Shirdi Sai Rural Institute's

ARTS, SCIENCE AND COMMERCE COLLEGE, RAHATA

"NAAC REACCREDITED "B++" GRADE COLLEGE"

A/P/Tal-Rahata,Dist.-Ahmednagar.(M.S.)423107

Affiliated to Savitribai Phule Pune University, Pune

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SELF STUDY REPORT-CYCLE 3rd

2018-2023

Criterion: III

Research, Innovations and Extension

Key Indicator: 3.3

Research Publication and Awards

Metric: 3.3.1 (Q_nM)

Number of research papers published per teacher in the Journals as notified on UGC CARE list during the last five years

Submitted to

NATIONAL ASSESSMENT AND ACCREDITATION COUNCIL(NAAC)

BENGALURU

Shirdi Sai Rural Institutes,
Arts, Science and Commerce College, Rahata
Tal- Rahata, Dist-Ahmednagar, Pin - 423107 (MS)
(University of Pune Affiliated ID No. PU/AN/ASC/052/1997)
NAAC RE-ACCREDITED "B++" GRADE COLLEGE

Ref. : ASCCR /

Date

DECLARATION

We the undersigned, hereby declare that all information, reports, true copies of the supporting documents, and numerical data submitted by our institution for the purpose of NAAC accreditation have been thoroughly verified by the Internal Quality Assurance Cell (IQAC). We affirm that these submissions are accurate and correct as per our records.

This declaration pertains specifically to the accreditation process for the third cycle of the institution, covering the period from 2018-19 to 2022-23.

Thank you.

Sincerely,

Dr. Vikram P. Bhalekar
IQAC Coordinator
Internal Quality Assurance Cell
Arts,Science and Commerce College, Rahata

Arts,Science and Commerce College Rahata
Tel-Rahata
Dist-A'nagar

Prof.(Dr.) Somnath S. Gholap
Principal
Arts,Science and Commerce College
Rahata,Tel-Rahata,Dist-Ahmednagar

Date-**30/07/2024**

Place- **Rahata**

Sr. No.	Title of paper	Name of the author/s	Department of the teacher	Name of journal	Calendar Year of publication	ISSN number	Link to the recognition in UGC enlistment of the Journal /Digital Object Identifier (doi) number		
	Academic Year 2022-2023						Link to website of the Journal	Link to article / paper / abstract of the article	Is it listed in UGC Care list
1	Aqueous Balanites Roxburghii: a clean and green biocatalyst for synthesis of Sulfonamides	Prof. Dr.S.S.Gholap	Chemistry	Heterocyclic Letters	2023	ISSN : (print) 2231–3087 / (online) 2230-9632	LINK	Printed	YES
2	Novel Pumice Supported Perchloric Acid Promoted Protocol for the Synthesis of Tetrahydrobenzo[b]pyran via Multi-component Approach	Dr G.D.Shirole	Chemistry	Polycyclic Aromatic Compounds	2023	Print ISSN: 1040-6638 Online ISSN: 1563-5333	LINK	LINK	YES
3	Tea Powder Waste: As A Green Catalyst For The Synthesis Of 1-Amidoalkyl 2-Naphthols	Dr.G.D.Shirole	Chemistry	Heterocyclic Letters	2023	ISSN : (print) 2231–3087 / (online) 2230-9632	LINK	LINK	YES
4	Pumice@So3h Catalyzed Ultrasound Mediated Synthesis Of Polyhydroquinoline Derivatives.	Dr.G.D.Shirole	Chemistry	Heterocyclic Letters	2022	ISSN : (print) 2231–3087 / (online) 2230-9632	LINK	LINK	YES
5	Pumice-based sulfonic acid: a sustainable and recyclable acidic catalyst for one-pot synthesis of pyrazole	Dr.G.D.Shirole	Chemistry	Res. Chem. Intermed. (Springer	2022	0922-6168	LINK	LINK	YES

	anchored 1,4-dihydropyridine derivatives at room temperature,								
6	Novel Pumice Supported Perchloric Acid Promoted Protocol for the Synthesis of Tetrahydrobenzo[b]pyran via Multi-component Approach	A.S.Tambe	Chemistry	Polycyclic Aromatic Compounds	2023	Print ISSN: 1040-6638 Online ISSN: 1563-5333	LINK	LINK	YES
7	Pumice@So3h Catalyzed Ultrasound Mediated Synthesis Of Polyhydroquinoline Derivatives.	A.S.Tambe	Chemistry	Heterocyclic Letters	2022	ISSN : (print) 2231–3087 / (online) 2230-9632	LINK	LINK	YES
8	Pumice@So3h Catalyzed Ultrasound Mediated Synthesis Of Polyhydroquinoline Derivatives.	A.R.Pagare	Chemistry	Heterocyclic Letters	2022	ISSN : (print) 2231–3087 / (online) 2230-9632	LINK	LINK	YES
9	Novel Pumice Supported Perchloric Acid Promoted Protocol for the Synthesis of Tetrahydrobenzo[b]pyran via Multi-component Approach	R.V.Dhawale	Chemistry	Polycyclic Aromatic Compounds	2023	Print ISSN: 1040-6638 Online ISSN: 1563-5333	LINK	LINK	YES
10	Pumice-based sulfonic acid: a sustainable and recyclable acidic catalyst for one-pot synthesis of pyrazole anchored 1,4-dihydropyridine derivatives at room temperature,	R.V.Dhawale	Chemistry	Res. Chem. Intermed. (Springer)	2022	0922-6168	LINK	LINK	YES
11	Pumice@So3h Catalyzed Ultrasound Mediated Synthesis Of	Rahul Narode	Chemistry	Heterocyclic Letters	2022	ISSN : (print) 2231–3087	LINK	LINK	YES

	Polyhydroquinoline Derivatives.					/ (online) 2230-9632			
12	Bhartiy Bhasha Hindi aur Anuvad	Dr. Ainur S Shaikh	Hindi	Samvet	2023	ISSN :2321-6131	LINK	Printed	YES
13	India ‘s Water Management Polices for Sustainable Development	Dr. Jayshree Dighe	Economics	Education and Society	2023	ISSN-2278-6864	LINK	Printed	YES
14	ROLE OF IRRIGATION IN SUSTAINABLE AGRICULTURAL DEVELOPMENT	Dr. Archana Antre	Economics	Utkal Historical Research Journal	2023	ISSN: 0976-2132	LINK	Printed	YES
15	Dakshin Bhartiy Cinema, Dabing aur Hindi	Dr. D. N. Dange	Hindi	Samvet	2023	ISSN :2321-6131	LINK	Printed	YES
16	Women And Indian Politics After Independence	Ms. Jagatap S.J	Politics	Education And Society	2023	ISSN-2278-6864	LINK	Printed	YES
17	Reservation of women in politics And Actual Participation of women in politics in Maharashtra	Ms. Pendbhaje P.B	Politics	Sanshodhk	2023	ISSN;2394-5990	NA	Printed	YES
18	Effect of molasses on protein content of fresh water fish, Puntius chrysopterus	Mr. Sandip D. Talole	Zoology	Flora and Fauna	2022	ISSN 2456 - 9364 (Online) ISSN 0971 - 6920 (Print)	LINK	LINK	YES
19	Studies on the Wilson Dam Reservoir Water quality in relation to fishing, Ahmednagar District, Maharashtra, India	Mr. Sandip D. Talole	Zoology	Flora and Fauna	2023	ISSN 2456 - 9364 (Online) ISSN 0971 - 6920 (Print)	LINK	LINK	YES
20	Examining Challenges and Prospects in English Language	Dr R D Kasar	English	Education and Society	2023	ISSN-2278-6864	LINK	Printed	YES
21	Daisy in R.K. Narayan's The Painter of Signs: A Representative of the Modern Woman	Dr R D Kasar	English	Satraachee	2023	ISSN-2348-8425	LINK	Printed	YES
22	Aqueous Balanites	Dr V R Kadu	Chemistry	Heterocyclic	2023	ISSN :	LINK	Printed	YES

	Roxburghii: a clean and green biocatalyst for synthesis of Sulfonamides			Letters		(print) 2231–3087 / (online) 2230-9632			

IQAC Co-ordinator
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AQUEOUS BALANITES ROXBURGHII: A CLEAN AND GREEN BIOCATALYST FOR SYNTHESIS OF SULFONAMIDES

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ABSTRACT:
Sulfonamide group is a versatile group introduced as the key core for diverse bio-activities as antibacterial sulfonamides and non-anti-bacterial sulfonamides in drug industry. Two component one pot synthesis of sulfonamides have been effectively carried out using aqueous solution of natural surfactant viz; *Balanites Roxburghii* which is commonly known as hingan. The present study has been employed by environmentally available *Balanites Roxburghii* as catalyst at room temperature. The present methodology of synthesis of sulfonamides comes out with advantages like economically feasible, simple and biocompatible catalytic system states safely production of different sulfonamide derivatives on bulky scale.

KEYWORDS: Sulfonamide, natural surfactants, *Balanites Roxburghii,* hingan economically feasible, simple and biocompatible catalytic system.

INTRODUCTION:

The newer organic synthesis which is carried out by naturally available catalyst has great importance in the field of green chemistry. The naturally occurring catalyst will accompanied the organic synthesis may be whispered as environmentally benign. There is need for achieving great goals through green chemistry in the field of organic synthesis by building useful organic cores for bulky drug molecules that are presently synthesised by disadvantageous methodology. Naturally abundant available materials like clays[i], enzymes[ii] and surfactants[iii] are extensively applied for different routes of synthesis of organic targets. These naturally occurring materials are promising substitutes for the hazardous organic solvents and catalysts that are presently practised in organic synthesis. Presently used solvents and catalysts in the organic conversions are with disadvantages like expensiveness, short of biodegrability, tedious work-up procedures, use of halogenated organic solvents, use high temperature to get required yield organic compound etc. There are

also some different naturally occurring biochemicals giving distinctive classified active biocatalyst used in organic procedures[iv-vi]. These biocatalyst have gained much more attention of current researcher in the field of organic chemistry through pollution free and eco-friendly protocols[vii] as per the Green Chemistry principles. In this perspective, the plant cell culture of *Daucus carota* root[viii-xiii], soaked *Phaseolus Aureus* (green grams)[xiv], coconut juice (*Cocos Nucifera*)[xv] has been effectively used as catalysts for selective reduction of ketones, aq. extract of *Acacia concinna* has been utilized as reaction medium for the synthesis of 3-carboxycoumarins and Cinnamic acids[xvi], acylation of amines[xvii] and synthesis of aryl-hydrazones[xviii].

Sulfonamides are useful in the field of medicinal chemistry as its core is utilized in building up bulky drugs. Sulfonamides and their derivatives are widely used for HIV protease inhibitor (A) amprenavir[xix], antibacterial activity[xx], anti-carbonic anhydrase[xxi], hypoglycaemic[xxii] , antitumour[xxiii] , anti-thyroid[xxiv] and diuretic (B) Hydrochlorothiazide, (C) Hydroflumethiazide, (D) Quinethazone and (E) Metolazone[xxv], (Figure 1).

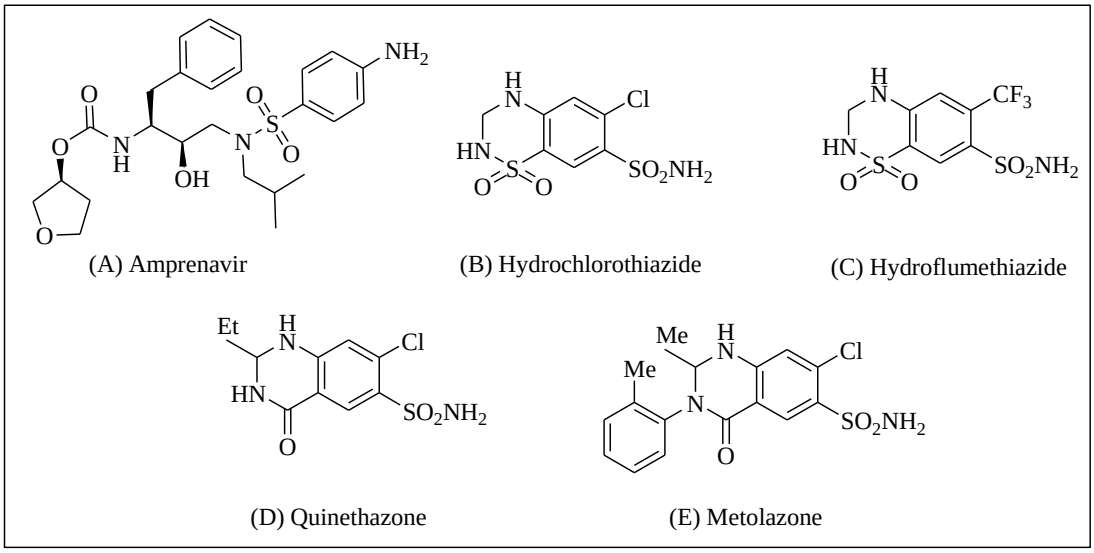


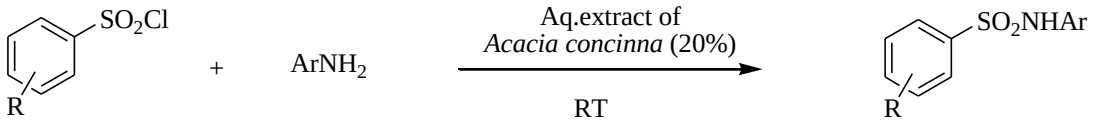
Figure 1. Chemical structure of some pharmacologically active sulfonamide derivatives

Sulfonamides were synthesised from sulfonylbenzotriazoles and different amine was general and efficient procedure[xxvi]. Now a days they are synthesised by oxidation of thiols to sulfonyl chlorides which on further reaction with amines yields sulfonamide is reported[xxvii]. Simply sulfonamides are also synthesised from sulfonic acids[xxviii]. Sulfonic acid on reaction with isocyanate also yields sulfonamides at room temperature[xxix].

Acacia concinna is generally known as Shikakai which has family Leguminosae and originates in tropical region of southern Asia. The fruits of *Acacia concinna* have cleansing property due to the presence of saponins that are foaming agents. These saponis produces leather when shaken in aqueous solutions. The fruit is known to have 10-11.5% saponins and their structure has been reported.[xxx,xxxi] These saponins resolves similar surfactant properties as that of dodecyl benzene sulphonates.[xxxii] The aqueous extract of these pods of *Acacia concinna* shows acidic pH which is due to the 'acacic acid' found in the solution.[xxxiii] Encapsulation of the reactants in micellar cages drives the equilibrium toward the product side by giving out the water molecule out of its interior yields of products (Figure 2). The action of micellar cages in formation of product excited us to use aqueous Acacia concinna solutions as an efficient and eco-friendly acidic surfactant catalyst for the synthesis of sulfonamide derivatives.

RESULT AND DISCUSSION:

Current methodology presents economical, simple and greener pathway for synthesis of sulfonamide catalyzed by aq. extract of *Acacia concinna* pods which in continuation of our ongoing research on development of newer synthetic method for bioactive compounds.[xxxiv-xxxix] Different sulfonamides (**3**) were synthesised using various aromatic sulfonyl chlorides (**1**) and aromatic amines (**2**) (Scheme 1). Synthesis of sulfonamides by current approach does not involve use hazardous organic solvents, and no tedious reaction workup. Green chemistry principles are followed in the current methodology.[xl-xli]



1 **2** **3**

Scheme 1. Natural surfactant catalyzed synthesis of sulfonamide derivatives

Reaction of benzene sulfonyl chloride (1mmol) and aniline (1mmol) in 10 mL aqueous extract of *Acacia concinna* pods (10% w/v) at room temperature was carried out in order to ensure the catalytic effectiveness of present natural surfactant and we are good yield of product **3a.** The result encouraged us for optimisation of concentration of aqueous solutions of *acacia concinna* pods. Optimisation study concluded that that 20% of the catalyst was sufficient to get highest yield of the product **3a** (>95%). Increasing concentration of *Acacia concinna* pods (25%, 30%, 35% and 40%) did not affect the yield of the final product. Hence, 20% (w/v) aqueous extract of *Acacia concinna* pods and 10 mL volume was selected as optimized to drive the reaction (Table 1). Different sulfonamide derivatives are synthesis at reaction time and in good yields as in Table 2.

Table 1. Optimization of catalyst concentration.

Entry	Catalyst concentration %(w/v)	Time (hr)	Yield(%)[a]
1.	10	2.5	92
2.	20	1.5	97
3.	25	1.5	95
4.	30	2	95
5.	40	2	92
6.	--	12	NR[b]

[a]Isolated yield of **3**. [b]No Reaction

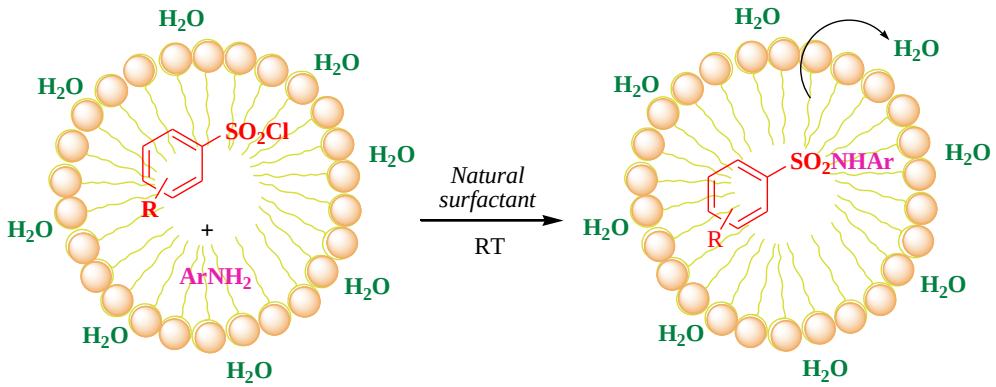
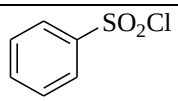
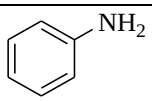
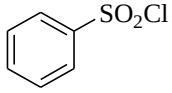
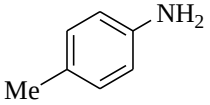
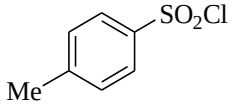
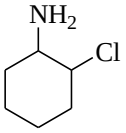
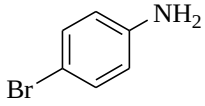
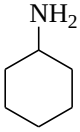
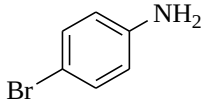
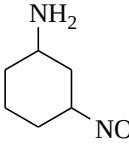
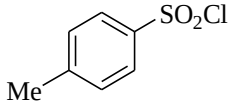
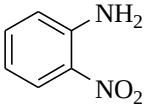
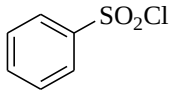
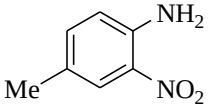
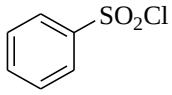
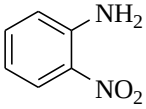
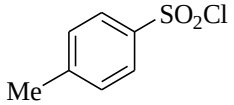
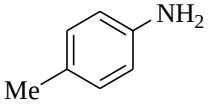
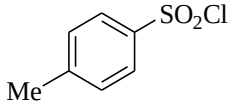
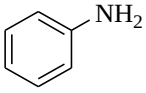
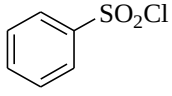
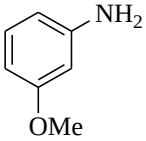


Figure 2. Micelle-promoted synthesis of sulfonamides

Table 2. Synthesis of sulfonamide derivatives (3a-k)

Entry	Sulfonyl chloride	Amine	Product	Time (hrs)	Yield (%)	M.P.(°C) Ref.
1.			**3a**	1.5	97	59-60[xlii]
2.			**3b**	1.2	92	118-119[xlii]
3.			**3c**	1.2	90	105-107[xliii]
4.			**3d**	1.5	88	100-102[xliii]
5.			**3e**	2.2	86	116-118[xliii]
6.			**3f**	2.2	92	112-113[xlii]
7.			**3g**	2.5	90	100-102[xlii]
8.			**3h**	2.5	96	101-103[xlii]
9.			**3i**	2.1	88	114-115[xlii]
10.			**3j**	1.5	90	95-97[xlii]
11.			**3k**	1.2	92	87-88[xliv]

CONCLUSION:

From the current methodology, we are able to describe an environmental friendly, efficient and economical catalyst for the synthesis of derivatives in aqueous extract of *Acacia concinna* pods medium. The application of biocatalyst in field of organic synthesis, water as medium, medium reaction condition and easy reaction workup are some of the advantages of present methodology.

EXPERIMENTAL SECTION:

General Remarks. All chemicals were obtained commercially from suppliers and were used without purification. Melting points were recorded on Digital Electro thermal Melting point apparatus and are uncorrected. Reaction monitoring was conducted using Thin Layer Chromatography (TLC) using pre-coated Silica gel 60 F_{254} plates with layer thickness 0.25nm purchased from Merck Ltd. TLC plates were visualized under ultraviolet light at 254 nm wavelength.

General procedure for the preparation of catalyst

A fine powder of *Acacia concinna* pods (20 g) in water (100 mL) was heated in a 250 mL conical flask at 100^{o}C for 20 min. The solid material was filtered and the aqueous extract was collected. The prepared extract has concentration 20% w/v.

General procedure for the synthesis of sulfonamide derivatives

A mixture of aromatic sulfonyl chloride (1mmol), and amine (1 mmol) in catalyst solution (20%, 10 mL) was stirred at room temperature for specified time (Table 2). After completion of the reaction (as indicated by TLC), a separated solid was filtered on Buchner funnel, washed with water and dried to obtain pure products in excellent yields.

Spectral data of representative compounds:

Phenyl(phenylsulfonyl)amine (3a)- White solid; Yield 80 %; mp: 59-60 ^{0}C;
^{1}HNMR (400MHz, DMSO-d^{6}): δ 4.39 (1H, bs, -NH), 7.01-7.02 (1H, d, Ar-H), 7.06-7.08 (2H, d, Ar-H), 7.19-7.23 (2H, m, Ar-H), 7.53-7.55 (2H, d, Ar-H), 7.58-7.59 (1H, d, Ar-H),7.73-7.75 (2H, d, Ar-H). **LCMS (ESI):** m/z 233

(4-Methylphenyl)(phenylsulfonyl)amine (3b)- White solid; Yield 80 %; mp: 118-119 ^{0}C;
^{1}H NMR (400MHz, DMSO-d^{6}): δ 2.17 (3H, s, CH_3), 4.57 (1H, bs, -NH), 6.94-6.96 (1H, d, Ar-H), 7.00-7.02 (1H, d, Ar-H), 7.50-7.60 (2H, m, Ar-H), 7.70-7.72 (1H, d, Ar-H). **LCMS (ESI):** m/z 247

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Novel Pumice Supported Perchloric Acid Promoted Protocol for the Synthesis of Tetrahydrobenzo[*b*]pyran via Multi-component Approach

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ABSTRACT

A novel heterogeneous pumice supported perchloric acid catalyzed synthesis of tetrahydrobenzo[*b*]pyran has developed via multi-component condensation of aromatic aldehydes, dimedone and malononitrile. The catalyst was characterized by IR, XRD, EDS, SEM, and TGA techniques which confirmed the formation novel pumice supported perchloric acid. The present protocol proved to have numerous advantages like one-pot reaction, good yield, short reaction time, inexpensive catalyst, recyclability and reusability of the catalyst, simple experimental and work up procedure, and purification of targeted molecules without column chromatography.

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KEYWORDS
Pumice supported perchloric acid; tetrahydrobenzo[*b*]pyran; multi-component reaction; dimedone; malanonitrile

Introduction

In the last two decades, volcanic pumice and pumice based materials have been employed in divergent organic transformations such as reduction reaction, oxidation reaction, photo catalytic degradation, multi-component condensation reaction and also water treatment process. These varied reactions are achieved because large silica content of the pumice which was converted into active catalytic material. The appreciable advantages of pumice supported catalytic materials are heterogeneous nature, good surface area, excellent catalytic activity, thermal stability, high porosity, high absorption capacity, recyclability and reusability, etc.[1–9]

Multi-component reaction (MCR) approach has gained excellent impact in the discovery of heterocyclic compounds due to the synthetic efficiency and economy. The MCR strategy is a one step synthetic operation with incredibly well-designed and quick approach to discover highly functionalized and complex biologically active molecules. It has also advantages like high flexibility, high atom economy and high selectivity.[10–12] The synthesis of tetrahydrobenzo[*b*]pyrans is also an important illustration of the multi-component reaction.

The tetrahydrobenzo[*b*]pyran derivatives are extremely significant to the organic chemists because of their prominent biological and pharmacological activities. They are fascinating polyfunctionalized compounds which possess a wide variety of biological activities like anti-allergic, antibacterial, anti-coagulant, anti-tumor, calcium channel antagonists and diuretic etc. Along with biological activities, some derivatives of tetrahydrobenzo[*b*]pyran have been employed as photoactive materials and agrochemicals. They are also used in cosmetics and pigments.[13–18] The some illustration of biologically active tetrahydrobenzo[*b*]pyran derivatives shown in Figure 1.

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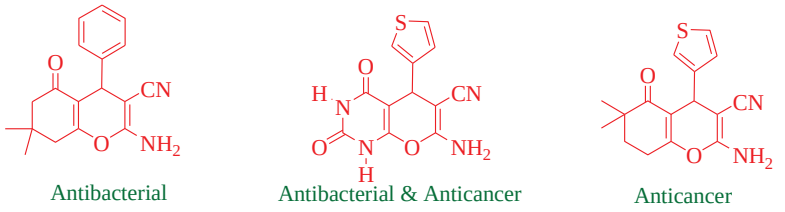


Figure 1. Some examples of biologically active tetrahydrobenzo[*b*]pyran derivatives.

In a vision of the enormous scope of tetrahydrobenzo[*b*]pyrans there is increased attention in developing new routes for their synthesis. The synthetic protocols include numerous catalyst such as tetraethylammonium perchlorate,[19] CTMAB-bentonite,[20] nano-titania sulfuric acid,[21] ultrasound,[22] MNPs–$PhSO_3H$,[23] molecular sieve-supported zinc catalyst,[24] silica nanoparticles,[25] oxyammonium-based ionic liquid,[26] $MeSO_3H$,[27] PEG-SO_3H,[28] WEMFSA,[29] tungstic acid functionalized mesoporous SBA-15,[30] amine-functionalized SiO_2@Fe_3O_4 nanoparticles,[31] choline chloride-oxalic acid,[32] L-proline,[33] chitosan,[34] xanthum gum supported Fe_3O_4,[35] phosphotungstic acid supported on SiO_2@$NHPhNH_2$ functionalized nanoparticles of $MnFe_2O_4$,[36] poly(Ethyleneoxide)-based magnetic nanocomposite,[37] magnetic aluminosilicate nanoclay,[38] amine-functionalized silica-supported magnetic nanoparticles,[39] etc.

In continuation of our work in developing new methodologies for the synthesis of active compounds[40] herein, we have reported an efficient and sustainable protocol for the synthesis of tetrahydrobenzo[*b*]pyrans via multi-component reaction of aromatic aldehyde, dimedone and malononitrile in the presence of novel pumice supported perchloric acid. The present work has a number of advantages in comparison with the literature reported protocols, such as good yields, high atom economy, smooth reaction conditions, simple work-up procedure and purification of targeted molecule without column chromatography.

Experimental procedures

General

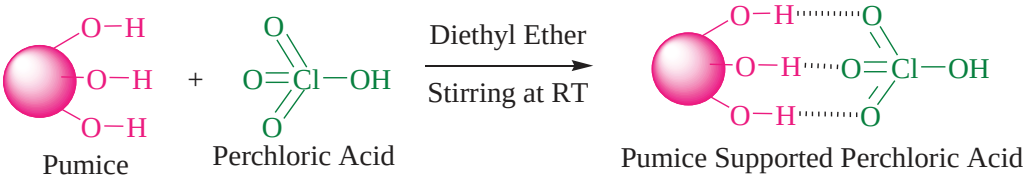
The progress of the reaction was monitored by thin-layer chromatography (TLC) by using silica gel coated aluminum plates and plates are visualized with UV light. Melting points were taken in an open capillary and are uncorrected. ^{1}H NMR (500 MHz) and ^{13}C NMR (125 MHz) spectra were recorded with the BRUCKER AVANCE NEO 500 MHz in $CDCl_3$ using TMS as an internal standard. IR spectra were taken on PerkinElmer FTIR Spectrometer. The pumice supported perchloric acid catalyst was prepared in the laboratory. Mass spectra were recorded on a MALDI SYNAPT XS HD Mass spectrometer.

General procedure for the preparation of pumice supported perchloric acid

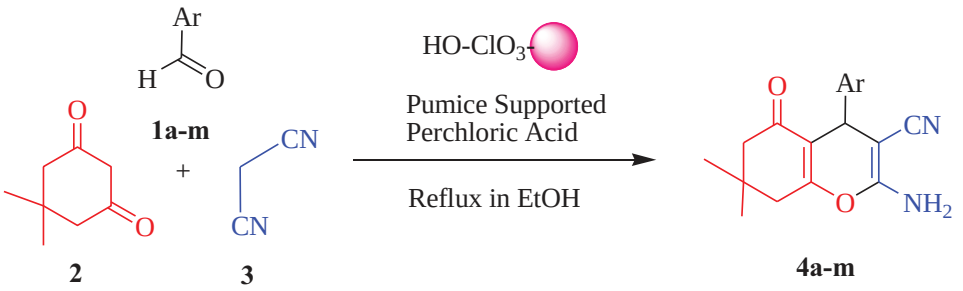
Perchloric acid (3.0 gm) was added to the suspension of pumice (45 gm) in diethyl ether (60 mL) with constant stirring for 2 h. The mixture was concentrated and the residue was washed with acetone to remove unreacted perchloric acid. The resultant residue was dried under vacuum at 80 °C for 6 h to afford free Pumice Supported Perchloric acid (Pumice@$HClO_4$) (Scheme 1).

General procedure for the synthesis of tetrahydrobenzo[b]pyran derivatives (4a–m)

In a 100 mL round bottom flask, the mixture of substituted benzaldehyde (2 mmol), dimedone (2 mmol), malanonitrile (2 mmol) and pumice supported perchloric acid (100 mg) was taken in 10 mL of ethanol (Scheme 2). The resulting reaction mixture was refluxed for appropriate time.



Scheme 1. Preparation of pumice supported perchloric acid.



Scheme 2. Synthesis of tetrahydrobenzo[*b*]pyran derivatives (**4a–m**).

The progress of the reaction was confirmed by TLC. To separate out the catalyst pumice supported perchloric acid, the content was filtered at hot condition. After cooling the filtrate, the solid was separate out which was dried and purified by recrystalization using ethanol.

Result and discussion

The pumice supported perchloric acid was prepared from volcanic pumice and perchloric acid by simple agitation in diethyl ether which has characterized by various analytical techniques such as FTIR, XRD, EDAX, SEM, and TGA. The FTIR spectra of pumice supported perchloric acid showed that, the significant absorption band at 3413.95 cm^{-1} corresponding to the acidic proton in Pumice@$HClO_4$. In addition to this, the band appeared at 1637.53 cm^{-1} is due to the (Cl = O) bond and the bands at 1147.39 and 1090.09 cm^{-1} are related to Si–O–Si bonds (Figure 2(a)). These bands are not observed in FTIR of plane pumice (Figure 2(c)) except the band at 1036.86 cm^{-1}due to Si–O–Si bonds. This clearly indicates that, the perchloric acid was supported on pumice. Also the FTIR of recycled pumice@$HClO_4$ (Figure 2(b)) did not show any noteworthy deviation from pure pumice@$HClO_4$.

The EDAX analysis showed the composition of Pumice supported perchloric acid. This indicates that the synthesized catalyst composed of Si, O, Al, K, and Cl elements. The higher percentage of chlorine and oxygen proved that the perchloric acid was supported on Pumice (Figure 3(a)). Also the EDAX of recycled pumice@$HClO_4$ (Figure 3(b)) did not show any noteworthy composition of elements.

The XRD pattern of the catalyst was exhibited the broad characteristic peak between diffraction angle $2\theta = 15\text{-}30$ which demonstrated the amorphous nature of the Pumice supported perchloric acid (Figure 4(a)). Also the XRD of recycled pumice@$HClO_4$ (Figure 4(b)) did not show any significant change.

The SEM image showed that, pure as well as recycled pumice supported perchloric acid has no particular size and morphology (Figure 5(a,b)).

To investigate the thermal stability of the newly prepared pumice supported perchloric acid and pumice, the thermogravimetric analysis (TGA) was performed in the temperature range from 30 to 650 °C as shown in Figure 6(a,b). The literature survey revealed that, the –OH groups

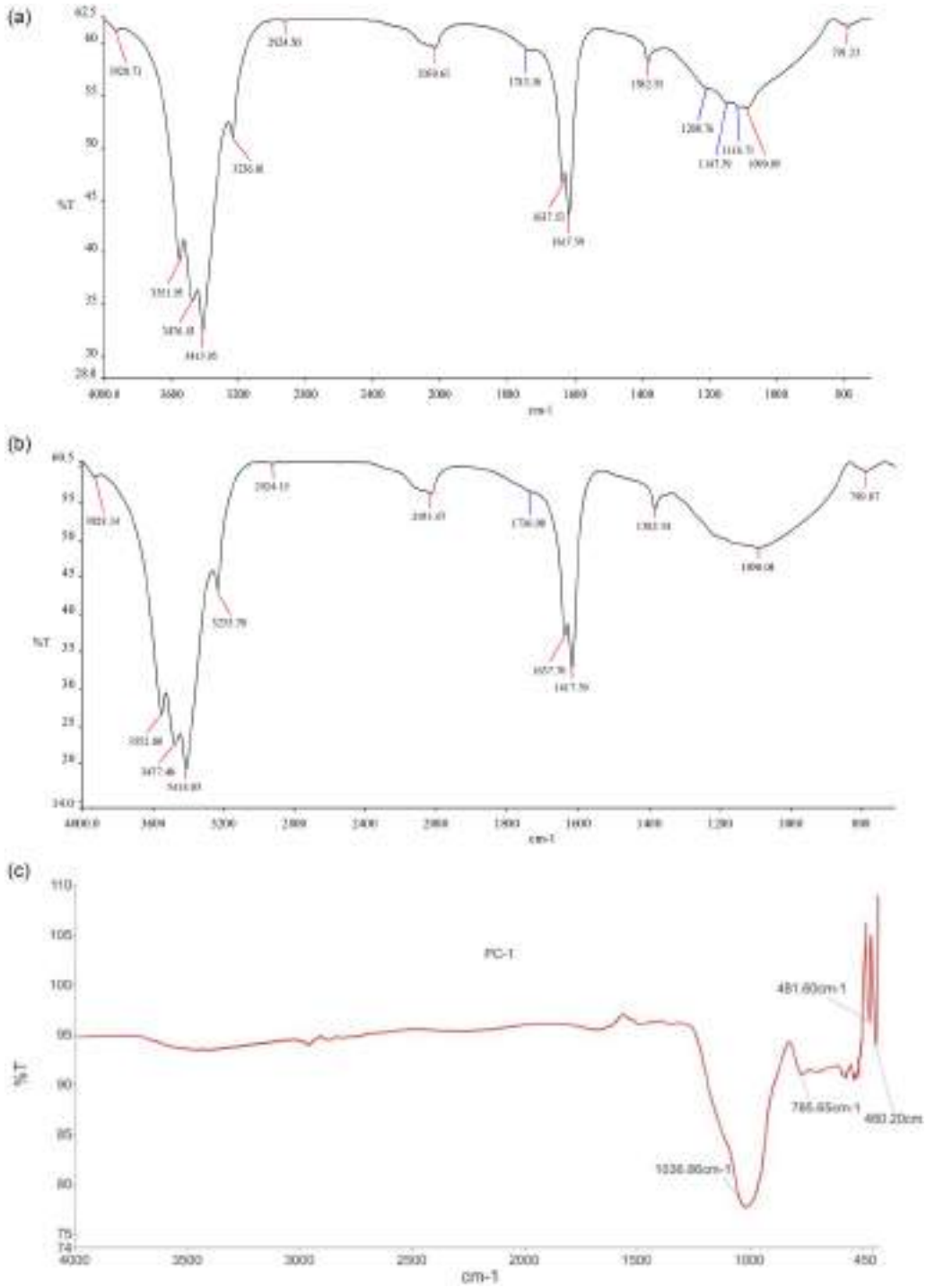


Figure 2. (a) FTIR of pumice supported perchloric acid (Pumice@$HClO_4$). (b) FTIR of recycled pumice supported perchloric acid (Pumice@$HClO_4$). (c) FTIR of pure pumice.

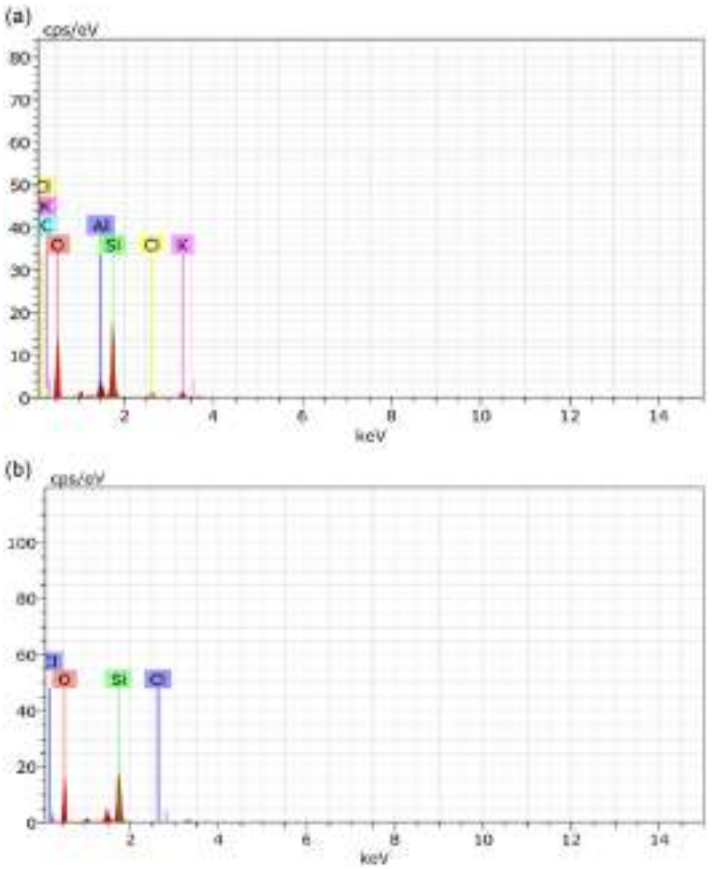


Figure 3. (a) EDAX of pumice supported perchloric acid (Pumice@$HClO_4$). (b) EDAX of recycled pumice supported perchloric acid (Pumice@$HClO_4$).

present in the catalytic material leave the structure by dehydration reaction at high temperature. The TGA of pumice supported perchloric acid (Figure 6(a)) and pumice (Figure 6(b)) showed that, 2.1% weight lost below 140 °C due to the removal of –OH groups in the form of water molecule present in the catalyst.

Study of acidic nature of pumice Supported perchloric Acid

The acidic nature of the catalyst was determined potentiometrically by following the standard method.[4] Initially the 0.1 g of pumice supported perchloric acid catalyst was taken in a titration flask containing 10 ml distilled water and the resultant mixture was titrated against the 0.1 N NaOH solution. The reading data of titration was used for plotting the graph of ΔE/ΔV against the volume of 0.1 N NaOH. From the graph, the acidic nature of catalyst was found to be 0.9 mmol/g at the equivalence point (Figure 7).

Optimization of the Reaction condition

The multi-component condensation reaction of 4-methyl benzaldehyde, dimedone and malononitrile was selected as pilot reaction (Scheme 3) to choose the optimize conditions for the synthesis of tetrahydrobenzo[*b*]pyran. Initially, the reaction was carried out under varying conditions such

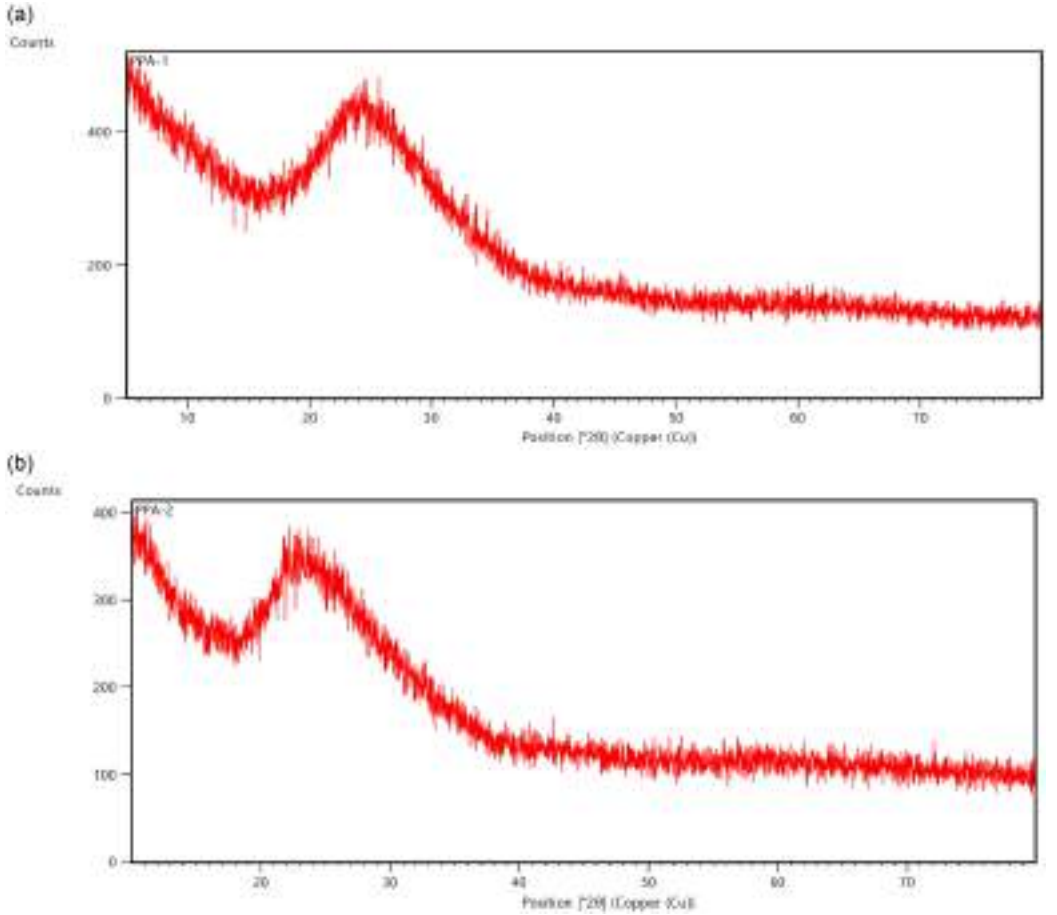


Figure 4. (a) XRD of pumice supported perchloric acid (Pumice@$HClO_4$). (b) XRD of recycled pumice supported perchloric acid (Pumice@$HClO_4$).

as the amount of catalyst, time, temperature and solvent medium (Table 1). The good result was obtained for pilot reaction with 100 mg of pumice supported perchloric acid catalyst (Table 2) in the presence of ethanol under reflux condition.

After the investigation of the exact optimized condition, it was employed for the synthesis of different tetrahydrobenzo[*b*]pyran derivatives by one-pot three component condensation of diverse aromatic aldehydes with malononitrile and dimedone. The best result was obtained for aldehydes containing electron donating as well as electron withdrawing groups in high yields and short period of time without appearing side product (Table 3).

Spectral data selected compounds

4a: 2-amino-5,6,7,8-tetrahydro-7,7-dimethyl-5-oxo-4-phenyl-4H-chromene-3-carbonitrile

White color; m.p. 222–224 °C; FTIR (cm^{-1}): 3396.57 (N–H), 2198.93 (CN), 1680.23 (C = O), 1660.44 (C = C), 1603.25 (C = C), 1451.14 (C = C), 1369.68 (C–O), 1213.49 (C–N); ^{1}H NMR ($CDCl_3$, 500 MHz) δ: 1.04 (s, 3H, $-CH_3$), 1.11 (s, 3H, $-CH_3$), 2.18–2.25 (m, 2H, $-CH_2-$), 2.45 (s, 2H, $-CH_2-$), 4.40 (s, 1H, –CH–), 4.57 (s, 2H, $-NH_2$), 7.19–7.30 (m, 5H, Ar–H) ; MS (ESI): m/z = 295.1469 [M + H].

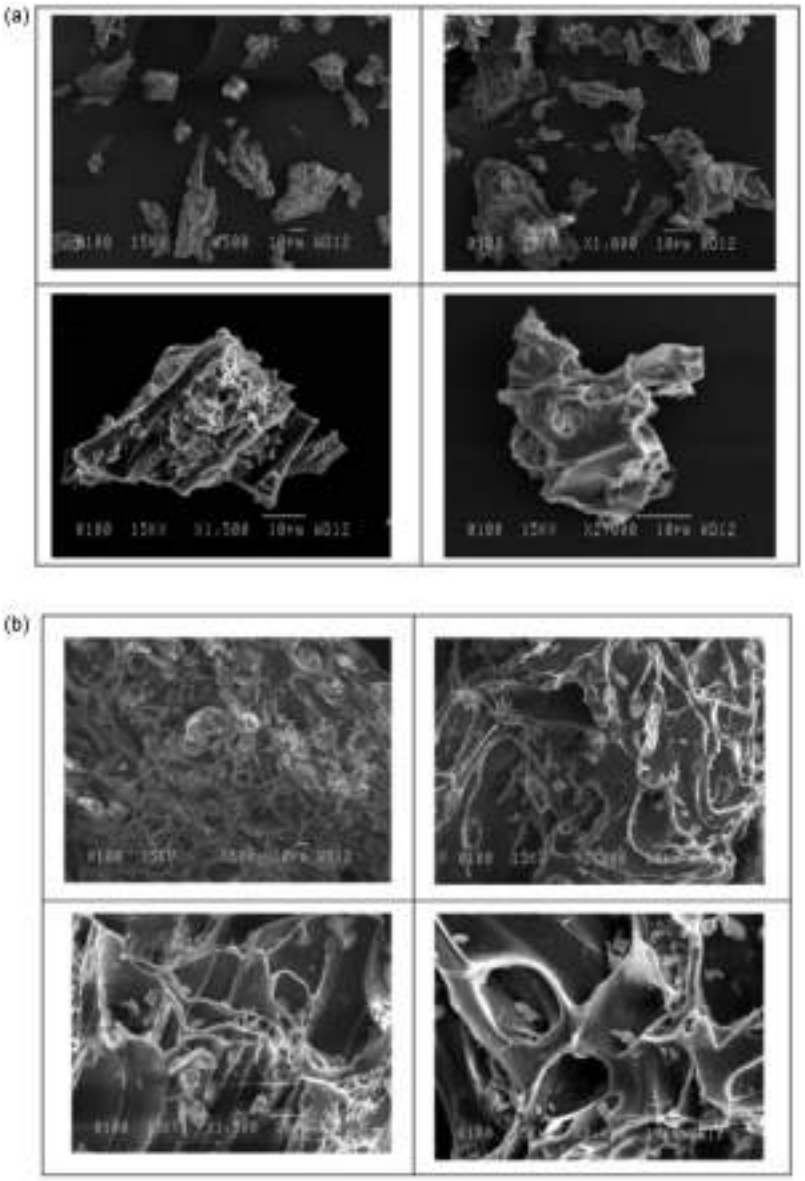


Figure 5. (a) SEM of pumice supported perchloric acid (Pumice@$HClO_4$). (b) SEM of recycled pumice supported perchloric acid (Pumice@$HClO_4$).

4b: 2-amino-5,6,7,8-tetrahydro-7,7-dimethyl-5-oxo-4-p-tolyl-4H-chromene-3-carbonitrile

White color; m.p. 214–216 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ: 1.04 (s, 3H, $-CH_3$), 1.11 (s, 3H, $-CH_3$), 2.17 (m, 2H, $-CH_2-$), 2.21 (s, 2H, $-CH_3$), 2.44 (s, 2H, $-CH_2-$), 4.36 (s, 1H, –CH–), 4.51 (s, 2H, $-NH_2$), 7.08 (m, 4H, Ar–H).

4c: 2-amino-4-(4-ethylphenyl)-5,6,7,8-tetrahydro-7,7-dimethyl-5-oxo-4H-chromene-3-carbonitrile

White color; m.p. 222–224 °C; FTIR (cm^{-1}): 3410.74 (N–H), 2188.62 (CN), 1682.53 (C = O), 1652.20 (C = C), 1618.21 (C = C), 1509.02 (C = C), 1369.47 (C–O), 1214.05 (C–N); ^{1}H NMR ($CDCl_3$, 500 MHz) δ: 0.99 (s, 3H, $-CH_3$), 1.10 (s, 3H, $-CH_3$), 1.26 (t, 3H, $-CH_3$), 2.19 (q, 2H,

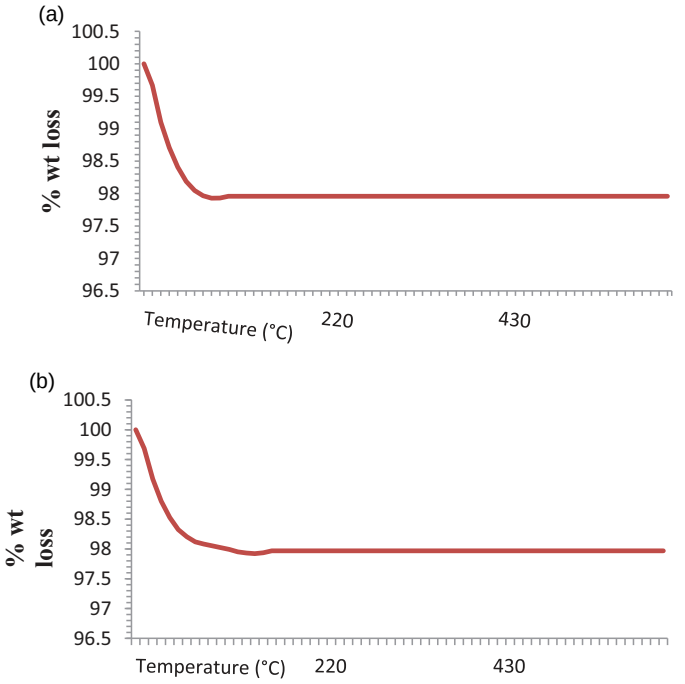


Figure 6. (a) TGA of pumice supported perchloric acid (Pumice@$HClO_4$). (b) TGA of pure pumice.

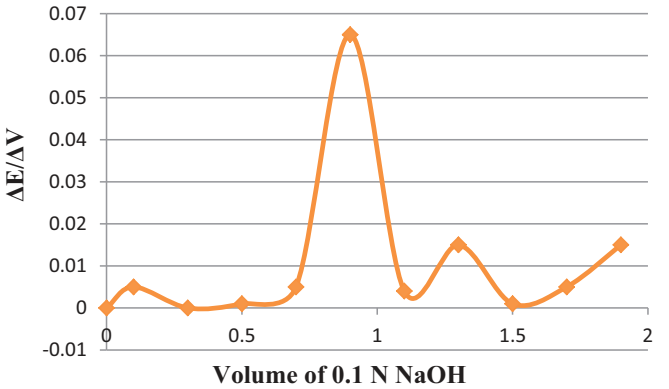
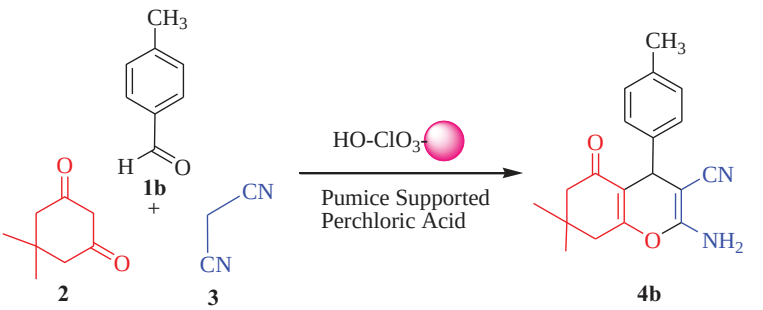


Figure 7. Study of acidic nature of pumice@$HClO_4$ by potentiometric titration.



