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One-Pot Green Synthesis of Pyridine-2-carbaldehyde based Chalcones under Solvent-Free Condition using Mesoporous MCM-41 Materials and their Antimicrobial Activities

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A simplistic one-pot synthetic protocol was performed using aromatic ketones (**1a-e**) and substituted pyridine-2-carbaldehydes (**2a-e**) to obtain various substituted chalcones (**3a-e**). The synthesis was catalyzed by various metal incorporated (Mn, Al) and acid functionalized (H_2SO_4, $H_3PW_{12}O_{40}$) mesoporous MCM-41 materials, under solvent free conditions. Using pyridine-2-carbaldehyde (**2a**), its analogs *viz.*, 4-methoxy (**2b**), 4-chloro (**2c**), 4-hydroxy (**2d**) and 4-nitro (**2e**) pyridine-2-carbaldehydes were synthesized separately, in order to use these precursors for the formation of the organic derivatives **3b** to **3e**. Their structural features were characterized by using ^{1}H NMR, ^{13}C NMR and mass spectral techniques. Both the acid functionalized MCM-41 were almost equal in their catalytic performance, whereas among the M^{n+}-MCM-41 [M^{n+} = Mn/Al], the Al incorporated material has shown slightly higher catalytic performance. The antimicrobial activities of the derivatives (**3a-e**), was investigated on the selected microorganisms, using standard procedures. In these studies, except the compound **3e**, remaining compounds have displayed superior biological activity.

Keywords: One-pot synthesis, Chalcones, Mesoporous silica, Solvent free conditions, Antibacterial activity, Antifungal activity.

INTRODUCTION

The chalcones exists as α,β-unsaturated ketones and organic compounds embedded with the chalcone moiety were known to display variable pharmacological applications such as antifungal [1,2], antimalarial [3,4], antiulcer [5], antioxidant [6,7], antibacterial [8,9], anticancer [10,11] and antidiabetic [12,13]. In the synthesis of various flavonoids and isoflavonoids, these scaffolds act as the starting materials [14,15]. The presence of appropriate electron activating and deactivating groups makes the conjugated structure of chalcones to be used as fluorescent probes in the mechanistic investigations and diagnostic applications [16]. Due to the prevailing vast applications of these compounds, various synthetic strategies were reported in forming these compounds with different catalysts. Several groups have utilized various metal salts such as copper(II) sulphate [17], tin(II) chloride [18] and aurenium(III) chloride [19] as homogeneous catalysts for their synthesis. However, the recovery of these catalysts from the reaction mixture was found to be a problematic task. Alternatively, amberlyst [20] and graphite oxide [21] have been incorporated as heterogeneous catalysts. Nevertheless, there were some lagging factors behind these methods such as non-green/toxic solvents, low production yields, high reaction temperature and less ability for regeneration of catalysts. Therefore, there it is inevitable to produce alternative heterogeneous catalysts, which can overcome these limitations and can bring out the chalcone derivatives, efficiently.

Mesoporous MCM-41 has been extensively used as a heterogeneous solid catalyst in the synthesis of fine chemicals [22,23]. It is possible to functionalize these materials by covalent anchoring of different organic moieties on the surfaces [24]. Incorporation of compounds having Brønsted acid sites into the framework of MCM-41 type materials enhances their surface acidic character [25]. Due to enhanced acidic character and high stability, these materials can be used as efficient and reusable heterogeneous catalysts for the synthesis of fine chemicals and pharmaceutically important compounds. Development of one-pot multicomponent synthesis using functionalized MCM-41 catalysts will be an ecofriendly approach [26]. Reactions carried out with this methodology are known to give excellent

yields without isolation of any intermediates during the processes [27].

