3, 145.3, 148.6, 167.4.

Diethyl 2,6-dimethyl-4-(3-nitrophenyl)-1,4-dihydropyridine-3,5-dicarboxylate

FT-IR (KBr, cm⁻¹) u: 3343, 2985, 1643, 1525, 1465, 1345, 1213; ¹H NMR (300 MHz, CDCl₃, 25 °C) δ (ppm)= 1.10-1.14 (t, 6H), 2.31 (s, 6H), 3.94-4.01 (q, 4H), 5.00 (s, 1H), 7.50-8.31 (m, 4H) 9.01 (s, 1H); ¹³C NMR (75 MHz, CDCl₃, 25 °C) δ (ppm)= 14.2, 19.5, 39.9, 60.0, 103.1, 121.2, 123.0, 128.6, 134.5, 145.0, 148.1, 150.0, 167.2.

Diethyl 4-(4-hydroxyphenyl)-2,6-dimethyl-1,4-dihydropyridine-3,5-dicarboxylate

FT-IR (KBr, cm⁻¹) u: 3346, 2982, 1661, 1467, 1444, 1369, 1230 cm⁻¹; ¹H-NMR (300 MHz, CDCl₃, 25 °C) δ (ppm)= 1.22-1.37 (t, 6H), 2.34 (s, 6H), 4.04-4.17 (q, 4H), 4.90 (s, 1H), 5.80 (s, 1H), 7.17-7.24 (m, 4H); ¹³C-NMR (75 MHz, CDCl₃, 25 °C) δ (ppm)= 14.2, 18.5, 39.2, 58.84, 100.8, 127.3, 129.4, 131.4, 144.5, 146.3, 167.4.

The catalyst performance of the Cu (II) Salen complex@KCC-1 in the Hantzsch reaction

The five amounts of Cu (II) Salen complex@KCC-1 were studied at 65 °C and 2 mL of H₂O/EtOH (1:1) as the solvent. According to Table 1, increasing the amount of Cu(II) Salen complex@KCC-1 from 0.03

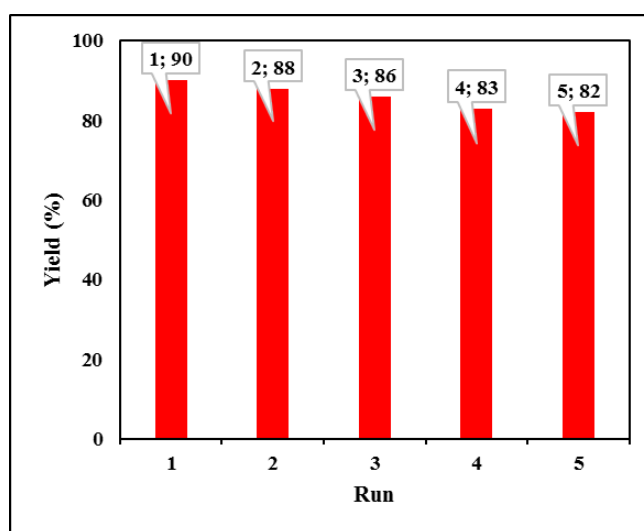


Fig. 8. Recyclability of Cu (II) Salen complex@KCC-1 for the model Hantzsch reaction

Table 6. Comparison of the efficiency of Cu(II) Salen complex@KCC-1 with diverse catalysts

Entry	Catalyst	Solvent	°C	min	Yield	Ref.
1	Hf(NPf ₂) ₄	C ₁₀ H ₁₈	60	180	95	[41]
2	CAN	PEG-400	50	240	91	[42]
3	CdO	Solvent-free	120	480	92	[43]
4	Boehmite-SSA	EtOH	Reflux	215	94	[44]
5	Cu (II) Salen complex@KCC-1	H ₂ O/EtOH	65	120	90	-

Reaction conditions: benzyl alcohol (1 mmol), ammonium acetate (1 mmol), ethyl acetoacetate (2 mmol).

to 0.08 grams, the yield of the 1,4-dihydropyridine (1,4-DHP) was increased. But a higher amount of 0.08 grams of the Cu (II) Salen complex@KCC-1, less yield of the product has resulted. Therefore, the best amount of catalyst was chosen 0.08 grams.