Scheme 3. Pilot reaction for the synthesis of tetrahydrobenzo[*b*]pyran (**4b**).

Table 1. Optimization of reaction conditions for the synthesis of tetrahydrobenzo[*b*]pyran (**4b**).

Entry	Solvent system	Temperature	Time (min)	Yield (%)
1	Grinding	RT	60	NR
2	H_2O	RT	120	NR
3	EtOH	RT	120	NR
4	EtOH + H_2O (50%)	RT	120	NR
5	H_2O	Reflux	120	Trace
6	EtOH	Reflux	60	88
7	EtOH + H_2O (50%)	Reflux	60	40

Reaction condition: 4-methyl benzaldehyde (2 mmol), malononitrile (2 mmol), and dimedone (2 mmol), pumice supported perchloric acid catalyst (100 mg).

Table 2. Optimization of amount of catalyst for the synthesis of tetrahydrobenzo[*b*]pyran.

Entry	Amount of catalyst (mg)	Time (min)	Yield (%)
1	Absence of catalyst	60	NR
2	25	60	Trace
3	50	60	55
4	75	60	80
5	100	60	88
6	125	60	88

–CH_2–), 2.44 (m, 2H, –CH_2–), 2.59 (m, 2H, –CH_2–), 4.37 (s, 1H, –CH–), 4.56 (s, 2H, –NH_2), 7.09–7.14 (m, 4H, Ar–H) ; ^{13}C NMR ($CDCl_3$, 500 MHz) δ: 15.33, 27.76, 28.64, 28.87, 32.21, 35.12, 40.70, 50.70, 63.70, 114.18, 118.81, 127.41, 128.09, 140.48, 142.93, 157.47, 161.47, 195.97; MS (ESI): m/z = 323.1790 [M + H].

4d: 2-amino-5,6,7,8-tetrahydro-7,7-dimethyl-4-(4-nitrophenyl)-5-oxo-4H-chromene-3-carbonitrile

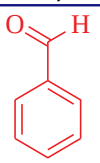
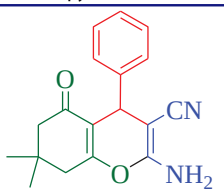
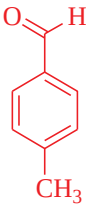
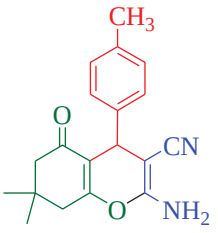
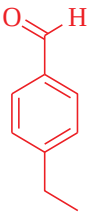
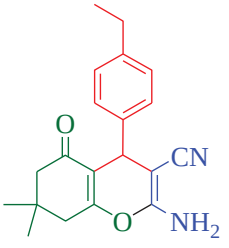
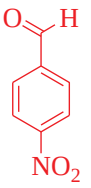
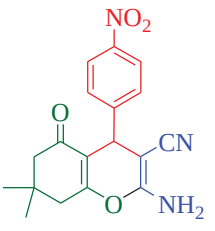
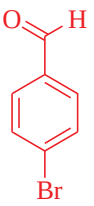
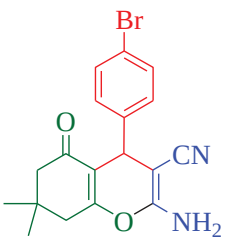
White color; m.p. 178–180 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ: 0.97 (s, 3H, –CH_3), 1.05 (s, 3H, –CH_3), 2.11–2.28 (m, 2H, –CH_2–), 2.54 (s, 2H, –CH_2–), 4.38 (s, 1H, –CH–), 7.17 (s, 2H, –NH_2), 7.45 (d, 2H, J = 8.7, Ar–H) , 8.17 (d, 2H, J = 8.7, Ar–H) ; ^{13}C NMR ($CDCl_3$, 500 MHz) δ: 26.83, 28.14, 31.69, 35.55, 49.75, 56.88, 111.63, 119.18, 123.53, 128.49, 146.15, 152.15, 158.47, 162.96, 195.54.

Recyclability and reusability of pumice supported perchloric acid

The recovery and reusability of the pumice supported perchloric acid catalyst make the protocol most valuable, unique and beneficial. After the completion of the reaction, the catalyst was separated from the reaction media at hot condition. It was washed with hot ethanol followed by chloroform and was dried at 80 °C temperature. The recovered catalyst was characterized by FTIR, EDAX, XRD and SEM as shown in Figures 2(b) to 5(b). The reusability of the catalyst was studied on the pilot reaction. The catalyst has been recycled and reused three times with 88, 87 and 84% of product yields, respectively.

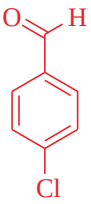
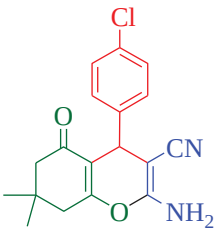
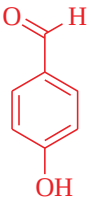
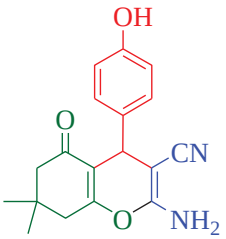
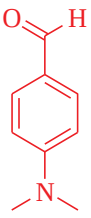
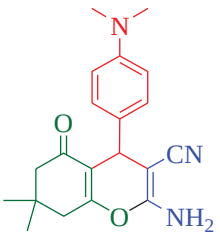
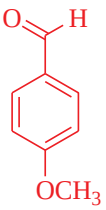
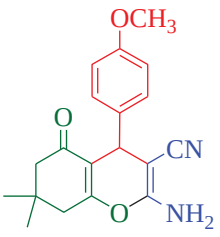
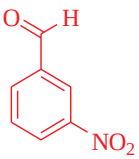
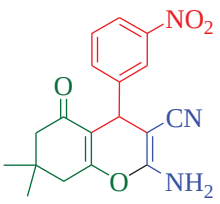
The comparison of the efficiency of pumice supported perchloric acid catalyst with the various reported protocols are mentioned in Table 4. From this investigation, it was found that the pumice supported perchloric acid catalyst showed a noteworthy activity for the synthesis tetrahydrobenzo[*b*]pyran derivatives. Also a current protocol has many advantages in comparison with

Table 3. Synthesis of tetrahydrobenzo[*b*]pyran derivatives (**4a–m**).

Entry	Aldehyde	Benzopyran derivative	Time (min.)	Yield (%)	M.P.(°C) Observed	M.P.(°C) Reported (ref.)
1		 **4a**	50	80	222–224	224[15]
2		 **4b**	60	88	214–216	213[15]
3		 **4c**	45	82	222–224	155–158[18]
4		 **4d**	50	84	178–180	179[15]
5		 **4e**	50	90	202–204	200–203[16]

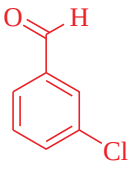
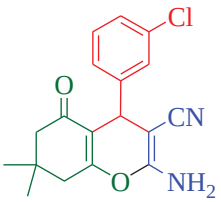
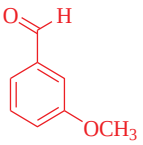
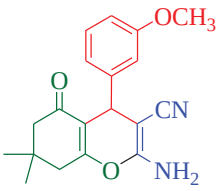
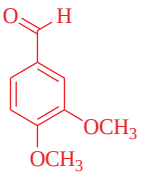
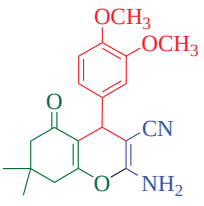
(*continued*)

Table 3. Continued.

Entry	Aldehyde	Benzopyran derivative	Time (min.)	Yield (%)	M.P.(°C) Observed	M.P.(°C) Reported (ref.)
6		 **4f**	45	90	198–200	206[15]
7		 **4g**	65	77	220–222	205[15]
8		 **4h**	60	82	188–190	198–200[15]
9		 **4i**	60	80	202–204	201[15]
10		 **4j**	60	76	212–214	210[15]

(*continued*)

Table 3. Continued.

Entry	Aldehyde	Benzopyran derivative	Time (min.)	Yield (%)	M.P.(°C) Observed	M.P.(°C) Reported (ref.)
11		 **4k**	40	82	202–204	226–228[16]
12		 **4l**	50	84	210–212	185–187[16]
13		 **4m**	65	78	164–166	132–141[18]

Reaction condition: Aldehyde (2 mmol), dimedone (2 mmol), and malanonitrile (2 mmol) were refluxed in 10 ml ethanol in the presence of pumice supported perchloric acid (100 mg)

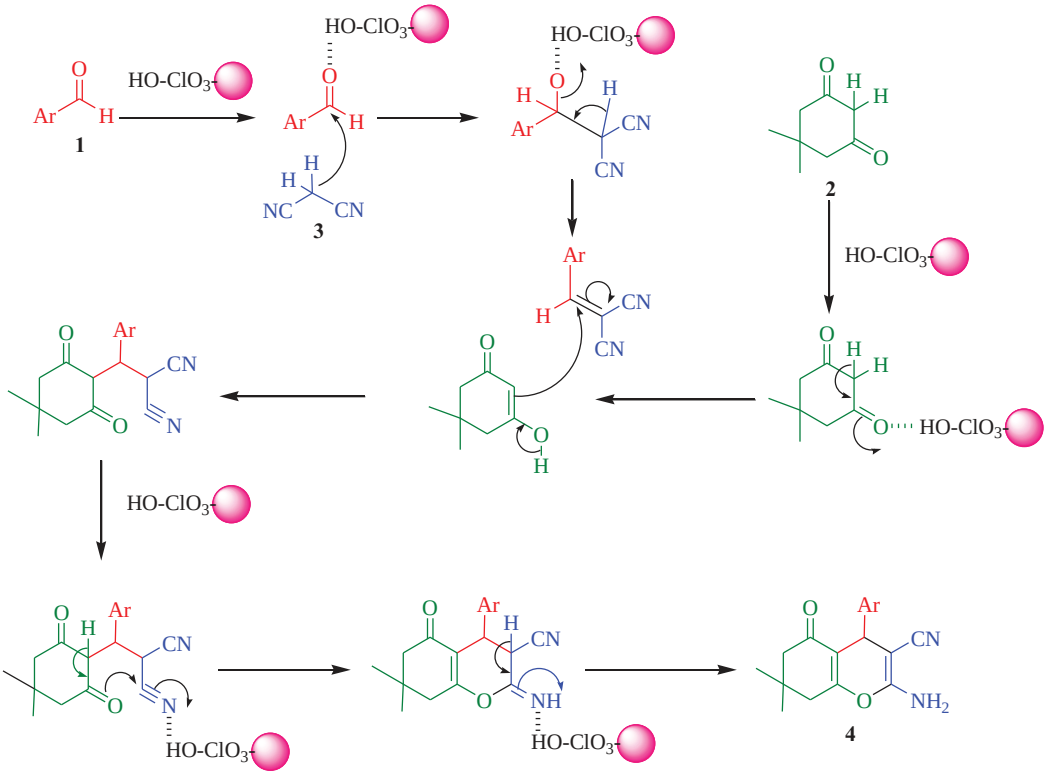
Table 4. Comparison of the efficiency of pumice@$HClO_4$ for the synthesis of tetrahydro-benzo[*b*]pyran derivative with other protocols.

Entry	Catalyst used	Reaction condition	Time (min)	Yield (%)	Ref. no.
1	CTMAB-bentonite	H_2O:EtOH (1:1) / RT	05–10	80–99	[20]
2	Nano-titania sulfuric acid	EtOH / US / 40 °C	10–30	85–97	[21]
3	MNPs–$PhSO_3H$	H_2O:EtOH (1:1) / 100 °C	10–60	65–95	[23]
4	Molecular sieve-supported Zinc	EtOH/reflux	240	85–98	[24]
5	SiO_2 nano-particles	EtOH/RT	25–30	86–98	[25]
6	Xanthum gum supported Fe_3O_4	EtOH/RT	05–20	84–96	[35]
7	Phosphotungstic acid supported on SiO_2@$NHPhNH_2$	SF/ 80 °C	25–30	85–94	[36]
8	Fe_3O_4@PEO-SO_3H	EtOH/RT	25–40	85–95	[37]
9	Magnetic aluminosilicate nanoclay	SF/ 40 °C	20–30	93–96	[38]
10	Fe_3O_4@SiO_2–NH_2	SF/ 60 °C	80–120	78–93	[39]
11	Pumice @$HClO_4$	EtOH/reflux	45–65	78–90	Present work

reported methods such as cheap and readily available volcanic material, smooth reaction condition and purification of targeted molecule without column chromatography.

Plausible mechanism

The plausible mechanism for the synthesis of tetrahydrobenzo[*b*]pyran derivatives using pumice supported perchloric acid were shown in Scheme 4.



Scheme 4. Plausible mechanism of Pumice@$HClO_4$ catalyzed synthesis of benzopyran.

Conclusion

In conclusion, we have investigated a novel, highly efficient protocol for the synthesis of tetrahydrobenzo[*b*]pyran in the presence of heterogeneous catalyst pumice supported perchloric acid via multi-component condensation of aromatic aldehydes, dimedone and malononitrile under reflux condition. The catalyst was characterized by IR, XRD, EDS, SEM, and TGA techniques which showed the formation novel pumice supported perchloric acid. The present protocol proved to have numerous advantages like one-pot reaction, quantitative yield of the targeted molecule, short reaction time, mild conditions inexpensive catalyst, recyclability and reusability of the catalyst, smooth experimental condition, simple work up procedure and purification of targeted molecule without column chromatography.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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TEA POWDER WASTE: AS A GREEN CATALYST FOR THE SYNTHESIS OF 1-AMIDOALKYL 2-NAPHTHOLS

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Abstract: Tea powder waste is used an efficient natural green catalyst for the one pot three component synthesis of amidoalkyl naphthol using aromatic aldehyde, 2-naphthol and acetamide at reflux condition. The catalyst could be recovered and reused at least five times without appreciable decreasing the catalytic activity. The nontoxic solvent, excellent yield, short reaction time, green synthesis and natural eco-friendly catalyst are the advantages of present protocol.

Keywords: Amidoalkyl naphthol, green synthesis, natural catalyst.

Introduction

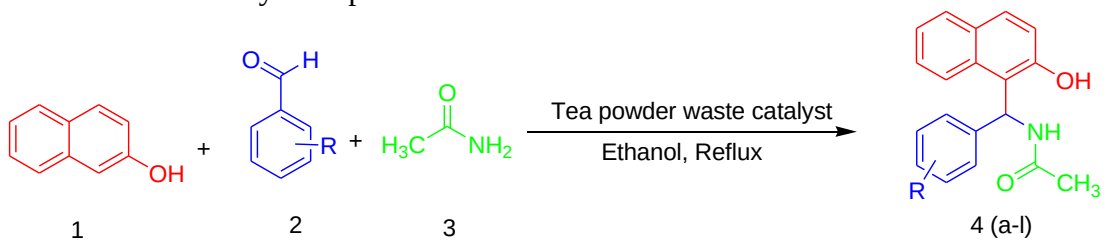
In organic synthesis multi-component reaction are used due to its selectivity and high atom economy. In Ritter type reaction the formation of C-N gives N-alkyl amide compounds are of biologically active ingredients[i]. This type of reaction is associated with condensation of aryl aldehydes, beta naphthol and acetamide in presence of different catalysts like silica sulphuric acid[ii], $Ce(SO_4)_2$[iii], $HClO_4$-SiO_2[iv], $FeCl_3$-SiO_2[v], montmorillonite K10[vi], Ag nanoparticles[vii], bismuth (III) nitrate pentahydrate[viii], nano sulphated zirconia[ix], nano-graphene oxide[x], magnetic nano-Fe_3O_4@SiO_2@Hexamethylene tetramine supported ionic liquid[xi], tetrachlorosilane[xii], $K_5CoW_{12}O_{40}\cdot 3H_2O$[xiii] and cation-exchanged resins[xiv]. The reported methods have some limitations such as use of toxic reagents, tedious work up, hazardous solvent, high reaction temperature and formation of by-products. Therefore, it become a challenge to develop new cost-effective method for synthesis of 1-amidoalkyl-2-naphthols.

According to Research Department of India the consumption of tea powder in India was approximately 1.1 billion kilograms during the financial year 2021. So, the large amount of waste tea powder was introduced in the environment. The tea powder consists of carboxylate, aromatic, phenolic, hydroxyl groups, oxyl groups, carbon and calcium[xv]. The tea waste was used as adsorbent for the removal of dyes and heavy metals[xv]. The attempt was

made in which tea powder waste was used as a heterogeneous catalyst in multi component reactions. In continuation of our research work[xvi-xviii], here we report new cost effective naturally occurring catalyst for the synthesis of 1-amidoalkyl-2-naphthols.

Results and discussion

The reaction was carried out by mixing benzaldehyde (1 mmol), 2-naphthol (1 mmol) and acetamide (1.2 mmol) in presence of 30 mg of tea waste catalyst. The mixture was refluxed with different solvents. The model reaction between benzaldehyde, 2-naphthol and acetamide in presence of tea waste catalyst was used to study the effect of solvent on synthesis of 1-amidoalkyl 2-naphthol derivatives (Table 1). The ethanol was the suitable solvent for the synthesis of 1-amidoalkyl 2-naphthol derivatives.



Scheme 1: Synthesis of 1-amidoalkyl 2-naphthols.

Table: 1 Effect of solvent on synthesis of 1-amidoalkyl 2-naphthols

Sr. No.	Solvent	Time (min)	Yield (%)
1	Solvent free	14	32
2	Water	13	61
3	Methanol	10	64
4	Ethanol	8	92
5	Chloroform	11	51
6	Dimethyl sulfoxide	10	49

The model reaction between benzaldehyde, 2-naphthol and acetamide was refluxed in presence of ethanol and tea waste catalyst to study the effect of amount of catalyst on synthesis of 1-amidoalkyl 2-naphthol derivatives (Table 2). The amount of tea waste catalyst was varied from 10-70 mg, the result shows that the 30 mg of catalyst was sufficient to carry out the reaction.

Table: 2 Effect of amount of catalyst on synthesis of 1-amidoalkyl 2-naphthols

Sr. No.	Amount of catalyst (mg)	Time (min)	Yields (%)
1	10	13	67
2	20	10	78
3	30	8	92
4	40	8	92
5	50	8	92
6	60	8	92
7	70	8	92

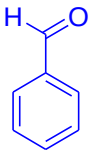
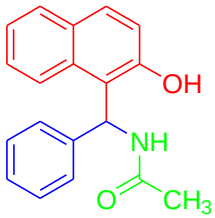
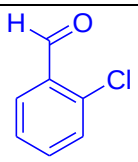
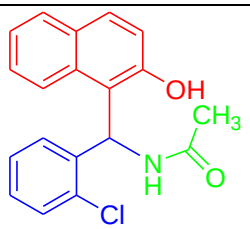
In order to study the effect of time on the synthesis of 1-amidoalkyl 2-naphthols, the model reaction between benzaldehyde, 2-naphthol and acetamide in presence of 30 mg of tea waste catalyst was carried out in the range 2-14 minutes (Table 3). The 8 minutes was the optimum time for the synthesis of 1-amidoalkyl 2-naphthol derivatives.

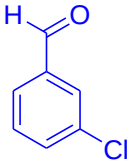
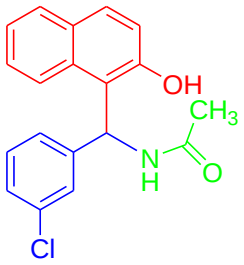
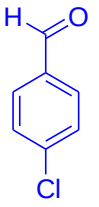
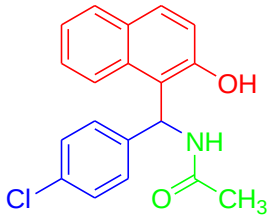
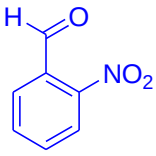
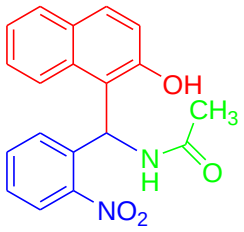
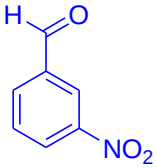
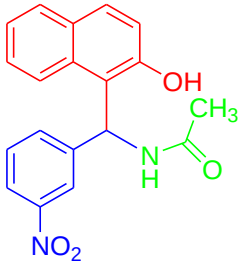
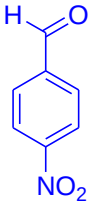
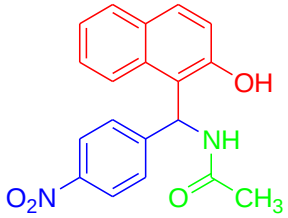
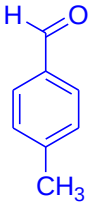
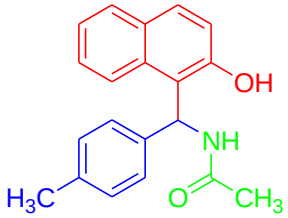
Table: 3 Effect of time on synthesis of 1-amidoalkyl 2-naphthols

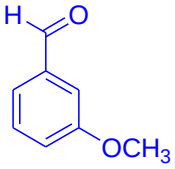
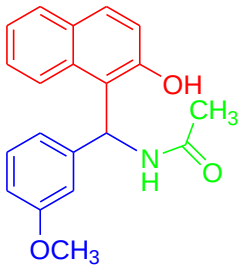
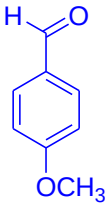
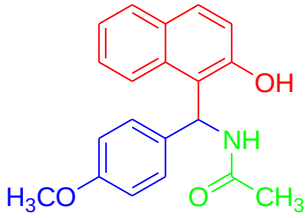
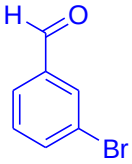
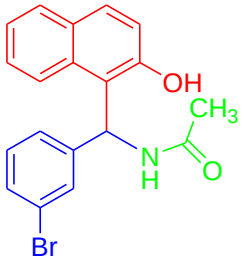
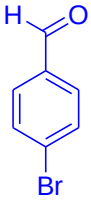
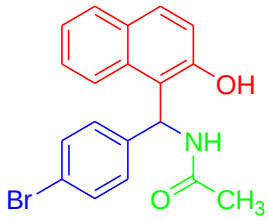
Sr. No.	Time (min)	Yields (%)
1	2	46
2	4	69
3	6	73
4	8	92
5	10	92
6	12	92
7	14	92

In order to check the applicability of the tea waste catalyst, the series of the 1-amidoalkyl 2-naphthol derivatives was synthesized (Table 4). A variety of aromatic aldehydes with electron donating and electron withdrawing groups were converted to 1 amidoalkyl 2-naphthols in excellent yields (88-95 %) with short reaction time (6-18 min). In the present method the 1-amidoalkyl 2-naphthols were the sole products and no by-product was observed.

Table: 4 Synthesis of 1-amidoalkyl 2-naphthol derivatives

Sr. No.	Aldehyde	Product	Time (min)	Yields (%)	M. P (°C)
1		 **4a**	8	92	237-239
2		 **4b**	12	94	191-194

3		 **4c**	14	91	236-238
4		 **4d**	6	90	224-226
5		 **4e**	13	91	215-217
6		 **4f**	7	94	239-241
7		 **4g**	6	95	234-236
8		 **4h**	7	91	218-220

9		 **4i**	16	89	202-204
10		 **4j**	13	90	180-182
11		 **4k**	16	88	227-229
12		 **4l**	18	90	226-228

Experimental

The commercially available chemicals were used without purification. The open capillary method was used to note the melting points. The 1-amidoalkyl 2-naphthol derivatives were matched with known compounds using their spectral data. The Perkin-Elmer FT-IR spectrometer was used to record the IR spectra. The Bruker Avance II (300 MHz) was used to record ^{1}H NMR spectra. The Varian-Saturn GC/MS instrument was used to record mass spectrum of 1-amidoalkyl 2-naphthol derivatives.

Preparation of catalyst

The tea waste was collected, washed with doubled distilled water and dried at room temperature. The waste material was heated in heating oven at 110^{o}C for 3 hrs, for the removal of adsorbed substance and water molecules. The tea waste was then grinded by using mortar and pestle. The tea waste was used again as catalyst in organic reactions.

General procedure for the synthesis of 1-amidoalkyl 2-naphthols

A mixture of aromatic aldehydes (1 mmol), 2-naphthol (1 mmol), acetamide (1 mmol) and tea waste catalyst (0.030 g) were refluxed in presence of ethyl alcohol in oil bath. The

progress of the reaction was monitored by thin layer chromatoghy technique. The solid products obtained were filtered, dried at room temperature.

Compound 4a: ^{1}H-NMR (300 MHz, DMSO-d_6): δ (ppm) 1.95 (s, 3H), 7.11-7.32 (m, 9H),7.75-7.84 (m, 3H), 8.36 (d, *J = 9 Hz*, 1H), 9.92 (s, 1H), ^{13}C NMR (75 MHz, DMSO-d_6): δ (ppm) 23.2, 41.1, 118.4, 120.4, 122.2, 123.7, 124.8, 125.5, 127.4, 128.3, 128.1, 128.2, 128.4, 134.1, 144.2, 152.4, 169.4, MS: m/z 231M^+.

Compound 4f: ^{1}H-NMR (300 MHz, DMSO-d_6): δ (ppm) 2.04 (s, 3H), 7.12-7.45 (m, 6H), 7.74-8.01 (m, 5H), 8.52 (d, *J = 8.1 Hz*, 1H), 10.10 (s, 1H), ^{13}C NMR (75 MHz, DMSO-d_6): 25.51, 66.11, 108.60, 118.12, 120.24, 122.30, 123.92, 125.53, 127.41, 128.10, 129.18, 129.44, 130.81, 132.06, 134.80, 147.67, 148.01, 152.45, 191.65, MS: m/z 276 M^+.

Conclusion

We report here a green protocol for the synthesis of 1-amidoalkyl 2-naphthol derivatives by the condensation of aromatic aldehydes, 2-naphthol and acetamide in presence of naturally available tea waste as a catalyst. The non-toxic solvent, easy work up, high yield and cost effective are the advantages of present method.

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PUMICE@SO_3H CATALYZED ULTRASOUND MEDIATED SYNTHESIS OF POLYHYDROQUINOLINE DERIVATIVES.

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Abstract:
A sustainable and convenient protocol is developed for the synthesis of polyhydroquinoline derivatives under ultrasound irradiation at 45°C in the presence of pumice anchored sulfonic acid (Pumice@SO_3H) as a recoverable catalyst. These polyhydroquinolines were synthesized from aldehydes, dimedone, ethylacetoacetate and ammonium acetate by Hantzsch reaction. The attractive features of the present protocol are green approach, good yield, recovery of catalyst, easy work-up procedure and simple purification of product whereas the catalyst offers simple preparation, high catalytic activity, inexpensive, easy to use, recyclability and stability.

Keywords:
Pumice@SO_3H, polyhydroquinolines, ultrasound irradiation, dimedone, etc.

Introduction:

Pumice stone obtained due to volcanic eruptions has many advantages such as abundance, availability, large surface area, low cost, non-homogeneous nature, and excellent stability. Also due to the remarkable properties such as high porosity and high adsorption capacities have gained much interest in the field of catalysis. In recent years, the volcanic pumice converted into variety of supported active catalytic materials such as pumice@SO_3H[i, ii], Pd–Ag catalysts supported on pumice[iii], Pumice-modified cellulose fiber[iv], Volcanic based hybrid nanocomposite[v], Pumice supported Pd catalyst[vi], Immobilization of TiO_2 on pumice stone[vii], iron-coated pumice[viii, ix], pumice-supported Pd–Cu catalysts[x], etc.

Multi-component reactions (MCRs) are a constructive approach to synthesize heterocyclic compounds with diverse structures. In MCRs, more than two components reacts together in single step to produce a targeted heterocyclic system without isolation of any intermediate. Due to this, requires short time, reduce energy requirement, reduce quantity of precursors, and are useful to increase atom economy. The Hantzsch reaction is one of the most important examples of multicomponent reaction which is used for synthesis of polyhydroquinoline derivatives[xi, xii]. The polyhydroquinoline derivatives is of great attention due to their various activities such as anti-cancer, anti-diabetic, anti-hypertensive, anti-inflammatory, anti-microbial, anti-

tubercular, anti-tumor, bronchodilator, calcium channel blockers, cardiovascular agents, geroprotective, hepatoprotective, neurotropic, and vasodilator[xiii-xxii] etc. These versatile activities have encouraged researchers to design sustainable and convenient catalytic materials for the synthesis of heterocyclic compounds containing polyhydroquinoline moiety. Some illustrations of drugs with 1,4-dihydropyridine framework are outlined in **Fig. 1**.

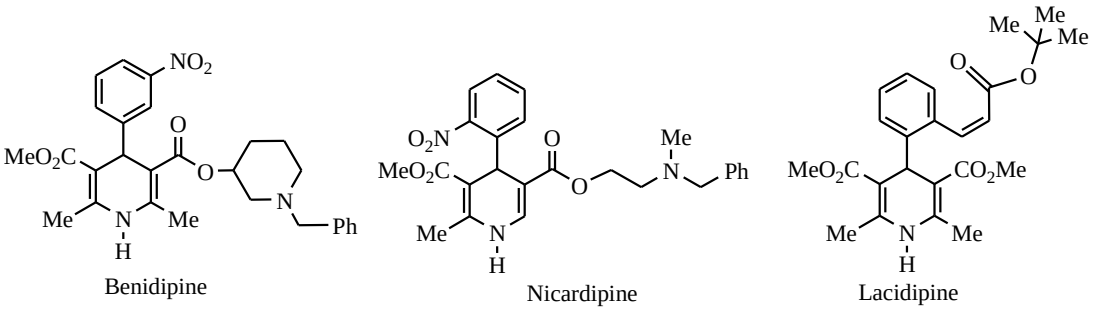


Fig.1. some drugs containing 1,4-dihydropyridine framework

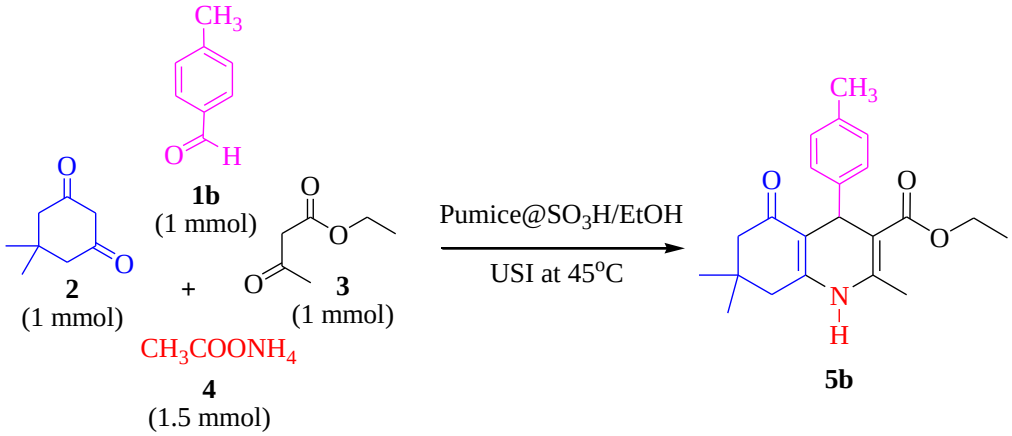
Recently, numerous protocols have been developed for the synthesis of polyhydroquinolines from aromatic aldehyde, dimedone, ethylacetoacetate and ammonium acetate such as nano-materials[xxiii], metal oxide supported materials[xxiv], magnetic materials[xxv], ionic liquids[xxvi], amino acids[xxvii], solar thermal energy[xxviii], Zeolite[xxix], microwave[xxx], and ultrasound[xxxi] etc. Also various bronsted acidic catalyst are used such as Fe_3O_4/SiO_2-OSO_3H[xxxii], silica sulfuric acid[xxxiii], nicotinic acid[xxxiv], Acetic acid[xxxv], Aluminized polyborate[xxxvi], PPA-SiO_2[xxxvii], SBA-15/SO_3H[xxxviii], SBA-15@Glycine[xxxix], PMO-ICS-PrSO_3H[xl], BINOL-phosphoric acid[xli], Carbon-based Solid acid (CBSA)[xlii], COF-SO_3H [xliii], Fe_3O_4@FSM-16-SO_3H [xliv], *p*-TSA[xlv], [MSAIM]HSO_4[xlvi], [Pyridine-SO_3H]Cl[xlvii], Caffeine-H_3PO_4[xlviii], ascorbic acid[xlix], Fe_3O_4@PEO-SO_3H[l], etc.

The ultrasound (US) assisted synthesis is well developed method used for the synthesis of variety of heterocyclic compounds. It proceeds through the development and adiabatic collapse of the transient cavitations bubble. It is used as a green approach that helping to reduce high energy requirements. The US approach provides smooth and cleaner reactions procedure with increasing yields in presence of various catalytic processes [li-lvii].

In continuation of our environmentally benign work [lviii-lxii] and on the application of pumice@SO_3H catalysts[i, ii], here we report a convenient green approach for one-pot synthesis of polyhydroquinolines in the presence pumice anchored sulfonic acid as a bronsted acidic catalyst with good catalytic activity and recyclability.

Results and Discussion:

In order to choose the better reaction condition a model reaction (**Scheme 1**) of *p*-methyl benzaldehyde, dimedone, ethyl acetoacetate and ammonium acetate was carried out in presence of catalyst pumice@SO_3H with and without catalyst and solvent. The reaction did not proceed to any extent in absence of catalyst with and without solvent during stirring at room temperature (**Table 1, Entry 1-3**). Also the negative result was obtained with pumice@SO_3H catalyst at room temperature in presence water and ethanol as well as without solvent under ultrasound irradiation (**Table 1, Entry 4-6**). The reaction proceeds smoothly with catalyst pumice@SO_3H in presence of ethanol as solvent at 45^{o}C under ultrasound irradiation with excellent yield (**Table 1, Entry 7**).



Scheme 1. Model reaction for synthesis of Polyhydroquinoline (**5b**) derivative

Table 1: Optimization of reaction condition for the synthesis of polyhydroquinoline (**5b**)

Entry	Catalyst / Solvent	Reaction Condition	Time in hrs.	Yield [b] in %
1	90 mg pumice@SO_3H / Solvent free	Grinding	0.5	No reaction (NR)
2	90 mg pumice@SO_3H / H_2O	Stirring at RT	3	NR
3	90 mg pumice@SO_3H / EtOH	Stirring at RT	3	NR
4	90 mg pumice@SO_3H / H_2O	USI at RT	3	NR
5	90 mg pumice@SO_3H / H_2O	USI at 45°C	3	NR
6	90 mg pumice@SO_3H / EtOH	USI at RT	3	Trace
7	90 mg pumice@SO_3H / EtOH	USI at 45°C	1.5	80

[a]Reaction condition: **1b** (0.120gm, 1mmol), **2** (0.140gm, 1mmol), **3** (0.130gm, 1mmol), **4** (0.107gm, 1.5mmol), pumice@SO_3H (90 mg), [b]Isolated Yield

Table 2: Optimization of quantity of catalyst for the synthesis of polyhydroquinoline (**4b**)

Entry	Pumice@SO_3H Catalyst (mg)	Time (hrs)	Yield[b] (%)
1	40	2	25
2	60	2	45
3	80	2	70
4	90	1.5	80
5	90	1.5	80

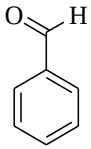
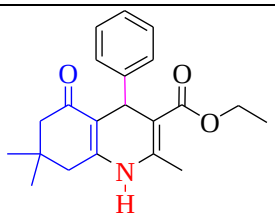
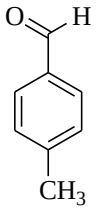
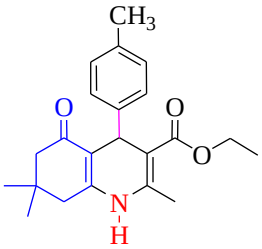
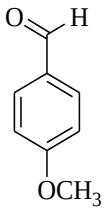
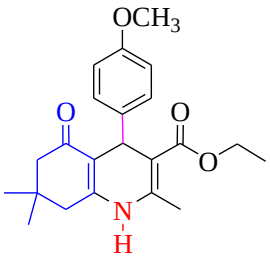
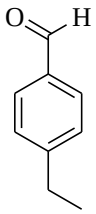
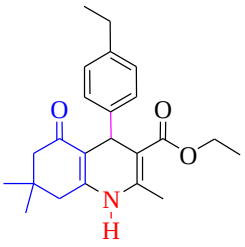
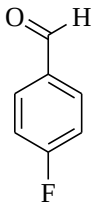
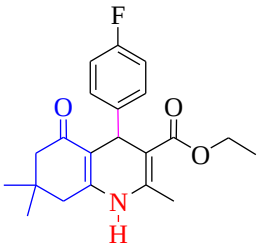
[a]Reaction condition: **1b** (0.120gm, 1mmol), **2** (0.140gm, 1mmol), **3** (0.130gm, 1mmol), **4** (0.107gm, 1.5mmol), USI at 45°C, [b] Isolated Yield

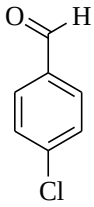
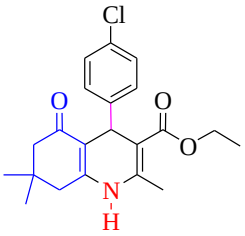
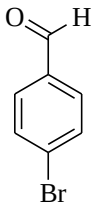
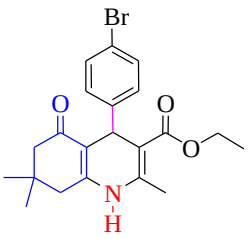
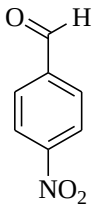
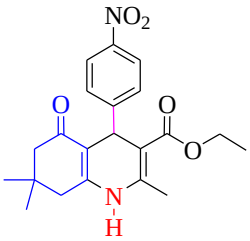
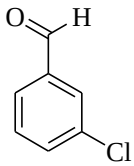
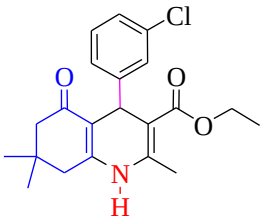
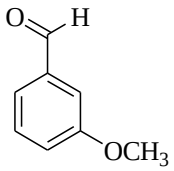
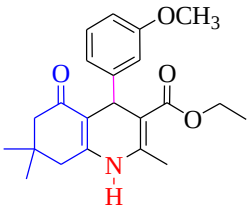
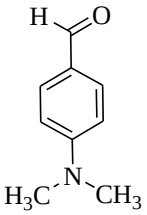
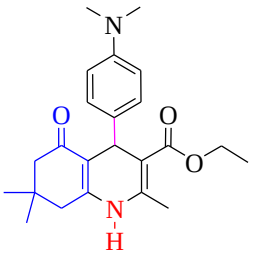
The model reaction was then studied for different amount of catalyst to optimize the amount of catalyst required (**Table 2**). It was found that further increase in the amount of catalyst, there was no significant improvement in the yield of the product.

This outcome enhanced our attention to study the scope, generality and relevance of this protocol for the synthesis of Polyhydroquinoline (**5a-k**) derivatives. The series of Polyhydroquinoline were synthesized using diverse aromatic aldehydes under above optimized

conditions with good yield (74-86%) as mentioned in **Table 3**. The protocol worked very well with aldehydes containing electron deficient and electron rich substituent.

Table 3: Data of synthesized Polyhydroquinoline (**5a-k**) derivatives

Entry	Aldehyde	Product	Time (hrs)	Yield (%)	M.P. (°C)	
					Observed	Reported
1		 **5a**	1.5	85	214-216	217–219[35]
2		 **5b**	1.5	80	252-256	260–262[35]
3		 **5c**	2.0	78	257-260	258–260[35]
4		 **5d**	1.5	80	220-224	--
5		 **5e**	1.5	79	182-184	185–186[35]

6		 **5f**	2.0	82	240-242	245–246[35]
7		 **5g**	2.0	78	250-252	254–256[35]
8		 **5h**	2.0	75	238-240	240–242[35]
9		 **5i**	1.5	80	204-206	205–206[35]
10		 **5j**	1.5	76	192-194	198–200[35]
11		 **5k**	1.5	80	236-238	228–231[29]

[a]Reaction condition: **1a-k** (0.120gm, 1mmol), **2** (0.140gm, 1mmol), **3** (0.130gm, 1mmol), **4** (0.107gm, 1.5mmol), USI at 45°C

After the completion of the reaction, the catalyst used has been recovered by heating the reaction mixture up to the boiling. The resultant hot solution was filtered at hot condition to separate the catalyst. The recovered catalyst was washed with dichloromethane 2-3 times and dried to reuse. The recycled catalyst was reused under the optimal conditions in three cycles of the similar transformation (**Fig. 2**). The formation of Pumice@SO_3H catalyst was proved by spectral studies such as FT-IR, XRD, SEM, TEM and EDS etc. which are reported in our previous work[i]. Here the evidences of recyclability study are provided. The FT-IR, XRD and EDS spectra of the recycled pumice@SO_3H catalyst after third cycle did not show any significant change in catalytic activity.

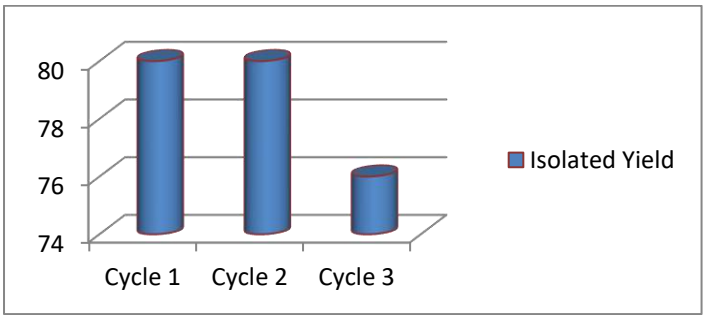


Fig. 2. Reusability of the pumice@SO_3H for the synthesis of Polyhydroquinoline (**4b**)

In the FT-IR spectrum of the recycled pumice@SO_3H (**Fig. 3**), the broad band at 3414.35 cm^{-1} is appeared due to O-H group in sulfonic acid. Also the important bands at 1637.32 cm^{-1} and 1111.05 cm^{-1} are appeared due to the S=O and Si–O–Si respectively. These significant bands indicate that, the recovery of -SO_3H group in the recycled catalyst.

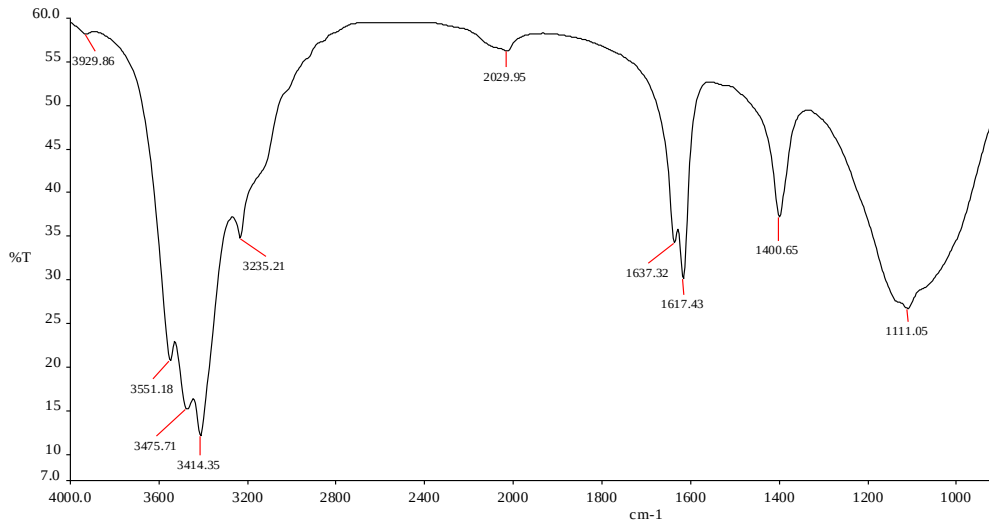


Fig. 3. IR Spectrum of Pumice@SO_3H catalyst

The nature of XRD (**Fig. 4**) and EDS (**Fig. 5**) of recycled catalyst was precisely matched with the reported catalyst. It showed that, the recycled catalyst did not show any variation in composition.

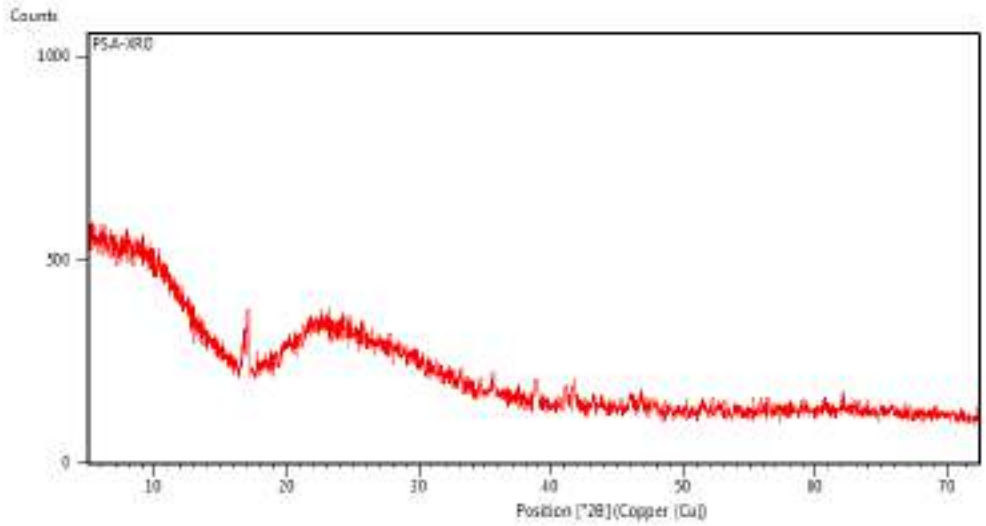


Fig.4. XRD of Pumice@SO_3H catalyst

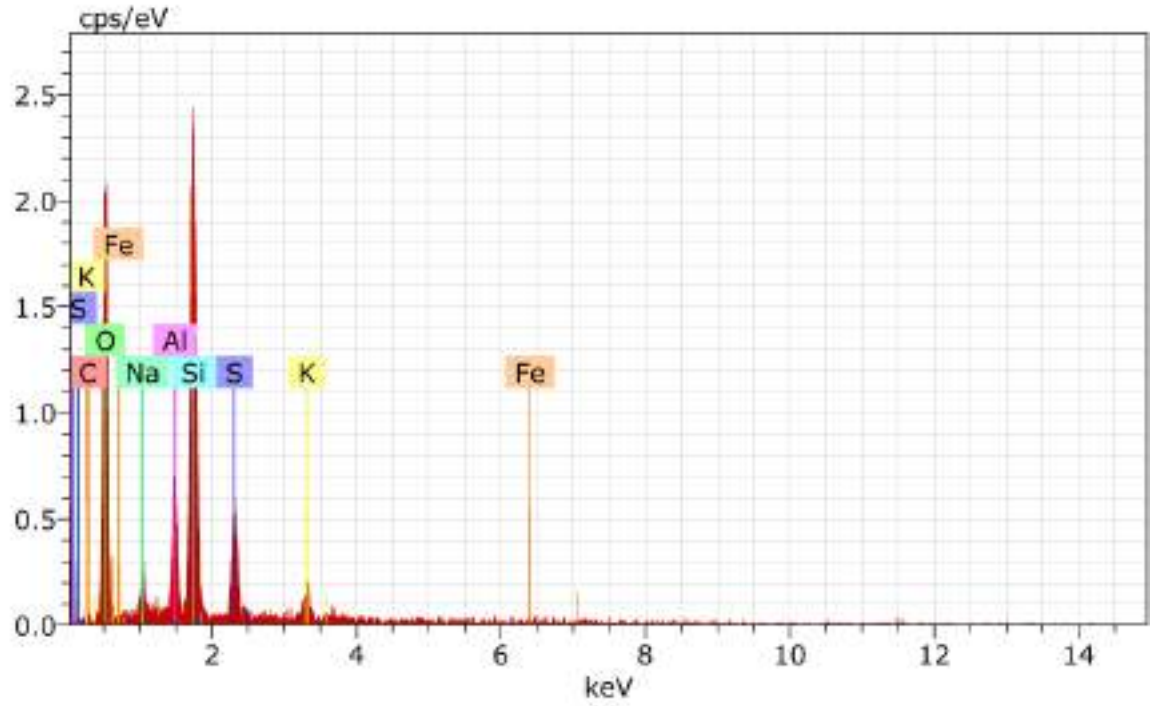


Fig.5. EDS of Pumice@SO_3H catalyst

The comparative study of different protocols for synthesis of polyhydroquinolene derivatives is illustrated in **Table 4**. While the plausible mechanism involved in Pumice@SO_3H promoted synthesis of polyhydroquinolines is shown in **Scheme 4.**

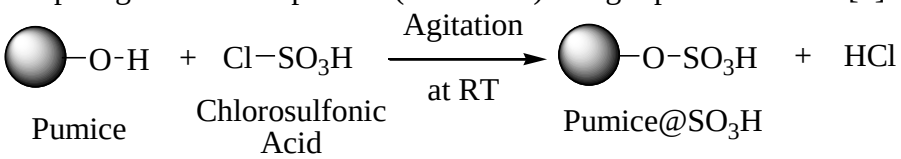
Table 4: Comparative study of different protocols for synthesis of polyhydroquinolene (**5b**)

Entry	Catalyst	Reaction Condition	Quantity of Catalyst in gm	Time in min	Yield (%)	Reference
1	Silica Sulfuric acid	Solvent free/60^oC	0.080	50	92	33

2	Nicotinic acid	Solvent free/80°C	0.1	07	92	34
3	PPA-SiO_2	Solvent free/80°C	0.030	60	90	37
4	PMO-ICS-PrSO_3H	Reflux/EtOH	0.020	20	95	40
5	CBSA	Solvent free/90°C	0.020	35	88	42
6	COF-SO_3H	Solvent free/90°C	0.020	10	95	43
7	Pumice@SO_3H	EtOH/USI, 45°C	0.090	90	80	Present work

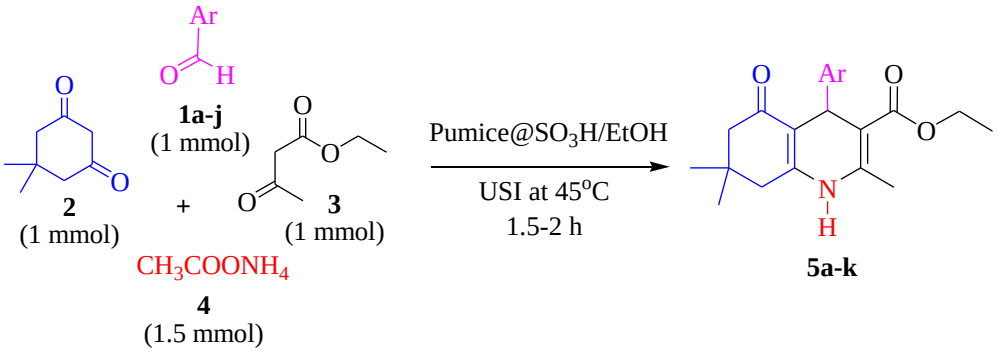
Experimental:
Melting points were recorded in an open capillary and are uncorrected. Infra Red spectra were recorded on a Perkin-Elmer FTIR spectrophotometer. The ^{1}H-NMR and ^{13}C-NMR spectra were recorded on a BRUCKER AVANCE NEO 500MHz NMR Spectrometer in $CDCl_3$ using Tetramethyl silane as a reference compound. Mass spectra were recorded on a Finnigan Mass spectrometer. TLC was carried out by Al-plates pre-coated with silica gel to check the purity of the compounds.