Pang *et al*. [28] demonstrated the region-selective synthesis of thiazolidin-4-ones, catalyzed by MCM-41@Si-L and copper sulphate in the presence of toluene solvent. The reaction was successful in forming the compound in greater yields. Amani *et al.* [29] reported the synthesis of 2-arylbenzimidazoles in the presence of nano-MCM-41-SO_3H materials. These materials were synthesized by a simple sulphonation of MCM-41-OH with chlorosulphonic acid and they were able to inhibit the condensation reaction among the selected precursors. Dhar *et al.* [30] presented the role of ethylene diamine anchored on MCM-41 materials as an efficient catalyst for Knoevenagel and aldol reactions. Dhar [31] developed a novel proline and benzyl penicillin covalently anchored to mesoporous MCM-41 materials, which were effectively incorporated as heterogeneous catalysts in conducting the traditional aldol condensation reaction. In all the above reactions, the ability of the mesoporous MCM-41 materials in bringing out the condensation reactions was noticed and hence, it was anticipated to integrate such newer modified MCM-41 mesoporous materials, in the formation of novel chalcone derivatives in facile reaction conditions.

The major objective of this research work is to synthesize pyridine-2-carbaldehyde based chalcone derivatives under solvent free conditions in the presence of various metal incorporated and acid functionalized MCM-41 materials. Supporting experimental features like role of solvent, catalytic efficiency of the modified MCM-41 materials were presented and the possible mechanism has been proposed. Finally, the biological activities of the compounds were investigated.

EXPERIMENTAL

All the chemical reagents required for the research work were procured from Sigma-Aldrich of AR grade (99% pure) and used without any further purification. The mesoporous MCM-41, Mn & Al-MCM-41, sulphonic acid and phosphotungstic acid functionalized MCM-41 materials (SA-MCM-41 & PA-MCM-41) were synthesized using co-precipitation method [32] and the chalcone derivatives were formed through multi-component one-pot synthesis method.

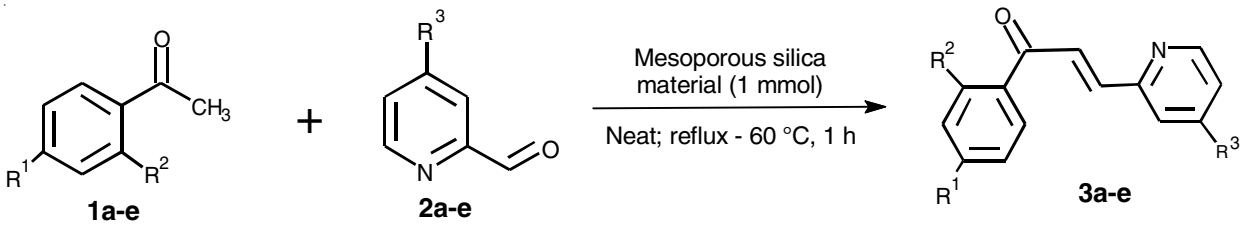
Melting points of the synthesized derivatives (**3a-e**) were determined in open capillaries on a Stuart SMP30 apparatus and are uncorrected. IR spectra were recorded as KBr pellets on a Shimadzu FTIR 8400S spectrophotometer. ^{1}H NMR (400 MHz) spectra was recorded on a BrukerDPX 400 spectrophotometer using tetramethylsilane (TMS) as internal standard, $CDCl_3$ and DMSO-d_6 as solvents. The HRMS spectra were recorded on a XevoQTof mass spectrometer. Elemental analysis was performed on a Perkin elemental analyzer. Merck precoated plates of silica gel 60 F_{24} were used for the thin layer chromatography (TLC) examination to verify the purity of the synthesized derivatives under ultraviolet light.

Synthesis of chalcone derivatives 3a-e: A mixture of acetophenone (**1a**, 1 mmol) and pyridine-2-carbaldehyde (**2a**, 1 mmol) were taken in round bottomed flask and to this mixture, 1 mmol of the synthesized modified mesoporous MCM-41 materials were dispersed in 5 separate sets (**Scheme-I**). All the set of round bottomed flasks were refluxed near 60 ºC for about 1 h, under solvent free conditions. The progress of the reaction was monitored by TLC and on confirming the product formation, the crude was separated. It was washed with EtOH: water mixture for about five times. The finally obtained product (**3a**) was collected under dry conditions and kept for characterization. In order to synthesize the other chalcone derivatives (**3b-e**), the corresponding pyridine-2-carbaldehyde precursors (**2b-e**), were synthesized separately, as shown in **Scheme-II**.