The solvent effect was the second parameter in which various solvents with diverse properties and polarity were experimented (Table 2). The H₂O/EtOH had the best effect by providing 90% efficiency at 65°C and 0.08 grams of Cu (II) Salen complex@KCC-1.

On the other hand, various temperatures (25, 50, 65, 80, 100 °C) on the model reaction were done in H₂O/EtOH (with a ratio of 1:1) as a solvent in the presence of Cu (II) Salen complex@KCC-1. The optimum temperature was 65°C. Efficiency decreased at lower temperatures (Table 3).

To elucidate the catalytic activity of Cu (II) Salen complex@KCC-1, in the synthesis of 1,4-dihydropyridine (1,4-DHP), several control tests were done on the model reaction under optimal circumstances. The outcomes are summarized in Table 4. The outcomes presented that the catalytic efficiency of Cu (II) Salen complex@KCC-1 was unparalleled compared with other catalyst components alone.

The catalytic activity of Cu (II) Salen complex@KCC-1 was investigated by a variety of different 1,3-dicarbonyl, benzaldehyde (BzH), and ammonium acetate in optimal conditions. As presented in Table 5, good to excellent yields (70-97 %) for all benzaldehyde (BzH), whether bearing electron-withdrawing and electron-donor substituents, were obtained for 2 hours. However, benzaldehyde (BzH) containing the electron-withdrawing produced higher efficiencies than those containing the electron-donor groups (compare 14 with 16).

The model reaction of the Hantzsch has been done by using 0.08 g Cu (II) Salen complex@KCC-1 in the reaction of benzaldehyde, ammonium acetate, and ethyl acetoacetate, in 65 °C via H₂O/

EtOH (1:1) as the solvent to observe the reusability of the catalyst. Based on the tests, the outcomes which are shown in Fig. 8, demonstrate that after four cycles, there is no particular reduction in the yield.

For the purpose of illustrate the heterogeneous nature of Cu (II) Salen complex@KCC-1 a control reaction was done. To this purpose, a mixture of Cu (II) Salen complex@KCC-1 (0.08 grams), in H₂O/EtOH (1:1(v/v)) was prepared and stirred at 65 °C for 120 min. Subsequently, the reaction mixture was filtrated and the catalyst was separated. Afterwards, the filtrate was used as a solvent for the reaction of benzaldehyde (1 mmol), ammonium acetate (1 mmol), ethyl acetoacetate (2 mmol), at 65 °C for 120 min. After the time, the productivity of the isolated product was 38%, which indicated that the reaction is heterogeneously catalyzed by Cu (II) Salen complex@KCC-1.

To understand the properties of Cu (II) Salen complex@KCC-1, we compare the results of the Hantzsch reaction with other heterogeneous catalysts, as shown in Table 6. This table shows that Cu (II) Salen complex@KCC-1 improved activity for the Hantzsch reaction [42-45].

CONCLUSION

In summary, we have proved a well-organized method for the preparation of 1,4-dihydropyridine (1,4-DHP) derivatives with the Cu (II) Salen complex. The outcome highlighted the green solvent method to be more effective than the conventional procedure. The benefits of the Hantzsch preparation are the effortlessness of the reaction, the reaction time is shorter, simple workup methods for the build-up to the reaction medium, low toxicity, and good to excellent yield of the 1,4-DHP, which is easy and cost-effective, with Cu (II) Salen complex@KCC-1 being a significant catalyst for the various organic preparations.

CONFLICT OF INTEREST

The authors declare that there is no conflict

of interests regarding the publication of this manuscript.

ACKNOWLEDGEMENTS

The authors are grateful to the University of Birjand for financial support.

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