Preparation of pumice anchored sulfonic acid (pumice@SO_3H) catalyst
In the present work, the catalyst pumice anchored sulfonic acid (pumice@SO_3H) has been prepared by simple agitation from pumice (**Scheme 2**) using reported method [1].



Scheme 2: Preparation of pumice anchored sulfonic acid (pumice@SO_3H) catalyst

General procedure for the synthesis of polyhydroquinoline derivatives (5a-k)
A mixture of aldehyde **1** (1 mmol), 5,5-dimethylcyclohexane-1,3-dione **2** (1mmol), ethyl acetoacetate **3** (1 mmol), ammonium acetate **4** (1.5 mmol) and 90 mg of pumice based sulfonic acid was taken in a 100 mL round bottom flask containing 15 mL of ethyl alcohol. The resulting reaction mixture was subjected for ultrasound irradiation at 45°C temperature for appropriate time (**Scheme 3**). The progress of the reaction was studied using TLC. After the completion, the reaction mixture was heated up to the boiling. The resultant hot solution was filtered at hot condition to separate the catalyst. The recovered catalyst was washed with dichloromethane 2-3 times and dried to reuse. After the separation of catalyst, cool the mother liquor, the solid polyhydroquinoline thus obtained. It was dried and in some cases it was purified by recrystallization using hot ethanol.



Scheme 3: Synthesis of Polyhydroquinoline (**5a-k**) derivatives

Discussion of Spectra:

5b: ethyl 1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxo-4-*p*-tolylquinoline-3-carboxylate

^{1}H NMR (500 MHz, $CDCl_3$): 0.93 (s, 3H, -CH_3), 1.05 (s, 3H, -CH_3), 1.21 (t, 3H, -CH_3), 2.20 (s, 3H, -CH_3), 2.12-2.24 (m, 4H, -CH_2-x2), 2.31 (s, 3H, -CH_3), 4.06 (q, 2H, -OCH_2-), 5.01 (s, 1H, -CH-), 6.66 (s, 1H, NH), 6.99 (d, 2H, *J*=8Hz, Ar-H), 7.18 (d, 2H, *J*=8Hz, Ar-H); ^{13}C NMR (125 MHz, $CDCl_3$): 195.75, 167.58, 148.79, 144.27, 143.56, 135.38, 128.60, 127.87, 112.05, 106.14, 59.78, 50.81, 40.91, 36.14, 32.67, 29.45, 27.19, 21.04, 19.26, 14.24; MS (ESI) : m/z = 354.2110 [M+H].

5c: ethyl 1,4,5,6,7,8-hexahydro-4-(4-methoxyphenyl)-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate

^{1}H NMR (500 MHz, $CDCl_3$): 0.93 (s, 3H, -CH_3), 1.06 (s, 3H, -CH_3), 1.20 (t, 3H, -CH_3), 2.13-2.30 (m, 4H, -CH_2-x2), 2.35 (s, 3H, -CH_3), 3.73 (s, 3H, -OCH_3), 4.07 (q, 2H, -OCH_2-), 4.99 (s, 1H, -CH-), 6.26 (s, 1H, NH), 6.73 (m, 2H, Ar-H), 7.20 (m, 2H, Ar-H); MS (ESI) : m/z = 370.2005 [M+H].

5d: ethyl 4-(4-ethylphenyl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate

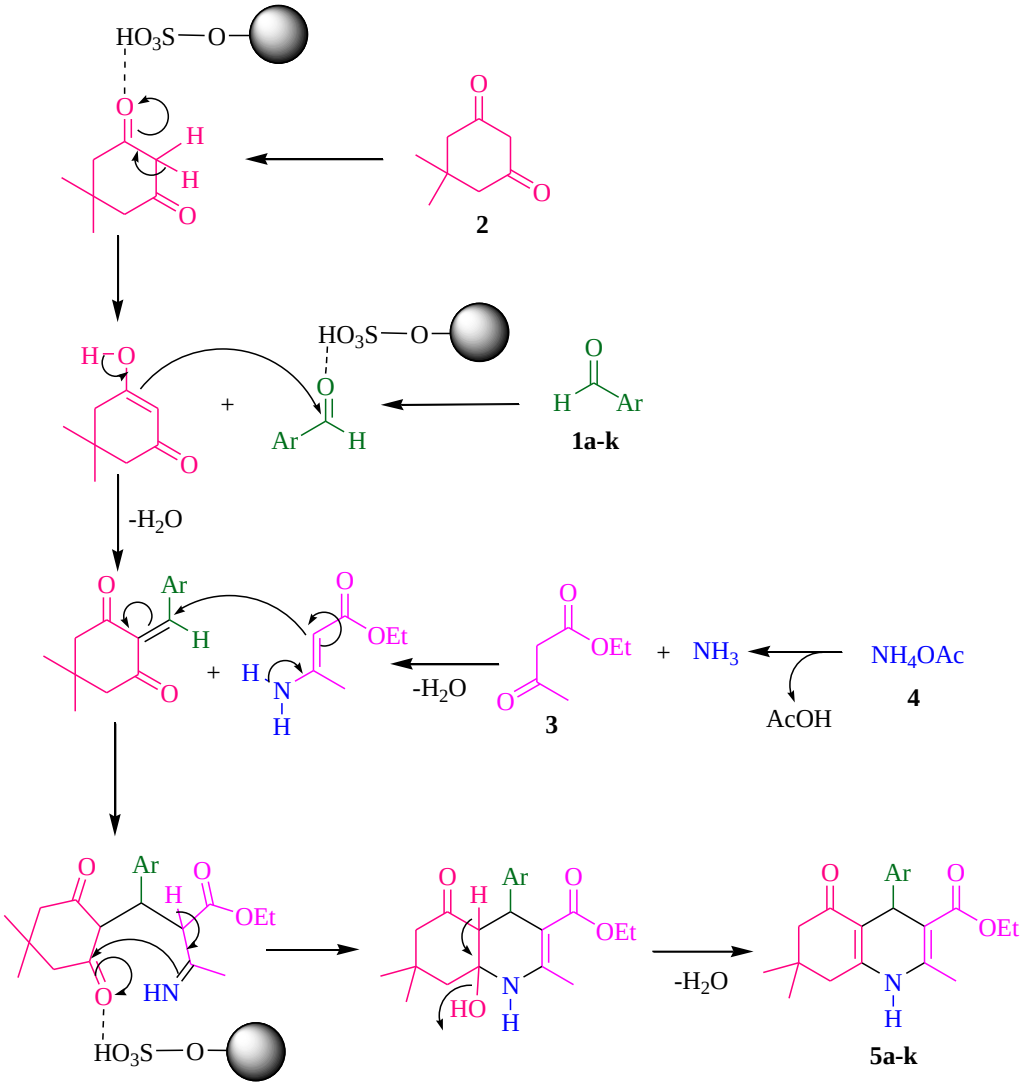
^{1}H NMR (500 MHz, $CDCl_3$): 0.95 (s, 3H, -CH_3), 1.06 (s, 3H, -CH_3), 1.17 (t, 3H, -CH_3), 1.21 (t, 3H, -CH_3), 2.13-2.29 (m, 4H, -CH_2-x2), 2.32 (s, 3H, -CH_3), 2.55 (q, 2H, -CH_2-), 4.06 (q, 2H, -OCH_2-), 5.02 (s, 1H, -CH-), 6.41 (s, 1H, NH), 7.01 (d, 2H, *J*=8Hz, Ar-H), 7.19 (d, 2H, *J*=8Hz, Ar-H); ^{13}C NMR (125 MHz, $CDCl_3$): 195.69, 167.58, 148.49, 144.39, 143.37, 141.68, 127.87, 127.35, 112.16, 106.25, 59.79, 50.79, 41.03, 36.10, 32.71, 29.41, 28.40, 27.28, 19.32, 15.35, 14.23.

5f: ethyl 4-(4-chlorophenyl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate

^{1}H NMR (500 MHz, $CDCl_3$): 0.92 (s, 3H, -CH_3), 1.07 (s, 3H, -CH_3), 1.18 (t, 3H, -CH_3), 2.13-2.32 (m, 4H, -CH_2-x2), 2.36 (s, 3H, -CH_3), 4.05 (q, 2H, -OCH_2-), 5.02 (s, 1H, -CH-), 6.29 (s, 1H, NH), 7.16 (m, 2H, Ar-H), 7.23 (m, 2H, Ar-H); MS (ESI) : m/z = 374.1595 [M+H].

5k: ethyl 4-(4-(dimethylamino)phenyl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate

^{1}H NMR (500 MHz, $CDCl_3$): 0.95 (s, 3H, -CH_3), 1.04 (s, 3H, -CH_3), 1.24 (t, 3H, -CH_3), 2.12-2.25 (m, 4H, -CH_2-x2), 2.33 (s, 3H, -CH_3), 2.85 (s, 6H, -$N(CH_3)_2$), 4.06 (q, 2H, -OCH_2-), 4.96 (s, 1H, -CH-), 6.58 (d, 2H, *J*=8.5Hz, Ar-H), 6.64 (s, 1H, NH), 7.15 (d, 2H, *J*=8.5Hz, Ar-H); ^{13}C NMR (125 MHz, $CDCl_3$): 195.84, 167.77, 148.94, 148.56, 143.18, 136.02, 128.61, 112.38, 112.24, 106.43, 59.71, 50.84, 40.85, 40.75, 35.38, 32.65, 29.49, 27.28, 19.28, 14.30; MS (ESI) : m/z = 383.2254 [M+H].



Scheme 4: Pluasible mechanism for the synthesis of Polyhydroquinolines

Conclusion:

In summary, we have discovered a sustainable and convenient protocol for the synthesis of polyhydroquinoline derivatives using pumice anchored sulfonic acid (Pumice@SO_3H) as an efficient catalyst under ultrasound irradiation. The attractive features of present protocol are green approach, good yield, recovery of catalyst and easy work-up procedure whereas the catalyst offers simple preparation, high catalytic activity, inexpensive, easy to use, recyclability and good stability.

Abbreviations:

MCRs	= Multicomponent Reactions,
Pumice@SO_3H	= Pumice supported sulfuric acid,
NR	= No Reaction,
RT	= Room Temperature,
SF	= Solvent Free,
USI	= Ultrasound Irradiation.

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Pumice-based sulfonic acid: a sustainable and recyclable acidic catalyst for one-pot synthesis of pyrazole anchored 1,4-dihydropyridine derivatives at room temperature

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Abstract

In the present investigation, we have developed an efficient and eco-friendly protocol for the synthesis of pyrazole anchored 1,4-dihydropyridine analogs using pumice-based sulfonic acid (pumice@SO_3H) as a recyclable solid acid catalyst under simple stirring at room temperature. The present protocol proceeded smoothly with 1,3-diaryl pyrazole-4-carbaldehydes, ethyl acetoacetate, and NH_4OAc in ethanol as a solvent with excellent yield. The pumice-based sulfonic acid catalyst is easily prepared from naturally occurring pumice by simple agitation with chlorosulfonic acid. The key features of this catalyst are its heterogeneous nature, high porosity, non-corrosive and non-toxic nature, recyclability, stable and highly efficient at room temperature. The application of this catalyst makes the protocol more environmentally benign.

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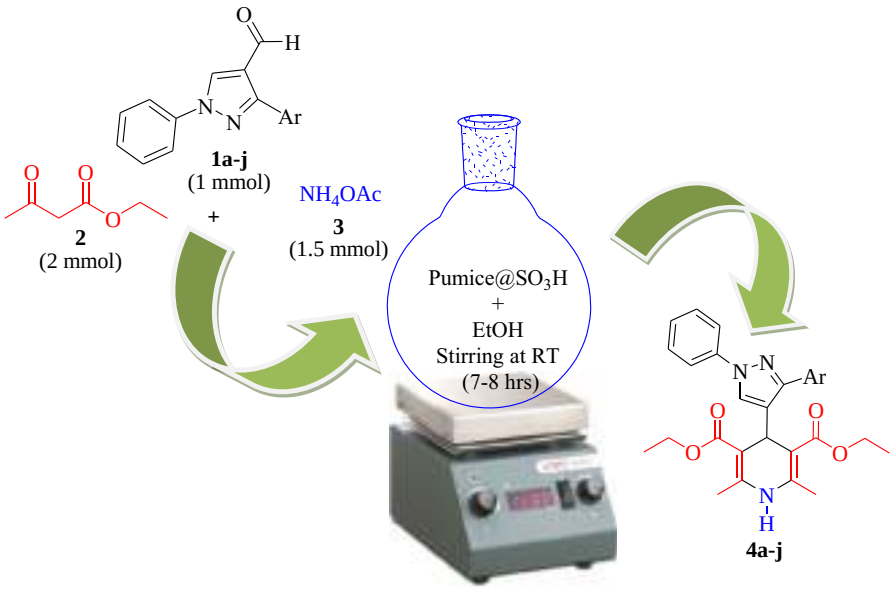
Graphical abstract



Keywords Pumice-based sulfonic acid · 1,4-dihydropyridine · 1,3-diaryl pyrazole-4-carbaldehydes

Introduction

Pumice is a naturally occurring porous material obtained after volcanic eruptions. Its high porous nature is due to the evaporation of the large number of gases. Along with porosity, it has many advantages such as high abundance, high performance, good surface area, less expensive, heterogeneous nature, excellent thermal, and chemical stability. The literature reveals that during the recent years, pumice is converted into various active materials which have been employed in many convergent and divergent organic syntheses as a catalyst [1–4].

Multicomponent reaction (MCR) offers an excellent approach for synthesizing the complex molecules. MCR approach has many advantages including, one-pot operation, high atom economy, and short reaction time. A wide variety of nitrogen heterocycles have been synthesized by MCR and are useful in the various fields like agriculture, medicinal, drug, and pharmaceutical chemistry. The synthesis of 1,4-dihydropyridine derivatives by Hantazsch reaction is an important example of multicomponent reaction. Pyridine nucleus containing compounds is a important group of heterocyclic compounds which shows a wide range of biological properties such as anticancer [5, 6], anti-inflammatory [7], anti-leishmanial [8], antimalarial [9], anti-microbial [10], anti-mycobacterial [11], antioxidant [12], anti-proliferative

[13], anti-tubercular [14, 15], anti-ulcer agents [16], antiviral [17], and cytotoxic activity [18], etc. The some important drugs containing of 1,4-dihydropyridine nucleus are given below (Fig. 1).

Owing to biological significance associated with 1,4-dihydropyridine many catalytic systems have been developed using MCR of ethylacetoacetate, aromatic aldehyde, and NH_4OAc. Among them, many protocols report use of simple aromatic aldehydes using catalytic systems such as nanomaterials [19], microwave irradiation [20], ultrasound irradiation [21], ionic liquids [22], hybrid materials [23], doped metal oxide [24], solar thermal energy [25], and acidic as well as basic catalyst. Also, many bronsted acidic catalyst have been reported includes acetic acid [26], COF-SO_3H [27], cellulose sulfuric acid [28], chitosan [29], DMAP [30], eggshell-based nanomagnetic solid acid catalyst [31], Fe_3O_4@PANI-SO_3H [32], guanidinium-based sulfonic acid [33], glycine [34], heteropolyacids [35], L-proline [36], magnetite/chitosan [37], *N*-propylbenzoguanamine sulfonic acid-functionalized magnetic nanoparticles [38], phosphoric acid [39], PPA–SiO_2 [40], PTSA–SDS [41], *p*-TSA [42], polyvinyl alcohol [43], silica-supported perchloric acid [44], TEA [45], etc. There is very less MCR reported for the synthesis of 1,4-dihydropyridine using 1,3-diaryl pyrazole-4-carbaldehydes as aldehyde component such as [HNMP][HSO_4] [46], magnesium oxide nanotubes [47], silica [48], silica sulphuric acid [49] sulfamic acid [50], etc.

In continuation of our ongoing studies on the application of pumice@SO_3H catalysts [2] towards the sustainable development of new facile protocols [51–55], we report herein the synthesis of 1,4-dihydropyridine derivatives anchored with pyrazole moiety. The key aspect of this protocol is the simple aromatic aldehyde was replaced by structurally hindered and bulkier 4-formyl pyrazole aldehyde using Brønsted acidic pumice-based sulfonic acid catalyst via

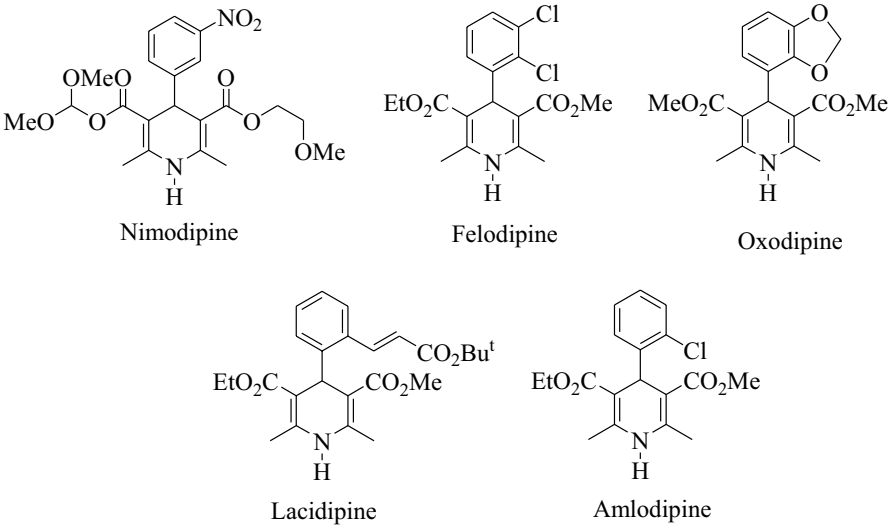
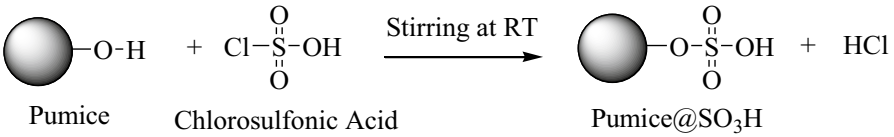


Fig. 1 Drugs containing 1,4-dihydropyridine nucleus



Scheme 1 Preparation of pumice-based sulfonic acid (pumice@SO_3H) catalyst

MCR strategy (Scheme 2). Even with this aldehyde, the pumice-based catalyst showed good catalytic activity. The 1,3-diaryl pyrazole-4-carbaldehydes were prepared by following Veilsmeier-haack formylation reaction reported in literature [56].

Experimental

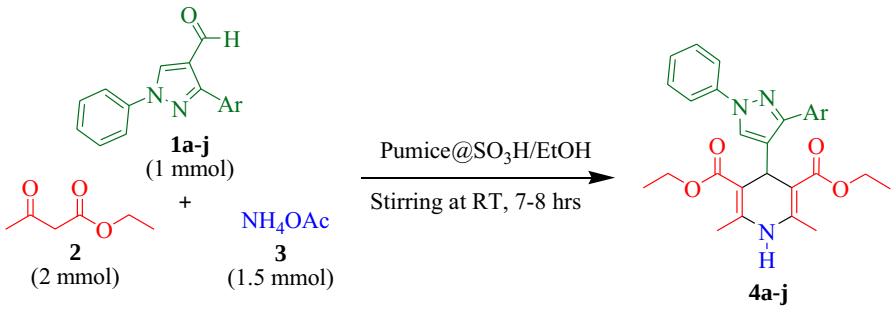
Melting points were recorded in an open capillary and are uncorrected. Infrared spectra were recorded on a Perkin-Elmer FTIR spectrophotometer. The ^{1}H-NMR and ^{13}C-NMR spectra were recorded on a BRUCKER AVANCE NEO 500 MHz NMR spectrometer in $CDCl_3$ using tetramethyl silane as a reference compound. Mass spectra were recorded on a Finnigan Mass spectrometer. TLC was carried out by Al-plates pre-coated with silica gel to check the purity of the compounds. In the present work, the pumice-based sulfonic acid catalyst has been prepared by previously reported method [2]. In that, the catalyst is fully characterized and confirmed its formation.

(1) General procedure for preparation of pumice-based sulfonic acid (pumice@SO_3H) catalyst.

The chlorosulfonic acid was added slowly into the round bottom flask containing pumice at room temperature as per the procedure in [2]. After the complete addition, the stirring was continued till a faint brownish white solid was obtained which was washed with acetone. Resultant solid was dried in heating oven to give desired pumice-based sulfonic acid (pumice@SO_3H) catalyst (Scheme 1).

(2) General procedure for the synthesis of 1,4-dihydropyridine derivatives **(4a–j)**.

In a single neck 100 mL, round bottom flask 3-aryl-1-phenyl-1*H*-pyrazole-4-carbaldehyde 1 (1 mmol), ethyl acetoacetate 2 (2 mmol), ammonium acetate 3 (1.5 mmol), and 150 mg of pumice-based sulfonic acid was taken in 15 mL of ethyl alcohol. The resulting reaction mixture was stirred at room temperature for appropriate time (Scheme 2). The progress of the transformation was monitored by TLC. Once the reaction was completed, the content was mixed with dichloromethane, and catalyst was separated by decantation. After the separation of catalyst, the dichloromethane was concentrated on rotary evaporator which gave solid 1,4-dihydropyridine derivatives. The obtained product was dried and purified by recrystallization from n-hexane–ethyl acetate. The recovered catalyst was washed with dichloromethane and dried to reuse for the next cycle.

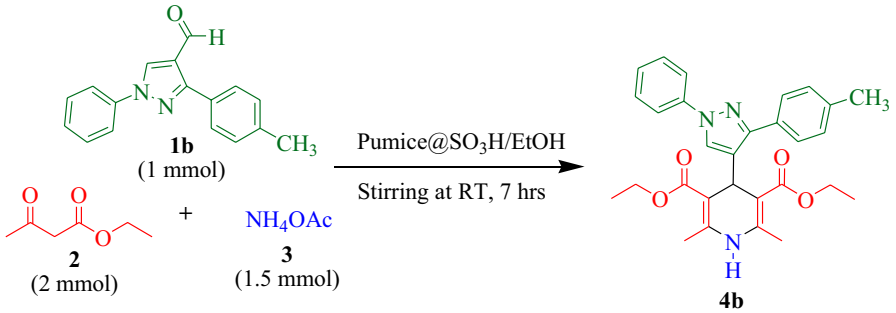


Scheme 2 Synthesis of 1,4-dihydropyridine derivatives **(4a–j)**

Result and Discussion

The pumice-based sulfonic acid (Pumice@SO_3H) catalyst was simply prepared by stirring naturally occurring pumice with chlorosulfonic acid. The catalyst formation occurs within one hour, which exhibits excellent properties such as high surface area, good thermal stability, high acidity (Scheme 1). The catalytic potential of synthesized pumice@SO_3H catalyst was checked in our previous work [2] again it was thought to check further applicability of pumice@SO_3H catalyst for one-pot synthesis of 1,4-dihydropyridines.

Initially, we have selected 1-phenyl-3-*p*-tolyl-1*H*-pyrazole-4-carbaldehyde 1b, ethyl acetoacetate 2, and NH_4OAc 3 as a pilot reaction (Scheme 3) and investigated under agitation at room temperature with and without solvent. The model reaction was also carried out in the absence and in presence of pure pumice in ethanol as solvent; it was found that no product formation occurred after a period of long time (Table 1, Entries 1, 2). Then the chosen model reaction was performed with 100 mg of pumice@SO_3H catalyst under solvent-free agitation; the reaction did not proceed (Table 1, Entry 3). Further study was continued by performing reaction in the presence of pumice@SO_3H catalyst in water as solvent, got the negative results after prolonged stirring at room temperature (Table 1, Entry 4). Then the reaction was



Scheme 3 Model reaction for the synthesis of 1,4-dihydropyridine derivatives (4b)

Table 1 Optimization of the reaction conditions for the synthesis of diethyl 1,4-dihydro-2,6-dimethyl-4-(1-phenyl-3-*p*-tolyl-1*H*-pyrazol-4-yl)pyridine-3,5-dicarboxylate (4b)

Entry	Catalyst/solvent	Reaction condition	Time in hr	Isolated yield (%)
1	No catalyst / Solvent free (SF)	Stirring at RT	24	NR
2	No catalyst / 10 ml EtOH	Stirring at RT	24	NR
3	Pure Pumice / SF	Stirring at RT	24	NR
4	Pure Pumice / 10 ml EtOH	Stirring at RT	24	NR
5	100 mg Pumice@SO_3H / SF	Stirring at RT	24	Trace
6	100 mg Pumice@SO_3H / 10 ml H_2O	Stirring at RT	24	Trace
7	100 mg Pumice@SO_3H / 10 ml EtOH	Stirring at RT	10	70%
8	150 mg Pumice@SO_3H / 10 ml EtOH	Stirring at RT	7.5	88%
9	200 mg Pumice@SO_3H / 10 ml EtOH	Stirring at RT	7.5	88%

Reaction condition: 1-phenyl-3-*p*-tolyl-1*H*-pyrazole-4-carbaldehyde 1b (1 mmol), ethyl acetoacetate 2 (2 mmol), NH_4OAc 3 (1.5 mmol), pumice@SO_3H

carried out with the 100 mg of pumice@SO_3H catalyst in ethanol under simple stirring at room temperature. This study reveals that the reaction proceeds with excellent yield (Table 1, Entry 5). We also studied the amount of catalyst pumice@SO_3H required for this reaction (Table 1, entries 5–7), which indicates that 150 mg pumice@SO_3H in the presence of 10 ml ethanol (Table 1, entry 6) was sufficient for the successful results. And further, with the use of excess of the pumice@SO_3H, the yield of the product did not change significantly.

Further, the study was continued to check the catalytic activity of pumice@SO_3H for the synthesis of 1,4-dihydropyridines anchored with variously substituted 1,3-diaryl pyrazole-4-carbaldehydes. We know that these aldehydes are sterically hindered and comparatively less reactive. The optimized conditions were applied for different 1,3-diaryl pyrazole-4-carbaldehydes and interestingly the catalyst showed good potential for the construction of bulky 1,4-dihydropyridines with good yield at even room temperature as illustrated in Table 2.

The one more important green feature of the pumice@SO_3H catalyst is recyclability. Once the model reaction (Scheme 3) was completed, the content was mixed with DCM and the insoluble pumice@SO_3H catalyst was separated by decantation. The recovered catalyst was washed again with DCM and dried well. It was reused in three cycles without significant loss in its catalytic activity. The reusability result is shown in Fig. 2. While the organic layer upon evaporation on a rotary evaporator under reduced pressure resulted in the solid 1,4-dihydropyridine derivatives.

The formation of catalyst was proved with IR, XRD, SEM, TEM, and EDAX studies which are reported in our previous work [2]. Here the evidence of recyclability study is provided.

Infrared spectrum of recycled pumice@SO_3H

In the IR spectrum of the recycled pumice@SO_3H (Fig. 3), the broad vibration band of O–H bond in (-SO_3H) group is observed at 3215.10 cm^{-1}. Also, the

Table 2 Synthesis of pyrazole anchored 1,4-dihydropyridine derivatives (4a-j)

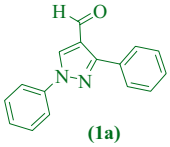
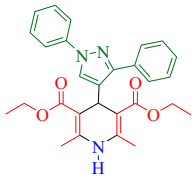
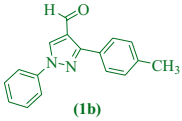
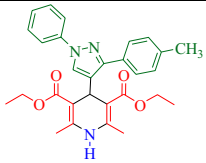
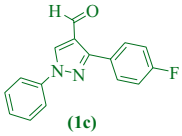
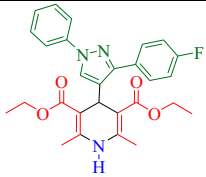
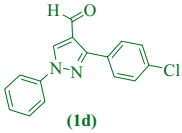
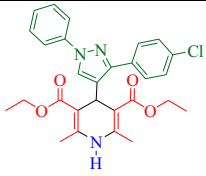
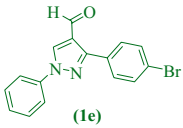
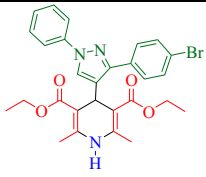
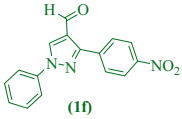
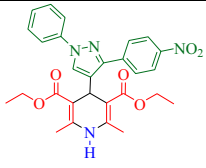
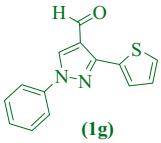
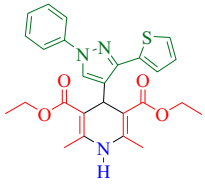
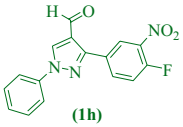
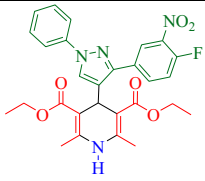
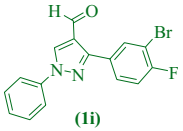
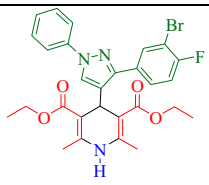
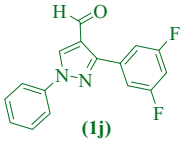
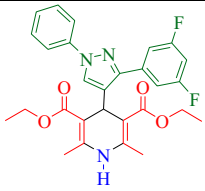
Entry	Aldehyde	1,4-dihydropyridine derivatives	Reaction Time in hrs	Yield in %	M.P. in ^{O}C	
					Found	Lit.[Ref]
1	 (1a)	 (4a)	7	84	161	154 [46]
2	 (1b)	 (4b)	7.5	88	178	176 [46]
3	 (1c)	 (4c)	7.5	80	165	160 [46]
4	 (1d)	 (4d)	7	85	156	158 [46]
5	 (1e)	 (4e)	7.5	80	174	182 [48]
6	 (1f)	 (4f)	8	75	191	178 [46]

Table 2 (continued)

7	 (1g)	 (4g)	7.5	88	173	170 [46]
8	 (1h)	 (4h)	8	80	180	
9	 (1i)	 (4i)	8	82	260	270 [46]
10	 (1j)	 (4j)	7.5	85	284	290 [46]

Reaction condition: 3-aryl-1-phenyl-1*H*-pyrazole-4-carboxaldehydes **1** (1 mmol), ethyl acetoacetate **2** (2 mmol), NH_4OAc **3** (1.5 mmol), 150 mg pumice@SO_3H and 10 mL EtOH

characteristic bands due to the presence of S = O and Si–O–Si were observed at 1636.86 cm^{-1} and 1090.76 cm^{-1}, respectively. These results suggest that, the recovery of -SO_3H group in the framework of recycled pumice@SO_3H catalyst.

The XRD spectra of recycled pumice@SO_3H

Also, the successful recyclability of pumice@SO_3H with -SO_3H groups was confirmed by XRD analysis (Fig. 4). The XRD pattern of recycled catalyst pumice@SO_3H was exactly matched with the literature data (Tambe et. al.). This indicates that the recycled pumice@SO_3H did not show any major change in composition.

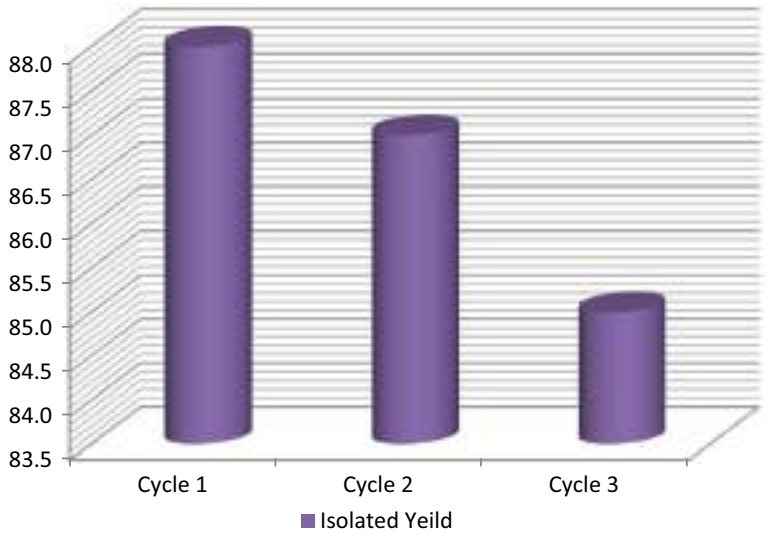


Fig. 2 Reusability of the pumice@SO_3H for the synthesis of 1,4-DHP derivative (4b)

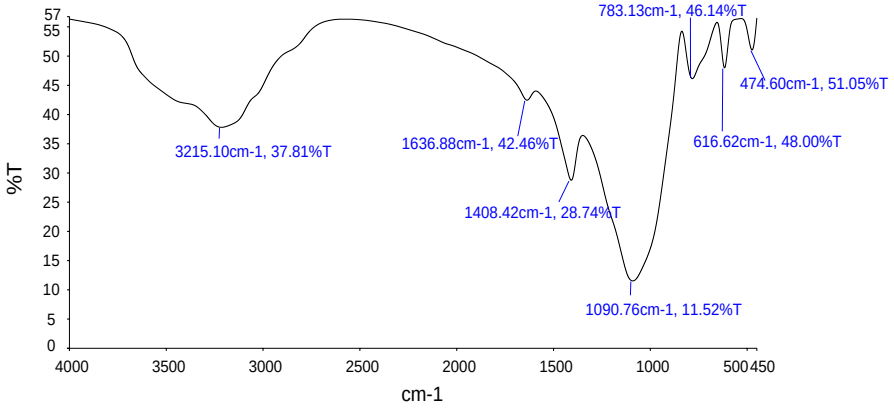


Fig. 3 IR spectra of recycled pumice-based sulfonic acid (pumice@SO_3H)

Spectral Data

4a: diethyl 1,4-dihydro-2,6-dimethyl-4-(1,3-diphenyl-1*H*-pyrazol-4-yl) pyridine-3,5-dicarboxylate

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 1.07 (t, 6H, -CH_3 X 2), 2.20 (s, 6H, -CH_3 X 2), 3.78 (m, 2H, -OCH_2-), 4.01 (m, 2H, -OCH_2-), 5.29 (s, 1H, -CH-), 5.59 (s, 1H, NH), 7.21–7.74 (m, 6H, Ar–H), 7.42 (m, 5H, Ar–H); 13C NMR ($CDCl_3$, 500 MHz) δ: 14.33, 19.45, 29.72, 59.69, 104.32, 118.83, 125.99, 127.10, 127.46,

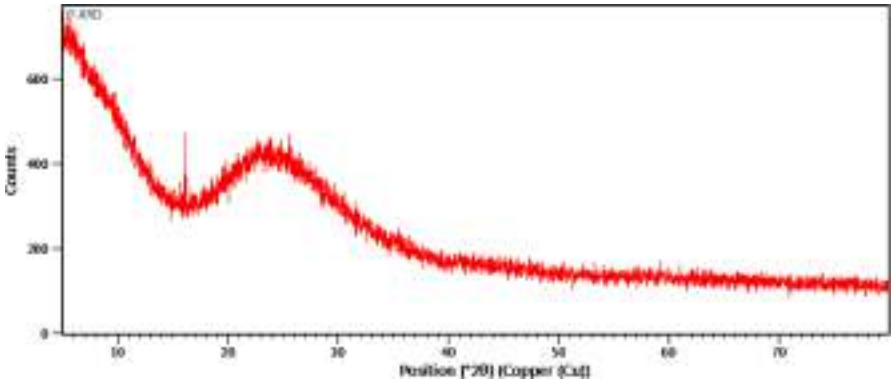


Fig. 4 The XRD spectra of recycled pumice-based sulfonic acid (pumice@SO_3H)

127.89, 128.67, 128.99, 129.22, 134.88, 140.10, 143.41, 151.27, 167.59; MS (ESI): m/z = 472.2275 [M + H].

4b: diethyl 1,4-dihydro-2,6-dimethyl-4-(1-phenyl-3-*p*-tolyl-1*H*-pyrazol-4-yl)pyridine-3,5-dicarboxylate

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 1.07 (t, 6H, -CH_3 X 2), 2.22 (s, 6H, -CH_3 X 2), 2.38 (s, 3H, Ar-CH_3), 3.77 (m, 2H, -OCH_2-), 4.02 (m, 2H, -OCH_2-), 5.29 (s, 1H, -CH), 5.58 (s, 1H, NH), 7.19–7.25 (m, 3H, Ar–H), 7.39 (t, 2H, Ar–H), 7.66 (d, 2H, Ar–H), 7.72 (d, 3H, Ar–H); MS (ESI): m/z = 486.2335 [M + H].

4d: diethyl 4-(3-(4-chlorophenyl)-1-phenyl-1*H*-pyrazol-4-yl)-1,4-dihydro-2,6-dimethylpyridine-3,5-dicarboxylate

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 1.04 (t, 6H, -CH_3 X 2), 2.24 (s, 6H, -CH_3 X 2), 3.66 (m, 2H, -OCH_2-), 3.88 (m, 2H, -OCH_2-), 5.27 (s, 1H, CH), 5.59 (s, 1H, NH), 7.29 (t, 1H, Ar–H), 7.47 (t, 2H, Ar–H), 7.53 (d, 2H, Ar–H), 7.81 (d, 2H, Ar–H), 7.94 (d, 2H, Ar–H), 8.04 (s, 1H, Ar–H); 13C NMR ($CDCl_3$, 500 MHz) δ: 14.31, 19.43, 29.68, 59.79, 104.41, 118.87, 126.21, 127.43, 128.07, 129.03, 129.28, 130.22, 133.40, 139.97, 143.54, 149.77, 167.54; MS (ESI): m/z = 506.1873 [M + H].

4f: diethyl 4-(3-(4-nitrophenyl)-1-phenyl-1*H*-pyrazol-4-yl)-1,4-dihydro-2,6-dimethylpyridine-3,5-dicarboxylate

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 1.03 (t, 6H, -CH_3 X 2), 2.31 (s, 6H, -CH_3 X 2), 3.79 (m, 2H, -OCH_2-), 4.01 (m, 2H, -OCH_2-), 5.32 (s, 1H, CH), 5.74 (s, 1H, NH), 7.28 (t, 1H, Ar–H), 7.43 (t, 2H, Ar–H), 7.68 (d, 2H, Ar–H), 7.78 (s, 1H, Ar–H), 8.24 (d, 2H, Ar–H), 8.31 (d, 2H, Ar–H).

4 g: diethyl 1,4-dihydro-2,6-dimethyl-4-(1-phenyl-3-(thiophen-2-yl)-1*H*-pyrazol-4-yl) pyridine-3,5-dicarboxylate

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 1.05 (t, 6H, -CH_3 X 2), 2.31 (s, 6H, -CH_3 X 2), 3.89 (m, 2H, -OCH_2-), 4.03 (m, 2H, -OCH_2-), 5.34 (s, 1H, CH), 5.55 (s, 1H, NH), 7.21–7.29 (m, 3H, Ar–H), 7.38–7.43 (m, 2H, Ar–H), 7.55–7.65 (m, 4H, Ar–H); 13C NMR ($CDCl_3$, 500 MHz) δ: 14.23, 19.63, 29.76, 59.83, 104.96, 118.81, 124.79, 126.09, 126.25, 127.07, 128.21, 129.35, 129.49, 136.17, 139.88, 143.12, 145.11, 167.51; MS (ESI): m/z = 478.1871 [M + H].

4j: diethyl 4-(3-(3,5-difluorophenyl)-1-phenyl-1*H*-pyrazol-4-yl)-1,4-dihydro-2,6-dimethylpyridine-3,5-dicarboxylate

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 1.08 (t, 6H, -CH_3 X 2), 2.28 (s, 6H, -CH_3 X 2), 3.83 (m, 2H, -OCH_2-), 4.06 (m, 2H, -OCH_2-), 5.28 (s, 1H, CH), 5.79 (s, 1H, NH), 6.80 (m, 1H, Ar–H), 7.26 (m, 1H, Ar–H), 7.41 (t, 2H, Ar–H), 7.56 (t, 2H, Ar–H), 7.66 (d, 2H, Ar–H), 7.75 (s, 1H, Ar–H).

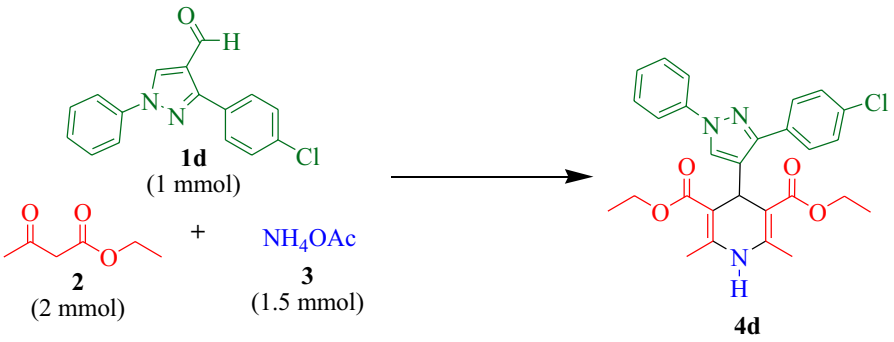
The comparative study on the use of pumice@SO_3H catalyst with the different reported catalytic systems is mentioned in Table 3. From this investigation, it was found that the pumice@SO_3H catalyst showed a remarkable catalytic activity for the synthesis for the synthesis of sterically hindered and bulky pyrazole anchored 1,4-dihydropyridine derivative (4d) by MCR (Scheme 4) of the 1,3-diaryl pyrazole carbaldehyde (1d), ethylacetoacetate (2) and NH_4OAc (3). In addition, this designed catalytic system has many advantages over the reported methods such as naturally occurring material, low cost, readily available, and reaction proceed at room temperature.

Plausible mechanism

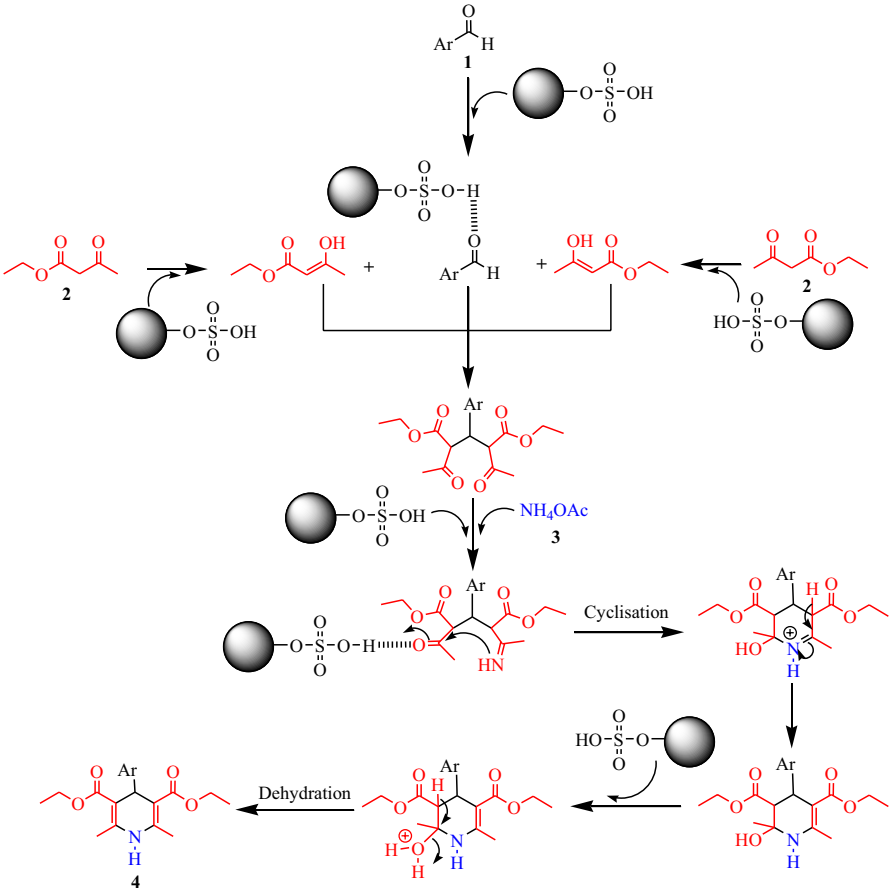
The proposed mechanism of synthesis of 1,4-dihydropyridine in presence of pumice@SO_3H catalyst is shown in Scheme 5.

Table 3 Comparative study of the efficiency of various catalytic systems for the synthesis of pyrazole anchored 1,4-dihydropyridine derivative (4d)

Entry	Catalyst	Reaction Condition	Time in hrs	Yield in %	Ref. No
1	[HNMP][HSO_4]	EtOH/Stirring at RT	5	84	[46]
2	Magnesium Oxide Nanotubes	CH_3CN/Reflux	0.5	91	[47]
3	Silica	SF/Heating at 90°C	4	90	[48]
4	Silica Sulphuric acid	EtOH/Stirring at Ambient temp	2.5	84	[49]
5	Sulfamic acid	EtOH /Reflux	5	80	[50]
6	Pumice @SO_3H	EtOH/Stirring at RT	7	85	**Present work**



Scheme 4 Synthesis of pyrazole anchored 1,4-dihydropyridine derivative (4d)



Scheme 5 Plausible Mechanism of pumice@SO_3H catalyzed synthesis of 1,4-dihydropyridine

Conclusions

In conclusion, the pumice-based sulfonic acid was proved to be a convenient and efficient catalyst for the synthesis of a series of 1,4-dihydropyridines anchored with biologically important pyrazole moiety via one-pot multi-component reaction. Even though the 1,3-diaryl pyrazole-4-carbaldehydes are bulky and less reactive the products were obtained at room temperature with good to excellent yields. The preparation of the catalyst is very simple and it can be reused in many cycles without loss of its catalytic activity. Also, it has many advantages including high porosity, heterogeneous nature, non-corrosive and non-toxic nature, and thermally stable and efficient at room temperature.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11164-021-04649-7.

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Novel Pumice Supported Perchloric Acid Promoted Protocol for the Synthesis of Tetrahydrobenzo[*b*]pyran via Multi-component Approach

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ABSTRACT

A novel heterogeneous pumice supported perchloric acid catalyzed synthesis of tetrahydrobenzo[*b*]pyran has developed via multi-component condensation of aromatic aldehydes, dimedone and malononitrile. The catalyst was characterized by IR, XRD, EDS, SEM, and TGA techniques which confirmed the formation novel pumice supported perchloric acid. The present protocol proved to have numerous advantages like one-pot reaction, good yield, short reaction time, inexpensive catalyst, recyclability and reusability of the catalyst, simple experimental and work up procedure, and purification of targeted molecules without column chromatography.

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KEYWORDS
Pumice supported perchloric acid; tetrahydrobenzo[*b*]pyran; multi-component reaction; dimedone; malanonitrile

Introduction

In the last two decades, volcanic pumice and pumice based materials have been employed in divergent organic transformations such as reduction reaction, oxidation reaction, photo catalytic degradation, multi-component condensation reaction and also water treatment process. These varied reactions are achieved because large silica content of the pumice which was converted into active catalytic material. The appreciable advantages of pumice supported catalytic materials are heterogeneous nature, good surface area, excellent catalytic activity, thermal stability, high porosity, high absorption capacity, recyclability and reusability, etc.[1–9]

Multi-component reaction (MCR) approach has gained excellent impact in the discovery of heterocyclic compounds due to the synthetic efficiency and economy. The MCR strategy is a one step synthetic operation with incredibly well-designed and quick approach to discover highly functionalized and complex biologically active molecules. It has also advantages like high flexibility, high atom economy and high selectivity.[10–12] The synthesis of tetrahydrobenzo[*b*]pyrans is also an important illustration of the multi-component reaction.

The tetrahydrobenzo[*b*]pyran derivatives are extremely significant to the organic chemists because of their prominent biological and pharmacological activities. They are fascinating polyfunctionalized compounds which possess a wide variety of biological activities like anti-allergic, antibacterial, anti-coagulant, anti-tumor, calcium channel antagonists and diuretic etc. Along with biological activities, some derivatives of tetrahydrobenzo[*b*]pyran have been employed as photoactive materials and agrochemicals. They are also used in cosmetics and pigments.[13–18] The some illustration of biologically active tetrahydrobenzo[*b*]pyran derivatives shown in Figure 1.

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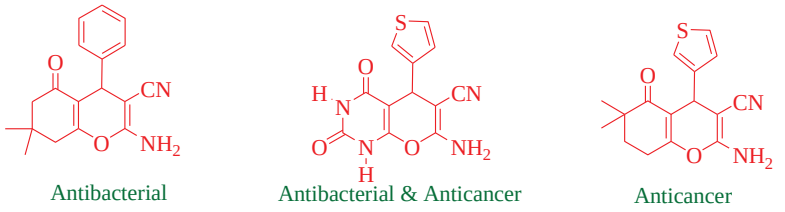


Figure 1. Some examples of biologically active tetrahydrobenzo[*b*]pyran derivatives.

In a vision of the enormous scope of tetrahydrobenzo[*b*]pyrans there is increased attention in developing new routes for their synthesis. The synthetic protocols include numerous catalyst such as tetraethylammonium perchlorate,[19] CTMAB-bentonite,[20] nano-titania sulfuric acid,[21] ultrasound,[22] MNPs–$PhSO_3H$,[23] molecular sieve-supported zinc catalyst,[24] silica nanoparticles,[25] oxyammonium-based ionic liquid,[26] $MeSO_3H$,[27] PEG-SO_3H,[28] WEMFSA,[29] tungstic acid functionalized mesoporous SBA-15,[30] amine-functionalized SiO_2@Fe_3O_4 nanoparticles,[31] choline chloride-oxalic acid,[32] L-proline,[33] chitosan,[34] xanthum gum supported Fe_3O_4,[35] phosphotungstic acid supported on SiO_2@$NHPhNH_2$ functionalized nanoparticles of $MnFe_2O_4$,[36] poly(Ethyleneoxide)-based magnetic nanocomposite,[37] magnetic aluminosilicate nanoclay,[38] amine-functionalized silica-supported magnetic nanoparticles,[39] etc.

In continuation of our work in developing new methodologies for the synthesis of active compounds[40] herein, we have reported an efficient and sustainable protocol for the synthesis of tetrahydrobenzo[*b*]pyrans via multi-component reaction of aromatic aldehyde, dimedone and malononitrile in the presence of novel pumice supported perchloric acid. The present work has a number of advantages in comparison with the literature reported protocols, such as good yields, high atom economy, smooth reaction conditions, simple work-up procedure and purification of targeted molecule without column chromatography.

Experimental procedures

General

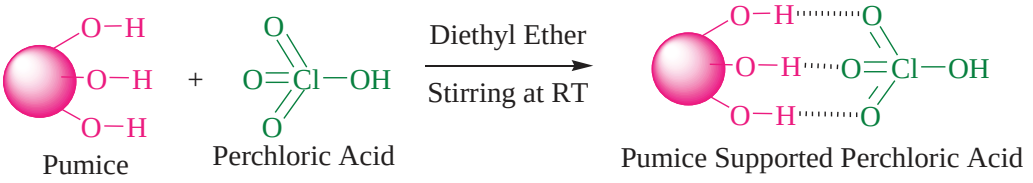
The progress of the reaction was monitored by thin-layer chromatography (TLC) by using silica gel coated aluminum plates and plates are visualized with UV light. Melting points were taken in an open capillary and are uncorrected. ^{1}H NMR (500 MHz) and ^{13}C NMR (125 MHz) spectra were recorded with the BRUCKER AVANCE NEO 500 MHz in $CDCl_3$ using TMS as an internal standard. IR spectra were taken on PerkinElmer FTIR Spectrometer. The pumice supported perchloric acid catalyst was prepared in the laboratory. Mass spectra were recorded on a MALDI SYNAPT XS HD Mass spectrometer.