Synthesis of precursors, 2b-e from pyridine-2-carbaldehyde (2a): The schematic representation of the synthesis of the precursors, **2b** to **2e** is shown in **Scheme-II**.

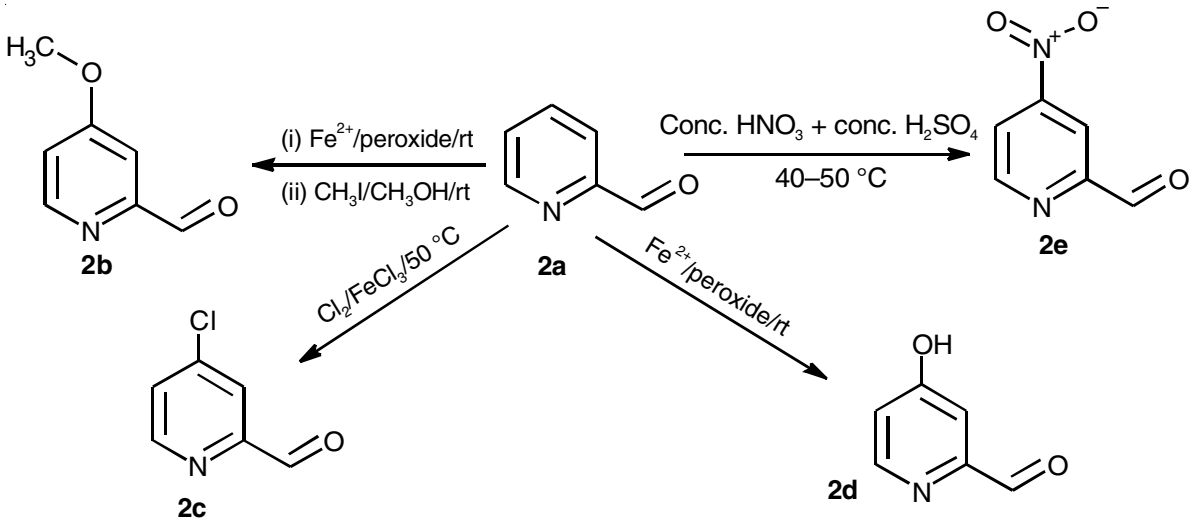
Synthesis of 4-methoxypyridine-2-carbaldehyde (2b): To, 1 mmol of compound **2a**, 1:1 ratio of ferrous chloride and hydrogen peroxide (30%) were added and the contents were kept under magnetic stirring (500 rpm), for about 45 min near the room temperature. The obtained mixture was separated, washed and dried. To this crude product, an equimolar mixture of methanol and methyl iodide was added and the entire reaction contents were kept under further magnetic stirring for about 1 h, until the solid crude product was obtained. After confirming the product formation through TLC, compound **2b** was washed with water and dried. The preceding synthetic steps were also confirmed with the same technique.

Synthesis of 4-chloropyridine-2-carbaldehyde (2c): The compound **2a** (1 mmol) was subjected to chlorination in the presence of iron(III) chloride (0.2 mmol) at 50 ºC, under refluxing conditions for about 2 h. The obtained solid product was separated from the reaction mixture and extracted with EtOH, following by washing with EtOH:H_2O mixture. Finally, product **2c** was dried and characterized.



1a: R^1 = H; R^2 = H; **1b**: R^1 = H; R^2 = -OMe; **1c**: R^1 = -OMe; R^2 = H; **1d**: R^1 = -OH; R^2 = H; **1e**: R^1 = H; R^2 = -OH; **2a**: R^3 = H; **2b**: R^3 = -OMe; **2c**: R^3 = -Cl; **2d**: R^3 = -OH; **2e**: R^3 = -NO_2; **3a**: R^1 = H; R^2 = H; R^3 = H; **3b**: R^1 = H; R^2 = -OMe; R^3 = -OMe; **3c**: R^1 = -OMe; R^2 = H; R^3 = -Cl; **3d**: R^1 = -OH; R^2 = H; R^3 = -OH; **3e**: R^1 = H; R^2 = -OH; R^3 = -NO_2

Scheme-I: Synthetic approach for formation of substituted chalcones



Scheme-II: Synthesis of substituted pyridine-2-carbaldehyes **2**(**b-e**) from **2a**

Synthesis of 4-hydroxypyridine-2-carbaldehyde (2d): To, 1 mmol of compound **2a**, 1:1 ratio of ferrous chloride and hydrogen peroxide (30%) were added and the contents were kept under magnetic stirring (500 rpm), for about 45 min near the room temperature. The obtained mixture was separated, washed and dried, to obtain compound **2d**.