General procedure for the preparation of pumice supported perchloric acid

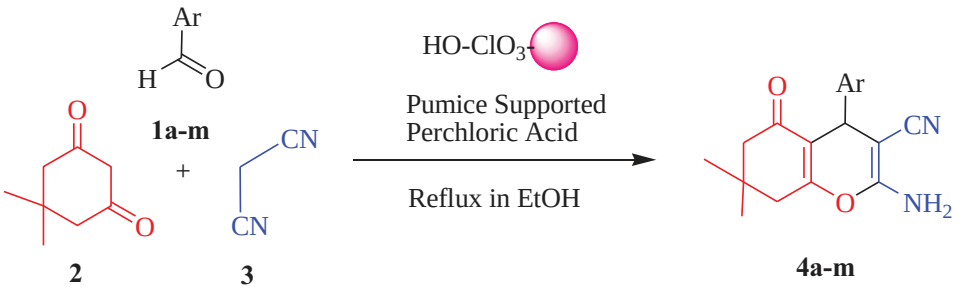
Perchloric acid (3.0 gm) was added to the suspension of pumice (45 gm) in diethyl ether (60 mL) with constant stirring for 2 h. The mixture was concentrated and the residue was washed with acetone to remove unreacted perchloric acid. The resultant residue was dried under vacuum at 80 °C for 6 h to afford free Pumice Supported Perchloric acid (Pumice@$HClO_4$) (Scheme 1).

General procedure for the synthesis of tetrahydrobenzo[b]pyran derivatives (4a–m)

In a 100 mL round bottom flask, the mixture of substituted benzaldehyde (2 mmol), dimedone (2 mmol), malanonitrile (2 mmol) and pumice supported perchloric acid (100 mg) was taken in 10 mL of ethanol (Scheme 2). The resulting reaction mixture was refluxed for appropriate time.



Scheme 1. Preparation of pumice supported perchloric acid.



Scheme 2. Synthesis of tetrahydrobenzo[*b*]pyran derivatives (**4a–m**).

The progress of the reaction was confirmed by TLC. To separate out the catalyst pumice supported perchloric acid, the content was filtered at hot condition. After cooling the filtrate, the solid was separate out which was dried and purified by recrystalization using ethanol.

Result and discussion

The pumice supported perchloric acid was prepared from volcanic pumice and perchloric acid by simple agitation in diethyl ether which has characterized by various analytical techniques such as FTIR, XRD, EDAX, SEM, and TGA. The FTIR spectra of pumice supported perchloric acid showed that, the significant absorption band at 3413.95 cm^{-1} corresponding to the acidic proton in Pumice@$HClO_4$. In addition to this, the band appeared at 1637.53 cm^{-1} is due to the (Cl = O) bond and the bands at 1147.39 and 1090.09 cm^{-1} are related to Si–O–Si bonds (Figure 2(a)). These bands are not observed in FTIR of plane pumice (Figure 2(c)) except the band at 1036.86 cm^{-1}due to Si–O–Si bonds. This clearly indicates that, the perchloric acid was supported on pumice. Also the FTIR of recycled pumice@$HClO_4$ (Figure 2(b)) did not show any noteworthy deviation from pure pumice@$HClO_4$.

The EDAX analysis showed the composition of Pumice supported perchloric acid. This indicates that the synthesized catalyst composed of Si, O, Al, K, and Cl elements. The higher percentage of chlorine and oxygen proved that the perchloric acid was supported on Pumice (Figure 3(a)). Also the EDAX of recycled pumice@$HClO_4$ (Figure 3(b)) did not show any noteworthy composition of elements.

The XRD pattern of the catalyst was exhibited the broad characteristic peak between diffraction angle $2\theta = 15\text{-}30$ which demonstrated the amorphous nature of the Pumice supported perchloric acid (Figure 4(a)). Also the XRD of recycled pumice@$HClO_4$ (Figure 4(b)) did not show any significant change.

The SEM image showed that, pure as well as recycled pumice supported perchloric acid has no particular size and morphology (Figure 5(a,b)).

To investigate the thermal stability of the newly prepared pumice supported perchloric acid and pumice, the thermogravimetric analysis (TGA) was performed in the temperature range from 30 to 650 °C as shown in Figure 6(a,b). The literature survey revealed that, the –OH groups

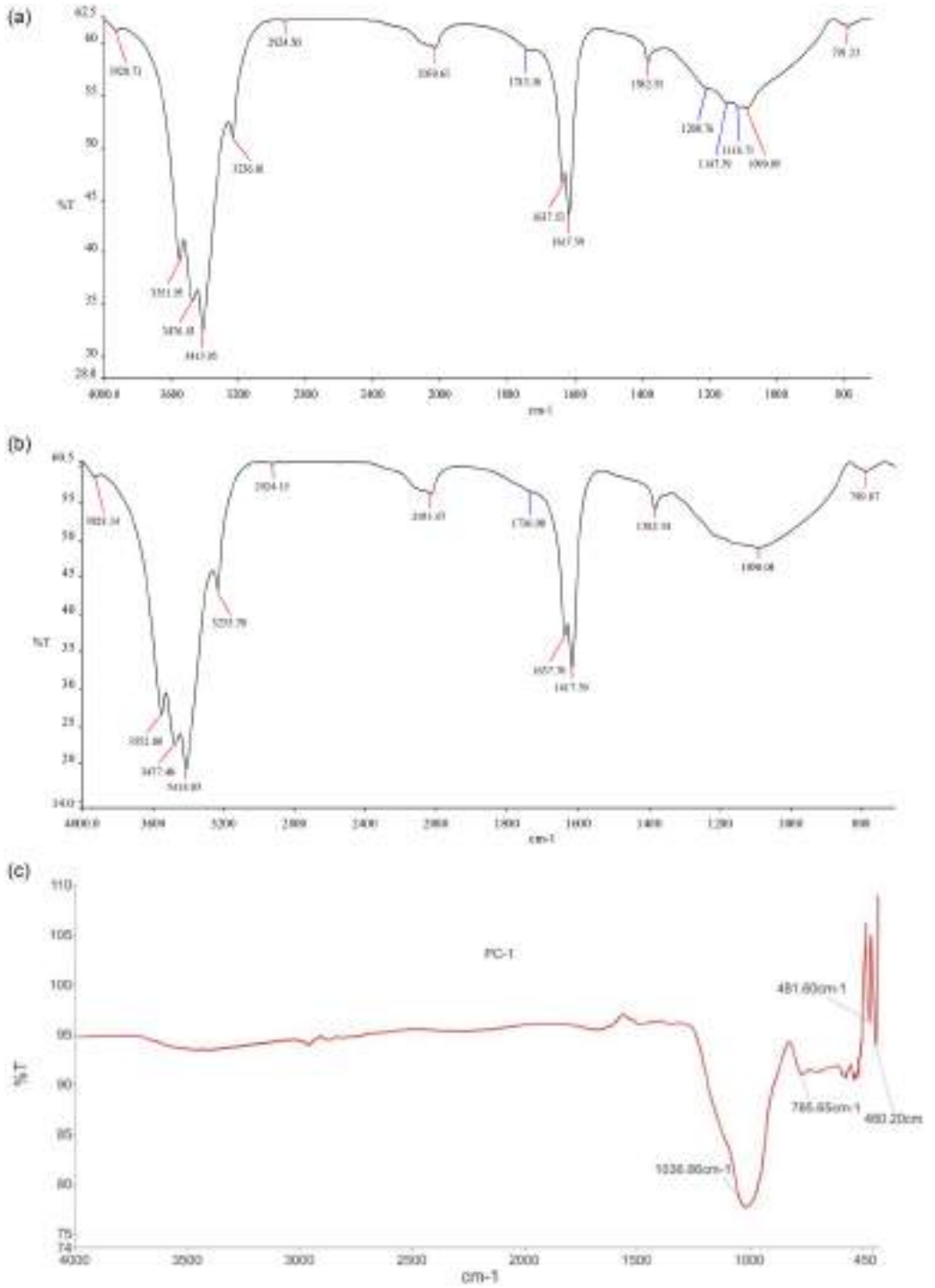


Figure 2. (a) FTIR of pumice supported perchloric acid (Pumice@$HClO_4$). (b) FTIR of recycled pumice supported perchloric acid (Pumice@$HClO_4$). (c) FTIR of pure pumice.

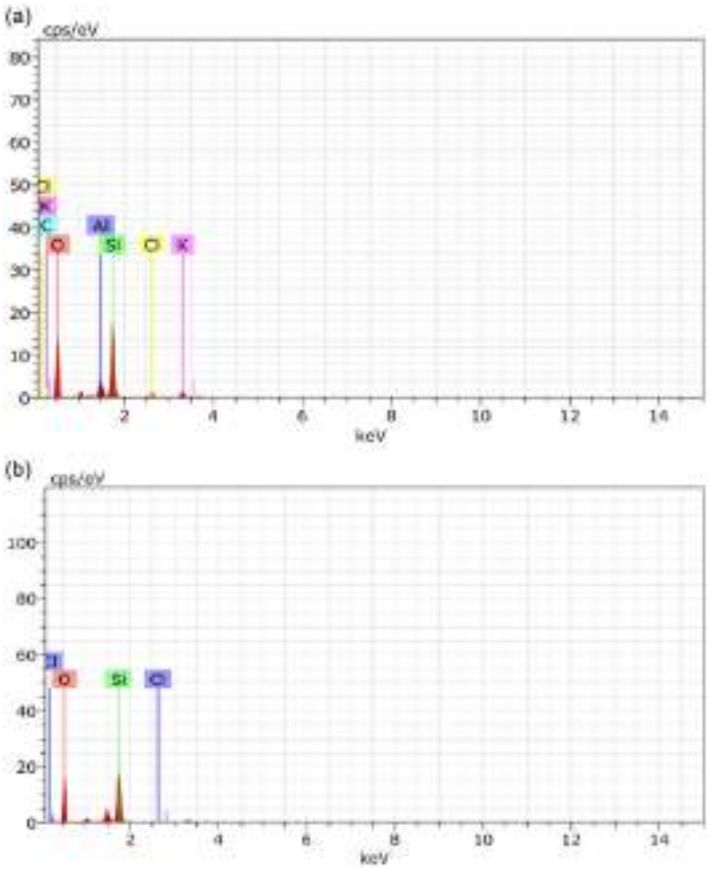


Figure 3. (a) EDAX of pumice supported perchloric acid (Pumice@$HClO_4$). (b) EDAX of recycled pumice supported perchloric acid (Pumice@$HClO_4$).

present in the catalytic material leave the structure by dehydration reaction at high temperature. The TGA of pumice supported perchloric acid (Figure 6(a)) and pumice (Figure 6(b)) showed that, 2.1% weight lost below 140 °C due to the removal of –OH groups in the form of water molecule present in the catalyst.

Study of acidic nature of pumice Supported perchloric Acid

The acidic nature of the catalyst was determined potentiometrically by following the standard method.[4] Initially the 0.1 g of pumice supported perchloric acid catalyst was taken in a titration flask containing 10 ml distilled water and the resultant mixture was titrated against the 0.1 N NaOH solution. The reading data of titration was used for plotting the graph of ΔE/ΔV against the volume of 0.1 N NaOH. From the graph, the acidic nature of catalyst was found to be 0.9 mmol/g at the equivalence point (Figure 7).

Optimization of the Reaction condition

The multi-component condensation reaction of 4-methyl benzaldehyde, dimedone and malononitrile was selected as pilot reaction (Scheme 3) to choose the optimize conditions for the synthesis of tetrahydrobenzo[*b*]pyran. Initially, the reaction was carried out under varying conditions such

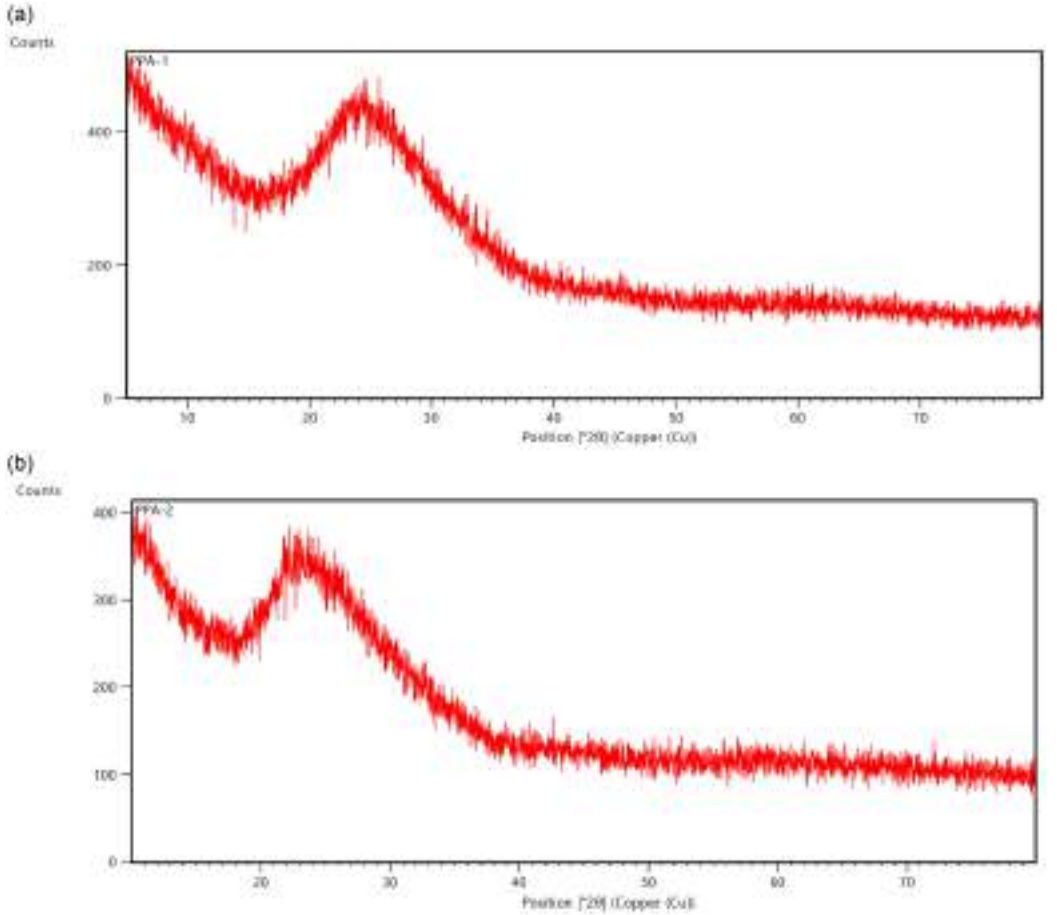


Figure 4. (a) XRD of pumice supported perchloric acid (Pumice@$HClO_4$). (b) XRD of recycled pumice supported perchloric acid (Pumice@$HClO_4$).

as the amount of catalyst, time, temperature and solvent medium (Table 1). The good result was obtained for pilot reaction with 100 mg of pumice supported perchloric acid catalyst (Table 2) in the presence of ethanol under reflux condition.

After the investigation of the exact optimized condition, it was employed for the synthesis of different tetrahydrobenzo[*b*]pyran derivatives by one-pot three component condensation of diverse aromatic aldehydes with malononitrile and dimedone. The best result was obtained for aldehydes containing electron donating as well as electron withdrawing groups in high yields and short period of time without appearing side product (Table 3).

Spectral data selected compounds

4a: 2-amino-5,6,7,8-tetrahydro-7,7-dimethyl-5-oxo-4-phenyl-4H-chromene-3-carbonitrile

White color; m.p. 222–224 °C; FTIR (cm^{-1}): 3396.57 (N–H), 2198.93 (CN), 1680.23 (C = O), 1660.44 (C = C), 1603.25 (C = C), 1451.14 (C = C), 1369.68 (C–O), 1213.49 (C–N); ^{1}H NMR ($CDCl_3$, 500 MHz) δ: 1.04 (s, 3H, $-CH_3$), 1.11 (s, 3H, $-CH_3$), 2.18–2.25 (m, 2H, $-CH_2-$), 2.45 (s, 2H, $-CH_2-$), 4.40 (s, 1H, –CH–), 4.57 (s, 2H, $-NH_2$), 7.19–7.30 (m, 5H, Ar–H) ; MS (ESI): m/z = 295.1469 [M + H].

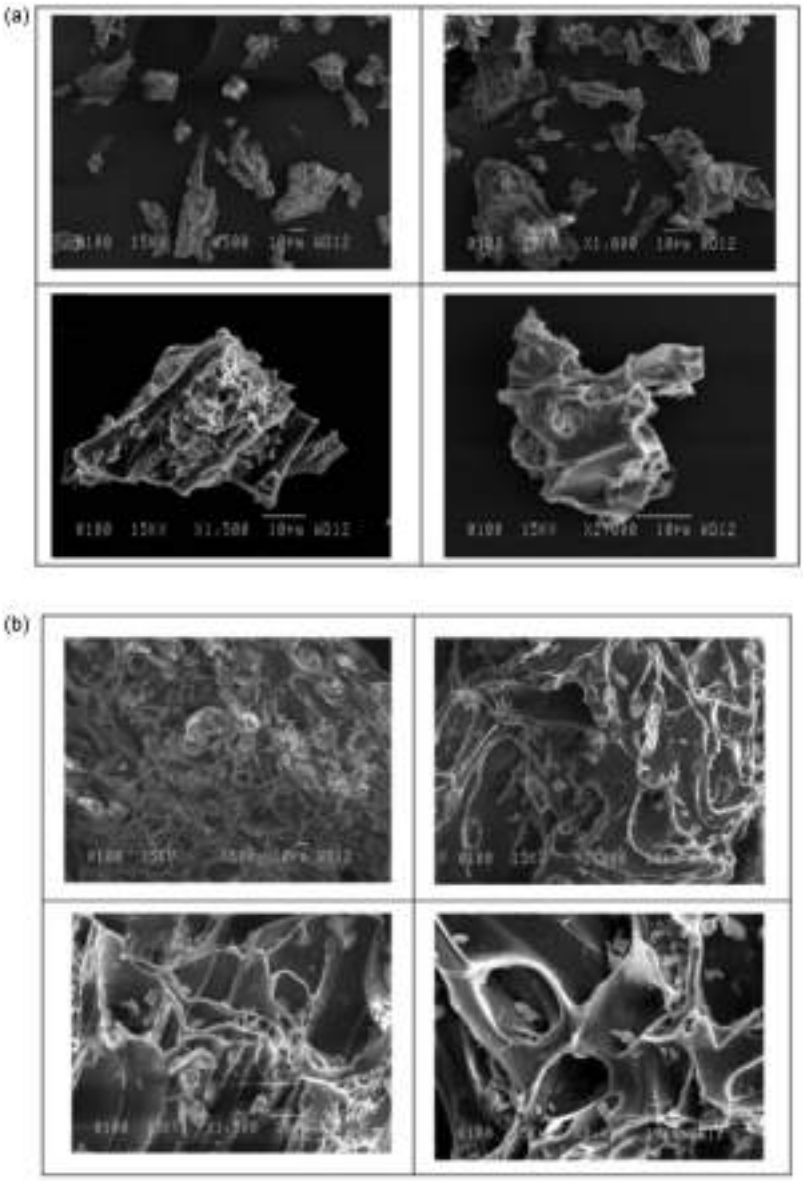


Figure 5. (a) SEM of pumice supported perchloric acid (Pumice@$HClO_4$). (b) SEM of recycled pumice supported perchloric acid (Pumice@$HClO_4$).

4b: 2-amino-5,6,7,8-tetrahydro-7,7-dimethyl-5-oxo-4-p-tolyl-4H-chromene-3-carbonitrile

White color; m.p. 214–216 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ: 1.04 (s, 3H, $-CH_3$), 1.11 (s, 3H, $-CH_3$), 2.17 (m, 2H, $-CH_2-$), 2.21 (s, 2H, $-CH_3$), 2.44 (s, 2H, $-CH_2-$), 4.36 (s, 1H, –CH–), 4.51 (s, 2H, $-NH_2$), 7.08 (m, 4H, Ar–H).

4c: 2-amino-4-(4-ethylphenyl)-5,6,7,8-tetrahydro-7,7-dimethyl-5-oxo-4H-chromene-3-carbonitrile

White color; m.p. 222–224 °C; FTIR (cm^{-1}): 3410.74 (N–H), 2188.62 (CN), 1682.53 (C = O), 1652.20 (C = C), 1618.21 (C = C), 1509.02 (C = C), 1369.47 (C–O), 1214.05 (C–N); ^{1}H NMR ($CDCl_3$, 500 MHz) δ: 0.99 (s, 3H, $-CH_3$), 1.10 (s, 3H, $-CH_3$), 1.26 (t, 3H, $-CH_3$), 2.19 (q, 2H,

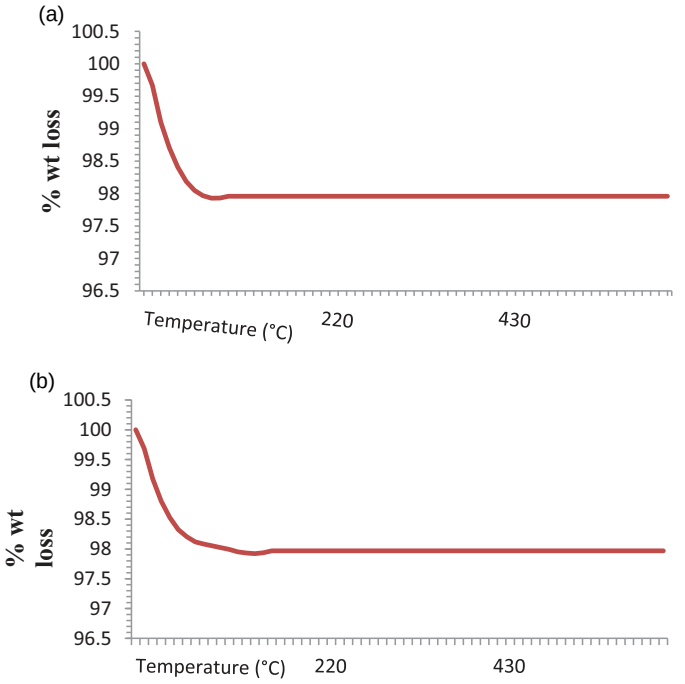


Figure 6. (a) TGA of pumice supported perchloric acid (Pumice@$HClO_4$). (b) TGA of pure pumice.

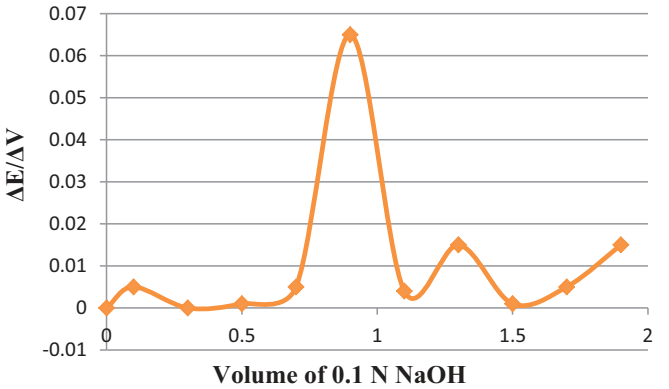
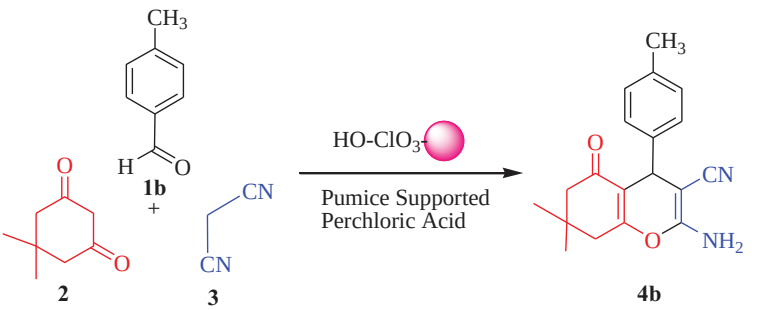


Figure 7. Study of acidic nature of pumice@$HClO_4$ by potentiometric titration.



Scheme 3. Pilot reaction for the synthesis of tetrahydrobenzo[*b*]pyran (**4b**).

Table 1. Optimization of reaction conditions for the synthesis of tetrahydrobenzo[*b*]pyran (**4b**).

Entry	Solvent system	Temperature	Time (min)	Yield (%)
1	Grinding	RT	60	NR
2	H_2O	RT	120	NR
3	EtOH	RT	120	NR
4	EtOH + H_2O (50%)	RT	120	NR
5	H_2O	Reflux	120	Trace
6	EtOH	Reflux	60	88
7	EtOH + H_2O (50%)	Reflux	60	40

Reaction condition: 4-methyl benzaldehyde (2 mmol), malononitrile (2 mmol), and dimedone (2 mmol), pumice supported perchloric acid catalyst (100 mg).

Table 2. Optimization of amount of catalyst for the synthesis of tetrahydrobenzo[*b*]pyran.

Entry	Amount of catalyst (mg)	Time (min)	Yield (%)
1	Absence of catalyst	60	NR
2	25	60	Trace
3	50	60	55
4	75	60	80
5	100	60	88
6	125	60	88

–CH_2–), 2.44 (m, 2H, –CH_2–), 2.59 (m, 2H, –CH_2–), 4.37 (s, 1H, –CH–), 4.56 (s, 2H, –NH_2), 7.09–7.14 (m, 4H, Ar–H) ; ^{13}C NMR ($CDCl_3$, 500 MHz) δ: 15.33, 27.76, 28.64, 28.87, 32.21, 35.12, 40.70, 50.70, 63.70, 114.18, 118.81, 127.41, 128.09, 140.48, 142.93, 157.47, 161.47, 195.97; MS (ESI): m/z = 323.1790 [M + H].

4d: 2-amino-5,6,7,8-tetrahydro-7,7-dimethyl-4-(4-nitrophenyl)-5-oxo-4H-chromene-3-carbonitrile

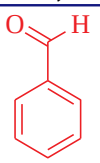
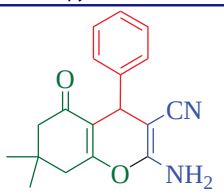
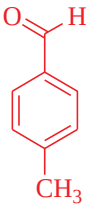
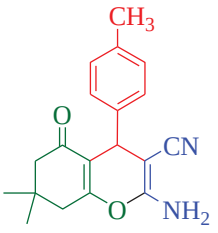
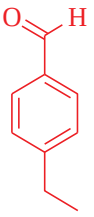
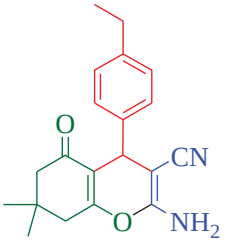
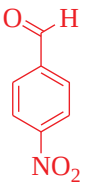
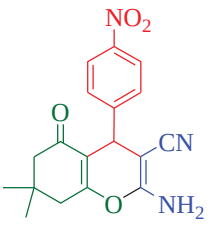
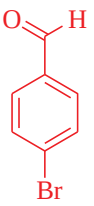
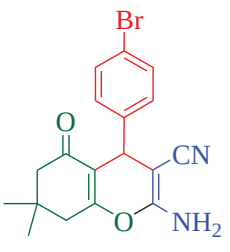
White color; m.p. 178–180 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ: 0.97 (s, 3H, –CH_3), 1.05 (s, 3H, –CH_3), 2.11–2.28 (m, 2H, –CH_2–), 2.54 (s, 2H, –CH_2–), 4.38 (s, 1H, –CH–), 7.17 (s, 2H, –NH_2), 7.45 (d, 2H, J = 8.7, Ar–H) , 8.17 (d, 2H, J = 8.7, Ar–H) ; ^{13}C NMR ($CDCl_3$, 500 MHz) δ: 26.83, 28.14, 31.69, 35.55, 49.75, 56.88, 111.63, 119.18, 123.53, 128.49, 146.15, 152.15, 158.47, 162.96, 195.54.

Recyclability and reusability of pumice supported perchloric acid

The recovery and reusability of the pumice supported perchloric acid catalyst make the protocol most valuable, unique and beneficial. After the completion of the reaction, the catalyst was separated from the reaction media at hot condition. It was washed with hot ethanol followed by chloroform and was dried at 80 °C temperature. The recovered catalyst was characterized by FTIR, EDAX, XRD and SEM as shown in Figures 2(b) to 5(b). The reusability of the catalyst was studied on the pilot reaction. The catalyst has been recycled and reused three times with 88, 87 and 84% of product yields, respectively.

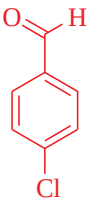
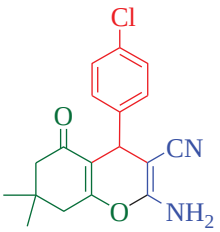
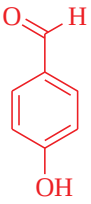
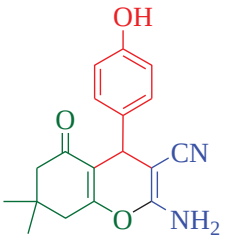
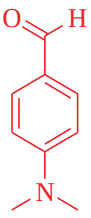
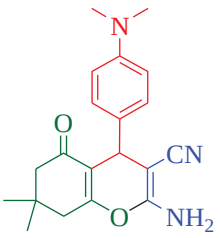
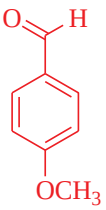
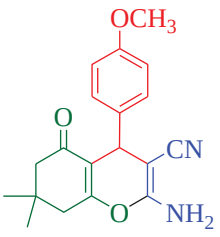
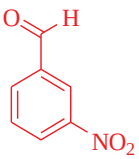
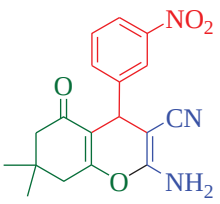
The comparison of the efficiency of pumice supported perchloric acid catalyst with the various reported protocols are mentioned in Table 4. From this investigation, it was found that the pumice supported perchloric acid catalyst showed a noteworthy activity for the synthesis tetrahydrobenzo[*b*]pyran derivatives. Also a current protocol has many advantages in comparison with

Table 3. Synthesis of tetrahydrobenzo[*b*]pyran derivatives (**4a–m**).

Entry	Aldehyde	Benzopyran derivative	Time (min.)	Yield (%)	M.P.(°C) Observed	M.P.(°C) Reported (ref.)
1		 **4a**	50	80	222–224	224[15]
2		 **4b**	60	88	214–216	213[15]
3		 **4c**	45	82	222–224	155–158[18]
4		 **4d**	50	84	178–180	179[15]
5		 **4e**	50	90	202–204	200–203[16]

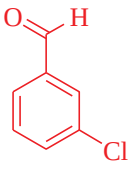
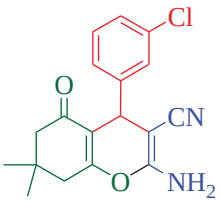
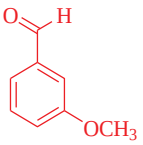
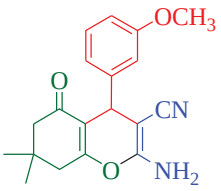
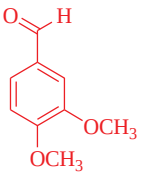
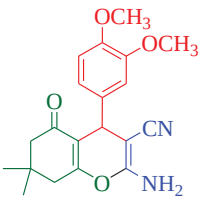
(*continued*)

Table 3. Continued.

Entry	Aldehyde	Benzopyran derivative	Time (min.)	Yield (%)	M.P.(°C) Observed	M.P.(°C) Reported (ref.)
6		 **4f**	45	90	198–200	206[15]
7		 **4g**	65	77	220–222	205[15]
8		 **4h**	60	82	188–190	198–200[15]
9		 **4i**	60	80	202–204	201[15]
10		 **4j**	60	76	212–214	210[15]

(*continued*)

Table 3. Continued.

Entry	Aldehyde	Benzopyran derivative	Time (min.)	Yield (%)	M.P.(°C) Observed	M.P.(°C) Reported (ref.)
11		 **4k**	40	82	202–204	226–228[16]
12		 **4l**	50	84	210–212	185–187[16]
13		 **4m**	65	78	164–166	132–141[18]

Reaction condition: Aldehyde (2 mmol), dimedone (2 mmol), and malanonitrile (2 mmol) were refluxed in 10 ml ethanol in the presence of pumice supported perchloric acid (100 mg)

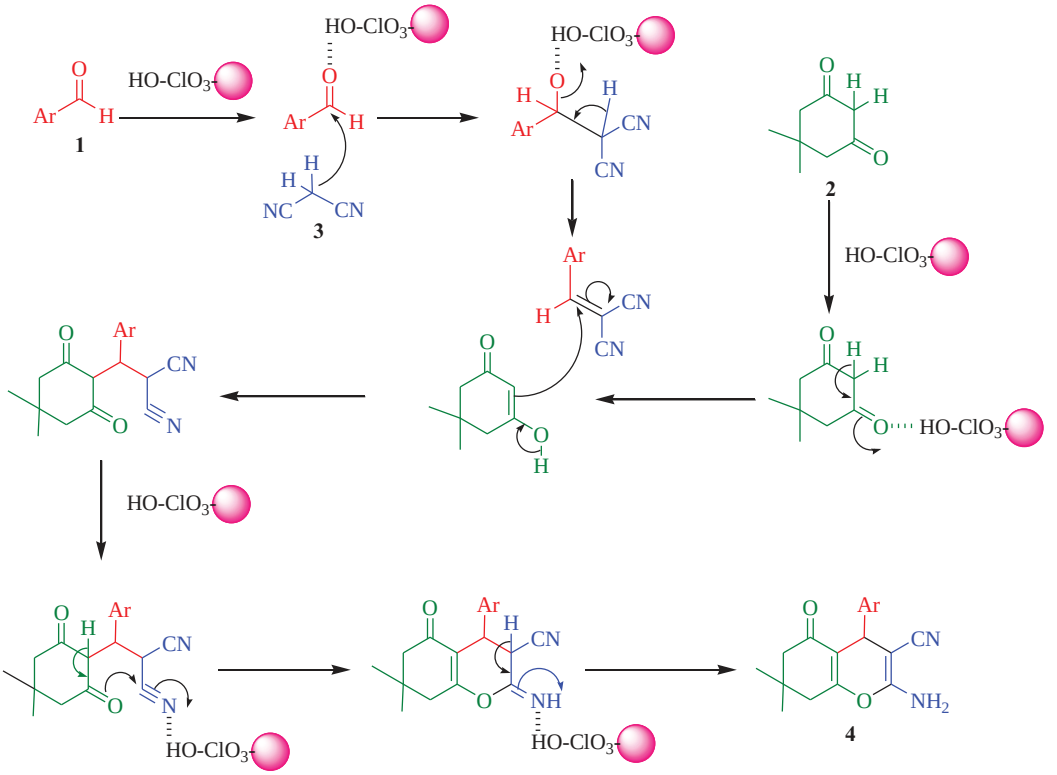
Table 4. Comparison of the efficiency of pumice@$HClO_4$ for the synthesis of tetrahydro-benzo[*b*]pyran derivative with other protocols.

Entry	Catalyst used	Reaction condition	Time (min)	Yield (%)	Ref. no.
1	CTMAB-bentonite	H_2O:EtOH (1:1) / RT	05–10	80–99	[20]
2	Nano-titania sulfuric acid	EtOH / US / 40 °C	10–30	85–97	[21]
3	MNPs–$PhSO_3H$	H_2O:EtOH (1:1) / 100 °C	10–60	65–95	[23]
4	Molecular sieve-supported Zinc	EtOH/reflux	240	85–98	[24]
5	SiO_2 nano-particles	EtOH/RT	25–30	86–98	[25]
6	Xanthum gum supported Fe_3O_4	EtOH/RT	05–20	84–96	[35]
7	Phosphotungstic acid supported on SiO_2@$NHPhNH_2$	SF/ 80 °C	25–30	85–94	[36]
8	Fe_3O_4@PEO-SO_3H	EtOH/RT	25–40	85–95	[37]
9	Magnetic aluminosilicate nanoclay	SF/ 40 °C	20–30	93–96	[38]
10	Fe_3O_4@SiO_2–NH_2	SF/ 60 °C	80–120	78–93	[39]
11	Pumice @$HClO_4$	EtOH/reflux	45–65	78–90	Present work

reported methods such as cheap and readily available volcanic material, smooth reaction condition and purification of targeted molecule without column chromatography.

Plausible mechanism

The plausible mechanism for the synthesis of tetrahydrobenzo[*b*]pyran derivatives using pumice supported perchloric acid were shown in Scheme 4.



Scheme 4. Plausible mechanism of Pumice@$HClO_4$ catalyzed synthesis of benzopyran.

Conclusion

In conclusion, we have investigated a novel, highly efficient protocol for the synthesis of tetrahydrobenzo[*b*]pyran in the presence of heterogeneous catalyst pumice supported perchloric acid via multi-component condensation of aromatic aldehydes, dimedone and malononitrile under reflux condition. The catalyst was characterized by IR, XRD, EDS, SEM, and TGA techniques which showed the formation novel pumice supported perchloric acid. The present protocol proved to have numerous advantages like one-pot reaction, quantitative yield of the targeted molecule, short reaction time, mild conditions inexpensive catalyst, recyclability and reusability of the catalyst, smooth experimental condition, simple work up procedure and purification of targeted molecule without column chromatography.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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PUMICE@SO_3H CATALYZED ULTRASOUND MEDIATED SYNTHESIS OF POLYHYDROQUINOLINE DERIVATIVES.

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Abstract:
A sustainable and convenient protocol is developed for the synthesis of polyhydroquinoline derivatives under ultrasound irradiation at 45°C in the presence of pumice anchored sulfonic acid (Pumice@SO_3H) as a recoverable catalyst. These polyhydroquinolines were synthesized from aldehydes, dimedone, ethylacetoacetate and ammonium acetate by Hantzsch reaction. The attractive features of the present protocol are green approach, good yield, recovery of catalyst, easy work-up procedure and simple purification of product whereas the catalyst offers simple preparation, high catalytic activity, inexpensive, easy to use, recyclability and stability.

Keywords:
Pumice@SO_3H, polyhydroquinolines, ultrasound irradiation, dimedone, etc.

Introduction:

Pumice stone obtained due to volcanic eruptions has many advantages such as abundance, availability, large surface area, low cost, non-homogeneous nature, and excellent stability. Also due to the remarkable properties such as high porosity and high adsorption capacities have gained much interest in the field of catalysis. In recent years, the volcanic pumice converted into variety of supported active catalytic materials such as pumice@SO_3H[i, ii], Pd–Ag catalysts supported on pumice[iii], Pumice-modified cellulose fiber[iv], Volcanic based hybrid nanocomposite[v], Pumice supported Pd catalyst[vi], Immobilization of TiO_2 on pumice stone[vii], iron-coated pumice[viii, ix], pumice-supported Pd–Cu catalysts[x], etc.

Multi-component reactions (MCRs) are a constructive approach to synthesize heterocyclic compounds with diverse structures. In MCRs, more than two components reacts together in single step to produce a targeted heterocyclic system without isolation of any intermediate. Due to this, requires short time, reduce energy requirement, reduce quantity of precursors, and are useful to increase atom economy. The Hantzsch reaction is one of the most important examples of multicomponent reaction which is used for synthesis of polyhydroquinoline derivatives[xi, xii]. The polyhydroquinoline derivatives is of great attention due to their various activities such as anti-cancer, anti-diabetic, anti-hypertensive, anti-inflammatory, anti-microbial, anti-

tubercular, anti-tumor, bronchodilator, calcium channel blockers, cardiovascular agents, geroprotective, hepatoprotective, neurotropic, and vasodilator[xiii-xxii] etc. These versatile activities have encouraged researchers to design sustainable and convenient catalytic materials for the synthesis of heterocyclic compounds containing polyhydroquinoline moiety. Some illustrations of drugs with 1,4-dihydropyridine framework are outlined in **Fig. 1**.

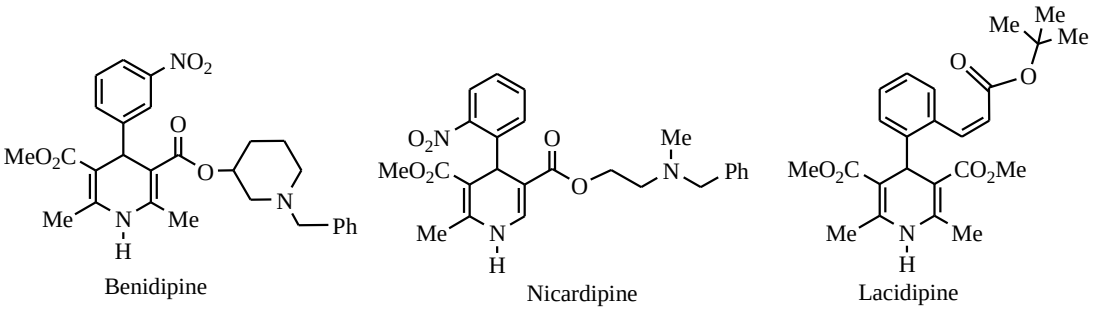


Fig.1. some drugs containing 1,4-dihydropyridine framework

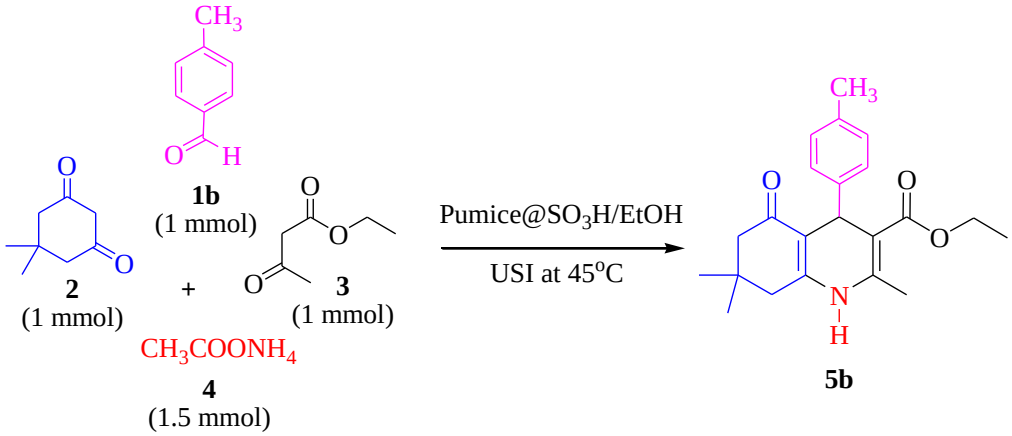
Recently, numerous protocols have been developed for the synthesis of polyhydroquinolines from aromatic aldehyde, dimedone, ethylacetoacetate and ammonium acetate such as nano-materials[xxiii], metal oxide supported materials[xxiv], magnetic materials[xxv], ionic liquids[xxvi], amino acids[xxvii], solar thermal energy[xxviii], Zeolite[xxix], microwave[xxx], and ultrasound[xxxi] etc. Also various bronsted acidic catalyst are used such as Fe_3O_4/SiO_2-OSO_3H[xxxii], silica sulfuric acid[xxxiii], nicotinic acid[xxxiv], Acetic acid[xxxv], Aluminized polyborate[xxxvi], PPA-SiO_2[xxxvii], SBA-15/SO_3H[xxxviii], SBA-15@Glycine[xxxix], PMO-ICS-PrSO_3H[xl], BINOL-phosphoric acid[xli], Carbon-based Solid acid (CBSA)[xlii], COF-SO_3H [xliii], Fe_3O_4@FSM-16-SO_3H [xliv], *p*-TSA[xlv], [MSAIM]HSO_4[xlvi], [Pyridine-SO_3H]Cl[xlvii], Caffeine-H_3PO_4[xlviii], ascorbic acid[xlix], Fe_3O_4@PEO-SO_3H[l], etc.

The ultrasound (US) assisted synthesis is well developed method used for the synthesis of variety of heterocyclic compounds. It proceeds through the development and adiabatic collapse of the transient cavitations bubble. It is used as a green approach that helping to reduce high energy requirements. The US approach provides smooth and cleaner reactions procedure with increasing yields in presence of various catalytic processes [li-lvii].

In continuation of our environmentally benign work [lviii-lxii] and on the application of pumice@SO_3H catalysts[i, ii], here we report a convenient green approach for one-pot synthesis of polyhydroquinolines in the presence pumice anchored sulfonic acid as a bronsted acidic catalyst with good catalytic activity and recyclability.

Results and Discussion:

In order to choose the better reaction condition a model reaction (**Scheme 1**) of *p*-methyl benzaldehyde, dimedone, ethyl acetoacetate and ammonium acetate was carried out in presence of catalyst pumice@SO_3H with and without catalyst and solvent. The reaction did not proceed to any extent in absence of catalyst with and without solvent during stirring at room temperature (**Table 1, Entry 1-3**). Also the negative result was obtained with pumice@SO_3H catalyst at room temperature in presence water and ethanol as well as without solvent under ultrasound irradiation (**Table 1, Entry 4-6**). The reaction proceeds smoothly with catalyst pumice@SO_3H in presence of ethanol as solvent at 45^{o}C under ultrasound irradiation with excellent yield (**Table 1, Entry 7**).



Scheme 1. Model reaction for synthesis of Polyhydroquinoline (**5b**) derivative

Table 1: Optimization of reaction condition for the synthesis of polyhydroquinoline (**5b**)

Entry	Catalyst / Solvent	Reaction Condition	Time in hrs.	Yield [b] in %
1	90 mg pumice@SO_3H / Solvent free	Grinding	0.5	No reaction (NR)
2	90 mg pumice@SO_3H / H_2O	Stirring at RT	3	NR
3	90 mg pumice@SO_3H / EtOH	Stirring at RT	3	NR
4	90 mg pumice@SO_3H / H_2O	USI at RT	3	NR
5	90 mg pumice@SO_3H / H_2O	USI at 45°C	3	NR
6	90 mg pumice@SO_3H / EtOH	USI at RT	3	Trace
7	90 mg pumice@SO_3H / EtOH	USI at 45°C	1.5	80

[a]Reaction condition: **1b** (0.120gm, 1mmol), **2** (0.140gm, 1mmol), **3** (0.130gm, 1mmol), **4** (0.107gm, 1.5mmol), pumice@SO_3H (90 mg), [b]Isolated Yield

Table 2: Optimization of quantity of catalyst for the synthesis of polyhydroquinoline (**4b**)

Entry	Pumice@SO_3H Catalyst (mg)	Time (hrs)	Yield[b] (%)
1	40	2	25
2	60	2	45
3	80	2	70
4	90	1.5	80
5	90	1.5	80

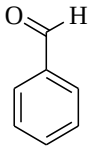
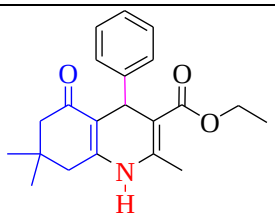
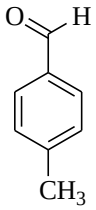
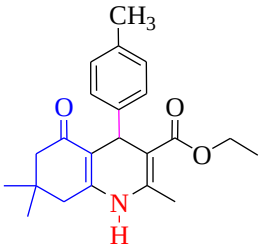
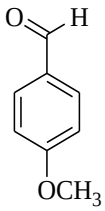
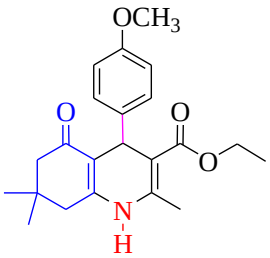
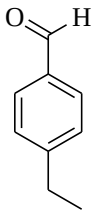
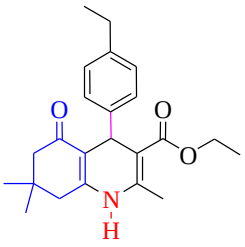
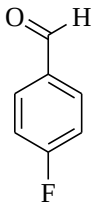
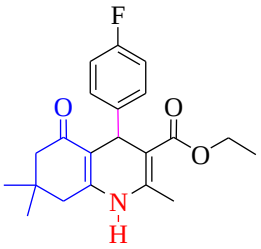
[a]Reaction condition: **1b** (0.120gm, 1mmol), **2** (0.140gm, 1mmol), **3** (0.130gm, 1mmol), **4** (0.107gm, 1.5mmol), USI at 45°C, [b] Isolated Yield

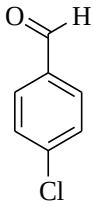
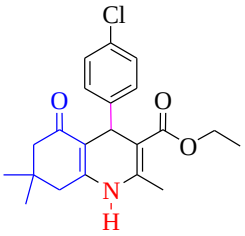
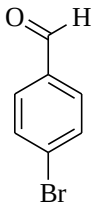
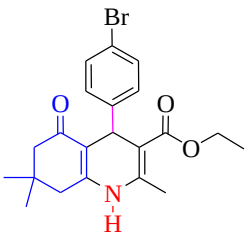
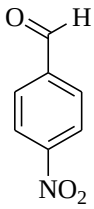
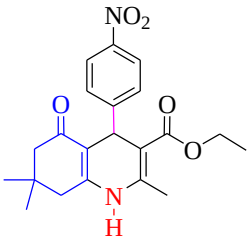
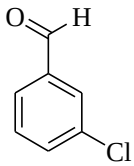
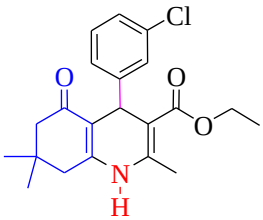
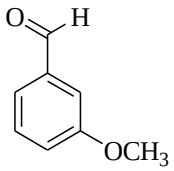
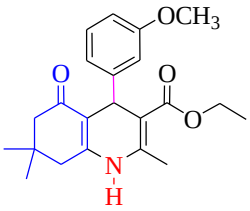
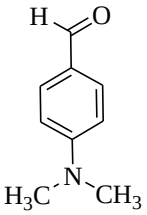
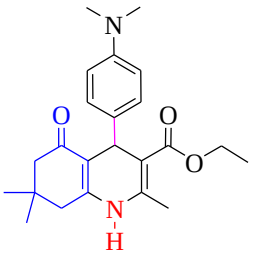
The model reaction was then studied for different amount of catalyst to optimize the amount of catalyst required (**Table 2**). It was found that further increase in the amount of catalyst, there was no significant improvement in the yield of the product.

This outcome enhanced our attention to study the scope, generality and relevance of this protocol for the synthesis of Polyhydroquinoline (**5a-k**) derivatives. The series of Polyhydroquinoline were synthesized using diverse aromatic aldehydes under above optimized

conditions with good yield (74-86%) as mentioned in **Table 3**. The protocol worked very well with aldehydes containing electron deficient and electron rich substituent.

Table 3: Data of synthesized Polyhydroquinoline (**5a-k**) derivatives

Entry	Aldehyde	Product	Time (hrs)	Yield (%)	M.P. (°C)	
					Observed	Reported
1		 **5a**	1.5	85	214-216	217–219[35]
2		 **5b**	1.5	80	252-256	260–262[35]
3		 **5c**	2.0	78	257-260	258–260[35]
4		 **5d**	1.5	80	220-224	--
5		 **5e**	1.5	79	182-184	185–186[35]

6		 **5f**	2.0	82	240-242	245–246[35]
7		 **5g**	2.0	78	250-252	254–256[35]
8		 **5h**	2.0	75	238-240	240–242[35]
9		 **5i**	1.5	80	204-206	205–206[35]
10		 **5j**	1.5	76	192-194	198–200[35]
11		 **5k**	1.5	80	236-238	228–231[29]

[a]Reaction condition: **1a-k** (0.120gm, 1mmol), **2** (0.140gm, 1mmol), **3** (0.130gm, 1mmol), **4** (0.107gm, 1.5mmol), USI at 45°C

After the completion of the reaction, the catalyst used has been recovered by heating the reaction mixture up to the boiling. The resultant hot solution was filtered at hot condition to separate the catalyst. The recovered catalyst was washed with dichloromethane 2-3 times and dried to reuse. The recycled catalyst was reused under the optimal conditions in three cycles of the similar transformation (**Fig. 2**). The formation of Pumice@SO_3H catalyst was proved by spectral studies such as FT-IR, XRD, SEM, TEM and EDS etc. which are reported in our previous work[i]. Here the evidences of recyclability study are provided. The FT-IR, XRD and EDS spectra of the recycled pumice@SO_3H catalyst after third cycle did not show any significant change in catalytic activity.

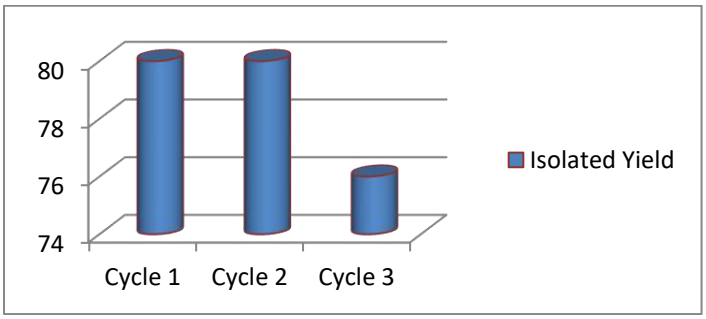


Fig. 2. Reusability of the pumice@SO_3H for the synthesis of Polyhydroquinoline (**4b**)

In the FT-IR spectrum of the recycled pumice@SO_3H (**Fig. 3**), the broad band at 3414.35 cm^{-1} is appeared due to O-H group in sulfonic acid. Also the important bands at 1637.32 cm^{-1} and 1111.05 cm^{-1} are appeared due to the S=O and Si–O–Si respectively. These significant bands indicate that, the recovery of -SO_3H group in the recycled catalyst.

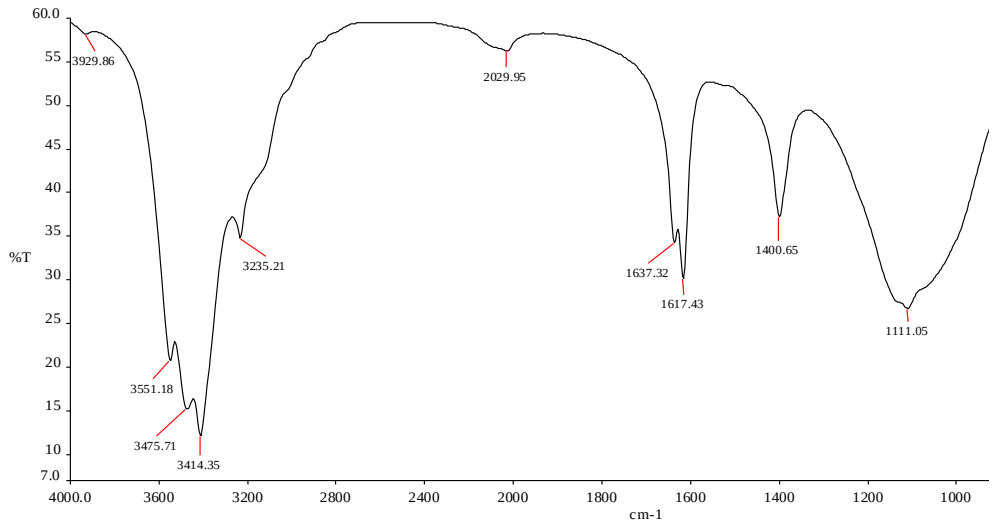


Fig. 3. IR Spectrum of Pumice@SO_3H catalyst

The nature of XRD (**Fig. 4**) and EDS (**Fig. 5**) of recycled catalyst was precisely matched with the reported catalyst. It showed that, the recycled catalyst did not show any variation in composition.

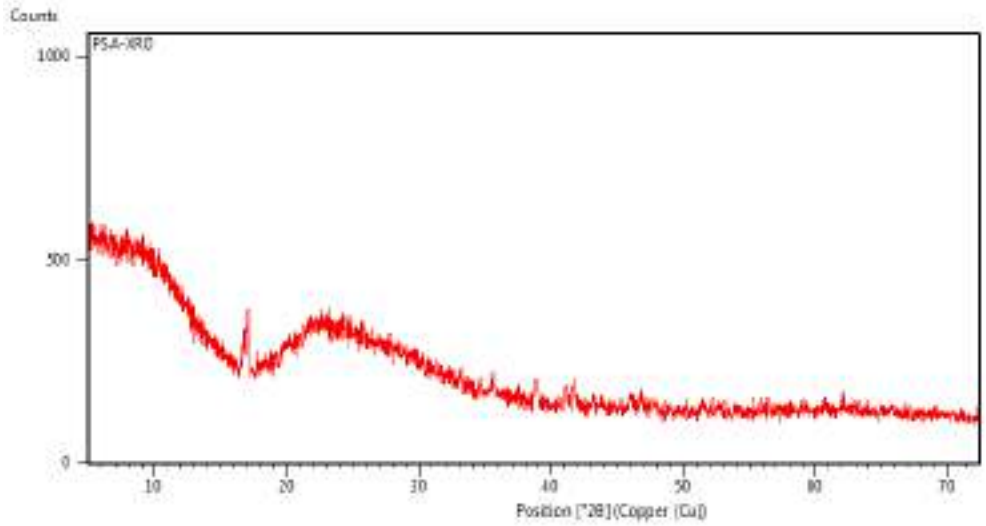


Fig.4. XRD of Pumice@SO_3H catalyst

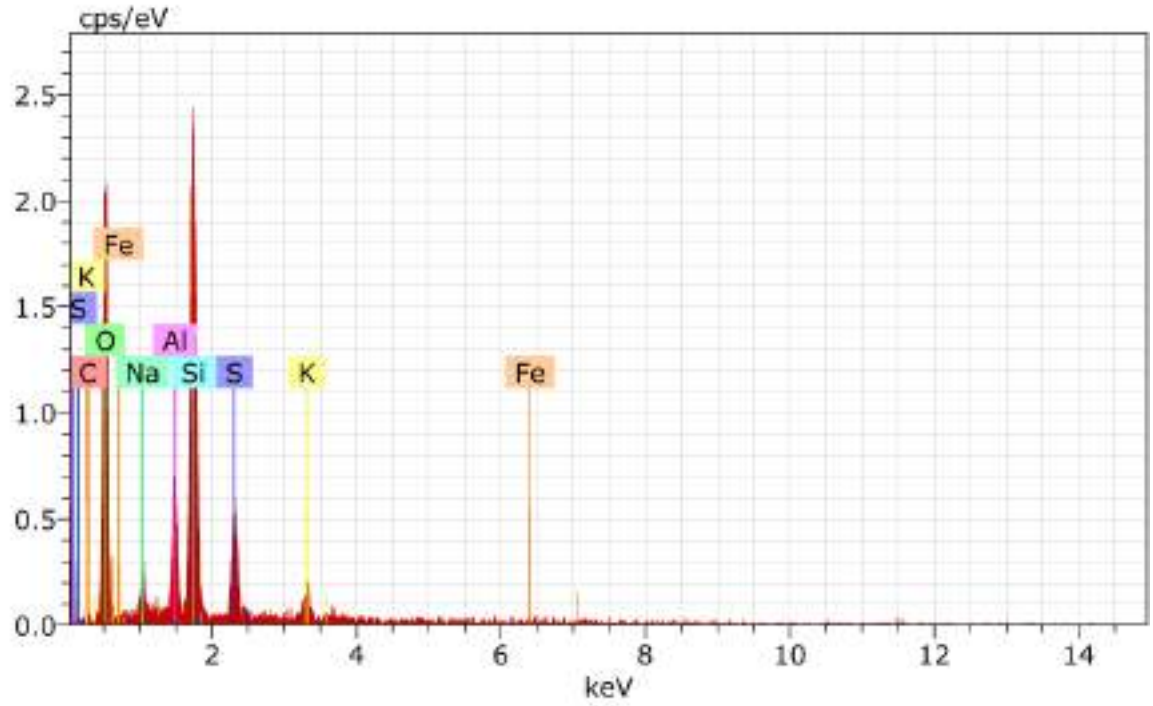


Fig.5. EDS of Pumice@SO_3H catalyst

The comparative study of different protocols for synthesis of polyhydroquinolene derivatives is illustrated in **Table 4**. While the plausible mechanism involved in Pumice@SO_3H promoted synthesis of polyhydroquinolines is shown in **Scheme 4.**

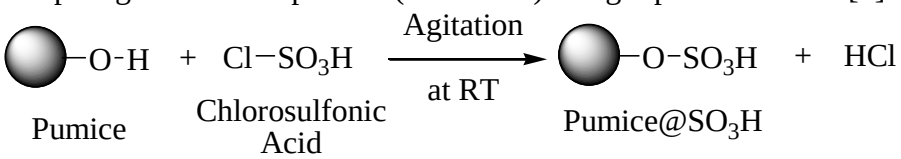
Table 4: Comparative study of different protocols for synthesis of polyhydroquinolene (**5b**)

Entry	Catalyst	Reaction Condition	Quantity of Catalyst in gm	Time in min	Yield (%)	Reference
1	Silica Sulfuric acid	Solvent free/60^oC	0.080	50	92	33

2	Nicotinic acid	Solvent free/80°C	0.1	07	92	34
3	PPA-SiO_2	Solvent free/80°C	0.030	60	90	37
4	PMO-ICS-PrSO_3H	Reflux/EtOH	0.020	20	95	40
5	CBSA	Solvent free/90°C	0.020	35	88	42
6	COF-SO_3H	Solvent free/90°C	0.020	10	95	43
7	Pumice@SO_3H	EtOH/USI, 45°C	0.090	90	80	Present work

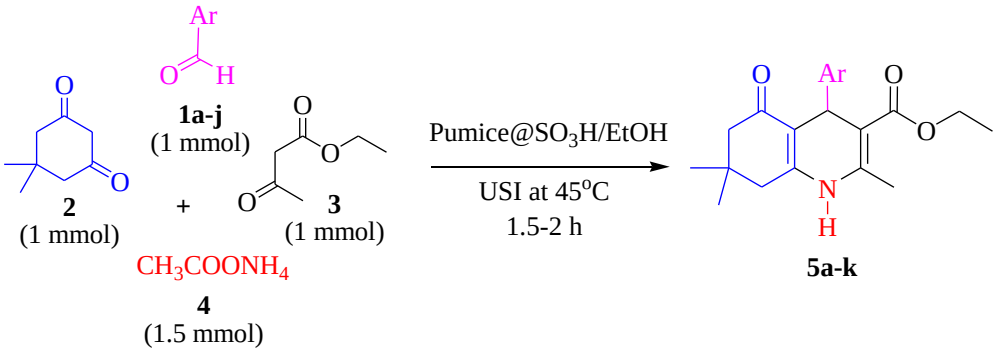
Experimental:
Melting points were recorded in an open capillary and are uncorrected. Infra Red spectra were recorded on a Perkin-Elmer FTIR spectrophotometer. The ^{1}H-NMR and ^{13}C-NMR spectra were recorded on a BRUCKER AVANCE NEO 500MHz NMR Spectrometer in $CDCl_3$ using Tetramethyl silane as a reference compound. Mass spectra were recorded on a Finnigan Mass spectrometer. TLC was carried out by Al-plates pre-coated with silica gel to check the purity of the compounds.

Preparation of pumice anchored sulfonic acid (pumice@SO_3H) catalyst
In the present work, the catalyst pumice anchored sulfonic acid (pumice@SO_3H) has been prepared by simple agitation from pumice (**Scheme 2**) using reported method [1].



Scheme 2: Preparation of pumice anchored sulfonic acid (pumice@SO_3H) catalyst

General procedure for the synthesis of polyhydroquinoline derivatives (5a-k)
A mixture of aldehyde **1** (1 mmol), 5,5-dimethylcyclohexane-1,3-dione **2** (1mmol), ethyl acetoacetate **3** (1 mmol), ammonium acetate **4** (1.5 mmol) and 90 mg of pumice based sulfonic acid was taken in a 100 mL round bottom flask containing 15 mL of ethyl alcohol. The resulting reaction mixture was subjected for ultrasound irradiation at 45°C temperature for appropriate time (**Scheme 3**). The progress of the reaction was studied using TLC. After the completion, the reaction mixture was heated up to the boiling. The resultant hot solution was filtered at hot condition to separate the catalyst. The recovered catalyst was washed with dichloromethane 2-3 times and dried to reuse. After the separation of catalyst, cool the mother liquor, the solid polyhydroquinoline thus obtained. It was dried and in some cases it was purified by recrystallization using hot ethanol.



Scheme 3: Synthesis of Polyhydroquinoline (**5a-k**) derivatives

Discussion of Spectra:

5b: ethyl 1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxo-4-*p*-tolylquinoline-3-carboxylate

^{1}H NMR (500 MHz, $CDCl_3$): 0.93 (s, 3H, -CH_3), 1.05 (s, 3H, -CH_3), 1.21 (t, 3H, -CH_3), 2.20 (s, 3H, -CH_3), 2.12-2.24 (m, 4H, -CH_2-x2), 2.31 (s, 3H, -CH_3), 4.06 (q, 2H, -OCH_2-), 5.01 (s, 1H, -CH-), 6.66 (s, 1H, NH), 6.99 (d, 2H, *J*=8Hz, Ar-H), 7.18 (d, 2H, *J*=8Hz, Ar-H); ^{13}C NMR (125 MHz, $CDCl_3$): 195.75, 167.58, 148.79, 144.27, 143.56, 135.38, 128.60, 127.87, 112.05, 106.14, 59.78, 50.81, 40.91, 36.14, 32.67, 29.45, 27.19, 21.04, 19.26, 14.24; MS (ESI) : m/z = 354.2110 [M+H].

5c: ethyl 1,4,5,6,7,8-hexahydro-4-(4-methoxyphenyl)-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate

^{1}H NMR (500 MHz, $CDCl_3$): 0.93 (s, 3H, -CH_3), 1.06 (s, 3H, -CH_3), 1.20 (t, 3H, -CH_3), 2.13-2.30 (m, 4H, -CH_2-x2), 2.35 (s, 3H, -CH_3), 3.73 (s, 3H, -OCH_3), 4.07 (q, 2H, -OCH_2-), 4.99 (s, 1H, -CH-), 6.26 (s, 1H, NH), 6.73 (m, 2H, Ar-H), 7.20 (m, 2H, Ar-H); MS (ESI) : m/z = 370.2005 [M+H].

5d: ethyl 4-(4-ethylphenyl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate

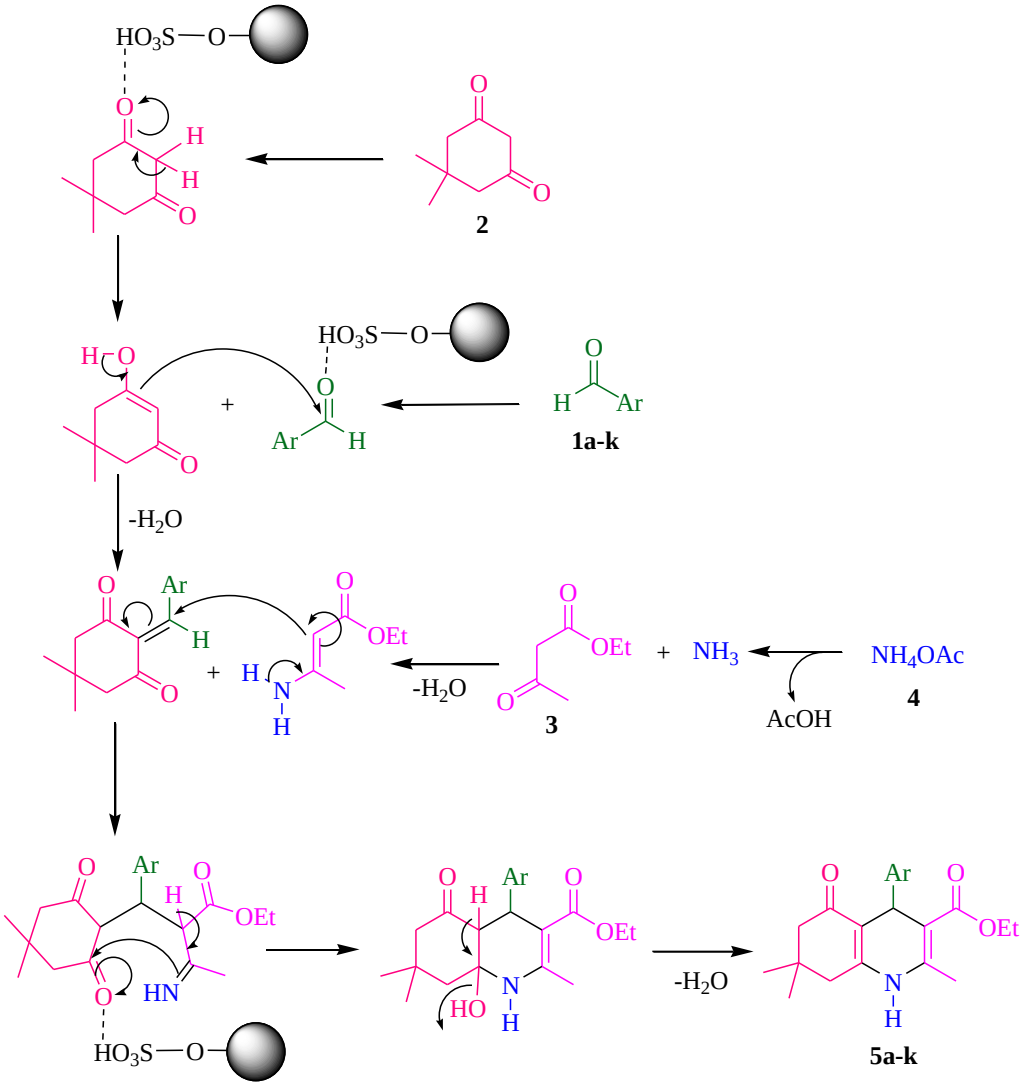
^{1}H NMR (500 MHz, $CDCl_3$): 0.95 (s, 3H, -CH_3), 1.06 (s, 3H, -CH_3), 1.17 (t, 3H, -CH_3), 1.21 (t, 3H, -CH_3), 2.13-2.29 (m, 4H, -CH_2-x2), 2.32 (s, 3H, -CH_3), 2.55 (q, 2H, -CH_2-), 4.06 (q, 2H, -OCH_2-), 5.02 (s, 1H, -CH-), 6.41 (s, 1H, NH), 7.01 (d, 2H, *J*=8Hz, Ar-H), 7.19 (d, 2H, *J*=8Hz, Ar-H); ^{13}C NMR (125 MHz, $CDCl_3$): 195.69, 167.58, 148.49, 144.39, 143.37, 141.68, 127.87, 127.35, 112.16, 106.25, 59.79, 50.79, 41.03, 36.10, 32.71, 29.41, 28.40, 27.28, 19.32, 15.35, 14.23.

5f: ethyl 4-(4-chlorophenyl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate

^{1}H NMR (500 MHz, $CDCl_3$): 0.92 (s, 3H, -CH_3), 1.07 (s, 3H, -CH_3), 1.18 (t, 3H, -CH_3), 2.13-2.32 (m, 4H, -CH_2-x2), 2.36 (s, 3H, -CH_3), 4.05 (q, 2H, -OCH_2-), 5.02 (s, 1H, -CH-), 6.29 (s, 1H, NH), 7.16 (m, 2H, Ar-H), 7.23 (m, 2H, Ar-H); MS (ESI) : m/z = 374.1595 [M+H].

5k: ethyl 4-(4-(dimethylamino)phenyl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate

^{1}H NMR (500 MHz, $CDCl_3$): 0.95 (s, 3H, -CH_3), 1.04 (s, 3H, -CH_3), 1.24 (t, 3H, -CH_3), 2.12-2.25 (m, 4H, -CH_2-x2), 2.33 (s, 3H, -CH_3), 2.85 (s, 6H, -$N(CH_3)_2$), 4.06 (q, 2H, -OCH_2-), 4.96 (s, 1H, -CH-), 6.58 (d, 2H, *J*=8.5Hz, Ar-H), 6.64 (s, 1H, NH), 7.15 (d, 2H, *J*=8.5Hz, Ar-H); ^{13}C NMR (125 MHz, $CDCl_3$): 195.84, 167.77, 148.94, 148.56, 143.18, 136.02, 128.61, 112.38, 112.24, 106.43, 59.71, 50.84, 40.85, 40.75, 35.38, 32.65, 29.49, 27.28, 19.28, 14.30; MS (ESI) : m/z = 383.2254 [M+H].



Scheme 4: Pluasible mechanism for the synthesis of Polyhydroquinolines

Conclusion:

In summary, we have discovered a sustainable and convenient protocol for the synthesis of polyhydroquinoline derivatives using pumice anchored sulfonic acid (Pumice@SO_3H) as an efficient catalyst under ultrasound irradiation. The attractive features of present protocol are green approach, good yield, recovery of catalyst and easy work-up procedure whereas the catalyst offers simple preparation, high catalytic activity, inexpensive, easy to use, recyclability and good stability.

Abbreviations:

MCRs	= Multicomponent Reactions,
Pumice@SO_3H	= Pumice supported sulfuric acid,
NR	= No Reaction,
RT	= Room Temperature,
SF	= Solvent Free,
USI	= Ultrasound Irradiation.

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PUMICE@SO_3H CATALYZED ULTRASOUND MEDIATED SYNTHESIS OF POLYHYDROQUINOLINE DERIVATIVES.

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Abstract:
A sustainable and convenient protocol is developed for the synthesis of polyhydroquinoline derivatives under ultrasound irradiation at 45°C in the presence of pumice anchored sulfonic acid (Pumice@SO_3H) as a recoverable catalyst. These polyhydroquinolines were synthesized from aldehydes, dimedone, ethylacetoacetate and ammonium acetate by Hantzsch reaction. The attractive features of the present protocol are green approach, good yield, recovery of catalyst, easy work-up procedure and simple purification of product whereas the catalyst offers simple preparation, high catalytic activity, inexpensive, easy to use, recyclability and stability.

Keywords:
Pumice@SO_3H, polyhydroquinolines, ultrasound irradiation, dimedone, etc.

Introduction:

Pumice stone obtained due to volcanic eruptions has many advantages such as abundance, availability, large surface area, low cost, non-homogeneous nature, and excellent stability. Also due to the remarkable properties such as high porosity and high adsorption capacities have gained much interest in the field of catalysis. In recent years, the volcanic pumice converted into variety of supported active catalytic materials such as pumice@SO_3H[i, ii], Pd–Ag catalysts supported on pumice[iii], Pumice-modified cellulose fiber[iv], Volcanic based hybrid nanocomposite[v], Pumice supported Pd catalyst[vi], Immobilization of TiO_2 on pumice stone[vii], iron-coated pumice[viii, ix], pumice-supported Pd–Cu catalysts[x], etc.

Multi-component reactions (MCRs) are a constructive approach to synthesize heterocyclic compounds with diverse structures. In MCRs, more than two components reacts together in single step to produce a targeted heterocyclic system without isolation of any intermediate. Due to this, requires short time, reduce energy requirement, reduce quantity of precursors, and are useful to increase atom economy. The Hantzsch reaction is one of the most important examples of multicomponent reaction which is used for synthesis of polyhydroquinoline derivatives[xi, xii]. The polyhydroquinoline derivatives is of great attention due to their various activities such as anti-cancer, anti-diabetic, anti-hypertensive, anti-inflammatory, anti-microbial, anti-

tubercular, anti-tumor, bronchodilator, calcium channel blockers, cardiovascular agents, geroprotective, hepatoprotective, neurotropic, and vasodilator[xiii-xxii] etc. These versatile activities have encouraged researchers to design sustainable and convenient catalytic materials for the synthesis of heterocyclic compounds containing polyhydroquinoline moiety. Some illustrations of drugs with 1,4-dihydropyridine framework are outlined in **Fig. 1**.

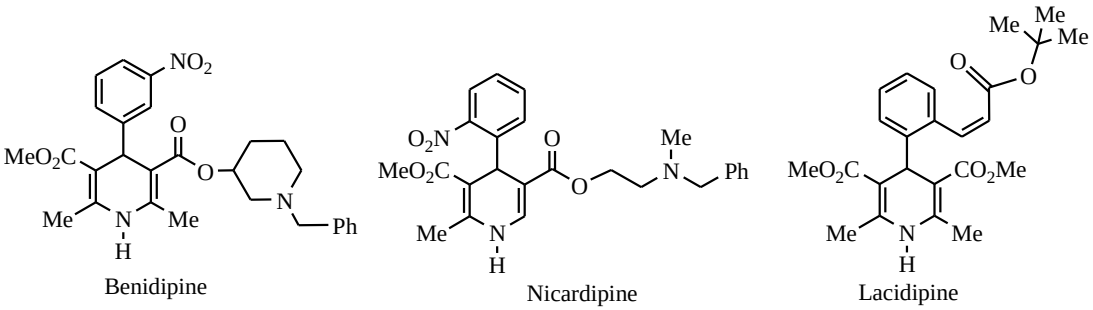


Fig.1. some drugs containing 1,4-dihydropyridine framework

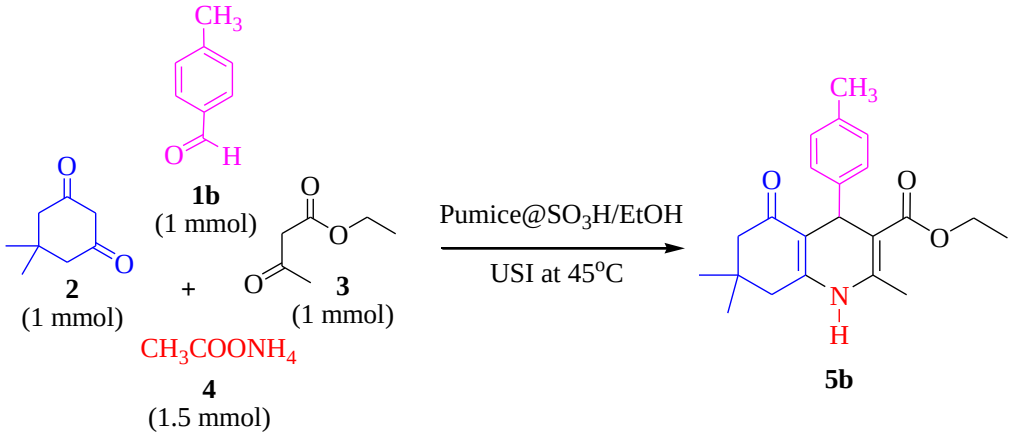
Recently, numerous protocols have been developed for the synthesis of polyhydroquinolines from aromatic aldehyde, dimedone, ethylacetoacetate and ammonium acetate such as nano-materials[xxiii], metal oxide supported materials[xxiv], magnetic materials[xxv], ionic liquids[xxvi], amino acids[xxvii], solar thermal energy[xxviii], Zeolite[xxix], microwave[xxx], and ultrasound[xxxi] etc. Also various bronsted acidic catalyst are used such as Fe_3O_4/SiO_2-OSO_3H[xxxii], silica sulfuric acid[xxxiii], nicotinic acid[xxxiv], Acetic acid[xxxv], Aluminized polyborate[xxxvi], PPA-SiO_2[xxxvii], SBA-15/SO_3H[xxxviii], SBA-15@Glycine[xxxix], PMO-ICS-PrSO_3H[xl], BINOL-phosphoric acid[xli], Carbon-based Solid acid (CBSA)[xlii], COF-SO_3H [xliii], Fe_3O_4@FSM-16-SO_3H [xliv], *p*-TSA[xlv], [MSAIM]HSO_4[xlvi], [Pyridine-SO_3H]Cl[xlvii], Caffeine-H_3PO_4[xlviii], ascorbic acid[xlix], Fe_3O_4@PEO-SO_3H[l], etc.

The ultrasound (US) assisted synthesis is well developed method used for the synthesis of variety of heterocyclic compounds. It proceeds through the development and adiabatic collapse of the transient cavitations bubble. It is used as a green approach that helping to reduce high energy requirements. The US approach provides smooth and cleaner reactions procedure with increasing yields in presence of various catalytic processes [li-lvii].

In continuation of our environmentally benign work [lviii-lxii] and on the application of pumice@SO_3H catalysts[i, ii], here we report a convenient green approach for one-pot synthesis of polyhydroquinolines in the presence pumice anchored sulfonic acid as a bronsted acidic catalyst with good catalytic activity and recyclability.

Results and Discussion:

In order to choose the better reaction condition a model reaction (**Scheme 1**) of *p*-methyl benzaldehyde, dimedone, ethyl acetoacetate and ammonium acetate was carried out in presence of catalyst pumice@SO_3H with and without catalyst and solvent. The reaction did not proceed to any extent in absence of catalyst with and without solvent during stirring at room temperature (**Table 1, Entry 1-3**). Also the negative result was obtained with pumice@SO_3H catalyst at room temperature in presence water and ethanol as well as without solvent under ultrasound irradiation (**Table 1, Entry 4-6**). The reaction proceeds smoothly with catalyst pumice@SO_3H in presence of ethanol as solvent at 45^{o}C under ultrasound irradiation with excellent yield (**Table 1, Entry 7**).



Scheme 1. Model reaction for synthesis of Polyhydroquinoline (**5b**) derivative

Table 1: Optimization of reaction condition for the synthesis of polyhydroquinoline (**5b**)

Entry	Catalyst / Solvent	Reaction Condition	Time in hrs.	Yield [b] in %
1	90 mg pumice@SO_3H / Solvent free	Grinding	0.5	No reaction (NR)
2	90 mg pumice@SO_3H / H_2O	Stirring at RT	3	NR
3	90 mg pumice@SO_3H / EtOH	Stirring at RT	3	NR
4	90 mg pumice@SO_3H / H_2O	USI at RT	3	NR
5	90 mg pumice@SO_3H / H_2O	USI at 45°C	3	NR
6	90 mg pumice@SO_3H / EtOH	USI at RT	3	Trace
7	90 mg pumice@SO_3H / EtOH	USI at 45°C	1.5	80

[a]Reaction condition: **1b** (0.120gm, 1mmol), **2** (0.140gm, 1mmol), **3** (0.130gm, 1mmol), **4** (0.107gm, 1.5mmol), pumice@SO_3H (90 mg), [b]Isolated Yield

Table 2: Optimization of quantity of catalyst for the synthesis of polyhydroquinoline (**4b**)

Entry	Pumice@SO_3H Catalyst (mg)	Time (hrs)	Yield[b] (%)
1	40	2	25
2	60	2	45
3	80	2	70
4	90	1.5	80
5	90	1.5	80

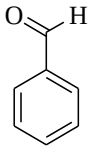
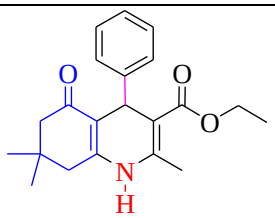
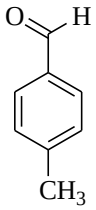
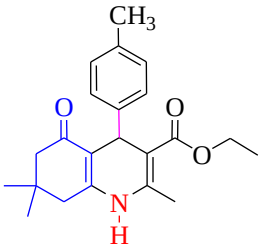
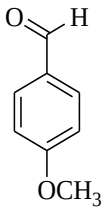
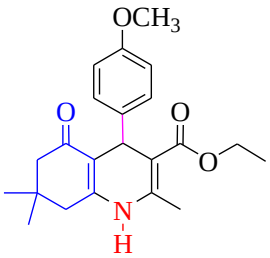
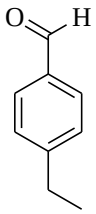
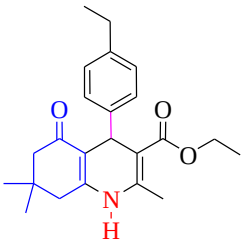
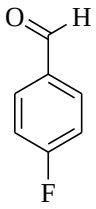
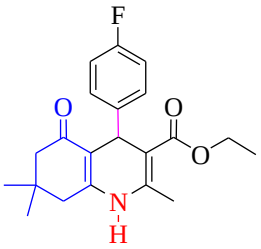
[a]Reaction condition: **1b** (0.120gm, 1mmol), **2** (0.140gm, 1mmol), **3** (0.130gm, 1mmol), **4** (0.107gm, 1.5mmol), USI at 45°C, [b] Isolated Yield

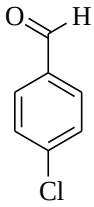
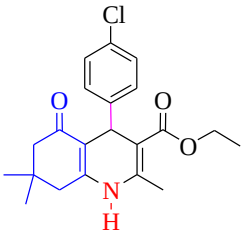
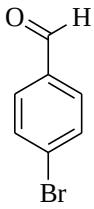
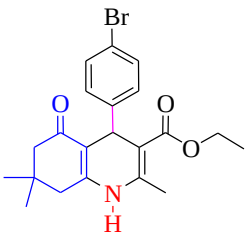
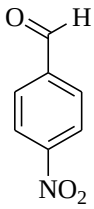
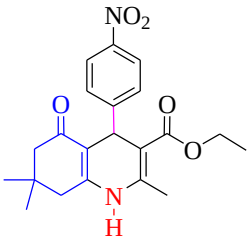
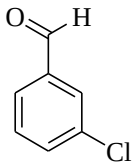
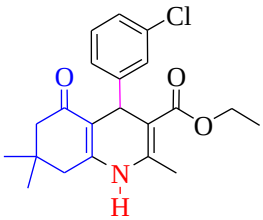
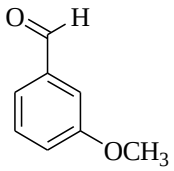
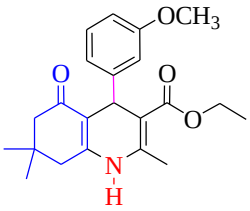
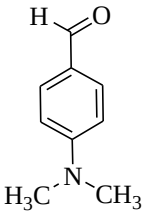
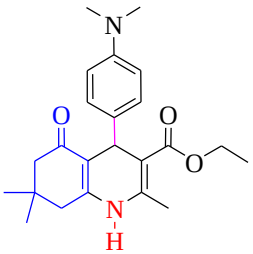
The model reaction was then studied for different amount of catalyst to optimize the amount of catalyst required (**Table 2**). It was found that further increase in the amount of catalyst, there was no significant improvement in the yield of the product.

This outcome enhanced our attention to study the scope, generality and relevance of this protocol for the synthesis of Polyhydroquinoline (**5a-k**) derivatives. The series of Polyhydroquinoline were synthesized using diverse aromatic aldehydes under above optimized

conditions with good yield (74-86%) as mentioned in **Table 3**. The protocol worked very well with aldehydes containing electron deficient and electron rich substituent.

Table 3: Data of synthesized Polyhydroquinoline (**5a-k**) derivatives

Entry	Aldehyde	Product	Time (hrs)	Yield (%)	M.P. (°C)	
					Observed	Reported
1		 **5a**	1.5	85	214-216	217–219[35]
2		 **5b**	1.5	80	252-256	260–262[35]
3		 **5c**	2.0	78	257-260	258–260[35]
4		 **5d**	1.5	80	220-224	--
5		 **5e**	1.5	79	182-184	185–186[35]

6		 **5f**	2.0	82	240-242	245–246[35]
7		 **5g**	2.0	78	250-252	254–256[35]
8		 **5h**	2.0	75	238-240	240–242[35]
9		 **5i**	1.5	80	204-206	205–206[35]
10		 **5j**	1.5	76	192-194	198–200[35]
11		 **5k**	1.5	80	236-238	228–231[29]

[a]Reaction condition: **1a-k** (0.120gm, 1mmol), **2** (0.140gm, 1mmol), **3** (0.130gm, 1mmol), **4** (0.107gm, 1.5mmol), USI at 45°C

After the completion of the reaction, the catalyst used has been recovered by heating the reaction mixture up to the boiling. The resultant hot solution was filtered at hot condition to separate the catalyst. The recovered catalyst was washed with dichloromethane 2-3 times and dried to reuse. The recycled catalyst was reused under the optimal conditions in three cycles of the similar transformation (**Fig. 2**). The formation of Pumice@SO_3H catalyst was proved by spectral studies such as FT-IR, XRD, SEM, TEM and EDS etc. which are reported in our previous work[i]. Here the evidences of recyclability study are provided. The FT-IR, XRD and EDS spectra of the recycled pumice@SO_3H catalyst after third cycle did not show any significant change in catalytic activity.

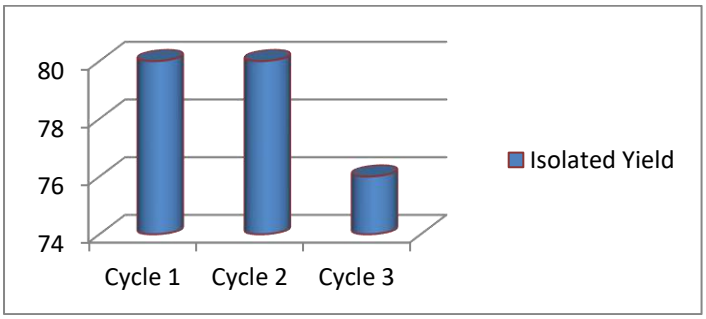


Fig. 2. Reusability of the pumice@SO_3H for the synthesis of Polyhydroquinoline (**4b**)

In the FT-IR spectrum of the recycled pumice@SO_3H (**Fig. 3**), the broad band at 3414.35 cm^{-1} is appeared due to O-H group in sulfonic acid. Also the important bands at 1637.32 cm^{-1} and 1111.05 cm^{-1} are appeared due to the S=O and Si–O–Si respectively. These significant bands indicate that, the recovery of -SO_3H group in the recycled catalyst.

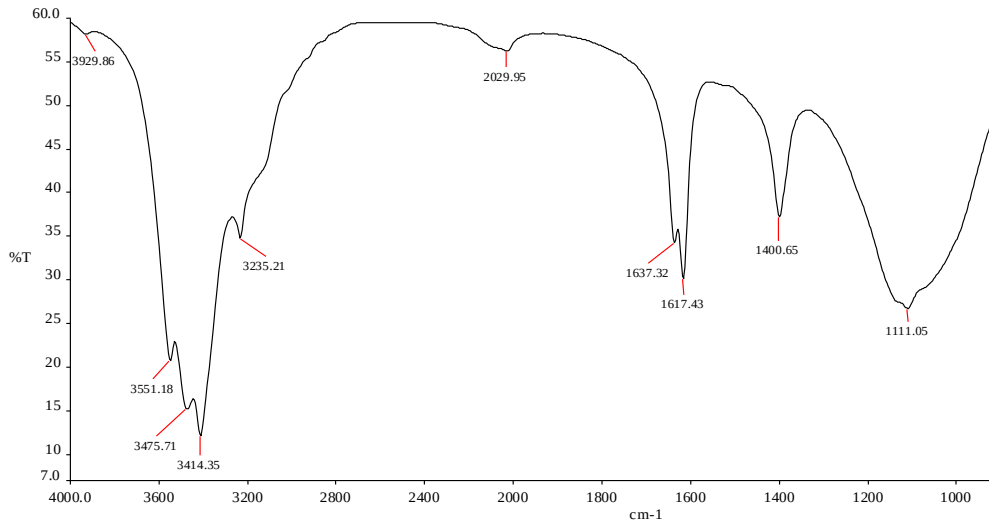


Fig. 3. IR Spectrum of Pumice@SO_3H catalyst

The nature of XRD (**Fig. 4**) and EDS (**Fig. 5**) of recycled catalyst was precisely matched with the reported catalyst. It showed that, the recycled catalyst did not show any variation in composition.

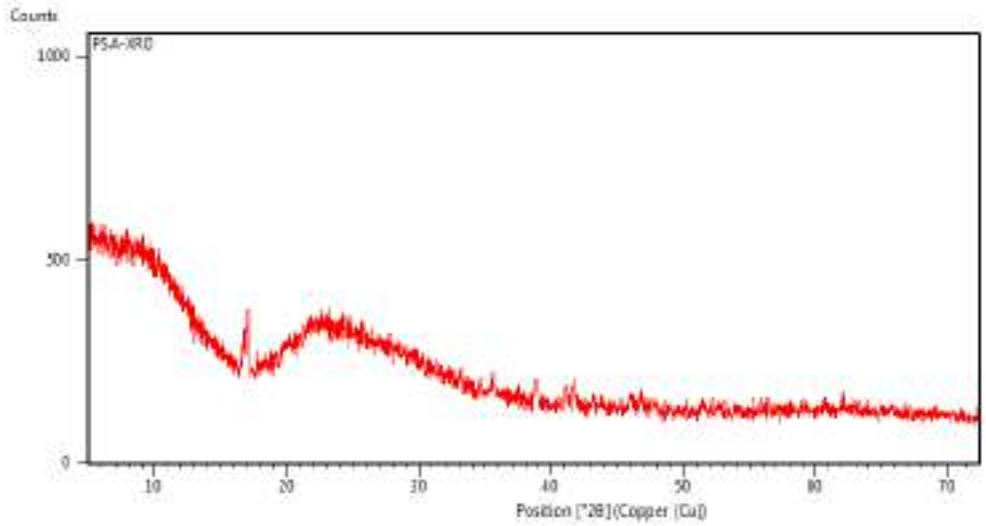


Fig.4. XRD of Pumice@SO_3H catalyst

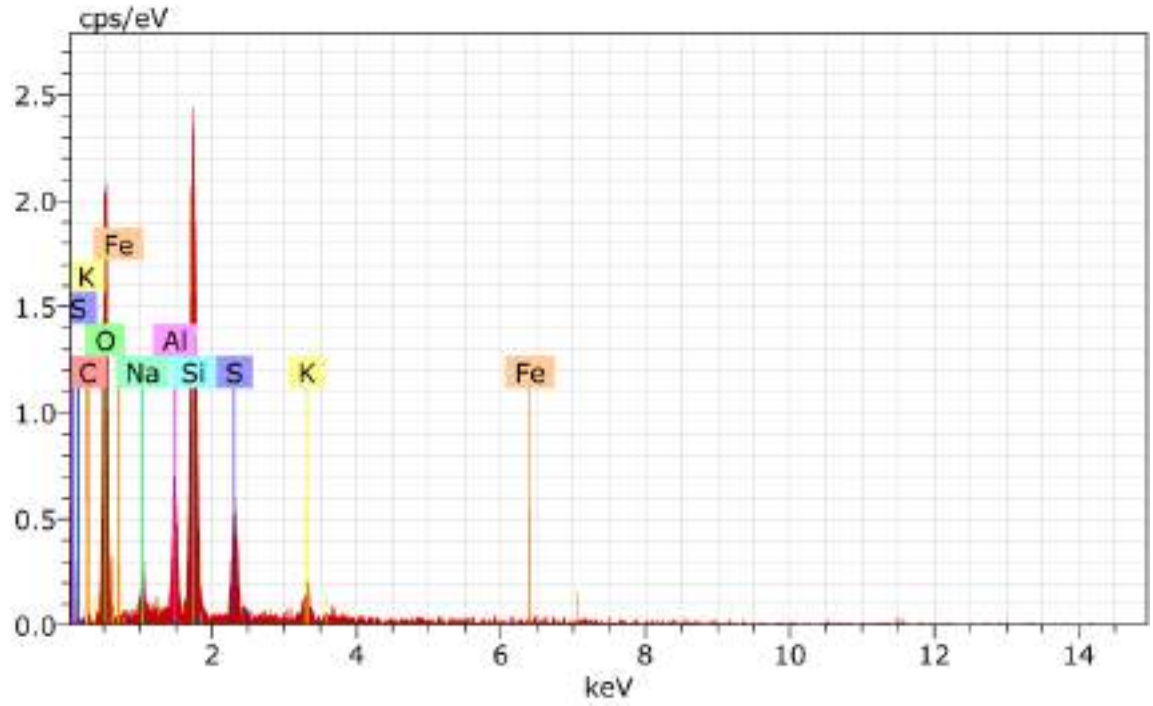


Fig.5. EDS of Pumice@SO_3H catalyst

The comparative study of different protocols for synthesis of polyhydroquinolene derivatives is illustrated in **Table 4**. While the plausible mechanism involved in Pumice@SO_3H promoted synthesis of polyhydroquinolines is shown in **Scheme 4.**

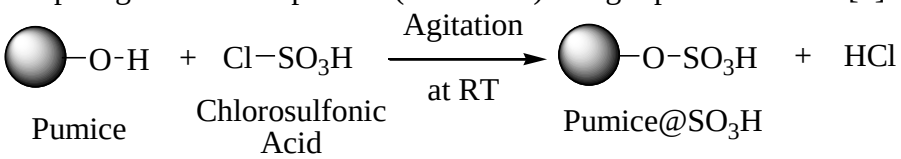
Table 4: Comparative study of different protocols for synthesis of polyhydroquinolene (**5b**)

Entry	Catalyst	Reaction Condition	Quantity of Catalyst in gm	Time in min	Yield (%)	Reference
1	Silica Sulfuric acid	Solvent free/60^oC	0.080	50	92	33

2	Nicotinic acid	Solvent free/80°C	0.1	07	92	34
3	PPA-SiO_2	Solvent free/80°C	0.030	60	90	37
4	PMO-ICS-PrSO_3H	Reflux/EtOH	0.020	20	95	40
5	CBSA	Solvent free/90°C	0.020	35	88	42
6	COF-SO_3H	Solvent free/90°C	0.020	10	95	43
7	Pumice@SO_3H	EtOH/USI, 45°C	0.090	90	80	Present work

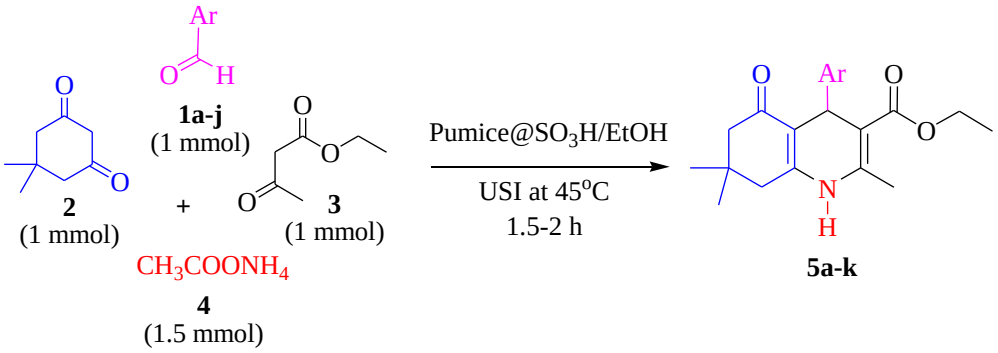
Experimental:
Melting points were recorded in an open capillary and are uncorrected. Infra Red spectra were recorded on a Perkin-Elmer FTIR spectrophotometer. The ^{1}H-NMR and ^{13}C-NMR spectra were recorded on a BRUCKER AVANCE NEO 500MHz NMR Spectrometer in $CDCl_3$ using Tetramethyl silane as a reference compound. Mass spectra were recorded on a Finnigan Mass spectrometer. TLC was carried out by Al-plates pre-coated with silica gel to check the purity of the compounds.

Preparation of pumice anchored sulfonic acid (pumice@SO_3H) catalyst
In the present work, the catalyst pumice anchored sulfonic acid (pumice@SO_3H) has been prepared by simple agitation from pumice (**Scheme 2**) using reported method [1].



Scheme 2: Preparation of pumice anchored sulfonic acid (pumice@SO_3H) catalyst

General procedure for the synthesis of polyhydroquinoline derivatives (5a-k)
A mixture of aldehyde **1** (1 mmol), 5,5-dimethylcyclohexane-1,3-dione **2** (1mmol), ethyl acetoacetate **3** (1 mmol), ammonium acetate **4** (1.5 mmol) and 90 mg of pumice based sulfonic acid was taken in a 100 mL round bottom flask containing 15 mL of ethyl alcohol. The resulting reaction mixture was subjected for ultrasound irradiation at 45°C temperature for appropriate time (**Scheme 3**). The progress of the reaction was studied using TLC. After the completion, the reaction mixture was heated up to the boiling. The resultant hot solution was filtered at hot condition to separate the catalyst. The recovered catalyst was washed with dichloromethane 2-3 times and dried to reuse. After the separation of catalyst, cool the mother liquor, the solid polyhydroquinoline thus obtained. It was dried and in some cases it was purified by recrystallization using hot ethanol.



Scheme 3: Synthesis of Polyhydroquinoline (**5a-k**) derivatives

Discussion of Spectra:

5b: ethyl 1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxo-4-*p*-tolylquinoline-3-carboxylate

^{1}H NMR (500 MHz, $CDCl_3$): 0.93 (s, 3H, -CH_3), 1.05 (s, 3H, -CH_3), 1.21 (t, 3H, -CH_3), 2.20 (s, 3H, -CH_3), 2.12-2.24 (m, 4H, -CH_2-x2), 2.31 (s, 3H, -CH_3), 4.06 (q, 2H, -OCH_2-), 5.01 (s, 1H, -CH-), 6.66 (s, 1H, NH), 6.99 (d, 2H, *J*=8Hz, Ar-H), 7.18 (d, 2H, *J*=8Hz, Ar-H); ^{13}C NMR (125 MHz, $CDCl_3$): 195.75, 167.58, 148.79, 144.27, 143.56, 135.38, 128.60, 127.87, 112.05, 106.14, 59.78, 50.81, 40.91, 36.14, 32.67, 29.45, 27.19, 21.04, 19.26, 14.24; MS (ESI) : m/z = 354.2110 [M+H].

5c: ethyl 1,4,5,6,7,8-hexahydro-4-(4-methoxyphenyl)-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate

^{1}H NMR (500 MHz, $CDCl_3$): 0.93 (s, 3H, -CH_3), 1.06 (s, 3H, -CH_3), 1.20 (t, 3H, -CH_3), 2.13-2.30 (m, 4H, -CH_2-x2), 2.35 (s, 3H, -CH_3), 3.73 (s, 3H, -OCH_3), 4.07 (q, 2H, -OCH_2-), 4.99 (s, 1H, -CH-), 6.26 (s, 1H, NH), 6.73 (m, 2H, Ar-H), 7.20 (m, 2H, Ar-H); MS (ESI) : m/z = 370.2005 [M+H].