Synthesis of 4-nitropyridine-2-carbaldehyde (2e): The nitration mixture composed of conc. HNO_3 and H_2SO_4 was prepared separately, under optimum conditions. This mixture (5 mL) was dispersed in 1 mmol of compound **2a** and the contents were kept under reflux, at about 50 ºC for 45 to 60 min. On observing a yellowish turbid liquid, the progress was monitored through TLC. Once confirming the product formation, compound **2e** was separated from the reaction contents, washed with ethanol:water mixture and then dried. On confirming the structural features of the precursors, **2b-e**, the remaining chalcones (**3b-e**) were synthesized using the similar procedure (**Scheme-I**).

1-Phenyl-3-(pyridin-2-yl)prop-2-en-1-one (3a): Yield: 92%; m.p.: 202 ºC; colour/state: white solid; FTIR (KBr, ν_{max}, cm^{-1}): 1690 (C=O *str.*); 1614, 1506, 1465 (arom. C=C *str.*) 1086, 1035, 735 (arom. C-H bend), 1660 (aliph. C=C *str.*); ^{1}H NMR (400 MHz, $CDCl_3$, δ ppm): 5.54 (m, *J* = 14 Hz), 8.1 (m, *J* = 2.1 Hz); 7.51 (m, *J* = 1.47 Hz), 7.65 (m, *J* = 1.17 Hz), 6.59-7.21 (m, Ar-H, *J* = 2.3 Hz); ^{13}C NMR (75 MHz: DMSO-d_6, δ ppm): 178.01 (C=O); 165.35, 159.10, 151.51 (arom. carbons), 133.37, 124.34; Mass (*m/z*): 209.21, observed 209.24; Elemental analysis calcd. (found) % $C_{14}H_{11}NO$: C, 80.3 (79.89); H, 5.25 (5.12); N, 6.7 (6.56).

1-(2-Methoxyphenyl)-3-(4-methoxypyridin-2-yl)prop-2-en-1-one (3b): Yield: 89%; m.p.: 231 ºC; colour/state: White/solid; FTIR (KBr, ν_{max}, cm^{-1}): 1686 (C=O *str.*), 1614, 1506, 1465 (arom. C=C *str.*) 1086, 1035, 735 (arom. C-H bend); 1245 (C-O *str.*, -OCH_3), 1043 (C-O bend, -OCH_3), 1667 (aliph. C=C *str.*); ^{1}H NMR (400 MHz, $CDCl_3$, δ ppm): 5.54 (m, *J* = 14 Hz), 8.1 (m, *J* = 2.1 Hz); 7.51 (m, *J* = 1.47 Hz), 7.65 (m, *J* = 1.17 Hz), 6.59-7.21 (m, Ar-H, *J* = 2.3 Hz); 3.72 (s, -OCH_3); ^{13}C NMR (75 MHz: DMSO-d_6, δ ppm): 167.94 (C=O); 165.35, 159.10, 151.51 (arom. carbons); 148.31, 134.71, 129.01, 123.45, 55.05 (-OCH_3), 134.37, 123.34; Mass (*m/z*): 269.29, observed: 268.28; Elemental analysis calcd. (found) % of $C_{16}H_{15}NO_3$: C, 71.29 (71.21); H, 5.57 (5.49); N, 5.19 (5.11).

3-(4-Chloropyridin-2-yl)-1-(4-methoxyphenyl)prop-2-en-1-one (3c): Yield: 87%; m.p.: 222 ºC; colour/state: Pale yellow/solid; FTIR (KBr, ν_{max}, cm^{-1}): 1684 (C=O *str.*), 1614, 1506, 1465 (arom. C=C *str.*) 1086, 1035, 735 (arom. C-H bend); 1245 (C-O *str.*, -OMe), 1043 (C-O bend, -OMe), 845-560 (C-Cl *str.*), 1663 (aliph. C=C *str.*); ^{1}H NMR (400 MHz, $CDCl_3$, δ ppm): 5.54 (m, *J* = 14 Hz), 8.2 (m, *J* = 2.1 Hz); 7.54 (m, *J* = 1.47 Hz), 7.65 (m, *J* = 1.17 Hz), 6.59-7.21 (m, Ar-H, *J* = 2.3 Hz); 3.69 (s, -OCH_3); ^{13}C NMR (75 MHz, DMSO-d_6, δ ppm): 169.12 (C=O); 165.35, 159.10, 151.51 (arom. carbons); 148.31, 134.71, 129.01, 123.45, 55.12 (-OCH_3), 134.27, 123.27; Mass (*m/z*): 273.71, observed: 273.69; Elemental analysis calc. (found): $C_{15}H_{12}ClNO_2$: % C 65.76 (65.68), % H 4.39 (4.34), % N 5.11 (5.08), % Cl 12.96 (12.88).

1-(4-Hydroxyphenyl)-3-(4-hydroxypyridin-2-yl)prop-2-en-1-one (3d): Yield: 91%; m.p.: 231 °C; colour/state: White/solid; FTIR (KBr, ν_{max}, cm^{-1}): 3591 (O-H *str.*), 1689 (C=O *str.*), 1614, 1506, 1465 (arom. C=C *str.*) 1086, 1035, 735 (arom. C-H bend), 1665 (aliph. C=C *str.*); ^{1}H NMR (400 MHz, $CDCl_3$, δ ppm): 5.54 (m, *J* = 14 Hz), 8.2 (m, *J* = 2.1 Hz); 7.54 (m, *J* = 1.47 Hz), 7.65 (m, *J* = 1.17 Hz), 6.59-7.21 (m, Ar-H, *J* = 2.3 Hz), 3.4 (s, Phenolic proton, -OH); ^{13}C NMR (75 MHz: DMSO-d_6, δ ppm): 171.22 (C=O); 165.35, 159.10, 151.51 (aromatic carbons); 148.31; 134.71; 129.01; 123.45, 134.37, 123.34; Mass (*m/z*): 241.24, observed: 241.21; Elemental analysis calc. (found): $C_{14}H_{11}NO_3$: % C 69.64 (69.61), % H 4.5 (4.46), % N 5.80 (5.78).

1-(2-Hydroxyphenyl)-3-(4-nitropyridin-2-yl)prop-2-en-1-one (3e): Yield: 90%; m.p.: 218 ºC; colour/state: Yellow/solid; FTIR (KBr, ν_{max}, cm^{-1}): 3591 (O-H *str.*), 1689 (C=O *str.*), 1614, 1506, 1465 (arom. C=C *str.*) 1086, 1035, 735 (arom. C-H bend), 1667 (aliphatic C=C *str.*), 1511 (N=O *str.*); ^{1}H NMR (400 MHz, $CDCl_3$, δ ppm): 5.54 (m, *J* = 14 Hz), 8.2 (m, *J* = 2.1 Hz); 7.54 (m, *J* = 1.47 Hz), 7.65 (m, *J* = 1.17 Hz), 6.59-7.21

(m, Ar-H, J = 2.3 Hz); 3.6 (s, Phenolic proton, -OH); ^{13}C NMR (75 MHz, DMSO-d_6, δ ppm): 172.31 (C=O), 165.35, 159.10, 151.51 (arom. carbons), 148.31, 134.71, 129.01, 123.45, 133.37, 124.34; Mass (*m/z*): 270.24, observed: 270.21; Elemental analysis calcd. (found) % $C_{14}H_{10}N_2O_4$: C, 62.16 (62.11); H 3.70 (3.67); N, 10.36 (10.31).