5d: ethyl 4-(4-ethylphenyl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate

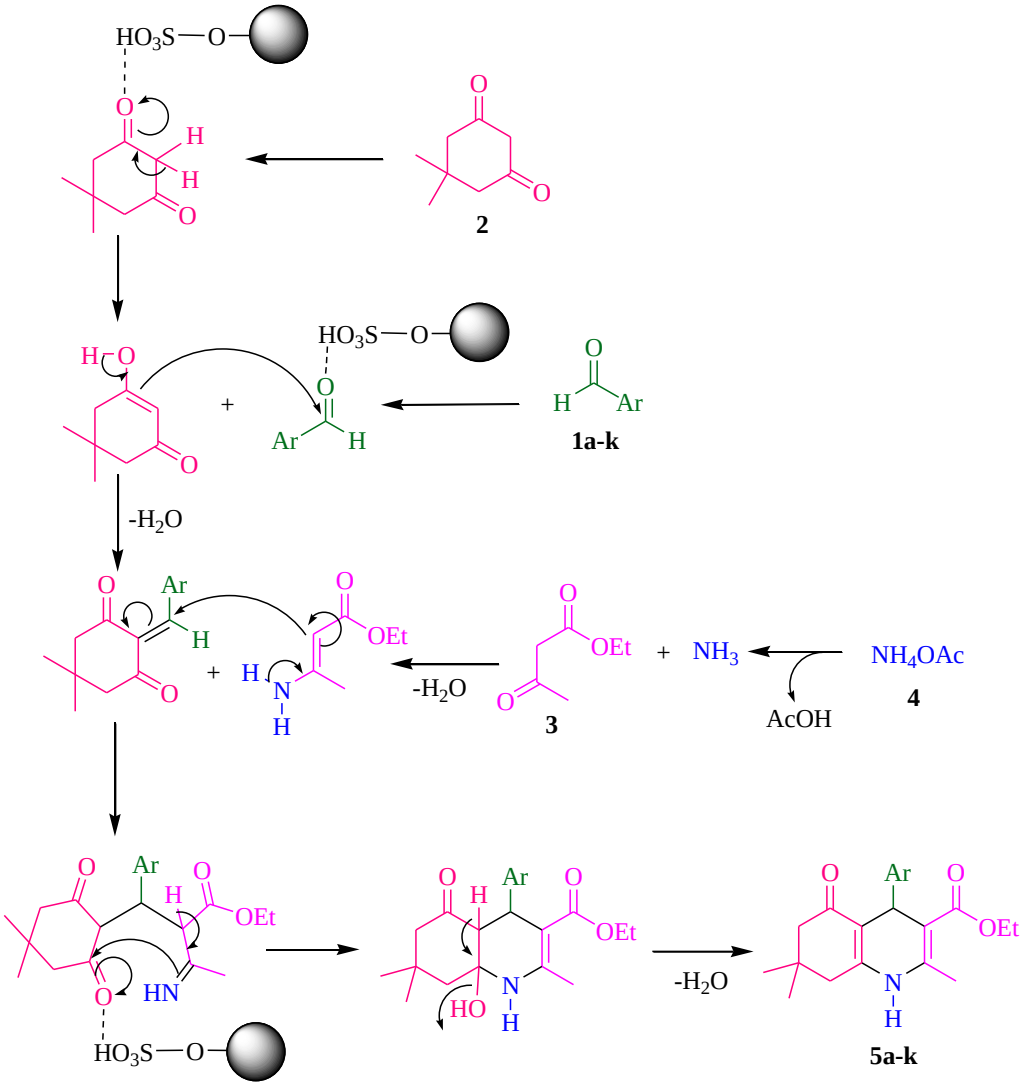
^{1}H NMR (500 MHz, $CDCl_3$): 0.95 (s, 3H, -CH_3), 1.06 (s, 3H, -CH_3), 1.17 (t, 3H, -CH_3), 1.21 (t, 3H, -CH_3), 2.13-2.29 (m, 4H, -CH_2-x2), 2.32 (s, 3H, -CH_3), 2.55 (q, 2H, -CH_2-), 4.06 (q, 2H, -OCH_2-), 5.02 (s, 1H, -CH-), 6.41 (s, 1H, NH), 7.01 (d, 2H, *J*=8Hz, Ar-H), 7.19 (d, 2H, *J*=8Hz, Ar-H); ^{13}C NMR (125 MHz, $CDCl_3$): 195.69, 167.58, 148.49, 144.39, 143.37, 141.68, 127.87, 127.35, 112.16, 106.25, 59.79, 50.79, 41.03, 36.10, 32.71, 29.41, 28.40, 27.28, 19.32, 15.35, 14.23.

5f: ethyl 4-(4-chlorophenyl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate

^{1}H NMR (500 MHz, $CDCl_3$): 0.92 (s, 3H, -CH_3), 1.07 (s, 3H, -CH_3), 1.18 (t, 3H, -CH_3), 2.13-2.32 (m, 4H, -CH_2-x2), 2.36 (s, 3H, -CH_3), 4.05 (q, 2H, -OCH_2-), 5.02 (s, 1H, -CH-), 6.29 (s, 1H, NH), 7.16 (m, 2H, Ar-H), 7.23 (m, 2H, Ar-H); MS (ESI) : m/z = 374.1595 [M+H].

5k: ethyl 4-(4-(dimethylamino)phenyl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate

^{1}H NMR (500 MHz, $CDCl_3$): 0.95 (s, 3H, -CH_3), 1.04 (s, 3H, -CH_3), 1.24 (t, 3H, -CH_3), 2.12-2.25 (m, 4H, -CH_2-x2), 2.33 (s, 3H, -CH_3), 2.85 (s, 6H, -$N(CH_3)_2$), 4.06 (q, 2H, -OCH_2-), 4.96 (s, 1H, -CH-), 6.58 (d, 2H, *J*=8.5Hz, Ar-H), 6.64 (s, 1H, NH), 7.15 (d, 2H, *J*=8.5Hz, Ar-H); ^{13}C NMR (125 MHz, $CDCl_3$): 195.84, 167.77, 148.94, 148.56, 143.18, 136.02, 128.61, 112.38, 112.24, 106.43, 59.71, 50.84, 40.85, 40.75, 35.38, 32.65, 29.49, 27.28, 19.28, 14.30; MS (ESI) : m/z = 383.2254 [M+H].



Scheme 4: Pluasible mechanism for the synthesis of Polyhydroquinolines

Conclusion:

In summary, we have discovered a sustainable and convenient protocol for the synthesis of polyhydroquinoline derivatives using pumice anchored sulfonic acid (Pumice@SO_3H) as an efficient catalyst under ultrasound irradiation. The attractive features of present protocol are green approach, good yield, recovery of catalyst and easy work-up procedure whereas the catalyst offers simple preparation, high catalytic activity, inexpensive, easy to use, recyclability and good stability.

Abbreviations:

MCRs	= Multicomponent Reactions,
Pumice@SO_3H	= Pumice supported sulfuric acid,
NR	= No Reaction,
RT	= Room Temperature,
SF	= Solvent Free,
USI	= Ultrasound Irradiation.

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Novel Pumice Supported Perchloric Acid Promoted Protocol for the Synthesis of Tetrahydrobenzo[*b*]pyran via Multi-component Approach

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ABSTRACT

A novel heterogeneous pumice supported perchloric acid catalyzed synthesis of tetrahydrobenzo[*b*]pyran has developed via multi-component condensation of aromatic aldehydes, dimedone and malononitrile. The catalyst was characterized by IR, XRD, EDS, SEM, and TGA techniques which confirmed the formation novel pumice supported perchloric acid. The present protocol proved to have numerous advantages like one-pot reaction, good yield, short reaction time, inexpensive catalyst, recyclability and reusability of the catalyst, simple experimental and work up procedure, and purification of targeted molecules without column chromatography.

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KEYWORDS
Pumice supported perchloric acid; tetrahydrobenzo[*b*]pyran; multi-component reaction; dimedone; malanonitrile

Introduction

In the last two decades, volcanic pumice and pumice based materials have been employed in divergent organic transformations such as reduction reaction, oxidation reaction, photo catalytic degradation, multi-component condensation reaction and also water treatment process. These varied reactions are achieved because large silica content of the pumice which was converted into active catalytic material. The appreciable advantages of pumice supported catalytic materials are heterogeneous nature, good surface area, excellent catalytic activity, thermal stability, high porosity, high absorption capacity, recyclability and reusability, etc.[1–9]

Multi-component reaction (MCR) approach has gained excellent impact in the discovery of heterocyclic compounds due to the synthetic efficiency and economy. The MCR strategy is a one step synthetic operation with incredibly well-designed and quick approach to discover highly functionalized and complex biologically active molecules. It has also advantages like high flexibility, high atom economy and high selectivity.[10–12] The synthesis of tetrahydrobenzo[*b*]pyrans is also an important illustration of the multi-component reaction.

The tetrahydrobenzo[*b*]pyran derivatives are extremely significant to the organic chemists because of their prominent biological and pharmacological activities. They are fascinating polyfunctionalized compounds which possess a wide variety of biological activities like anti-allergic, antibacterial, anti-coagulant, anti-tumor, calcium channel antagonists and diuretic etc. Along with biological activities, some derivatives of tetrahydrobenzo[*b*]pyran have been employed as photoactive materials and agrochemicals. They are also used in cosmetics and pigments.[13–18] The some illustration of biologically active tetrahydrobenzo[*b*]pyran derivatives shown in Figure 1.

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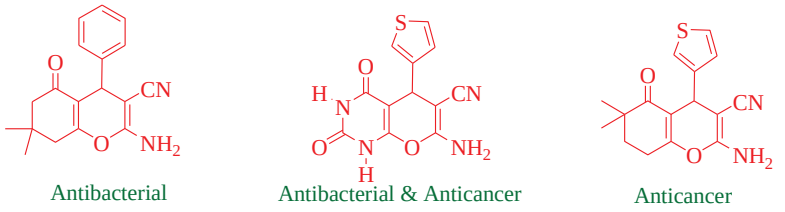


Figure 1. Some examples of biologically active tetrahydrobenzo[*b*]pyran derivatives.

In a vision of the enormous scope of tetrahydrobenzo[*b*]pyrans there is increased attention in developing new routes for their synthesis. The synthetic protocols include numerous catalyst such as tetraethylammonium perchlorate,[19] CTMAB-bentonite,[20] nano-titania sulfuric acid,[21] ultrasound,[22] MNPs–$PhSO_3H$,[23] molecular sieve-supported zinc catalyst,[24] silica nanoparticles,[25] oxyammonium-based ionic liquid,[26] $MeSO_3H$,[27] PEG-SO_3H,[28] WEMFSA,[29] tungstic acid functionalized mesoporous SBA-15,[30] amine-functionalized SiO_2@Fe_3O_4 nanoparticles,[31] choline chloride-oxalic acid,[32] L-proline,[33] chitosan,[34] xanthum gum supported Fe_3O_4,[35] phosphotungstic acid supported on SiO_2@$NHPhNH_2$ functionalized nanoparticles of $MnFe_2O_4$,[36] poly(Ethyleneoxide)-based magnetic nanocomposite,[37] magnetic aluminosilicate nanoclay,[38] amine-functionalized silica-supported magnetic nanoparticles,[39] etc.

In continuation of our work in developing new methodologies for the synthesis of active compounds[40] herein, we have reported an efficient and sustainable protocol for the synthesis of tetrahydrobenzo[*b*]pyrans via multi-component reaction of aromatic aldehyde, dimedone and malononitrile in the presence of novel pumice supported perchloric acid. The present work has a number of advantages in comparison with the literature reported protocols, such as good yields, high atom economy, smooth reaction conditions, simple work-up procedure and purification of targeted molecule without column chromatography.

Experimental procedures

General

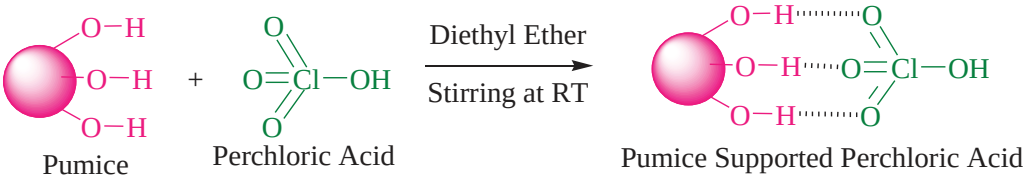
The progress of the reaction was monitored by thin-layer chromatography (TLC) by using silica gel coated aluminum plates and plates are visualized with UV light. Melting points were taken in an open capillary and are uncorrected. ^{1}H NMR (500 MHz) and ^{13}C NMR (125 MHz) spectra were recorded with the BRUCKER AVANCE NEO 500 MHz in $CDCl_3$ using TMS as an internal standard. IR spectra were taken on PerkinElmer FTIR Spectrometer. The pumice supported perchloric acid catalyst was prepared in the laboratory. Mass spectra were recorded on a MALDI SYNAPT XS HD Mass spectrometer.

General procedure for the preparation of pumice supported perchloric acid

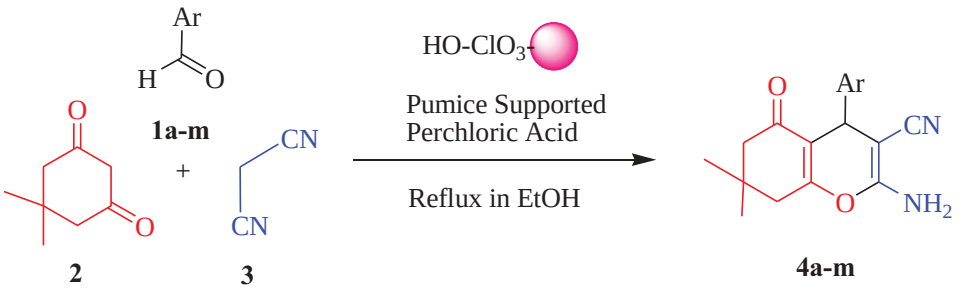
Perchloric acid (3.0 gm) was added to the suspension of pumice (45 gm) in diethyl ether (60 mL) with constant stirring for 2 h. The mixture was concentrated and the residue was washed with acetone to remove unreacted perchloric acid. The resultant residue was dried under vacuum at 80 °C for 6 h to afford free Pumice Supported Perchloric acid (Pumice@$HClO_4$) (Scheme 1).

General procedure for the synthesis of tetrahydrobenzo[b]pyran derivatives (4a–m)

In a 100 mL round bottom flask, the mixture of substituted benzaldehyde (2 mmol), dimedone (2 mmol), malanonitrile (2 mmol) and pumice supported perchloric acid (100 mg) was taken in 10 mL of ethanol (Scheme 2). The resulting reaction mixture was refluxed for appropriate time.



Scheme 1. Preparation of pumice supported perchloric acid.



Scheme 2. Synthesis of tetrahydrobenzo[*b*]pyran derivatives (**4a–m**).

The progress of the reaction was confirmed by TLC. To separate out the catalyst pumice supported perchloric acid, the content was filtered at hot condition. After cooling the filtrate, the solid was separate out which was dried and purified by recrystalization using ethanol.

Result and discussion

The pumice supported perchloric acid was prepared from volcanic pumice and perchloric acid by simple agitation in diethyl ether which has characterized by various analytical techniques such as FTIR, XRD, EDAX, SEM, and TGA. The FTIR spectra of pumice supported perchloric acid showed that, the significant absorption band at 3413.95 cm^{-1} corresponding to the acidic proton in Pumice@$HClO_4$. In addition to this, the band appeared at 1637.53 cm^{-1} is due to the (Cl = O) bond and the bands at 1147.39 and 1090.09 cm^{-1} are related to Si–O–Si bonds (Figure 2(a)). These bands are not observed in FTIR of plane pumice (Figure 2(c)) except the band at 1036.86 cm^{-1}due to Si–O–Si bonds. This clearly indicates that, the perchloric acid was supported on pumice. Also the FTIR of recycled pumice@$HClO_4$ (Figure 2(b)) did not show any noteworthy deviation from pure pumice@$HClO_4$.

The EDAX analysis showed the composition of Pumice supported perchloric acid. This indicates that the synthesized catalyst composed of Si, O, Al, K, and Cl elements. The higher percentage of chlorine and oxygen proved that the perchloric acid was supported on Pumice (Figure 3(a)). Also the EDAX of recycled pumice@$HClO_4$ (Figure 3(b)) did not show any noteworthy composition of elements.

The XRD pattern of the catalyst was exhibited the broad characteristic peak between diffraction angle $2\theta = 15\text{-}30$ which demonstrated the amorphous nature of the Pumice supported perchloric acid (Figure 4(a)). Also the XRD of recycled pumice@$HClO_4$ (Figure 4(b)) did not show any significant change.

The SEM image showed that, pure as well as recycled pumice supported perchloric acid has no particular size and morphology (Figure 5(a,b)).

To investigate the thermal stability of the newly prepared pumice supported perchloric acid and pumice, the thermogravimetric analysis (TGA) was performed in the temperature range from 30 to 650 °C as shown in Figure 6(a,b). The literature survey revealed that, the –OH groups

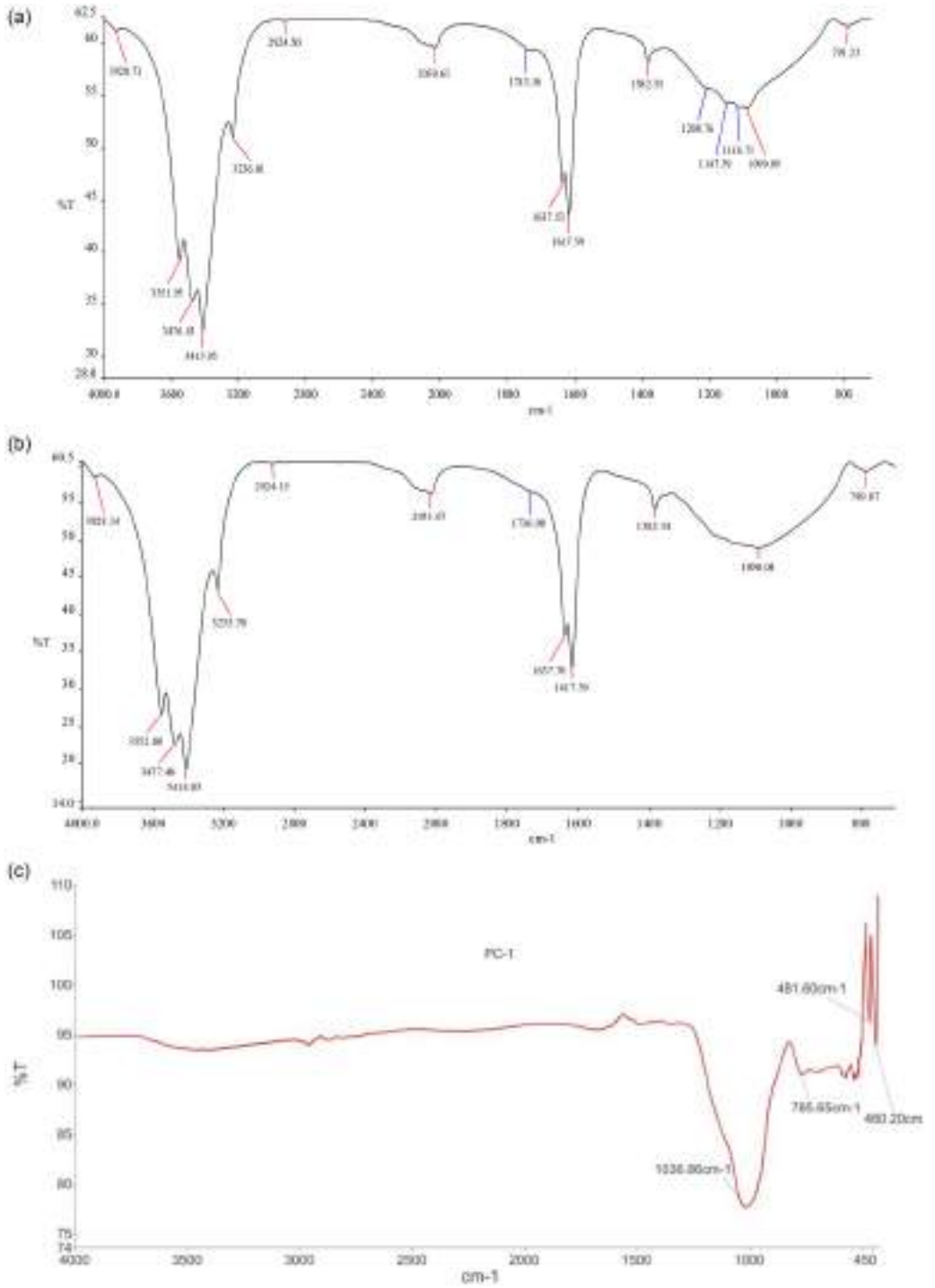


Figure 2. (a) FTIR of pumice supported perchloric acid (Pumice@$HClO_4$). (b) FTIR of recycled pumice supported perchloric acid (Pumice@$HClO_4$). (c) FTIR of pure pumice.

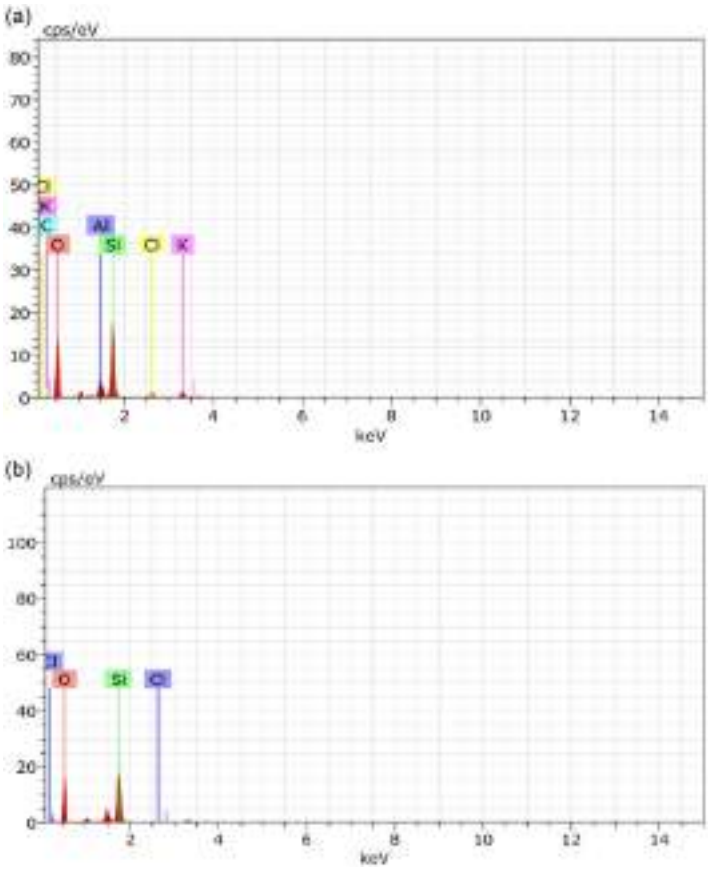


Figure 3. (a) EDAX of pumice supported perchloric acid (Pumice@$HClO_4$). (b) EDAX of recycled pumice supported perchloric acid (Pumice@$HClO_4$).

present in the catalytic material leave the structure by dehydration reaction at high temperature. The TGA of pumice supported perchloric acid (Figure 6(a)) and pumice (Figure 6(b)) showed that, 2.1% weight lost below 140 °C due to the removal of –OH groups in the form of water molecule present in the catalyst.

Study of acidic nature of pumice Supported perchloric Acid

The acidic nature of the catalyst was determined potentiometrically by following the standard method.[4] Initially the 0.1 g of pumice supported perchloric acid catalyst was taken in a titration flask containing 10 ml distilled water and the resultant mixture was titrated against the 0.1 N NaOH solution. The reading data of titration was used for plotting the graph of ΔE/ΔV against the volume of 0.1 N NaOH. From the graph, the acidic nature of catalyst was found to be 0.9 mmol/g at the equivalence point (Figure 7).

Optimization of the Reaction condition

The multi-component condensation reaction of 4-methyl benzaldehyde, dimedone and malononitrile was selected as pilot reaction (Scheme 3) to choose the optimize conditions for the synthesis of tetrahydrobenzo[*b*]pyran. Initially, the reaction was carried out under varying conditions such

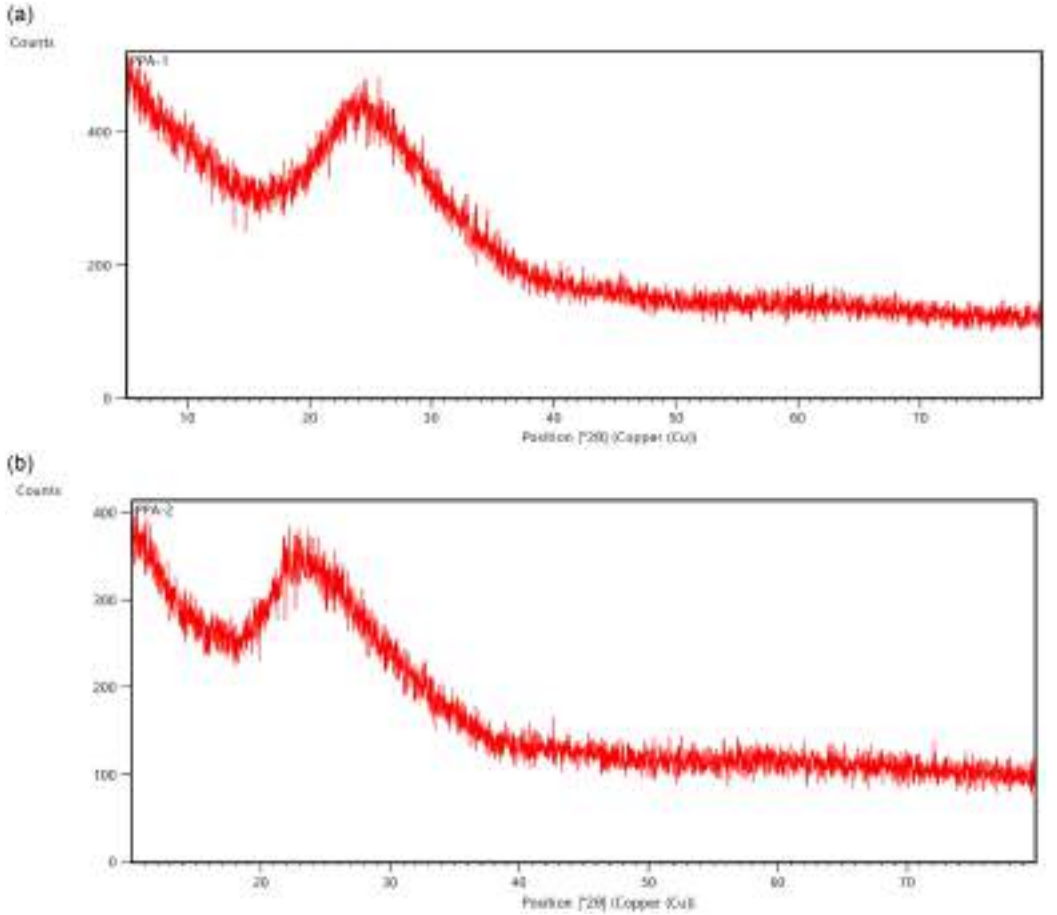


Figure 4. (a) XRD of pumice supported perchloric acid (Pumice@$HClO_4$). (b) XRD of recycled pumice supported perchloric acid (Pumice@$HClO_4$).

as the amount of catalyst, time, temperature and solvent medium (Table 1). The good result was obtained for pilot reaction with 100 mg of pumice supported perchloric acid catalyst (Table 2) in the presence of ethanol under reflux condition.

After the investigation of the exact optimized condition, it was employed for the synthesis of different tetrahydrobenzo[*b*]pyran derivatives by one-pot three component condensation of diverse aromatic aldehydes with malononitrile and dimedone. The best result was obtained for aldehydes containing electron donating as well as electron withdrawing groups in high yields and short period of time without appearing side product (Table 3).

Spectral data selected compounds

4a: 2-amino-5,6,7,8-tetrahydro-7,7-dimethyl-5-oxo-4-phenyl-4H-chromene-3-carbonitrile

White color; m.p. 222–224 °C; FTIR (cm^{-1}): 3396.57 (N–H), 2198.93 (CN), 1680.23 (C = O), 1660.44 (C = C), 1603.25 (C = C), 1451.14 (C = C), 1369.68 (C–O), 1213.49 (C–N); ^{1}H NMR ($CDCl_3$, 500 MHz) δ: 1.04 (s, 3H, $-CH_3$), 1.11 (s, 3H, $-CH_3$), 2.18–2.25 (m, 2H, $-CH_2-$), 2.45 (s, 2H, $-CH_2-$), 4.40 (s, 1H, –CH–), 4.57 (s, 2H, $-NH_2$), 7.19–7.30 (m, 5H, Ar–H) ; MS (ESI): m/z = 295.1469 [M + H].

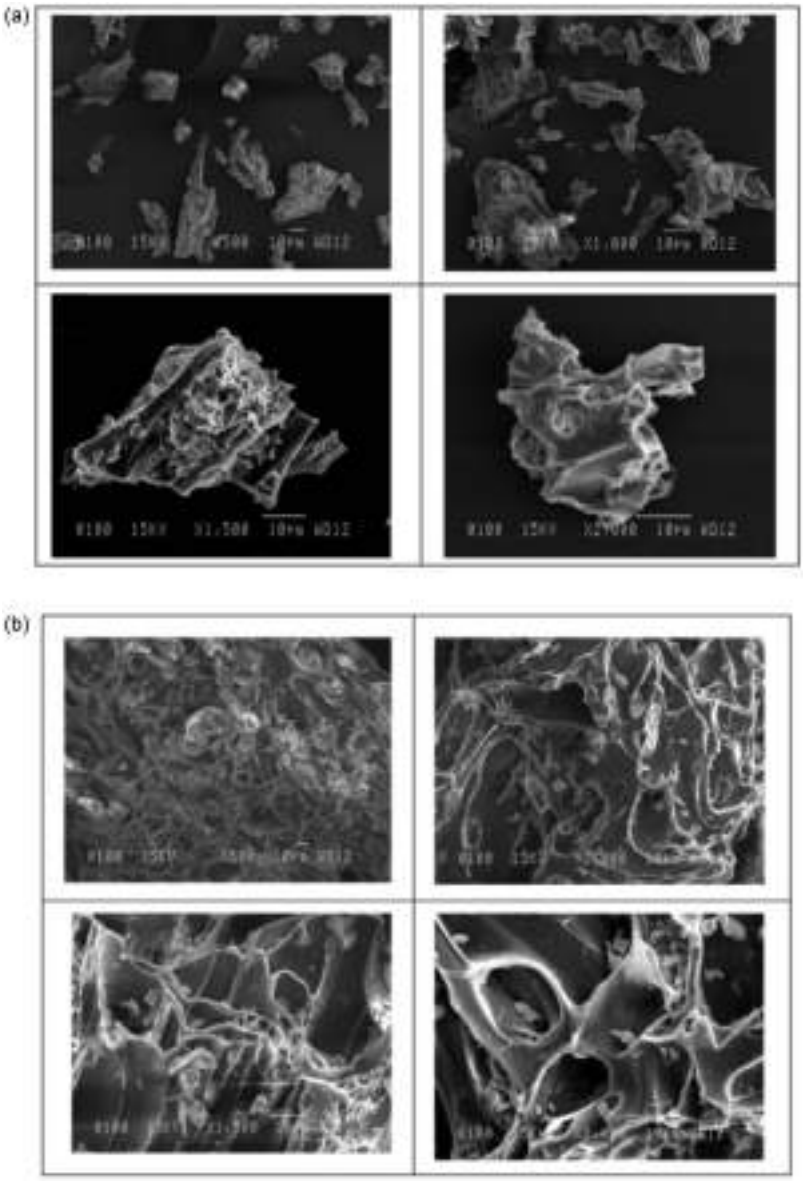


Figure 5. (a) SEM of pumice supported perchloric acid (Pumice@$HClO_4$). (b) SEM of recycled pumice supported perchloric acid (Pumice@$HClO_4$).

4b: 2-amino-5,6,7,8-tetrahydro-7,7-dimethyl-5-oxo-4-p-tolyl-4H-chromene-3-carbonitrile

White color; m.p. 214–216 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ: 1.04 (s, 3H, $-CH_3$), 1.11 (s, 3H, $-CH_3$), 2.17 (m, 2H, $-CH_2-$), 2.21 (s, 2H, $-CH_3$), 2.44 (s, 2H, $-CH_2-$), 4.36 (s, 1H, –CH–), 4.51 (s, 2H, $-NH_2$), 7.08 (m, 4H, Ar–H).

4c: 2-amino-4-(4-ethylphenyl)-5,6,7,8-tetrahydro-7,7-dimethyl-5-oxo-4H-chromene-3-carbonitrile

White color; m.p. 222–224 °C; FTIR (cm^{-1}): 3410.74 (N–H), 2188.62 (CN), 1682.53 (C = O), 1652.20 (C = C), 1618.21 (C = C), 1509.02 (C = C), 1369.47 (C–O), 1214.05 (C–N); ^{1}H NMR ($CDCl_3$, 500 MHz) δ: 0.99 (s, 3H, $-CH_3$), 1.10 (s, 3H, $-CH_3$), 1.26 (t, 3H, $-CH_3$), 2.19 (q, 2H,

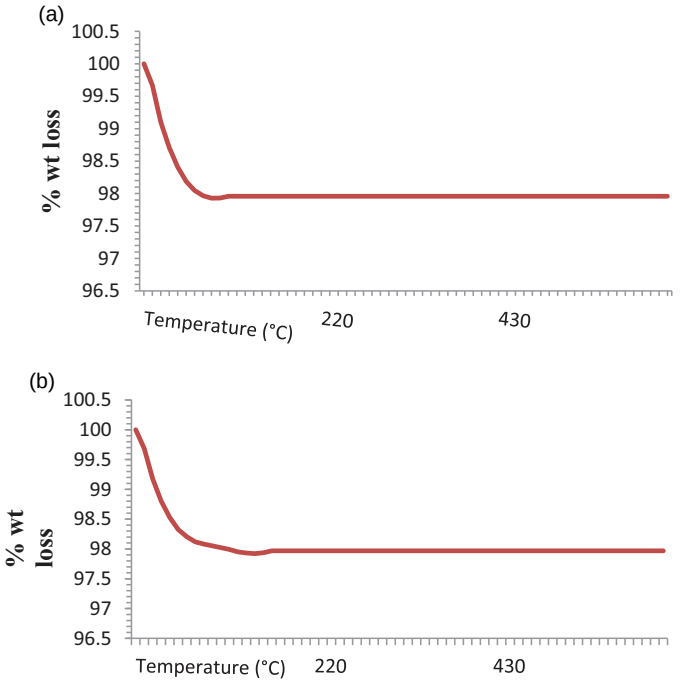


Figure 6. (a) TGA of pumice supported perchloric acid (Pumice@$HClO_4$). (b) TGA of pure pumice.

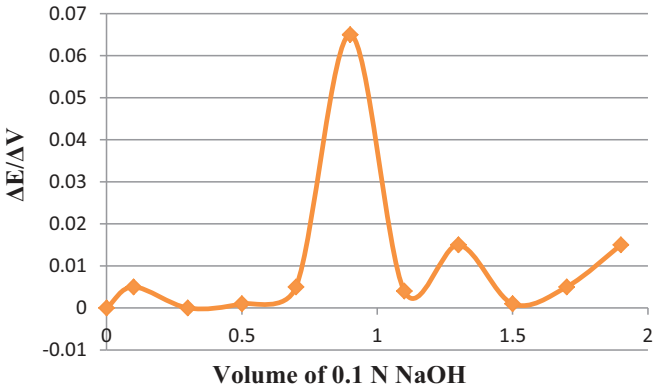
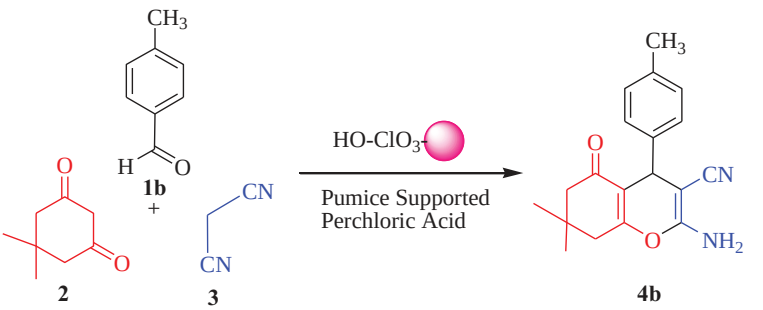


Figure 7. Study of acidic nature of pumice@$HClO_4$ by potentiometric titration.



Scheme 3. Pilot reaction for the synthesis of tetrahydrobenzo[*b*]pyran (**4b**).

Table 1. Optimization of reaction conditions for the synthesis of tetrahydrobenzo[*b*]pyran (**4b**).

Entry	Solvent system	Temperature	Time (min)	Yield (%)
1	Grinding	RT	60	NR
2	H_2O	RT	120	NR
3	EtOH	RT	120	NR
4	EtOH + H_2O (50%)	RT	120	NR
5	H_2O	Reflux	120	Trace
6	EtOH	Reflux	60	88
7	EtOH + H_2O (50%)	Reflux	60	40

Reaction condition: 4-methyl benzaldehyde (2 mmol), malononitrile (2 mmol), and dimedone (2 mmol), pumice supported perchloric acid catalyst (100 mg).

Table 2. Optimization of amount of catalyst for the synthesis of tetrahydrobenzo[*b*]pyran.

Entry	Amount of catalyst (mg)	Time (min)	Yield (%)
1	Absence of catalyst	60	NR
2	25	60	Trace
3	50	60	55
4	75	60	80
5	100	60	88
6	125	60	88

–CH_2–), 2.44 (m, 2H, –CH_2–), 2.59 (m, 2H, –CH_2–), 4.37 (s, 1H, –CH–), 4.56 (s, 2H, –NH_2), 7.09–7.14 (m, 4H, Ar–H) ; ^{13}C NMR ($CDCl_3$, 500 MHz) δ: 15.33, 27.76, 28.64, 28.87, 32.21, 35.12, 40.70, 50.70, 63.70, 114.18, 118.81, 127.41, 128.09, 140.48, 142.93, 157.47, 161.47, 195.97; MS (ESI): m/z = 323.1790 [M + H].

4d: 2-amino-5,6,7,8-tetrahydro-7,7-dimethyl-4-(4-nitrophenyl)-5-oxo-4H-chromene-3-carbonitrile

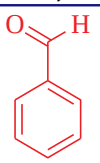
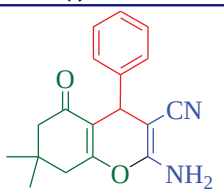
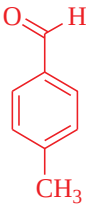
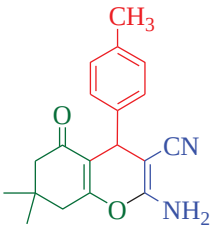
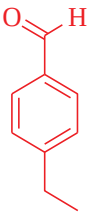
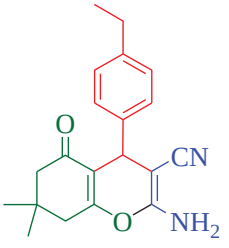
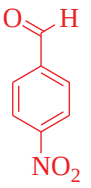
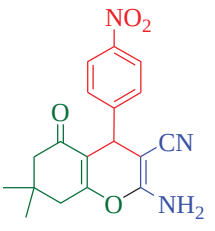
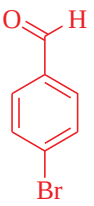
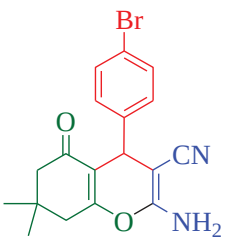
White color; m.p. 178–180 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ: 0.97 (s, 3H, –CH_3), 1.05 (s, 3H, –CH_3), 2.11–2.28 (m, 2H, –CH_2–), 2.54 (s, 2H, –CH_2–), 4.38 (s, 1H, –CH–), 7.17 (s, 2H, –NH_2), 7.45 (d, 2H, J = 8.7, Ar–H) , 8.17 (d, 2H, J = 8.7, Ar–H) ; ^{13}C NMR ($CDCl_3$, 500 MHz) δ: 26.83, 28.14, 31.69, 35.55, 49.75, 56.88, 111.63, 119.18, 123.53, 128.49, 146.15, 152.15, 158.47, 162.96, 195.54.

Recyclability and reusability of pumice supported perchloric acid

The recovery and reusability of the pumice supported perchloric acid catalyst make the protocol most valuable, unique and beneficial. After the completion of the reaction, the catalyst was separated from the reaction media at hot condition. It was washed with hot ethanol followed by chloroform and was dried at 80 °C temperature. The recovered catalyst was characterized by FTIR, EDAX, XRD and SEM as shown in Figures 2(b) to 5(b). The reusability of the catalyst was studied on the pilot reaction. The catalyst has been recycled and reused three times with 88, 87 and 84% of product yields, respectively.

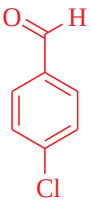
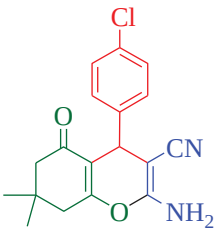
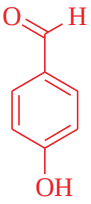
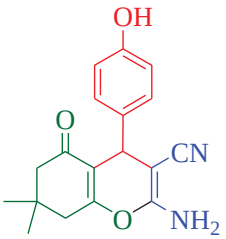
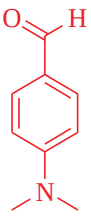
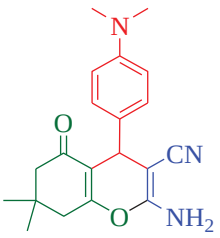
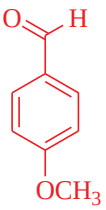
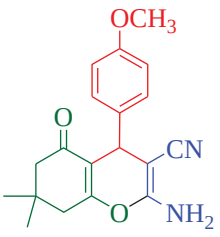
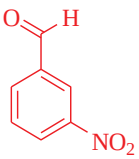
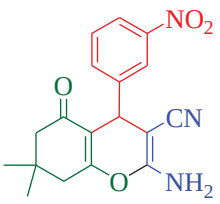
The comparison of the efficiency of pumice supported perchloric acid catalyst with the various reported protocols are mentioned in Table 4. From this investigation, it was found that the pumice supported perchloric acid catalyst showed a noteworthy activity for the synthesis tetrahydrobenzo[*b*]pyran derivatives. Also a current protocol has many advantages in comparison with

Table 3. Synthesis of tetrahydrobenzo[*b*]pyran derivatives (**4a–m**).

Entry	Aldehyde	Benzopyran derivative	Time (min.)	Yield (%)	M.P.(°C) Observed	M.P.(°C) Reported (ref.)
1		 **4a**	50	80	222–224	224[15]
2		 **4b**	60	88	214–216	213[15]
3		 **4c**	45	82	222–224	155–158[18]
4		 **4d**	50	84	178–180	179[15]
5		 **4e**	50	90	202–204	200–203[16]

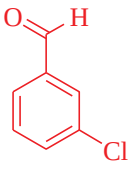
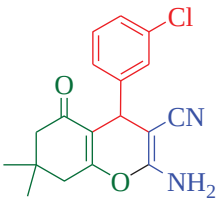
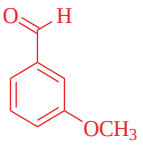
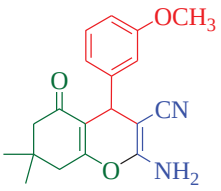
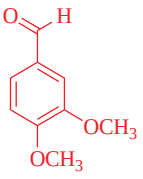
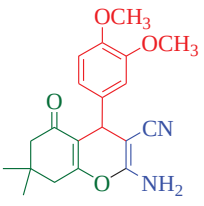
(*continued*)

Table 3. Continued.

Entry	Aldehyde	Benzopyran derivative	Time (min.)	Yield (%)	M.P.(°C) Observed	M.P.(°C) Reported (ref.)
6		 **4f**	45	90	198–200	206[15]
7		 **4g**	65	77	220–222	205[15]
8		 **4h**	60	82	188–190	198–200[15]
9		 **4i**	60	80	202–204	201[15]
10		 **4j**	60	76	212–214	210[15]

(*continued*)

Table 3. Continued.

Entry	Aldehyde	Benzopyran derivative	Time (min.)	Yield (%)	M.P.(°C) Observed	M.P.(°C) Reported (ref.)
11		 **4k**	40	82	202–204	226–228[16]
12		 **4l**	50	84	210–212	185–187[16]
13		 **4m**	65	78	164–166	132–141[18]

Reaction condition: Aldehyde (2 mmol), dimedone (2 mmol), and malanonitrile (2 mmol) were refluxed in 10 ml ethanol in the presence of pumice supported perchloric acid (100 mg)

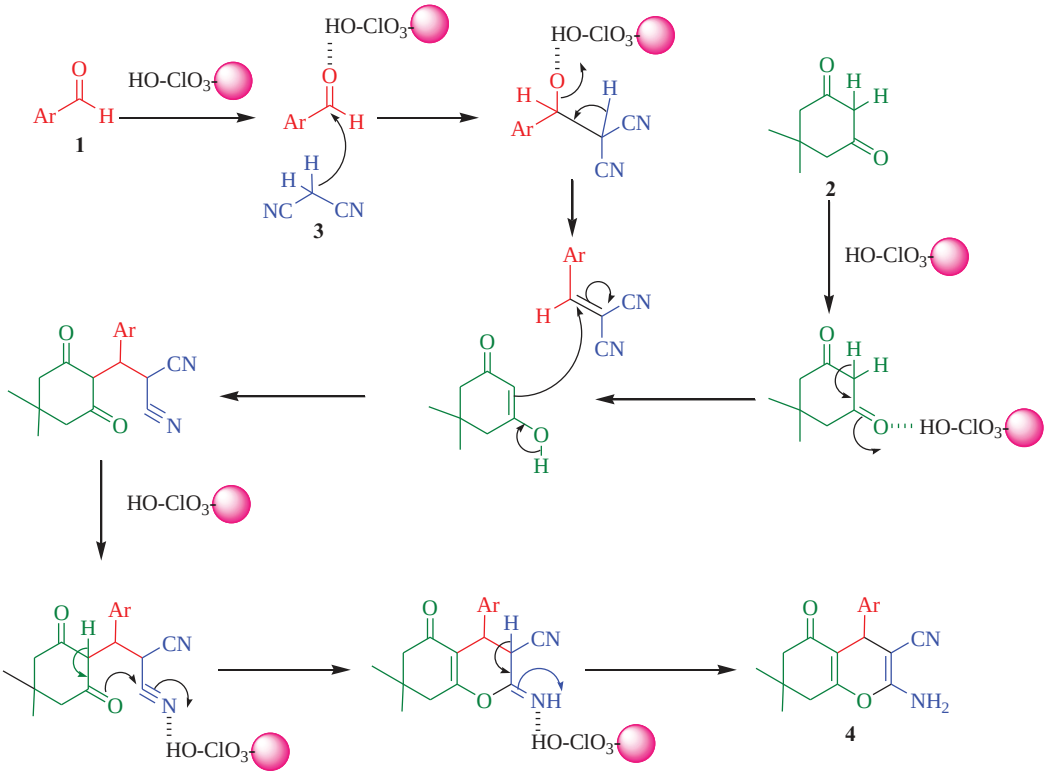
Table 4. Comparison of the efficiency of pumice@$HClO_4$ for the synthesis of tetrahydro-benzo[*b*]pyran derivative with other protocols.

Entry	Catalyst used	Reaction condition	Time (min)	Yield (%)	Ref. no.
1	CTMAB-bentonite	H_2O:EtOH (1:1) / RT	05–10	80–99	[20]
2	Nano-titania sulfuric acid	EtOH / US / 40 °C	10–30	85–97	[21]
3	MNPs–$PhSO_3H$	H_2O:EtOH (1:1) / 100 °C	10–60	65–95	[23]
4	Molecular sieve-supported Zinc	EtOH/reflux	240	85–98	[24]
5	SiO_2 nano-particles	EtOH/RT	25–30	86–98	[25]
6	Xanthum gum supported Fe_3O_4	EtOH/RT	05–20	84–96	[35]
7	Phosphotungstic acid supported on SiO_2@$NHPhNH_2$	SF/ 80 °C	25–30	85–94	[36]
8	Fe_3O_4@PEO-SO_3H	EtOH/RT	25–40	85–95	[37]
9	Magnetic aluminosilicate nanoclay	SF/ 40 °C	20–30	93–96	[38]
10	Fe_3O_4@SiO_2–NH_2	SF/ 60 °C	80–120	78–93	[39]
11	Pumice @$HClO_4$	EtOH/reflux	45–65	78–90	Present work

reported methods such as cheap and readily available volcanic material, smooth reaction condition and purification of targeted molecule without column chromatography.

Plausible mechanism

The plausible mechanism for the synthesis of tetrahydrobenzo[*b*]pyran derivatives using pumice supported perchloric acid were shown in Scheme 4.



Scheme 4. Plausible mechanism of Pumice@$HClO_4$ catalyzed synthesis of benzopyran.

Conclusion

In conclusion, we have investigated a novel, highly efficient protocol for the synthesis of tetrahydrobenzo[*b*]pyran in the presence of heterogeneous catalyst pumice supported perchloric acid via multi-component condensation of aromatic aldehydes, dimedone and malononitrile under reflux condition. The catalyst was characterized by IR, XRD, EDS, SEM, and TGA techniques which showed the formation novel pumice supported perchloric acid. The present protocol proved to have numerous advantages like one-pot reaction, quantitative yield of the targeted molecule, short reaction time, mild conditions inexpensive catalyst, recyclability and reusability of the catalyst, smooth experimental condition, simple work up procedure and purification of targeted molecule without column chromatography.

Acknowledgments

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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Pumice-based sulfonic acid: a sustainable and recyclable acidic catalyst for one-pot synthesis of pyrazole anchored 1,4-dihydropyridine derivatives at room temperature

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Abstract

In the present investigation, we have developed an efficient and eco-friendly protocol for the synthesis of pyrazole anchored 1,4-dihydropyridine analogs using pumice-based sulfonic acid (pumice@SO_3H) as a recyclable solid acid catalyst under simple stirring at room temperature. The present protocol proceeded smoothly with 1,3-diaryl pyrazole-4-carbaldehydes, ethyl acetoacetate, and NH_4OAc in ethanol as a solvent with excellent yield. The pumice-based sulfonic acid catalyst is easily prepared from naturally occurring pumice by simple agitation with chlorosulfonic acid. The key features of this catalyst are its heterogeneous nature, high porosity, non-corrosive and non-toxic nature, recyclability, stable and highly efficient at room temperature. The application of this catalyst makes the protocol more environmentally benign.

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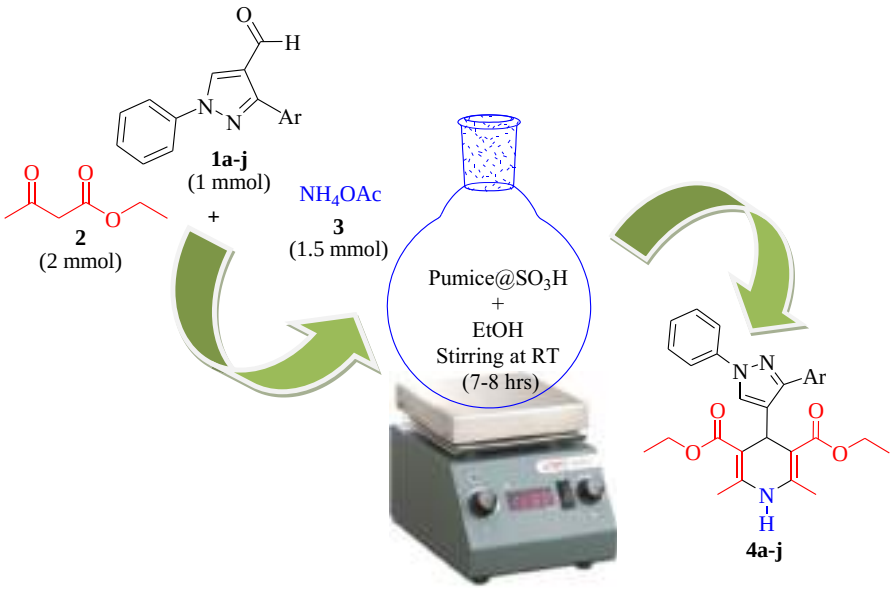
Graphical abstract



Keywords Pumice-based sulfonic acid · 1,4-dihydropyridine · 1,3-diaryl pyrazole-4-carbaldehydes

Introduction

Pumice is a naturally occurring porous material obtained after volcanic eruptions. Its high porous nature is due to the evaporation of the large number of gases. Along with porosity, it has many advantages such as high abundance, high performance, good surface area, less expensive, heterogeneous nature, excellent thermal, and chemical stability. The literature reveals that during the recent years, pumice is converted into various active materials which have been employed in many convergent and divergent organic syntheses as a catalyst [1–4].

Multicomponent reaction (MCR) offers an excellent approach for synthesizing the complex molecules. MCR approach has many advantages including, one-pot operation, high atom economy, and short reaction time. A wide variety of nitrogen heterocycles have been synthesized by MCR and are useful in the various fields like agriculture, medicinal, drug, and pharmaceutical chemistry. The synthesis of 1,4-dihydropyridine derivatives by Hantazsch reaction is an important example of multicomponent reaction. Pyridine nucleus containing compounds is a important group of heterocyclic compounds which shows a wide range of biological properties such as anticancer [5, 6], anti-inflammatory [7], anti-leishmanial [8], antimalarial [9], anti-microbial [10], anti-mycobacterial [11], antioxidant [12], anti-proliferative

[13], anti-tubercular [14, 15], anti-ulcer agents [16], antiviral [17], and cytotoxic activity [18], etc. The some important drugs containing of 1,4-dihydropyridine nucleus are given below (Fig. 1).