Bacterial activity: The biological efficiency of the synthesized chalcones (**3a-e**) was evaluated for the antibacterial and antifungal activities. The antibacterial activity studies were conducted with the selected microorganisms like Gram-negative *Escherichia coli* and Gram-positive *Staphylococcus aurues*. Broth dilution method was applied for the studies [33]. The antibacterial activity was performed by taking penicillin and streptomycin as standards and the minimum inhibitory concentration (MIC, μg/mL) was determined.

The fungicidal activity of all the synthesized compounds was studied at 1000 ppm concentration *in vitro*. Plant pathogenic organisms used were *Nigrospora* sp, *Aspergillus niger*, *Botrydepladia thiobromine* and *Rhizopus nigricum*, *Fusarium oxyporium*. The antifungal activities of all the compounds (**3a-e**) were measured on each of these plant pathogenic strains on a potato dextrose agar (PDA) medium [34]. Such a PDA medium contained potato 200 g, dextrose 20 g, agar 20 g and water 1 mL. 5 days old cultures were employed. The compounds to be tested were suspended (1000 ppm) in a PDA medium and autoclaved at 120 ºC for 15 min at 15 atm. pressure. These media were poured into sterile Petri plates and the organisms were inoculated after cooling the Petri plates. The percentage inhibition for fungi was calculated after 5 days using eqn. 1:

$$\text{Inhibition } (\%) = \frac{X - Y}{X} \times 100 \quad (1)$$

where, X = area of colony in control plate, Y = area of colony in test plate.

RESULTS AND DISCUSSION

The precursors (**2b-e**) were characterized using IR and ^{1}H NMR instrumental techniques.

IR spectra: The C=O (streching) value of the aldehyde group were obtained in the range of 1723-1715 cm^{-1}. C=C (aromatic, *str.*): 1700-1500 cm^{-1}, C=N (pyridine, *str.*): 1632 cm^{-1}, C-H (aromatic, bending) 701, 745 cm^{-1}, were obtained commonly in all the precursors (**2b-e**). The C-O (*str.*) and C-O (bend) vibrations in the methoxy groups (-OMe) in compound **2b** were obtained at 1245 and 1043 respectively. At 1510, the Nitro group of compound **2e** (N=O *str.*) stretching was observed. The C-Cl (*str.*) and O-H (*str.*) in compounds **2c** and **2d** were obtained in the range of 845-560 cm^{-1} and 3591 cm^{-1} respectively.

^{1}H NMR (400 MHz, δ ppm): In all the compounds (**2b-e**) the aromatic protons resonated in the range of 6.59-7.21 (m, Ar-H, J = 2.3 Hz). The phenolic proton in compound **2d** resonated at 3.5 (singlet). The methoxy proton (-OC**H**$_3$) in compound **2b** resonated as singlet at 3.72.

Role of various MCM-41 materials: In order to investigate the best mesoporous material in forming these chalcones in higher yields with fine purity, the **Scheme-I** was conducted with each of the synthesized MCM-41 materials (1 mmol) to form the compound **3a**. The results were presented in Table-1. It was observed that the M^{n+}-MCM-41 [M^{n+}= Mn/Al] and acid functionalized MCM-41 materials have performed better than the pure MCM-41 material (68%). Furthermore, the yields were in the range of 85-87% with the Mn and Al-MCM-41, whereas significantly higher and similar yields were obtained with SA-MCM-41 (89%) and PW-MCM-41 (92%) materials. These results demonstrate the prominent influence of the modified MCM-41 forms in drawing out the better yields of the chalcones.

TABLE-1
CATALYTIC EFFICIENCY OF THE MESOPOROUS MATERIALS

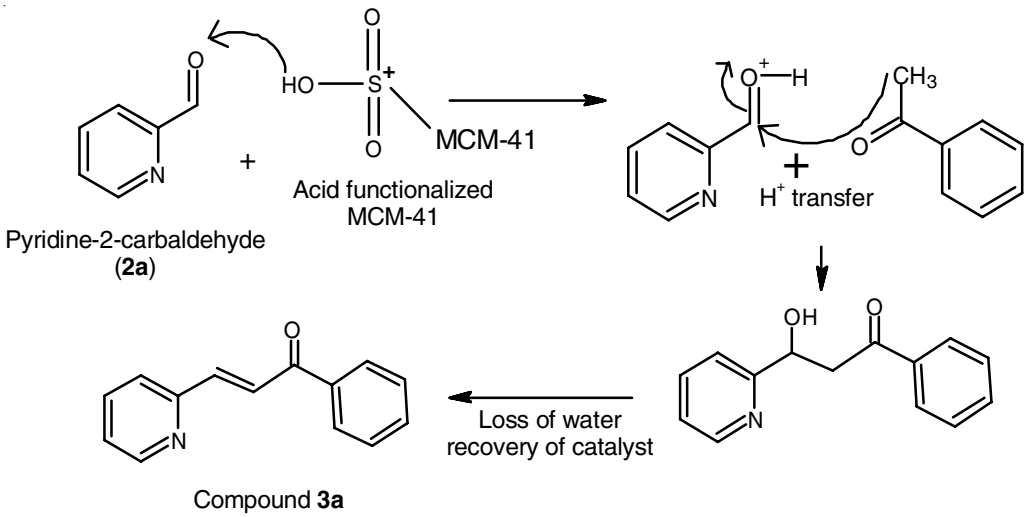
Mesoporous material (1 mmol)	% Yield of compound **3a**
MCM-41	68
Mn-MCM-41	85
Al-MCM-41	87
SA-MCM-41	89
PA-MCM-41	92

Role of solvents: Using PA-MCM-41 material (1 mmol), the experiment were conducted to optimize the appropriate solvent to bring out the best possible yields of the chalcones (**3a**). Hence, various solvents (Table-2) like DCM, EtOH, acetone, THF and water were used and the reaction was conducted according to **Scheme-I**. The substrate was dispersed in a known volume of each solvent (3-4 mL) and the reaction was conducted according to the established conditions. Even though moderate to higher yields were obtained with EtOH and THF solvents, best yields were obtained only in the presence of water. This reaction condition was observed to be major outcome of the schematic approach and was notified to proceed at par with the principles of green synthesis.

TABLE-2
ROLE OF SOLVENT IN THE
FORMATION OF THE CHALCONE **3a**

Solvent (3-4 mL)	% Yield of compound **3a**
DCM	79
EtOH	82
Acetone	76
THF	83
Water (Neat)	92

In present scheme, the modified forms of MCM-41 materials act as heterogeneous catalyst with acidic nature [35]. It favours the attraction of non-bonding electrons on the carbonyl oxygen in pyridine-2-carbaldehyde (**2a**) and makes the carbonyl carbon more electrophilic in nature. The methyl proton of the aromatic ketone acts as carbanion, with the loss of a proton and forms a C-C bond, followed by loss of water to form compound **3a**. During this step, the mesoporous material could be regenerated again with the acceptance of the proton from the reaction process. This facile mechanism has been proposed based on the traditional acid catalyst Claisen-Schmidt condensation reaction [36]. These steps are presented in **Scheme-III**. Solhy *et al.* [37] reported the formation of chalcone derivatives with 80% yield in the presence of water solvent and hydroxyapatite



Scheme-III: Plausible mechanism of acid functionalized MCM-41 catalyzed formation of novel chalcone derivatives under solvent free conditions