Owing to biological significance associated with 1,4-dihydropyridine many catalytic systems have been developed using MCR of ethylacetoacetate, aromatic aldehyde, and NH_4OAc. Among them, many protocols report use of simple aromatic aldehydes using catalytic systems such as nanomaterials [19], microwave irradiation [20], ultrasound irradiation [21], ionic liquids [22], hybrid materials [23], doped metal oxide [24], solar thermal energy [25], and acidic as well as basic catalyst. Also, many bronsted acidic catalyst have been reported includes acetic acid [26], COF-SO_3H [27], cellulose sulfuric acid [28], chitosan [29], DMAP [30], eggshell-based nanomagnetic solid acid catalyst [31], Fe_3O_4@PANI-SO_3H [32], guanidinium-based sulfonic acid [33], glycine [34], heteropolyacids [35], L-proline [36], magnetite/chitosan [37], *N*-propylbenzoguanamine sulfonic acid-functionalized magnetic nanoparticles [38], phosphoric acid [39], PPA–SiO_2 [40], PTSA–SDS [41], *p*-TSA [42], polyvinyl alcohol [43], silica-supported perchloric acid [44], TEA [45], etc. There is very less MCR reported for the synthesis of 1,4-dihydropyridine using 1,3-diaryl pyrazole-4-carbaldehydes as aldehyde component such as [HNMP][HSO_4] [46], magnesium oxide nanotubes [47], silica [48], silica sulphuric acid [49] sulfamic acid [50], etc.

In continuation of our ongoing studies on the application of pumice@SO_3H catalysts [2] towards the sustainable development of new facile protocols [51–55], we report herein the synthesis of 1,4-dihydropyridine derivatives anchored with pyrazole moiety. The key aspect of this protocol is the simple aromatic aldehyde was replaced by structurally hindered and bulkier 4-formyl pyrazole aldehyde using Brønsted acidic pumice-based sulfonic acid catalyst via

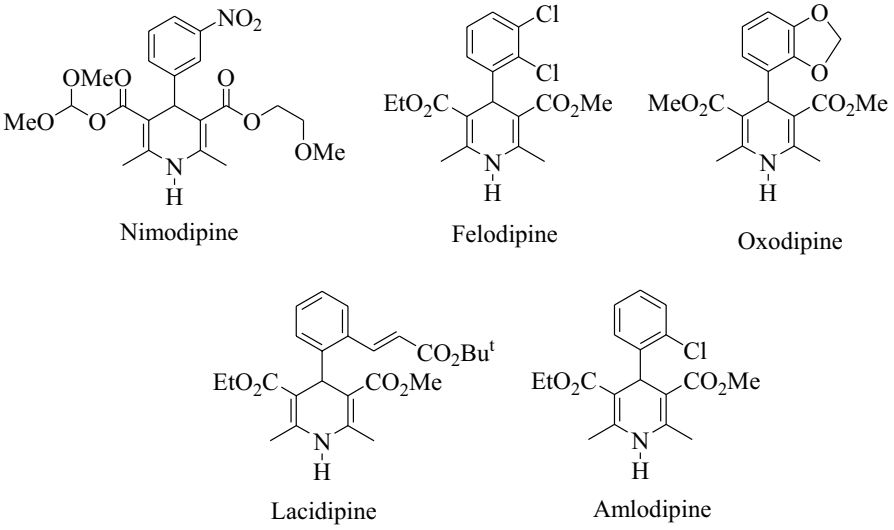
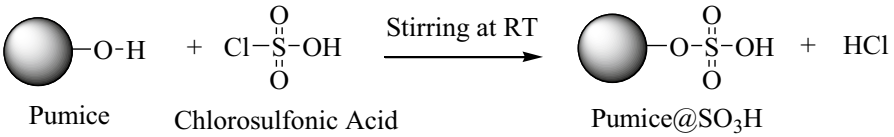


Fig. 1 Drugs containing 1,4-dihydropyridine nucleus



Scheme 1 Preparation of pumice-based sulfonic acid (pumice@SO_3H) catalyst

MCR strategy (Scheme 2). Even with this aldehyde, the pumice-based catalyst showed good catalytic activity. The 1,3-diaryl pyrazole-4-carbaldehydes were prepared by following Veilsmeier-haack formylation reaction reported in literature [56].

Experimental

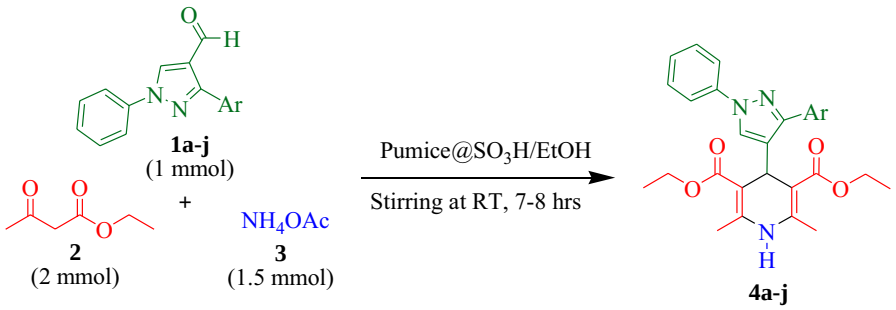
Melting points were recorded in an open capillary and are uncorrected. Infrared spectra were recorded on a Perkin-Elmer FTIR spectrophotometer. The ^{1}H-NMR and ^{13}C-NMR spectra were recorded on a BRUCKER AVANCE NEO 500 MHz NMR spectrometer in $CDCl_3$ using tetramethyl silane as a reference compound. Mass spectra were recorded on a Finnigan Mass spectrometer. TLC was carried out by Al-plates pre-coated with silica gel to check the purity of the compounds. In the present work, the pumice-based sulfonic acid catalyst has been prepared by previously reported method [2]. In that, the catalyst is fully characterized and confirmed its formation.

(1) General procedure for preparation of pumice-based sulfonic acid (pumice@SO_3H) catalyst.

The chlorosulfonic acid was added slowly into the round bottom flask containing pumice at room temperature as per the procedure in [2]. After the complete addition, the stirring was continued till a faint brownish white solid was obtained which was washed with acetone. Resultant solid was dried in heating oven to give desired pumice-based sulfonic acid (pumice@SO_3H) catalyst (Scheme 1).

(2) General procedure for the synthesis of 1,4-dihydropyridine derivatives **(4a–j)**.

In a single neck 100 mL, round bottom flask 3-aryl-1-phenyl-1*H*-pyrazole-4-carbaldehyde 1 (1 mmol), ethyl acetoacetate 2 (2 mmol), ammonium acetate 3 (1.5 mmol), and 150 mg of pumice-based sulfonic acid was taken in 15 mL of ethyl alcohol. The resulting reaction mixture was stirred at room temperature for appropriate time (Scheme 2). The progress of the transformation was monitored by TLC. Once the reaction was completed, the content was mixed with dichloromethane, and catalyst was separated by decantation. After the separation of catalyst, the dichloromethane was concentrated on rotary evaporator which gave solid 1,4-dihydropyridine derivatives. The obtained product was dried and purified by recrystallization from n-hexane–ethyl acetate. The recovered catalyst was washed with dichloromethane and dried to reuse for the next cycle.

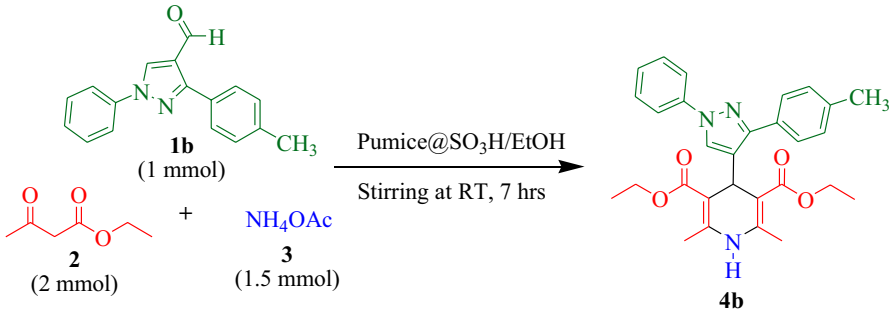


Scheme 2 Synthesis of 1,4-dihydropyridine derivatives **(4a–j)**

Result and Discussion

The pumice-based sulfonic acid (Pumice@SO_3H) catalyst was simply prepared by stirring naturally occurring pumice with chlorosulfonic acid. The catalyst formation occurs within one hour, which exhibits excellent properties such as high surface area, good thermal stability, high acidity (Scheme 1). The catalytic potential of synthesized pumice@SO_3H catalyst was checked in our previous work [2] again it was thought to check further applicability of pumice@SO_3H catalyst for one-pot synthesis of 1,4-dihydropyridines.

Initially, we have selected 1-phenyl-3-*p*-tolyl-1*H*-pyrazole-4-carbaldehyde 1b, ethyl acetoacetate 2, and NH_4OAc 3 as a pilot reaction (Scheme 3) and investigated under agitation at room temperature with and without solvent. The model reaction was also carried out in the absence and in presence of pure pumice in ethanol as solvent; it was found that no product formation occurred after a period of long time (Table 1, Entries 1, 2). Then the chosen model reaction was performed with 100 mg of pumice@SO_3H catalyst under solvent-free agitation; the reaction did not proceed (Table 1, Entry 3). Further study was continued by performing reaction in the presence of pumice@SO_3H catalyst in water as solvent, got the negative results after prolonged stirring at room temperature (Table 1, Entry 4). Then the reaction was



Scheme 3 Model reaction for the synthesis of 1,4-dihydropyridine derivatives (4b)

Table 1 Optimization of the reaction conditions for the synthesis of diethyl 1,4-dihydro-2,6-dimethyl-4-(1-phenyl-3-*p*-tolyl-1*H*-pyrazol-4-yl)pyridine-3,5-dicarboxylate (4b)

Entry	Catalyst/solvent	Reaction condition	Time in hr	Isolated yield (%)
1	No catalyst / Solvent free (SF)	Stirring at RT	24	NR
2	No catalyst / 10 ml EtOH	Stirring at RT	24	NR
3	Pure Pumice / SF	Stirring at RT	24	NR
4	Pure Pumice / 10 ml EtOH	Stirring at RT	24	NR
5	100 mg Pumice@SO_3H / SF	Stirring at RT	24	Trace
6	100 mg Pumice@SO_3H / 10 ml H_2O	Stirring at RT	24	Trace
7	100 mg Pumice@SO_3H / 10 ml EtOH	Stirring at RT	10	70%
8	150 mg Pumice@SO_3H / 10 ml EtOH	Stirring at RT	7.5	88%
9	200 mg Pumice@SO_3H / 10 ml EtOH	Stirring at RT	7.5	88%

Reaction condition: 1-phenyl-3-*p*-tolyl-1*H*-pyrazole-4-carbaldehyde 1b (1 mmol), ethyl acetoacetate 2 (2 mmol), NH_4OAc 3 (1.5 mmol), pumice@SO_3H

carried out with the 100 mg of pumice@SO_3H catalyst in ethanol under simple stirring at room temperature. This study reveals that the reaction proceeds with excellent yield (Table 1, Entry 5). We also studied the amount of catalyst pumice@SO_3H required for this reaction (Table 1, entries 5–7), which indicates that 150 mg pumice@SO_3H in the presence of 10 ml ethanol (Table 1, entry 6) was sufficient for the successful results. And further, with the use of excess of the pumice@SO_3H, the yield of the product did not change significantly.

Further, the study was continued to check the catalytic activity of pumice@SO_3H for the synthesis of 1,4-dihydropyridines anchored with variously substituted 1,3-diaryl pyrazole-4-carbaldehydes. We know that these aldehydes are sterically hindered and comparatively less reactive. The optimized conditions were applied for different 1,3-diaryl pyrazole-4-carbaldehydes and interestingly the catalyst showed good potential for the construction of bulky 1,4-dihydropyridines with good yield at even room temperature as illustrated in Table 2.

The one more important green feature of the pumice@SO_3H catalyst is recyclability. Once the model reaction (Scheme 3) was completed, the content was mixed with DCM and the insoluble pumice@SO_3H catalyst was separated by decantation. The recovered catalyst was washed again with DCM and dried well. It was reused in three cycles without significant loss in its catalytic activity. The reusability result is shown in Fig. 2. While the organic layer upon evaporation on a rotary evaporator under reduced pressure resulted in the solid 1,4-dihydropyridine derivatives.

The formation of catalyst was proved with IR, XRD, SEM, TEM, and EDAX studies which are reported in our previous work [2]. Here the evidence of recyclability study is provided.

Infrared spectrum of recycled pumice@SO_3H

In the IR spectrum of the recycled pumice@SO_3H (Fig. 3), the broad vibration band of O–H bond in (-SO_3H) group is observed at 3215.10 cm^{-1}. Also, the

Table 2 Synthesis of pyrazole anchored 1,4-dihydropyridine derivatives (4a-j)

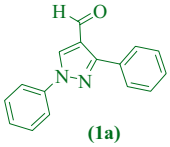
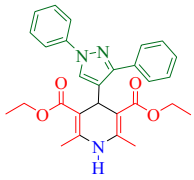
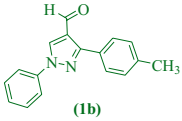
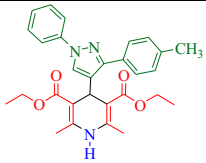
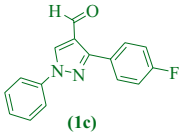
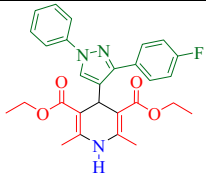
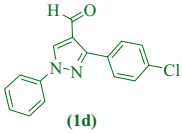
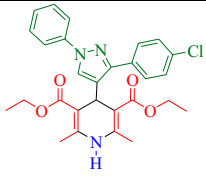
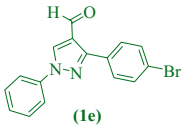
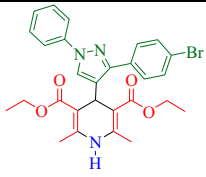
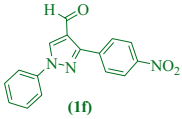
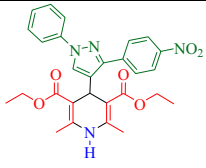
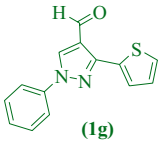
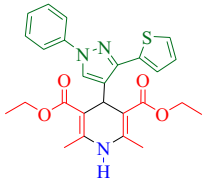
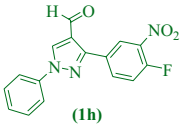
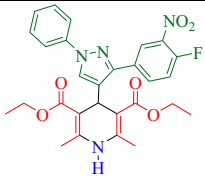
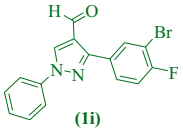
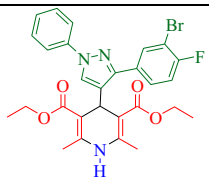
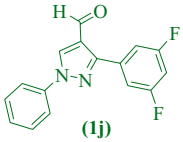
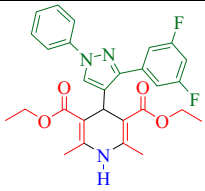
Entry	Aldehyde	1,4-dihydropyridine derivatives	Reaction Time in hrs	Yield in %	M.P. in ^{O}C	
					Found	Lit.[Ref]
1	 (1a)	 (4a)	7	84	161	154 [46]
2	 (1b)	 (4b)	7.5	88	178	176 [46]
3	 (1c)	 (4c)	7.5	80	165	160 [46]
4	 (1d)	 (4d)	7	85	156	158 [46]
5	 (1e)	 (4e)	7.5	80	174	182 [48]
6	 (1f)	 (4f)	8	75	191	178 [46]

Table 2 (continued)

7	 (1g)	 (4g)	7.5	88	173	170 [46]
8	 (1h)	 (4h)	8	80	180	
9	 (1i)	 (4i)	8	82	260	270 [46]
10	 (1j)	 (4j)	7.5	85	284	290 [46]

Reaction condition: 3-aryl-1-phenyl-1*H*-pyrazole-4-carboxaldehydes **1** (1 mmol), ethyl acetoacetate **2** (2 mmol), NH_4OAc **3** (1.5 mmol), 150 mg pumice@SO_3H and 10 mL EtOH

characteristic bands due to the presence of S = O and Si–O–Si were observed at 1636.86 cm^{-1} and 1090.76 cm^{-1}, respectively. These results suggest that, the recovery of -SO_3H group in the framework of recycled pumice@SO_3H catalyst.

The XRD spectra of recycled pumice@SO_3H

Also, the successful recyclability of pumice@SO_3H with -SO_3H groups was confirmed by XRD analysis (Fig. 4). The XRD pattern of recycled catalyst pumice@SO_3H was exactly matched with the literature data (Tambe et. al.). This indicates that the recycled pumice@SO_3H did not show any major change in composition.

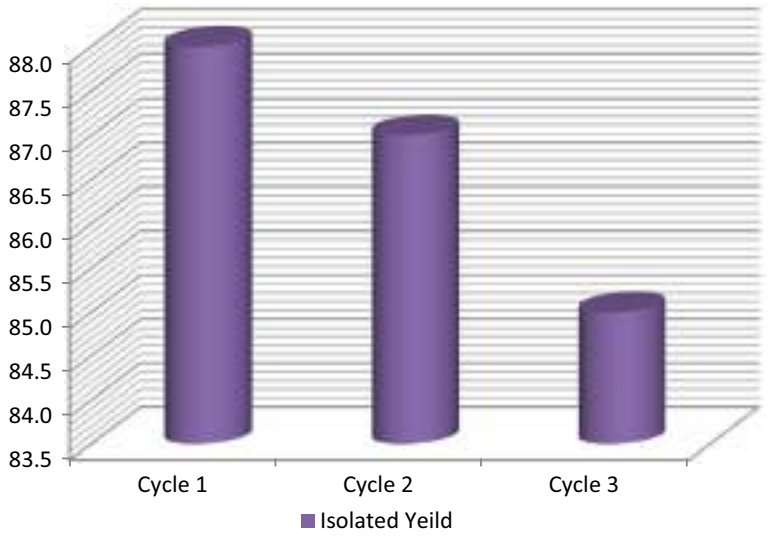


Fig. 2 Reusability of the pumice@SO_3H for the synthesis of 1,4-DHP derivative (4b)

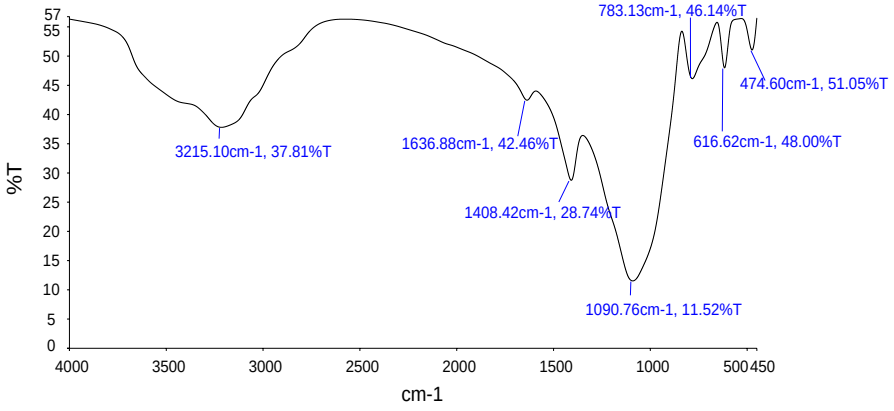


Fig. 3 IR spectra of recycled pumice-based sulfonic acid (pumice@SO_3H)

Spectral Data

4a: diethyl 1,4-dihydro-2,6-dimethyl-4-(1,3-diphenyl-1*H*-pyrazol-4-yl) pyridine-3,5-dicarboxylate

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 1.07 (t, 6H, -CH_3 X 2), 2.20 (s, 6H, -CH_3 X 2), 3.78 (m, 2H, -OCH_2-), 4.01 (m, 2H, -OCH_2-), 5.29 (s, 1H, -CH-), 5.59 (s, 1H, NH), 7.21–7.74 (m, 6H, Ar–H), 7.42 (m, 5H, Ar–H); 13C NMR ($CDCl_3$, 500 MHz) δ: 14.33, 19.45, 29.72, 59.69, 104.32, 118.83, 125.99, 127.10, 127.46,

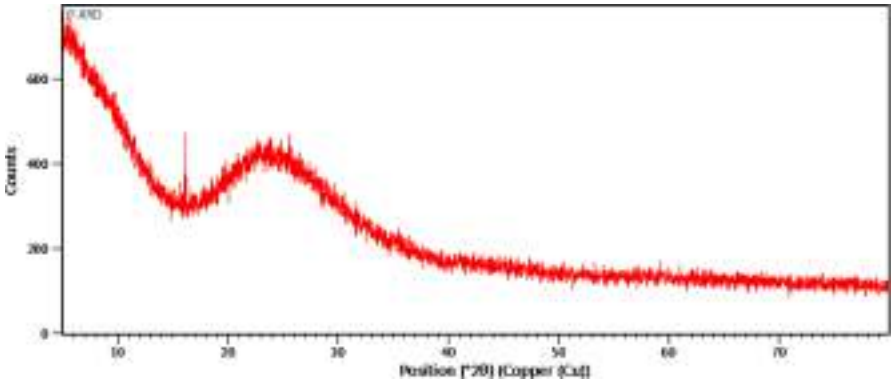


Fig. 4 The XRD spectra of recycled pumice-based sulfonic acid (pumice@SO_3H)

127.89, 128.67, 128.99, 129.22, 134.88, 140.10, 143.41, 151.27, 167.59; MS (ESI): m/z = 472.2275 [M + H].

4b: diethyl 1,4-dihydro-2,6-dimethyl-4-(1-phenyl-3-*p*-tolyl-1*H*-pyrazol-4-yl)pyridine-3,5-dicarboxylate

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 1.07 (t, 6H, -CH_3 X 2), 2.22 (s, 6H, -CH_3 X 2), 2.38 (s, 3H, Ar-CH_3), 3.77 (m, 2H, -OCH_2-), 4.02 (m, 2H, -OCH_2-), 5.29 (s, 1H, -CH), 5.58 (s, 1H, NH), 7.19–7.25 (m, 3H, Ar–H), 7.39 (t, 2H, Ar–H), 7.66 (d, 2H, Ar–H), 7.72 (d, 3H, Ar–H); MS (ESI): m/z = 486.2335 [M + H].

4d: diethyl 4-(3-(4-chlorophenyl)-1-phenyl-1*H*-pyrazol-4-yl)-1,4-dihydro-2,6-dimethylpyridine-3,5-dicarboxylate

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 1.04 (t, 6H, -CH_3 X 2), 2.24 (s, 6H, -CH_3 X 2), 3.66 (m, 2H, -OCH_2-), 3.88 (m, 2H, -OCH_2-), 5.27 (s, 1H, CH), 5.59 (s, 1H, NH), 7.29 (t, 1H, Ar–H), 7.47 (t, 2H, Ar–H), 7.53 (d, 2H, Ar–H), 7.81 (d, 2H, Ar–H), 7.94 (d, 2H, Ar–H), 8.04 (s, 1H, Ar–H); 13C NMR ($CDCl_3$, 500 MHz) δ: 14.31, 19.43, 29.68, 59.79, 104.41, 118.87, 126.21, 127.43, 128.07, 129.03, 129.28, 130.22, 133.40, 139.97, 143.54, 149.77, 167.54; MS (ESI): m/z = 506.1873 [M + H].

4f: diethyl 4-(3-(4-nitrophenyl)-1-phenyl-1*H*-pyrazol-4-yl)-1,4-dihydro-2,6-dimethylpyridine-3,5-dicarboxylate

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 1.03 (t, 6H, -CH_3 X 2), 2.31 (s, 6H, -CH_3 X 2), 3.79 (m, 2H, -OCH_2-), 4.01 (m, 2H, -OCH_2-), 5.32 (s, 1H, CH), 5.74 (s, 1H, NH), 7.28 (t, 1H, Ar–H), 7.43 (t, 2H, Ar–H), 7.68 (d, 2H, Ar–H), 7.78 (s, 1H, Ar–H), 8.24 (d, 2H, Ar–H), 8.31 (d, 2H, Ar–H).

4 g: diethyl 1,4-dihydro-2,6-dimethyl-4-(1-phenyl-3-(thiophen-2-yl)-1*H*-pyrazol-4-yl) pyridine-3,5-dicarboxylate

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 1.05 (t, 6H, -CH_3 X 2), 2.31 (s, 6H, -CH_3 X 2), 3.89 (m, 2H, -OCH_2-), 4.03 (m, 2H, -OCH_2-), 5.34 (s, 1H, CH), 5.55 (s, 1H, NH), 7.21–7.29 (m, 3H, Ar–H), 7.38–7.43 (m, 2H, Ar–H), 7.55–7.65 (m, 4H, Ar–H); 13C NMR ($CDCl_3$, 500 MHz) δ: 14.23, 19.63, 29.76, 59.83, 104.96, 118.81, 124.79, 126.09, 126.25, 127.07, 128.21, 129.35, 129.49, 136.17, 139.88, 143.12, 145.11, 167.51; MS (ESI): m/z = 478.1871 [M + H].

4j: diethyl 4-(3-(3,5-difluorophenyl)-1-phenyl-1*H*-pyrazol-4-yl)-1,4-dihydro-2,6-dimethylpyridine-3,5-dicarboxylate

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 1.08 (t, 6H, -CH_3 X 2), 2.28 (s, 6H, -CH_3 X 2), 3.83 (m, 2H, -OCH_2-), 4.06 (m, 2H, -OCH_2-), 5.28 (s, 1H, CH), 5.79 (s, 1H, NH), 6.80 (m, 1H, Ar–H), 7.26 (m, 1H, Ar–H), 7.41 (t, 2H, Ar–H), 7.56 (t, 2H, Ar–H), 7.66 (d, 2H, Ar–H), 7.75 (s, 1H, Ar–H).

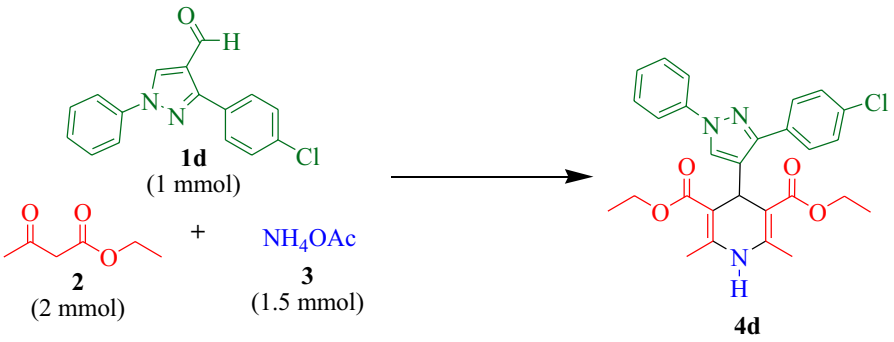
The comparative study on the use of pumice@SO_3H catalyst with the different reported catalytic systems is mentioned in Table 3. From this investigation, it was found that the pumice@SO_3H catalyst showed a remarkable catalytic activity for the synthesis for the synthesis of sterically hindered and bulky pyrazole anchored 1,4-dihydropyridine derivative (4d) by MCR (Scheme 4) of the 1,3-diaryl pyrazole carbaldehyde (1d), ethylacetoacetate (2) and NH_4OAc (3). In addition, this designed catalytic system has many advantages over the reported methods such as naturally occurring material, low cost, readily available, and reaction proceed at room temperature.

Plausible mechanism

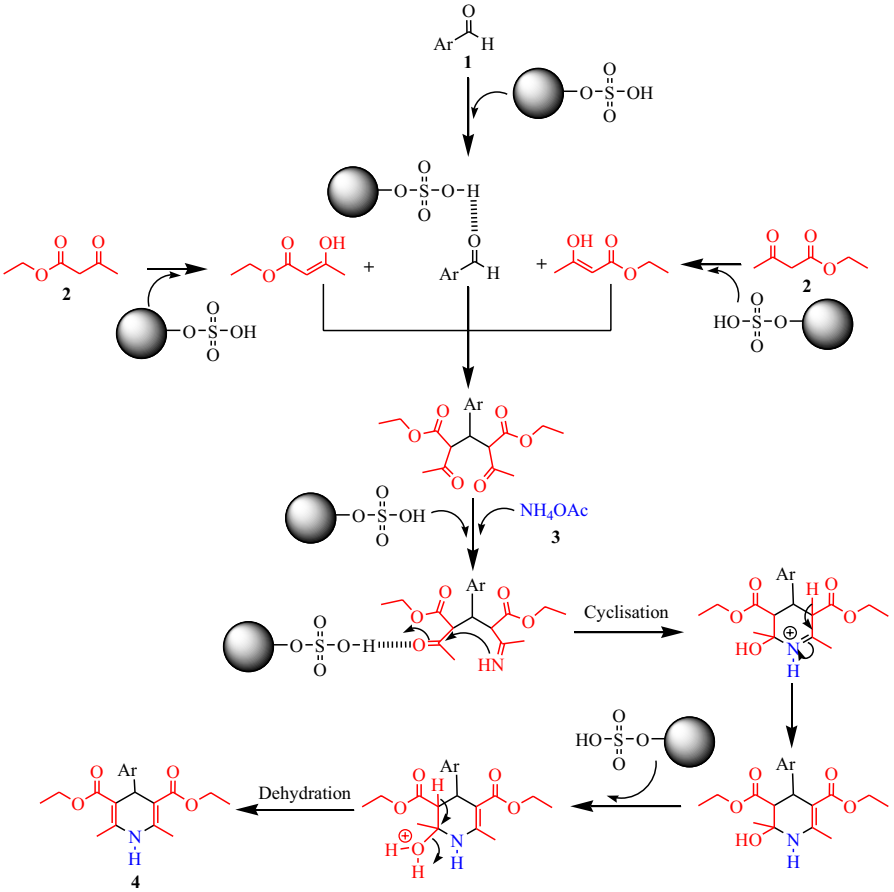
The proposed mechanism of synthesis of 1,4-dihydropyridine in presence of pumice@SO_3H catalyst is shown in Scheme 5.

Table 3 Comparative study of the efficiency of various catalytic systems for the synthesis of pyrazole anchored 1,4-dihydropyridine derivative (4d)

Entry	Catalyst	Reaction Condition	Time in hrs	Yield in %	Ref. No
1	[HNMP][HSO_4]	EtOH/Stirring at RT	5	84	[46]
2	Magnesium Oxide Nanotubes	CH_3CN/Reflux	0.5	91	[47]
3	Silica	SF/Heating at 90°C	4	90	[48]
4	Silica Sulphuric acid	EtOH/Stirring at Ambient temp	2.5	84	[49]
5	Sulfamic acid	EtOH /Reflux	5	80	[50]
6	Pumice @SO_3H	EtOH/Stirring at RT	7	85	**Present work**



Scheme 4 Synthesis of pyrazole anchored 1,4-dihydropyridine derivative (4d)



Scheme 5 Plausible Mechanism of pumice@SO_3H catalyzed synthesis of 1,4-dihydropyridine

Conclusions

In conclusion, the pumice-based sulfonic acid was proved to be a convenient and efficient catalyst for the synthesis of a series of 1,4-dihydropyridines anchored with biologically important pyrazole moiety via one-pot multi-component reaction. Even though the 1,3-diaryl pyrazole-4-carbaldehydes are bulky and less reactive the products were obtained at room temperature with good to excellent yields. The preparation of the catalyst is very simple and it can be reused in many cycles without loss of its catalytic activity. Also, it has many advantages including high porosity, heterogeneous nature, non-corrosive and non-toxic nature, and thermally stable and efficient at room temperature.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11164-021-04649-7.

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PUMICE@SO_3H CATALYZED ULTRASOUND MEDIATED SYNTHESIS OF POLYHYDROQUINOLINE DERIVATIVES.

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Abstract:
A sustainable and convenient protocol is developed for the synthesis of polyhydroquinoline derivatives under ultrasound irradiation at 45°C in the presence of pumice anchored sulfonic acid (Pumice@SO_3H) as a recoverable catalyst. These polyhydroquinolines were synthesized from aldehydes, dimedone, ethylacetoacetate and ammonium acetate by Hantzsch reaction. The attractive features of the present protocol are green approach, good yield, recovery of catalyst, easy work-up procedure and simple purification of product whereas the catalyst offers simple preparation, high catalytic activity, inexpensive, easy to use, recyclability and stability.

Keywords:
Pumice@SO_3H, polyhydroquinolines, ultrasound irradiation, dimedone, etc.

Introduction:

Pumice stone obtained due to volcanic eruptions has many advantages such as abundance, availability, large surface area, low cost, non-homogeneous nature, and excellent stability. Also due to the remarkable properties such as high porosity and high adsorption capacities have gained much interest in the field of catalysis. In recent years, the volcanic pumice converted into variety of supported active catalytic materials such as pumice@SO_3H[i, ii], Pd–Ag catalysts supported on pumice[iii], Pumice-modified cellulose fiber[iv], Volcanic based hybrid nanocomposite[v], Pumice supported Pd catalyst[vi], Immobilization of TiO_2 on pumice stone[vii], iron-coated pumice[viii, ix], pumice-supported Pd–Cu catalysts[x], etc.

Multi-component reactions (MCRs) are a constructive approach to synthesize heterocyclic compounds with diverse structures. In MCRs, more than two components reacts together in single step to produce a targeted heterocyclic system without isolation of any intermediate. Due to this, requires short time, reduce energy requirement, reduce quantity of precursors, and are useful to increase atom economy. The Hantzsch reaction is one of the most important examples of multicomponent reaction which is used for synthesis of polyhydroquinoline derivatives[xi, xii]. The polyhydroquinoline derivatives is of great attention due to their various activities such as anti-cancer, anti-diabetic, anti-hypertensive, anti-inflammatory, anti-microbial, anti-

tubercular, anti-tumor, bronchodilator, calcium channel blockers, cardiovascular agents, geroprotective, hepatoprotective, neurotropic, and vasodilator[xiii-xxii] etc. These versatile activities have encouraged researchers to design sustainable and convenient catalytic materials for the synthesis of heterocyclic compounds containing polyhydroquinoline moiety. Some illustrations of drugs with 1,4-dihydropyridine framework are outlined in **Fig. 1**.

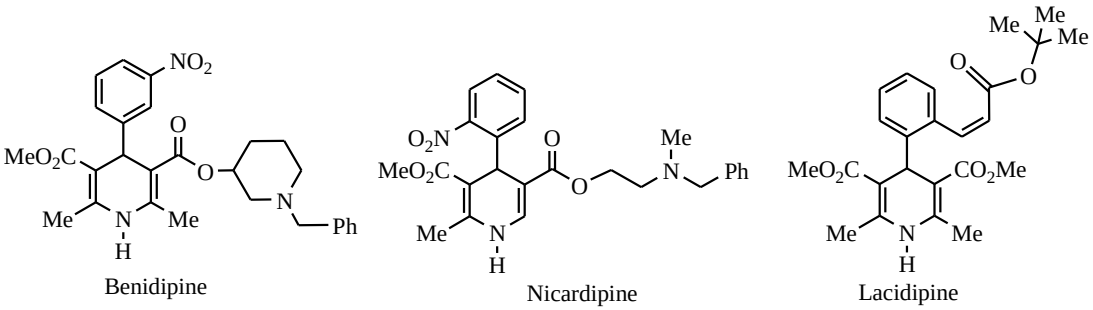


Fig.1. some drugs containing 1,4-dihydropyridine framework

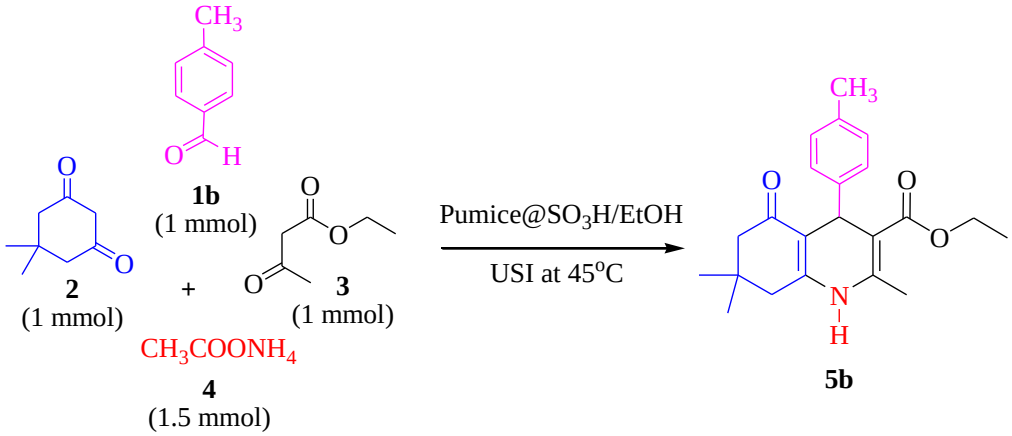
Recently, numerous protocols have been developed for the synthesis of polyhydroquinolines from aromatic aldehyde, dimedone, ethylacetoacetate and ammonium acetate such as nano-materials[xxiii], metal oxide supported materials[xxiv], magnetic materials[xxv], ionic liquids[xxvi], amino acids[xxvii], solar thermal energy[xxviii], Zeolite[xxix], microwave[xxx], and ultrasound[xxxi] etc. Also various bronsted acidic catalyst are used such as Fe_3O_4/SiO_2-OSO_3H[xxxii], silica sulfuric acid[xxxiii], nicotinic acid[xxxiv], Acetic acid[xxxv], Aluminized polyborate[xxxvi], PPA-SiO_2[xxxvii], SBA-15/SO_3H[xxxviii], SBA-15@Glycine[xxxix], PMO-ICS-PrSO_3H[xl], BINOL-phosphoric acid[xli], Carbon-based Solid acid (CBSA)[xlii], COF-SO_3H [xliii], Fe_3O_4@FSM-16-SO_3H [xliv], *p*-TSA[xlv], [MSAIM]HSO_4[xlvi], [Pyridine-SO_3H]Cl[xlvii], Caffeine-H_3PO_4[xlviii], ascorbic acid[xlix], Fe_3O_4@PEO-SO_3H[l], etc.

The ultrasound (US) assisted synthesis is well developed method used for the synthesis of variety of heterocyclic compounds. It proceeds through the development and adiabatic collapse of the transient cavitations bubble. It is used as a green approach that helping to reduce high energy requirements. The US approach provides smooth and cleaner reactions procedure with increasing yields in presence of various catalytic processes [li-lvii].

In continuation of our environmentally benign work [lviii-lxii] and on the application of pumice@SO_3H catalysts[i, ii], here we report a convenient green approach for one-pot synthesis of polyhydroquinolines in the presence pumice anchored sulfonic acid as a bronsted acidic catalyst with good catalytic activity and recyclability.

Results and Discussion:

In order to choose the better reaction condition a model reaction (**Scheme 1**) of *p*-methyl benzaldehyde, dimedone, ethyl acetoacetate and ammonium acetate was carried out in presence of catalyst pumice@SO_3H with and without catalyst and solvent. The reaction did not proceed to any extent in absence of catalyst with and without solvent during stirring at room temperature (**Table 1, Entry 1-3**). Also the negative result was obtained with pumice@SO_3H catalyst at room temperature in presence water and ethanol as well as without solvent under ultrasound irradiation (**Table 1, Entry 4-6**). The reaction proceeds smoothly with catalyst pumice@SO_3H in presence of ethanol as solvent at 45^{o}C under ultrasound irradiation with excellent yield (**Table 1, Entry 7**).



Scheme 1. Model reaction for synthesis of Polyhydroquinoline (**5b**) derivative

Table 1: Optimization of reaction condition for the synthesis of polyhydroquinoline (**5b**)

Entry	Catalyst / Solvent	Reaction Condition	Time in hrs.	Yield [b] in %
1	90 mg pumice@SO_3H / Solvent free	Grinding	0.5	No reaction (NR)
2	90 mg pumice@SO_3H / H_2O	Stirring at RT	3	NR
3	90 mg pumice@SO_3H / EtOH	Stirring at RT	3	NR
4	90 mg pumice@SO_3H / H_2O	USI at RT	3	NR
5	90 mg pumice@SO_3H / H_2O	USI at 45°C	3	NR
6	90 mg pumice@SO_3H / EtOH	USI at RT	3	Trace
7	90 mg pumice@SO_3H / EtOH	USI at 45°C	1.5	80

[a]Reaction condition: **1b** (0.120gm, 1mmol), **2** (0.140gm, 1mmol), **3** (0.130gm, 1mmol), **4** (0.107gm, 1.5mmol), pumice@SO_3H (90 mg), [b]Isolated Yield

Table 2: Optimization of quantity of catalyst for the synthesis of polyhydroquinoline (**4b**)

Entry	Pumice@SO_3H Catalyst (mg)	Time (hrs)	Yield[b] (%)
1	40	2	25
2	60	2	45
3	80	2	70
4	90	1.5	80
5	90	1.5	80

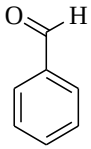
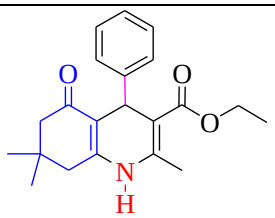
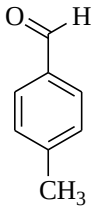
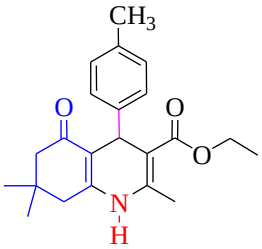
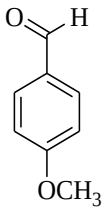
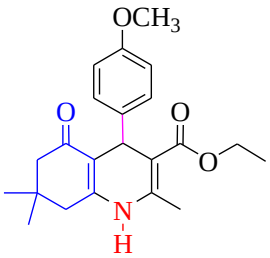
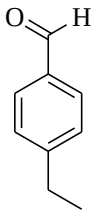
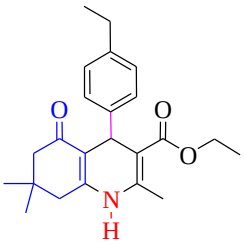
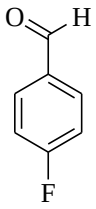
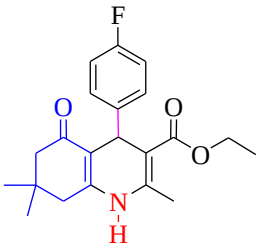
[a]Reaction condition: **1b** (0.120gm, 1mmol), **2** (0.140gm, 1mmol), **3** (0.130gm, 1mmol), **4** (0.107gm, 1.5mmol), USI at 45°C, [b] Isolated Yield

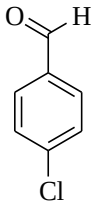
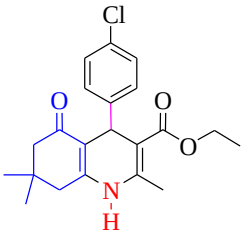
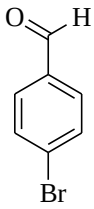
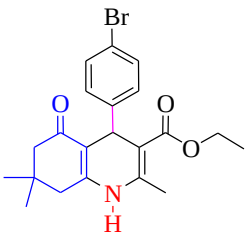
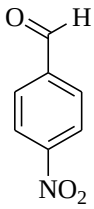
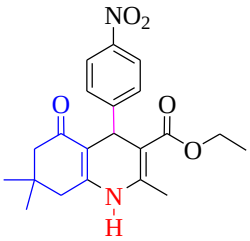
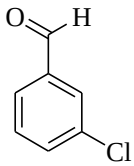
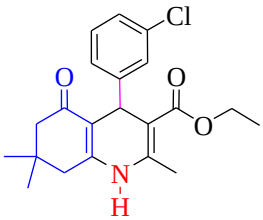
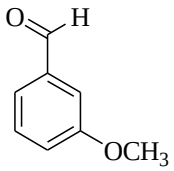
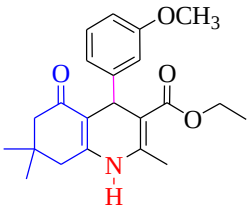
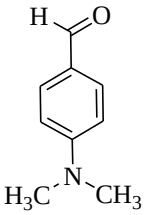
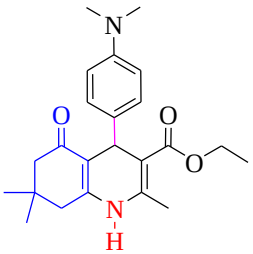
The model reaction was then studied for different amount of catalyst to optimize the amount of catalyst required (**Table 2**). It was found that further increase in the amount of catalyst, there was no significant improvement in the yield of the product.

This outcome enhanced our attention to study the scope, generality and relevance of this protocol for the synthesis of Polyhydroquinoline (**5a-k**) derivatives. The series of Polyhydroquinoline were synthesized using diverse aromatic aldehydes under above optimized

conditions with good yield (74-86%) as mentioned in **Table 3**. The protocol worked very well with aldehydes containing electron deficient and electron rich substituent.

Table 3: Data of synthesized Polyhydroquinoline (**5a-k**) derivatives

Entry	Aldehyde	Product	Time (hrs)	Yield (%)	M.P. (°C)	
					Observed	Reported
1		 **5a**	1.5	85	214-216	217–219[35]
2		 **5b**	1.5	80	252-256	260–262[35]
3		 **5c**	2.0	78	257-260	258–260[35]
4		 **5d**	1.5	80	220-224	--
5		 **5e**	1.5	79	182-184	185–186[35]

6		 **5f**	2.0	82	240-242	245–246[35]
7		 **5g**	2.0	78	250-252	254–256[35]
8		 **5h**	2.0	75	238-240	240–242[35]
9		 **5i**	1.5	80	204-206	205–206[35]
10		 **5j**	1.5	76	192-194	198–200[35]
11		 **5k**	1.5	80	236-238	228–231[29]

[a]Reaction condition: **1a-k** (0.120gm, 1mmol), **2** (0.140gm, 1mmol), **3** (0.130gm, 1mmol), **4** (0.107gm, 1.5mmol), USI at 45°C

After the completion of the reaction, the catalyst used has been recovered by heating the reaction mixture up to the boiling. The resultant hot solution was filtered at hot condition to separate the catalyst. The recovered catalyst was washed with dichloromethane 2-3 times and dried to reuse. The recycled catalyst was reused under the optimal conditions in three cycles of the similar transformation (**Fig. 2**). The formation of Pumice@SO_3H catalyst was proved by spectral studies such as FT-IR, XRD, SEM, TEM and EDS etc. which are reported in our previous work[i]. Here the evidences of recyclability study are provided. The FT-IR, XRD and EDS spectra of the recycled pumice@SO_3H catalyst after third cycle did not show any significant change in catalytic activity.

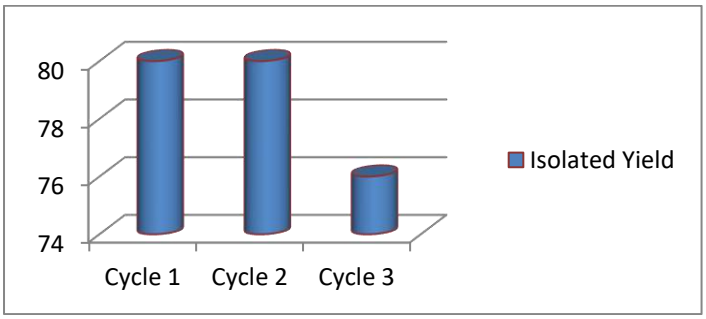


Fig. 2. Reusability of the pumice@SO_3H for the synthesis of Polyhydroquinoline (**4b**)

In the FT-IR spectrum of the recycled pumice@SO_3H (**Fig. 3**), the broad band at 3414.35 cm^{-1} is appeared due to O-H group in sulfonic acid. Also the important bands at 1637.32 cm^{-1} and 1111.05 cm^{-1} are appeared due to the S=O and Si–O–Si respectively. These significant bands indicate that, the recovery of -SO_3H group in the recycled catalyst.

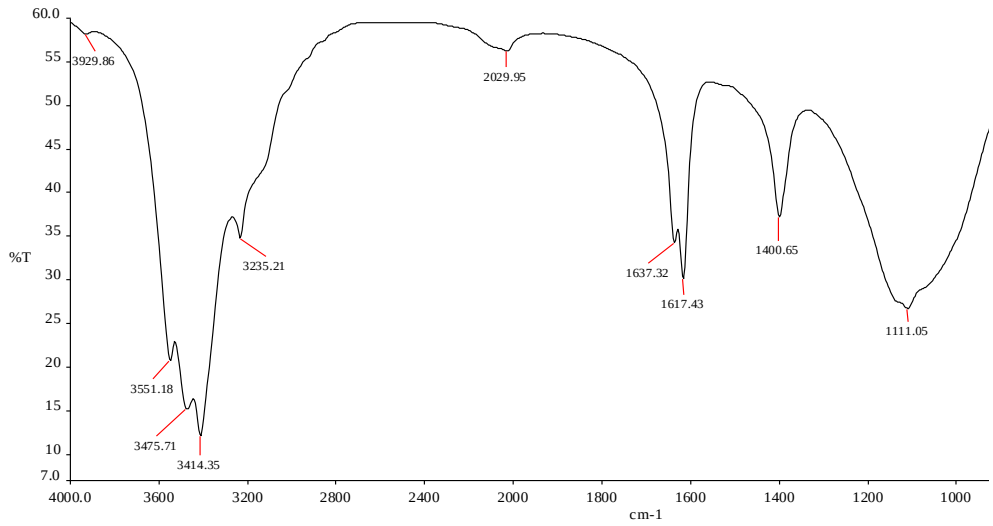


Fig. 3. IR Spectrum of Pumice@SO_3H catalyst

The nature of XRD (**Fig. 4**) and EDS (**Fig. 5**) of recycled catalyst was precisely matched with the reported catalyst. It showed that, the recycled catalyst did not show any variation in composition.