as the catalyst. The reaction was found to less prominent in the presence of organic solvents. Gupta *et al.* [38] have formed the chalcone derivatives in the presence of 60% potassium hydroxide solution. The derivatives were observed to be formed over the reaction time of 14-16 h. Daniel *et al.* [39] reported 20 various chalcone derivatives which were very simply synthesized in a mortar pestle, under solvent free conditions and solid NaOH. However, the reaction suffers with a minor limitation of additional requirement of separating the side products obtained through ketol and Micheal addition reactions. Eddarir *et al.* [40] reported the formation of chalcones through the Suzuki reaction. The reaction involved a coupling reaction between the cinnamoyl chloride and phenylboronic acid in the presence of $[(PPh_3)_4Pd]$ as catalyst, Cs_2CO_3 as base and toluene solvent. Under these conditions, the maximum yield of chalcones was obtained as 51%. Using the same reaction conditions and with precursors, benzoyl chloride and phenylvinylboronic acid, the maximum yields in unsubstituted and substituted chalcones were obtained as 93% and 80-90%, respectively. All the above reports are favourable in forming the desired products, but each of them was observed to be incurred with minor limitations such as higher reaction time, less product yields, difficulty in controlling the occurrence of the side reactions. The present reaction scheme was completely conducted to overcome these drawbacks through the usage of mesoporous MCM-41 materials. Maximum yields were obtained in the range of 90-92% with both substituted and un-substituted chalcones. The reaction was successful under solvent free conditions and the products were formed efficiently in a nominal time period of 1 h. These factors support the formation of novel chalcone derivatives in the present work under optimum reaction conditions.

Biological activity studies: The antibacterial activity of the synthesized chalcone derivatives was evaluated against bacteria like Gram-negative *Escherichia coli*, Gram-positive *Staphylococcus aurues* with Penicillin and Streptomycin as the standards. In these studies, compounds **3b**, **3c** and **3d** have shown a significant biological activity in terms of MIC (µg/mL) against the selected microorganisms, whereas compounds **3a** and **3e** have presented very poor activity. It was noticed that the presence of activating groups like methoxy, hydroxyl groups have contributed for the contamination of the bacteria (Table-3).

TABLE-3
RESULTS OF ANTIBACTERIAL ACTIVITY

Chalcone derivative	MIC (µg/mL)	
	E. coli	*S. aurues*
3a	33.21	31.42
3b	21.32	22.98
3c	20.12	19.11
3d	16.22	15.64
3e	32.12	29.21
Penicillin	12.50	1.56
Streptomycin	6.25	6.25

In the antifungal activity studies, only compound **3a** was able to deactivate the fungal strain, *Nigrospora* sp., with 50% zone of inhibition as compared with the standard amphotericin B. Compound **3c** has shown excellent antifungal activity (75%) against the fungal strain *Aspergillus niger* and the activity has slowly decreased with compounds **3b** and **3a**. The fungal strain *Botrydepladia thiobromine* was made inactive only by the compounds **3d** and **3e**. Interestingly, *Rhizopus nigricum* was deactivated by all the synthesized compounds and highest antifungal activity was obtained with this fungal strain. The fungal strain *Fusarium oxyporium* was made passive by the compounds **3b** and **3d**, whereas compound **3a** has shown the moderate activity. Hence, the selected fungal strains were collapsed with almost all the chalcone derivatives, with a major effect on *Rhizopus nigricum* and a moderate activity on the remaining strains. These results are displayed in Table-4.

Conclusion

A simple one-pot synthesis of novel chalcone derivatives (**3a-e**) was reported under solvent free conditions, catalyzed by various mesoporous MCM-41 materials. The protocol was identified to be unique in its form, conducted in the presence of

TABLE-4
RESULTS OF ANTIFUNGAL ACTIVITY

Chalcone derivative	Zone of inhibition (%)#				
	Nigrospora Sp	*Aspergillus niger*	*Botrydepladia thiobromine*	*Rhizopus nigricum*	*Fusarium oxyporium*
3a	0	15	0	50	35
3b	50	35	0	15	50
3c	0	75	0	50	0
3d	0	0	25	50	50
3e	0	0	20	15	0
Amphotericin B	100	100	100	100	100

#Zone of inhibition was calculated from eqn. 1.

acid functionalized and metal incorporated MCM-41 materials. These materials were highly efficient in bringing out the chalcone derivatives in the highest yields, under nominal experimental conditions. Among the synthesized modified MCM-41 materials, the acid functionalized MCM-41 materials have shown superior activity than the M^{n+}-MCM-41 materials [M^{n+} = Mn/Al]. The reaction was observed to be highly feasible for condensation in the presence of these mesoporous materials. Furthermore, the compounds have also shown the best antimicrobial activities against the selected bacterial and fungal strains. Hence, the developed chalcone derivatives, through green synthetic approach were successful and also the compounds are biologically active.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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