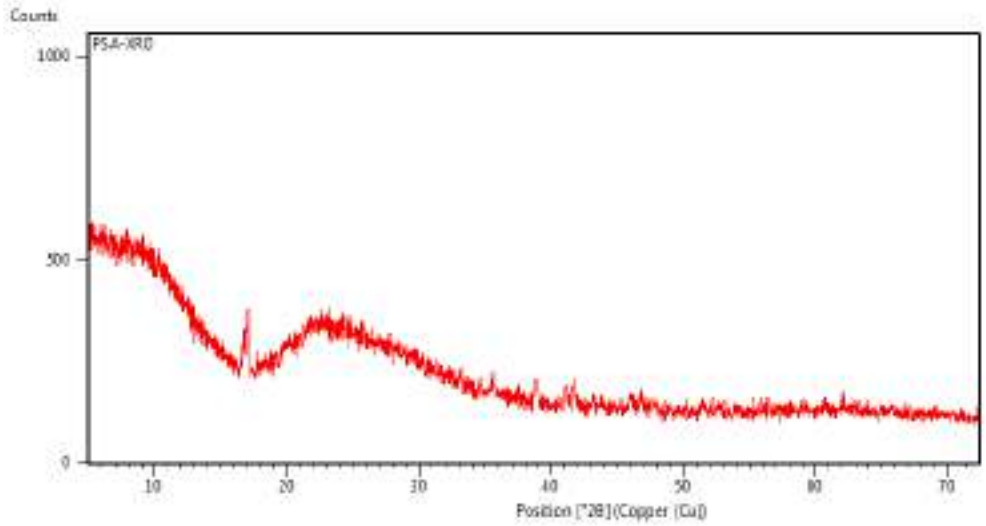


Fig.4. XRD of Pumice@SO_3H catalyst

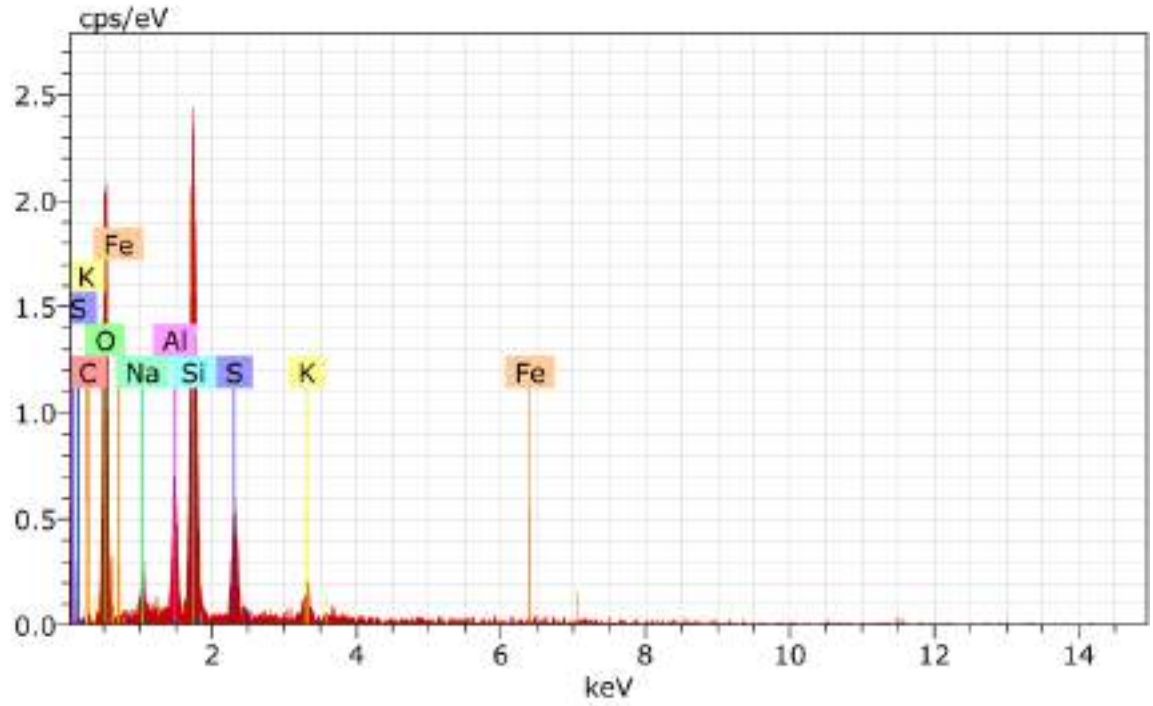


Fig.5. EDS of Pumice@SO_3H catalyst

The comparative study of different protocols for synthesis of polyhydroquinolene derivatives is illustrated in **Table 4**. While the plausible mechanism involved in Pumice@SO_3H promoted synthesis of polyhydroquinolines is shown in **Scheme 4.**

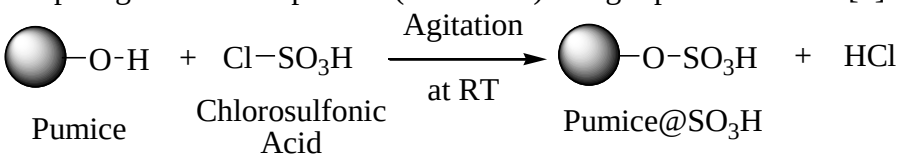
Table 4: Comparative study of different protocols for synthesis of polyhydroquinolene (**5b**)

Entry	Catalyst	Reaction Condition	Quantity of Catalyst in gm	Time in min	Yield (%)	Reference
1	Silica Sulfuric acid	Solvent free/60^oC	0.080	50	92	33

2	Nicotinic acid	Solvent free/80°C	0.1	07	92	34
3	PPA-SiO_2	Solvent free/80°C	0.030	60	90	37
4	PMO-ICS-PrSO_3H	Reflux/EtOH	0.020	20	95	40
5	CBSA	Solvent free/90°C	0.020	35	88	42
6	COF-SO_3H	Solvent free/90°C	0.020	10	95	43
7	Pumice@SO_3H	EtOH/USI, 45°C	0.090	90	80	Present work

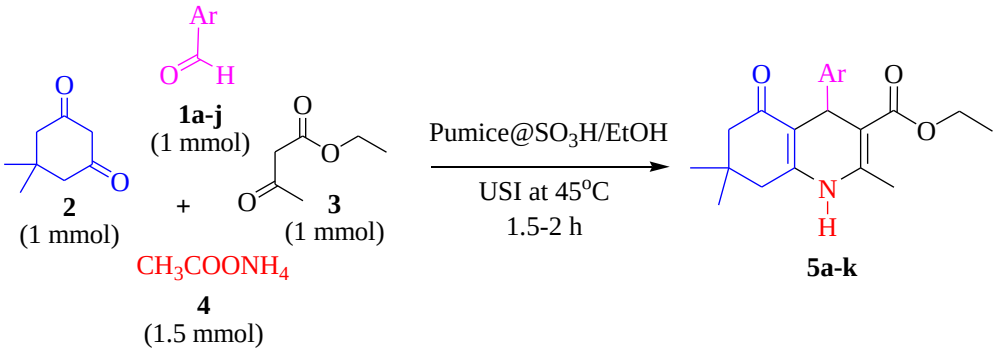
Experimental:
Melting points were recorded in an open capillary and are uncorrected. Infra Red spectra were recorded on a Perkin-Elmer FTIR spectrophotometer. The ^{1}H-NMR and ^{13}C-NMR spectra were recorded on a BRUCKER AVANCE NEO 500MHz NMR Spectrometer in $CDCl_3$ using Tetramethyl silane as a reference compound. Mass spectra were recorded on a Finnigan Mass spectrometer. TLC was carried out by Al-plates pre-coated with silica gel to check the purity of the compounds.

Preparation of pumice anchored sulfonic acid (pumice@SO_3H) catalyst
In the present work, the catalyst pumice anchored sulfonic acid (pumice@SO_3H) has been prepared by simple agitation from pumice (**Scheme 2**) using reported method [1].



Scheme 2: Preparation of pumice anchored sulfonic acid (pumice@SO_3H) catalyst

General procedure for the synthesis of polyhydroquinoline derivatives (5a-k)
A mixture of aldehyde **1** (1 mmol), 5,5-dimethylcyclohexane-1,3-dione **2** (1mmol), ethyl acetoacetate **3** (1 mmol), ammonium acetate **4** (1.5 mmol) and 90 mg of pumice based sulfonic acid was taken in a 100 mL round bottom flask containing 15 mL of ethyl alcohol. The resulting reaction mixture was subjected for ultrasound irradiation at 45°C temperature for appropriate time (**Scheme 3**). The progress of the reaction was studied using TLC. After the completion, the reaction mixture was heated up to the boiling. The resultant hot solution was filtered at hot condition to separate the catalyst. The recovered catalyst was washed with dichloromethane 2-3 times and dried to reuse. After the separation of catalyst, cool the mother liquor, the solid polyhydroquinoline thus obtained. It was dried and in some cases it was purified by recrystallization using hot ethanol.



Scheme 3: Synthesis of Polyhydroquinoline (**5a-k**) derivatives

Discussion of Spectra:

5b: ethyl 1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxo-4-*p*-tolylquinoline-3-carboxylate

^{1}H NMR (500 MHz, $CDCl_3$): 0.93 (s, 3H, -CH_3), 1.05 (s, 3H, -CH_3), 1.21 (t, 3H, -CH_3), 2.20 (s, 3H, -CH_3), 2.12-2.24 (m, 4H, -CH_2-x2), 2.31 (s, 3H, -CH_3), 4.06 (q, 2H, -OCH_2-), 5.01 (s, 1H, -CH-), 6.66 (s, 1H, NH), 6.99 (d, 2H, *J*=8Hz, Ar-H), 7.18 (d, 2H, *J*=8Hz, Ar-H); ^{13}C NMR (125 MHz, $CDCl_3$): 195.75, 167.58, 148.79, 144.27, 143.56, 135.38, 128.60, 127.87, 112.05, 106.14, 59.78, 50.81, 40.91, 36.14, 32.67, 29.45, 27.19, 21.04, 19.26, 14.24; MS (ESI) : m/z = 354.2110 [M+H].

5c: ethyl 1,4,5,6,7,8-hexahydro-4-(4-methoxyphenyl)-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate

^{1}H NMR (500 MHz, $CDCl_3$): 0.93 (s, 3H, -CH_3), 1.06 (s, 3H, -CH_3), 1.20 (t, 3H, -CH_3), 2.13-2.30 (m, 4H, -CH_2-x2), 2.35 (s, 3H, -CH_3), 3.73 (s, 3H, -OCH_3), 4.07 (q, 2H, -OCH_2-), 4.99 (s, 1H, -CH-), 6.26 (s, 1H, NH), 6.73 (m, 2H, Ar-H), 7.20 (m, 2H, Ar-H); MS (ESI) : m/z = 370.2005 [M+H].

5d: ethyl 4-(4-ethylphenyl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate

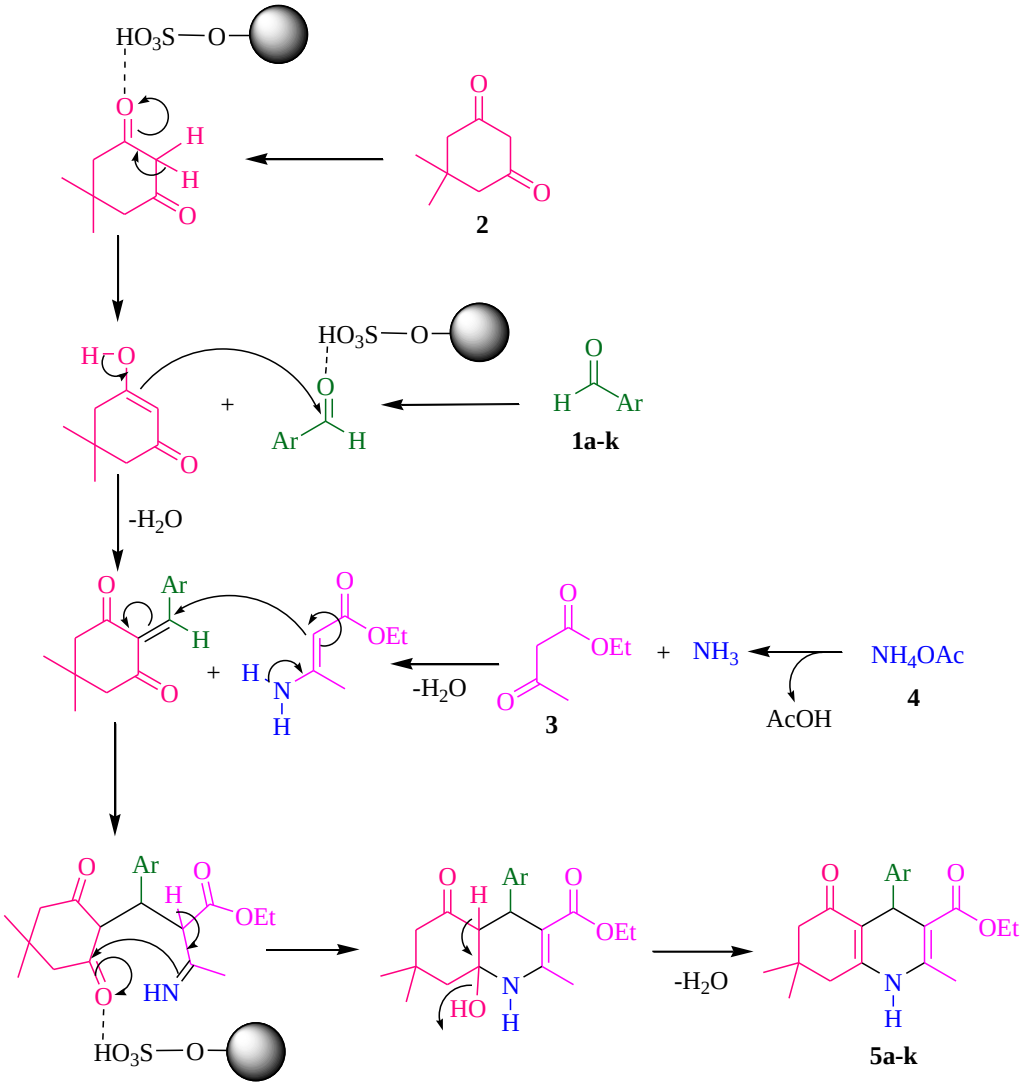
^{1}H NMR (500 MHz, $CDCl_3$): 0.95 (s, 3H, -CH_3), 1.06 (s, 3H, -CH_3), 1.17 (t, 3H, -CH_3), 1.21 (t, 3H, -CH_3), 2.13-2.29 (m, 4H, -CH_2-x2), 2.32 (s, 3H, -CH_3), 2.55 (q, 2H, -CH_2-), 4.06 (q, 2H, -OCH_2-), 5.02 (s, 1H, -CH-), 6.41 (s, 1H, NH), 7.01 (d, 2H, *J*=8Hz, Ar-H), 7.19 (d, 2H, *J*=8Hz, Ar-H); ^{13}C NMR (125 MHz, $CDCl_3$): 195.69, 167.58, 148.49, 144.39, 143.37, 141.68, 127.87, 127.35, 112.16, 106.25, 59.79, 50.79, 41.03, 36.10, 32.71, 29.41, 28.40, 27.28, 19.32, 15.35, 14.23.

5f: ethyl 4-(4-chlorophenyl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate

^{1}H NMR (500 MHz, $CDCl_3$): 0.92 (s, 3H, -CH_3), 1.07 (s, 3H, -CH_3), 1.18 (t, 3H, -CH_3), 2.13-2.32 (m, 4H, -CH_2-x2), 2.36 (s, 3H, -CH_3), 4.05 (q, 2H, -OCH_2-), 5.02 (s, 1H, -CH-), 6.29 (s, 1H, NH), 7.16 (m, 2H, Ar-H), 7.23 (m, 2H, Ar-H); MS (ESI) : m/z = 374.1595 [M+H].

5k: ethyl 4-(4-(dimethylamino)phenyl)-1,4,5,6,7,8-hexahydro-2,7,7-trimethyl-5-oxoquinoline-3-carboxylate

^{1}H NMR (500 MHz, $CDCl_3$): 0.95 (s, 3H, -CH_3), 1.04 (s, 3H, -CH_3), 1.24 (t, 3H, -CH_3), 2.12-2.25 (m, 4H, -CH_2-x2), 2.33 (s, 3H, -CH_3), 2.85 (s, 6H, -$N(CH_3)_2$), 4.06 (q, 2H, -OCH_2-), 4.96 (s, 1H, -CH-), 6.58 (d, 2H, *J*=8.5Hz, Ar-H), 6.64 (s, 1H, NH), 7.15 (d, 2H, *J*=8.5Hz, Ar-H); ^{13}C NMR (125 MHz, $CDCl_3$): 195.84, 167.77, 148.94, 148.56, 143.18, 136.02, 128.61, 112.38, 112.24, 106.43, 59.71, 50.84, 40.85, 40.75, 35.38, 32.65, 29.49, 27.28, 19.28, 14.30; MS (ESI) : m/z = 383.2254 [M+H].



Scheme 4: Pluasible mechanism for the synthesis of Polyhydroquinolines

Conclusion:

In summary, we have discovered a sustainable and convenient protocol for the synthesis of polyhydroquinoline derivatives using pumice anchored sulfonic acid (Pumice@SO_3H) as an efficient catalyst under ultrasound irradiation. The attractive features of present protocol are green approach, good yield, recovery of catalyst and easy work-up procedure whereas the catalyst offers simple preparation, high catalytic activity, inexpensive, easy to use, recyclability and good stability.

Abbreviations:

MCRs	= Multicomponent Reactions,
Pumice@SO_3H	= Pumice supported sulfuric acid,
NR	= No Reaction,
RT	= Room Temperature,
SF	= Solvent Free,
USI	= Ultrasound Irradiation.

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दक्षिण भारतीय सिनेमा, डबिंग और हिंदी

डॉ. दादासाहेब एन. डांगे*

भारतीय समाज के मन में सिनेमा एक अत्यंत प्रिय विषय है। शुरू से ही भारत में सिनेमा एक चर्चित कला प्रकार रहा है, जिसे भारतीय दर्शक चित्रपट, फिल्म, पिक्चर, मूवी आदि कई नामों से संबोधित करते हैं। भारतीय सिनेमा केवल भारत में ही नहीं बल्कि समूचे विश्व में अपनी पहचान बना चुका है। भारत के बाहर हिंदी सिनेमा को विशेष रूप से बॉलीवुड के नाम से पहचाना जाता है। यह बॉलीवुड एक फिल्म उद्योग है, जिसमें हिंदी भाषा की फिल्मों का निर्माण किया जाता है। यह फिल्म उद्योग भारत की आर्थिक राजधानी मुंबई में चलता है। यह दुनिया के प्रमुख फिल्म उद्योगों में से एक है।

भारत एक बहुभाषी राष्ट्र है। इसके अंतर्गत अनेक प्रांत हैं। उन सभी प्रांतों में भिन्न-भिन्न प्रकार की भाषा बोली जाती है। प्रत्येक प्रांत की अपनी एक अलग भाषा है, जिसका अपना महत्त्व है। सभी प्रांतों के क्रियाकलाप उनकी प्रादेशिक भाषा में ही किए जाते है। क्षेत्रीय फिल्म उद्योग भी इससे भिन्न नहीं है। बॉलीवुड के समान भारत के अनेक राज्यों में क्षेत्रीय फिल्म उद्योग बड़े पैमाने पर चलता है। यह क्षेत्रीय फिल्म उद्योग भी अपने-अपने प्रांतों में अपने पैर जमा चुका है। इतना ही नहीं बल्कि क्षेत्रीय फिल्म उद्योग ने कुछ हद तक हिंदी फिल्म उद्योग को भी प्रभावित किया है। इसमें प्रमुख रूप से दक्षिण भारतीय फिल्म उद्योग है, जिसमें तेलुगु, तमिल, कन्नड़ तथा मलयालम आदि भाषा के फिल्मों का समावेश है। इसके अलावा मराठी फिल्म उद्योग,

* सहयोगी प्राध्यापक, हिंदी विभाग, कला, विज्ञान एवं वाणिज्य महाविद्यालय, राहाता, जिला-अहमदनगर (महाराष्ट्र)

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इतिहासाचार्य वि. का. राजवाडे मंडळ, धुळे
या संस्थेचे त्रैमासिक

।। संशोधक।।

पुरवणी अंक १३ – डिसेंबर २०२२ (त्रैमासिक)

- **शके १९४४**
- **वर्ष : ९०**
- **पुरवणी अंक : १३**

*** प्रकाशक ***

श्री. संजय मुंदडा

कार्याध्यक्ष, इ. वि. का. राजवाडे संशोधन मंडळ, धुळे ४२४००१
दूरध्वनी (०२५६२) २३३८४८, ९४०४५७७०२०

कार्यालयीन वेळ

सकाळी ९.३० ते १.००, सायंकाळी ४.३० ते ८.०० (रविवारी सुट्टी)

मूल्य रु. १००/-
वार्षिक वर्गणी रु. ५००/-, आजीव वर्गणी रु. ५०००/- (१४ वर्षे)

विशेष सूचना : संशोधक त्रैमासिकाची वर्गणी चेक/ड्राफ्टने 'संशोधक त्रैमासिक राजवाडे मंडळ, धुळे' या नावाने पाठवावी.

अक्षरजुळणी : सौ. सीमा शिंत्रे, वारजे-माळवाडी, पुणे ५८.

महाराष्ट्र राज्य साहित्य आणि संस्कृती मंडळाने या नियतकालिकेच्या प्रकाशनार्थ अनुदान दिले आहे.

राजकारणातील महिला आरक्षण आणि महाराष्ट्रातील महिलांचा राजकारणातील प्रत्यक्ष सहभाग

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सारांश :

विकसनशील देशाचा विकास आणि महिलांचा विकास, यांचा अत्यंत जवळचा व प्रत्यक्ष संबंध आहे असे म्हणतात की महिलांच्या आर्थिक, सामाजिक परिस्थितीकडे बघितले असता तुम्हाला त्या देशाची संस्कृती समजू शकते. महिला आज विविध क्षेत्रांमध्ये महत्वाचे कार्य करताना दिसत आहेत. निसर्गाने बुध्दि, कौशल्य सर्वांना समान दिलेले असले तरी इतिहास काळापासून तर आजपर्यंत महिलांना प्रत्येक क्षेत्रात दुय्यम स्थान दिले गेले. त्यामुळे स्त्रीयांच्या मुलभूत अधिकार व हक्काबाबत शासनात व जनतेत जागृती निर्माण होणे गरजेचे आहे. स्वातंत्रपूर्व काळात महात्मा ज्योतिबा फुले, सावित्रीबाई फुले, रमाबाई रानडे, महादेव गोविंद रानडे, अण्णासाहेब कर्वे या सर्वांनी महिलांना सक्षम बनवण्यासाठी व महिलांच्या शिक्षणासाठी आपले सर्व आयुष्यफ खर्ची घातले. राजा राममोहन रॉय यांनी सतीची चाल बंद केली व स्त्री मुक्ती आंदोलनाला चालना दिली.

महिलांचा कुटुंबातील दर्जा, समाजातील स्थान व त्यांच्या सर्व क्षेत्रातील भूमिका पार पाडत असताना त्यांना दिली जाणारी अपमानास्पद वागणूक याला विरोध करून महिलांना कुटुंबात, समाजात व इतर सर्व क्षेत्रात पुरुषांच्या बरोबरीने समान स्थान मिळवण्यासाठी महिलांचे सामाजिक, मानसिक, आर्थिक, शैक्षणिक तसेच राजकीय सक्षमीकरण होणे आवश्यक आहे. भारतामध्ये ग्रामीण भागात महिलांची सद्यस्थिती लक्षात घेता असे दिसून येते की, महिलांमध्ये शिक्षणाचे प्रमाण खुप कमी आहे, बेरोजगारी, दारिद्रय, कुपोषण, आजार, कौटुंबिक हिंसा, आत्महत्या इ. अनेक समस्यांमुळे महिलांचा विकास होद्व मकित नाही त्यामध्ये अडथळे निर्माण होतात व हे अडथळे दूर करण्यासाठी महिलांची सामाजिक व आर्थिक, क्षणिक तसेच राजकीय स्थितीमध्ये सुधारणा होणे गरजेचे आहे. राजकारणातील महिलांचा सहभाग व त्यांची भूमिका आणि निठा याचा स्तर राज्याच्या राजकीय विकासाशी संबंधीत असतो.

की वर्ड्स : महिलांचा प्रत्यक्ष सहभाग, राजकारण, महिला आरक्षण विधेयक, महिलांचे प्रतिनिधीत्व

प्रस्तावना :

प्राचीन काळात महिलांना सामाजिक व राजकीय क्षेत्रात फारसे स्थान नव्हते. देशाचे राजकीय नेतृत्व महिलांच्या हाती सोपवण्याची पध्दत त्यावेळी नव्हती. सामाजिक स्तरावर महिलांची भूमिका दुलयम होती. या परिस्थितीत कालानुरूप फरक पडला तरी आधुनिक युगातही पुरुषांच्या बरोबरीने स्थान महिलेला मिळालेले नाही. सर्वच क्षेत्रांतील या पुरुष प्रधान संस्कृतीलाश ह देण्यासाठी जगभरात विविध ठिकाणी स्त्रीवादी चळवळी सुरु झाल्या.

जीवनाच्या सर्वच क्षेत्रात महिलांना पुरुषांच्या बरोबरीने हक्क व अधिकार मिळाले पाहिजे ही मागणी करणारा आवाज अठराव्या मशतकाच्या उत्तरार्धात जोरात उमटू लागला. १८४८ साली एलिझाबेथ कॅडी स्टॅन्टन व सुजान अँथनी या दोन महिलांनी अमेरिकेत ही चळवळ सुरु केली महिलांचे राजकारणातील स्थान कोणते असावे यावरही विचारमंथन सुरु झाले. हॅरिएट टेलर व जॉन एकत्र आल्या व त्याचा आवाज बुलंद झाला.

१८९३ साली न्युझिलंडने आपल्या महिलांना मताधिकार दिली. त्यानंतर ऑस्ट्रीया व कॅनडा था कमांक लागतो. ब्रिटीश पार्लमेंट मध्ये महिलांना राजकीय अधिकार देणारे विधेयक मांडण्यात आले होते १८७० साली मात्र महिलांना पूर्ण मताधिकार प्राप्त करुन घेण्याचा अधिकृत निर्णय तब्बल ५८ वर्गांनी म्हणजे १९२८ साली घेण्यात आला. फान्स मध्ये राजकीय हक्क १९४४ जर्मनीने १९१९ नार्वे व स्पेन मध्ये १९१५ व १९१३ मध्ये आघाडी घेतली. दुस. या महायुध्दानंतर इटली व ग्रीकसारख्या देशांनी महिलांना राजकारणाची द्वारे खुली केली. ब्रम्हदेशात १९३५ साली तर थायलंडमध्ये १९३२ साली तसेच चिनी व जपानमध्ये महिलांना मत देण्यात अधिकार १९४७ सालापासून प्राप्त झाला.

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Studies on the Wilson Dam Reservoir Water quality in relation to fishing, Ahmednagar District, Maharashtra, India

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ABSTRACT

For a duration of Twelve months starting from June 2021 to May, 2022, changes in Temp., pH, dissolved oxygen (DO), hardness, total alkalinity, chloride, magnesium, and calcium have been studied on monthly basis in Wilson Dam reservoir Ahmednagar (MS) India. To determine whether this reservoir was appropriate for fish and fishing methods, they were examined. All of the physicochemical data found showed that the water's Temp., pH, dissolved oxygen (DO), hardness, total alkalinity, chloride, magnesium, and calcium fluctuated within acceptable bounds. In contrast, calcium and magnesium levels were extremely low throughout the study period, whereas chloride levels were higher than ideal during the summer, post-monsoon and low during the monsoon.

Figure : 01 References : 10 Table : 01
KEY WORDS : Fishing, Seasonal variation, Water Parameter, Wilson Dam.

Introduction

Numerous physical, chemical, and biological elements influence water quality because they may have a direct or indirect impact on how well it supports the growth and distribution of fish and other aquatic life[7].

Physico-chemical components are taken into consideration in the limnological study while designing the many ecosystems that influence the trophic dynamics of the water body. Understanding how fish are raised in water bodies require an understanding of the Physicochemical properties of water[9].

The Ashwi water body of the Pravara River Physicochemical parameters were studied in relation to Fish culture[8]. The physical environment, chemical composition and biological interaction all have an impact on where aquatic organisms are found[3]. Fish growth and reproduction may be negatively impacted by a variety of Physico-chemical or biological conditions that function as stresses. Water bodies that have been contaminated lose their tropic status and become unstable for aquaculture[6]. The present work investigates the monthly variation of the Physico-chemical parameters of Wilson Dam and consequently, whether or not they fall inside acceptable bounds for fish and fishing methods.

Materials and Methods

Wilson Dam is located in the western portion of Maharashtra's Ahmednagar district, in the village of Bhandardara. The Pravara River's first reservoir is the Wilson Dam.

The Wilson Dam was the study area situated between 19031'45" N 73045'5" E. The catchment area of the dam was 12200 Sq. km. The Wilson dam's total water capacity was 11,039 TMCand 3 TMC dead water storage. The depth and width of the dam were 270 and 260.10 feet respectively. The principal sources of water in dams are fountains, small rivers, streams, *etc.* The

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TABLE-1 : Physico-chemical parameters of Wilson Dam. Seasonal mean ± S. D. are given (Variable range of parametersrepresented in bracket).

S. No	Water Parameters		Environmental Season			
			Monsoon	Post-monsoon	Winter	Summer
1	Temp. in ºC	Water	25.5 ± 0.57 (25-26)	24.05 ± 0.63 (23-25)	22.66 ±0.57 (22-23)	27.5 ± 0.5 (27-28)
		Air	27.12 ± 0.85 (26-28)	25.5 ± 0.70 (25-27)	23.83 ± 0.28 (23-24)	29.66 ± 0.57 (28-31)
2	Dissolved oxygen (ml/l).		6.68 ± 0.87 (5.75-7.75)	08.1 ± 0.14 (8.00-8.2)	8.8 ± 0.1 (8.7-8.9)	6.13± 0.96 (5.4-7.5)
3	pH		7.47 ± 0.10 (7.3-7.6)	8.15 ± 0.05 (8.1-8.2)	8.26 ±0.04 (8.2-8.3)	8.46 ± 0.05 (8.4-8.5)
4	Alkalinity (mg/l).		121.25± 34.73 (90-170)	235 ±35 (210-260)	213 ±20 (190-230)	160 ± 10 (150-170)
5	Hardness (mg/l).		103 ± 75 (60-130)	67.5 ± 2.5 (65-70)	143.33± 15.27 (130-160)	143.33 ± 20.81 (125-175)
6	Chloride(mg/l).		18.75 ± 8.53 (10-30)	110 ± 42 (80-140)	30 ± 7.05 (20-35)	91±36.50 (50-120)
7	Calcium (mg/l)		19.23 ± 6.49 (10-22)	20.5± 2.5 (18-23)	25±4.08 (20-30)	24.33± 6.64 (15-30)
8	Magnesium (mg/l)		18.45 ± 5.48 (10-21)	7.5± 2.5 (5-10)	10.33 ± 3.68 (6-15)	15.05± 1.45 (13-16)

23077 hectares area is irrigated under the Wilson dam.

Monthly water samples were collected. Polythene bottles were used for the collection of samples. Some parameters were recorded in fields like Temperature, and other parameters in the laboratory. The temperature was recorded by Thermometer, pH by using a pH meter, and Winkler's method was used for the estimation of dissolved oxygen from the water sample. Total alkalinity, Chloride, Water hardness magnesium, and Calcium were estimated by titration[1].

Collection sites

For the investigation following four sites were selected–

Site-A- Spil-way (Overflow Gate).

Site-B - Near Amruteshwar Temple, Ratanwadi Village.

Site-C-Shaleachiwadi – Panjare (Backside of the dam).

Site-D- Z. P. Guest house.

The monthly fluctuation of studied water parameters (Table-1). All twelve months are divided into four seasons,that are June to September- Monsoon; October to November- Post-Monsoon; December to February- Winter, and March to May-Summer.

Result and Discussion

In the Wilson Dam reservoir, the Dissolved oxygen range was 5.4 (May) to 8.9 (December). The overall dissolved oxygen level was high during the winter season

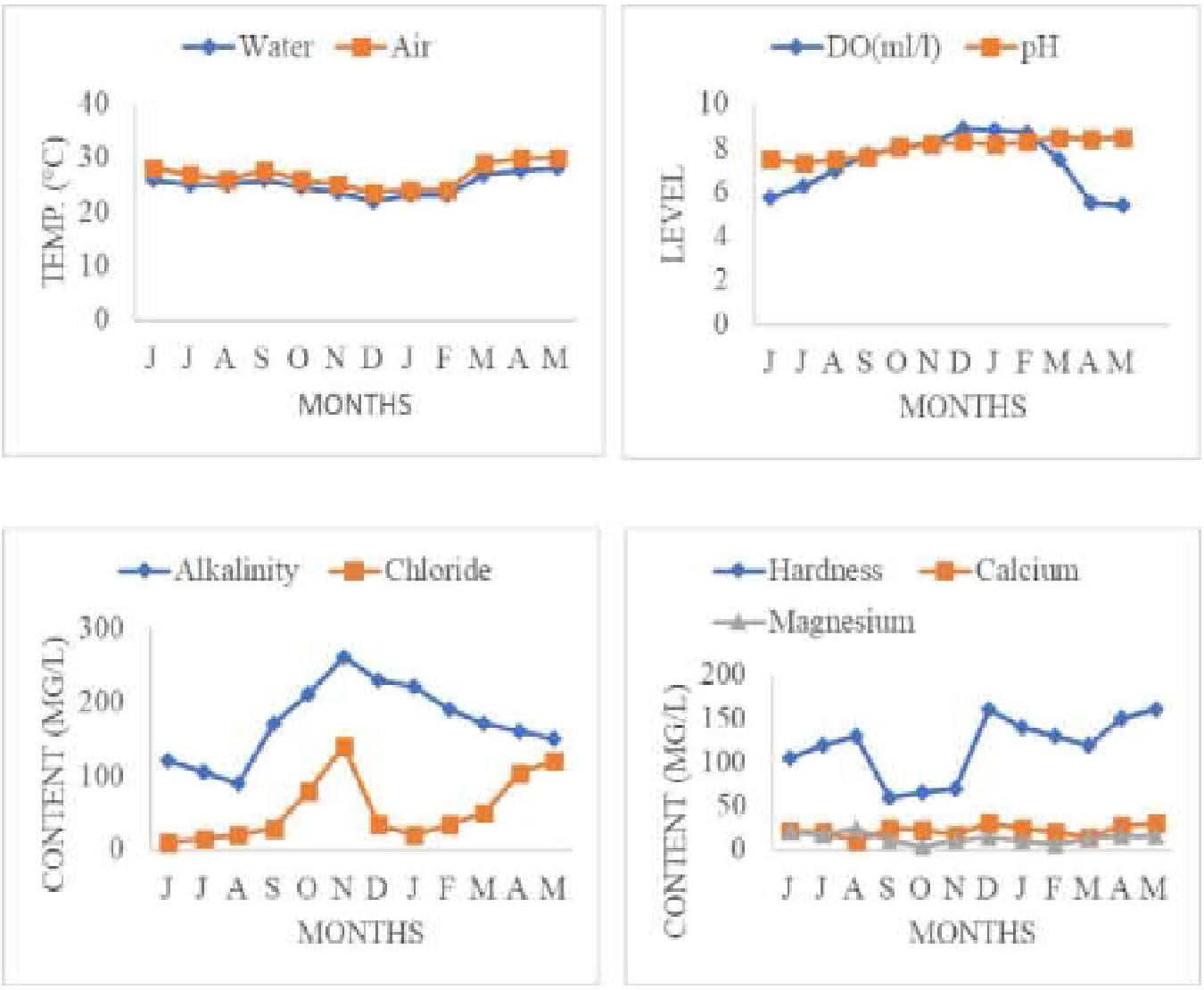

Fig. 1 : Monthly Changes in the Physico-chemical parameters of Wilson Dam from June 2021 to May 2022.

and the overall dissolved oxygen level was low during the summer season. Dissolved oxygen level was above the minimum level (>5 ppm)[2], so, Wilson dam supports the good fishery.

The minimum range of pH (7.3-7.5) was recorded during the monsoon due to heavy rainfall in the catchment area of the dam and the maximum range (8.4-8.5) was observed during the summer season and the water level of the dam was also low. The overall pH range of the Dam was 7.3 to 8.5. The pH range of the dam is suitable for will fish growth (6.4 to 8.5 optimum pH range for good fish growth[4]). Fish have blood pH levels that are slightly different from their usual blood pH of 7.4, which is middle of 7.0 to 8.5, which is good and beneficial to fish keep alive. Fish become metabolically stressed in water with a pH between 4.0 to 6.5 and 9.0 to 11.0, and Mortality increases practically at a pH of less than 4.0 or greater than 11.0. A pH of 7 to 8.5 is excellent for Aquatic production[5].

Alkalinity of water was low during the monsoon due to water dilution. The optimum range of alkalinity was 50-300 mg/l, which is for good fish rearing[10]. The Wilson dam reservoir alkalinity means the value was 121.25 in monsoon; 235in post-monsoon; 213 in winter and 160 in summer. All values of alkalinity are suitable for fish growth.

A high content of chloride in water represents water pollution. In this study post-monsoon had a high range of chloride than other seasons because in the monsoon season all polluted substances were collected in water bodies.In Wilson dam, the value of chloride was high in post-monsoon (140 mg/l in November) but that is not beyond the optimum range.

The hardness of water was maximum during December (160 mg/l) and minimum in September (90 mg/l). The hardness standard range of 30-180 mg/l was

better for fishery[10].Calcium and magnesium are also key parameters of water bodies. The level of calcium and magnesium also affects the growth of fish. In the present study the values of calcium and magnesium fluctuated throughout the year. The calcium Mean value of all seasons was between 19.23 to 25 mg/l and the magnesium Mean value of all seasons was between 7.5 to 18.45 mg/l.

Conclusion

All parameters of a water body were within a standard limit. In order to Wilson dam reservoir used for a fishery it is recommended that fish larvae of some culturable fish, such as *Catla catla, Cirhinus mrigala, Labeo rohita, etc*., be introduced at the start of the monsoon season and allowed to grow up to completion growth, but not harvested before a reproductive stage.

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Effect of molasses on protein content of fresh water fish, *Puntius chrysopterus*

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ABSTRACT

It was examined whether molasses was toxic to the freshwater fish, *Puntius chrysopterus*. There was a 5 percent LC_{50} value for Molasses. Rapid, jerky swimming with seemingly random motions; toxic convulsions; postural instability; an increase in surface activity and opercular movements; a loss of equilibrium; these are all symptoms of the Molasses poisoning. A layer of mucus formed over the gills, and the lamellae of the gills changed from red to brown. The fish were swimming in isolation from one another until they all perished. Protein was shown to be diminished throughout all fish tissues following exposure to a sub-lethal quantity of molasses.

Figures : 03 References : 08 Tables : 02
KEY WORDS : Acute toxicity, Molasses, Protein, *Puntius chrysopterus*

Introduction

Molasses comprises by product of sugar industry, which is generally discarded or used in distilleries for fermentation and alcohol production. If it randomly disposed, it may enter into water bodies, leading to water pollution. Attempts were made during present investigation to find out the effect of molasses on protein content of the fish.

Life depends on water as its primary nutrient. Fish are one of the most significant bio indicators of water contamination, while other aquatic creatures may serve this purpose. Pesticide usage in agricultural areas has expanded dramatically in recent years to meet rising demand for food, medicine, clothes, cosmetics, *etc.,* but this has led to a decline in the quality of aquatic ecosystems such as rivers, lakes, streams, and ponds. Aquatic life, especially fish, is influenced by this water pollution.

It is now well recognised that human activities have contributed significantly to the degradation of aquatic ecosystems due to water pollution from a wide variety of sources, most notably factories and agricultural chemicals. Rains, winds, rivers and floods may transport these industrial emissions to big water bodies, where they might alter the Physico-chemical characteristics of the water, potentially making it more harmful. Polluted water is harmful to marine life, particularly fish because of their extreme sensitivity to toxins[5].

Chemicals have varying effects on the body because of the way in which they work. Some toxins cause outward harm to the body by acting locally at the point of entrance.

Substances in fish products must sometimes be measured to ensure they are within regulatory limits or to fulfil special requirements. Take the fish in fish cakes as an example. Knowing the composition of fish is crucial for extracting its maximum nutritional value, since it is one of the most useful sources of high-quality protein accessible to man in today's food-starved world. Muscle protein content in fish typically ranges from 15% to 20%, but may be as low as 15% or as high as 28% in rare cases.

A wide variety of fish species actively absorb and accumulate several toxicants, including pesticides, heavy metals and molasses, from aquatic environments. Molasses is the most hazardous of all these agricultural poisons, wreaking havoc on aquatic environments and the species that call them home. Molasses' harmful effect on the body results in a change in the biochemical composition of the soft tissues.

Molasses is commonly known as sugar factory wastewater flood into the water bodies. It is broad-spectrum, noncumulative. *Puntius chrysopterus* is most of the prime cultured freshwater fish in poly-culture and has tremendous economic importance. Molasses is a typical byproduct of sugar factories that releases its sewage into nearby water sources. It has far-reaching effects and does not stack. In this work, we looked at the

TABLE-1: Mortality of *Puntius chrysopterus* in different concentrations of molasses at 96 hr exposure

S. No.	Conc. of molasses in Percentage X103		Log Conc. of Molasses	No. of fishes exposed	No. of fishes alive	No. of fishes dead	Percent mortality	Probit mortality
1	1	100	2.00	10	9	1	10	3.72
2	2	200	2.30	10	8	2	20	4.16
3	3	300	2.47	10	7	3	30	4.48
4	4	400	2.60	10	6	4	40	4.75
5	5	500	2.69	10	5	5	50	5.00
6	6	600	2.77	10	3	7	70	5.52
7	7	700	2.84	10	3	7	70	5.52
8	8	800	2.90	10	2	8	80	5.84
9	9	900	2.95	10	2	8	80	5.84
10	10	1000	3.00	10	1	9	90	6.28

effects of molasses on the protein content of the freshwater fish *Puntius chrysopterus* and attempted to calculate its LC_{50} value in the year 2021.

Aims and Objective

Fish toxicity is an important study for fisheries development. Therefore, the current study attempted to determine the LC_{50} for molasses.

Materials and Methods

The freshwater fish, *Puntius chrysopterus* was captured in its natural habitat at Savlivihir near Shirdi in Taluka Rahata, Ahmednagar District Maharashtra, India. The fish ranged in length from 2.22 to 3.00 centimetres and in breadth from 0.50 to 1.0 centimetres.

After being rinsed with a 0.1 percent $KMnO_4$ solution to clear walls from microbial infection, the fishes were acclimatised to laboratory condition for two weeks in big chlorinated tap water. Fish in the tank underwent acclimation by having their water changed every day and being fed rice bran. During the current investigation, molasses was obtained from a sugar plant and employed as a toxicant.

TABLE-2 : Change in the protein content (mg/g wet wt. soft body tissue) and % change over the control of *Puntius chrysopterus* exposed to sublethal concentration of molasses for 96 hr.

S. No.	Tissue	Protein		% Decrease
		Control	Experimental	
1	Whole body tissue	15	5	66.66

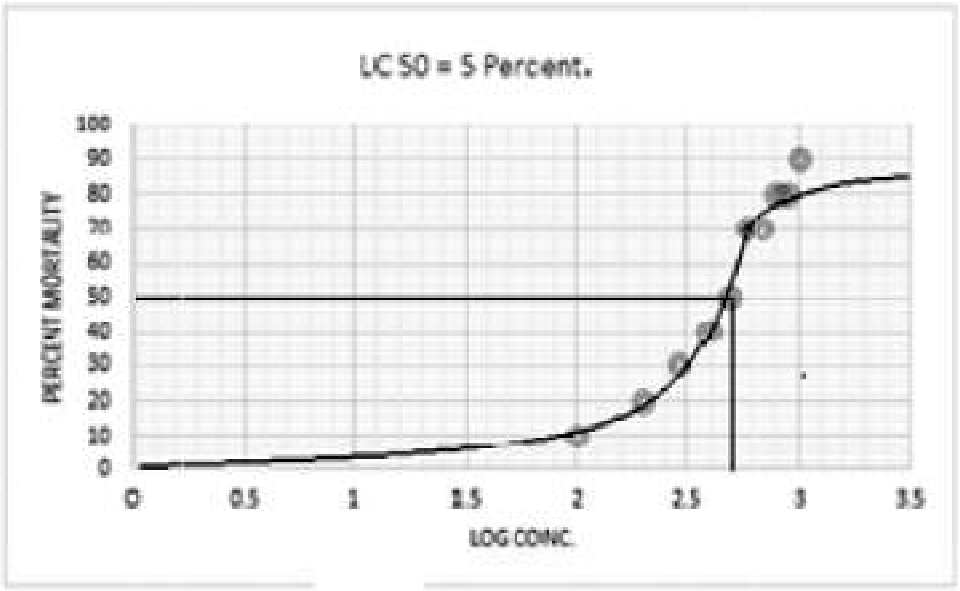

Fig. 1 : Percent mortality against Log concentration.

compliant protocols were used for all toxicity testing[1]. To test the effects of molasses on fish, we subjected them to various concentrations for 24, 48, 72, and 96 hours. It was decided to keep a separate group of fish as a control group. Mortality rates of fish were measured at 24, 48, 72, and 96 hours. The fatality rate was determined. Ten groups of fishes (10 fishes per group) were exposed to molasses at concentrations ranging from 1% to 10% for 24, 48, 72, and 96 hours to determine the median tolerance limit (LC_{50}).

The protein content estimated in whole body tissue samples following the method [7].

Result and Discussion

A higher molasses content in a water source is associated with a higher fish death rate (Table-1). As a percentage, the molasses concentration is plotted against the lethal concentration (LC_{50}) in a graph depicting the death rate. 5% was the LC_{50} value. Fish absorb molasses *via* their skin, gills, or mouth mucosa[4]. This study looked at the effects of a sublethal dose (5%) of molasses on the protein content of *Puntius chrysopterus* body tissues over the course of 96 hours. As a result of being immersed in molasses, the total amount of protein in their bodies fell dramatically. *Puntius chrysopterus* treated to sublethal

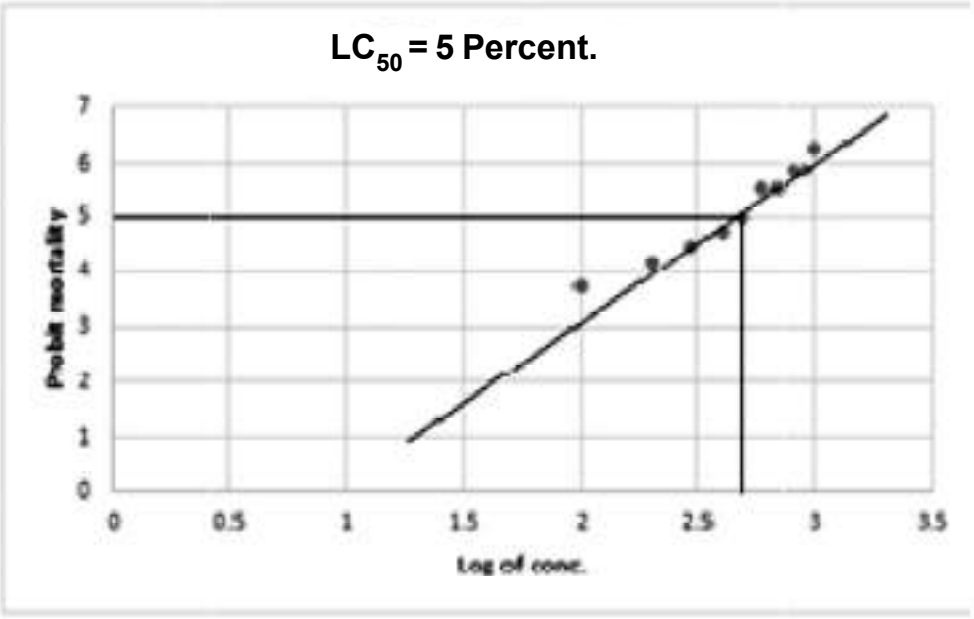

Fig. 2 : Probit mortality against Log concentration

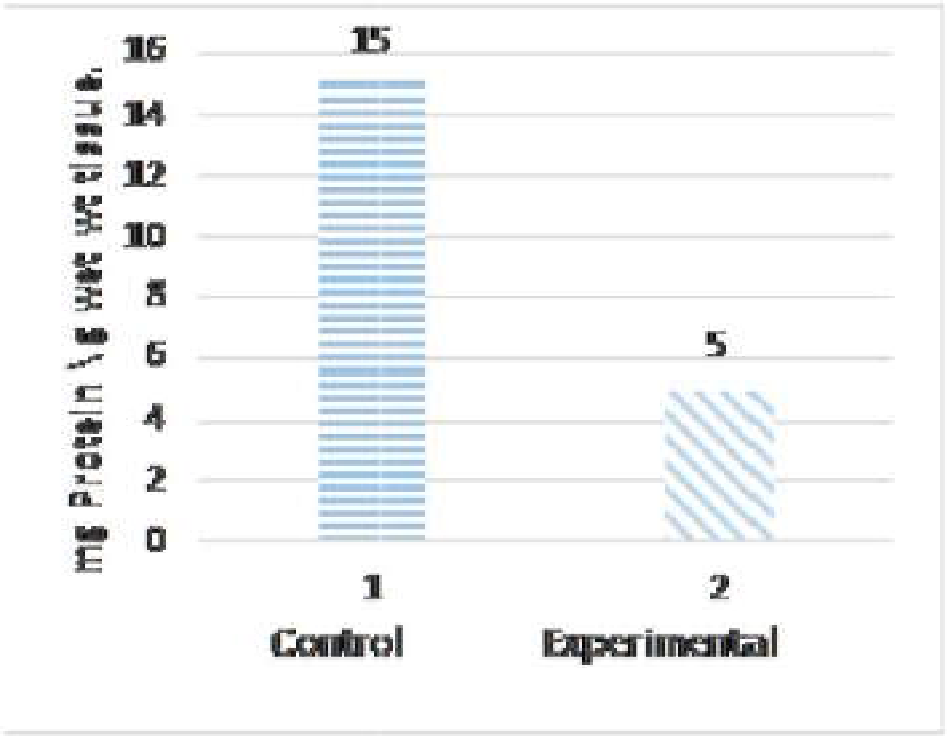

Fig. 3 : Change in the protein content (mg/g wet wt. of whole body tissue) over the control in *Puntius chrysopterus* exposed to sublethal concentration of molasses for 96.

concentrations of molasses for 96 hours: change in protein content (mg/g wet wt soft body tissue) and percent change from control (Table-2). Exposure to a sublethal quantity of molasses for 96 hours reduced the protein content of the fishes from the control group, which had a 15mg/g value, to a 5mg/g value. Investigators[6] documented a decrease in protein levels throughout the fish body as a whole. A lack of protein, as reported[6], may be due to the pesticide's interference with amino acid biosynthesis. Consumption of protein for its conversion into glucose is another probable cause.

Proteins seem to carry biological identity to different cell types, making them not only vital to cellular function but also to the survival of all forms of life[3]. When fish were given 5% molasses for 96 hours, a sub-lethal dose, the fish survived. After therapy, there was a notable drop in soft tissue protein levels. A catabolic process initiated by increased proteolysis led to rapid decline in protein concentration to meet the energy demand in an extremely stressful environment[2]. The early decline in muscle protein profile suggests stress in the metabolic process and impairment of protein synthesis machinery in fish. *Bengana elanga* whole-body tissues similarly showed a decreasing trend in total proteins. Fish in this research showed physiological flexibility in the face of toxicant stress, as seen by a drop in protein content. Fishes need a lot of energy to deal with stress. Due to the increased need for energy, protein catabolism may have been accelerated. Inhibition of metabolising enzymes by injection of toxicants may potentially account for the alterations and reduction in Protein level.

Multiple studies have shown that the use of toxic chemicals and fertilisers in farming reduces protein levels. These previous studies corroborate our current findings that molasses exposure reduces protein levels in *Puntius chrysopterus* tissues.

Conclusion

Protein metabolism of the fish, *Puntius chrysopterus* was altered as a result of exposure to molasses, as shown by a greater decrease in protein levels in treated fish tissues. The changed mobility and low content of Proteins represents a change in the rate of synthesis and degradation of Protein, reduced working capacity under the influence of accumulation of toxicant leading to a modification in function, and therefore increased susceptibility of the soft body tissue.

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AQUEOUS BALANITES ROXBURGHII: A CLEAN AND GREEN BIOCATALYST FOR SYNTHESIS OF SULFONAMIDES

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ABSTRACT:
Sulfonamide group is a versatile group introduced as the key core for diverse bio-activities as antibacterial sulfonamides and non-anti-bacterial sulfonamides in drug industry. Two component one pot synthesis of sulfonamides have been effectively carried out using aqueous solution of natural surfactant viz; *Balanites Roxburghii* which is commonly known as hingan. The present study has been employed by environmentally available *Balanites Roxburghii* as catalyst at room temperature. The present methodology of synthesis of sulfonamides comes out with advantages like economically feasible, simple and biocompatible catalytic system states safely production of different sulfonamide derivatives on bulky scale.

KEYWORDS: Sulfonamide, natural surfactants, *Balanites Roxburghii,* hingan economically feasible, simple and biocompatible catalytic system.

INTRODUCTION:

The newer organic synthesis which is carried out by naturally available catalyst has great importance in the field of green chemistry. The naturally occurring catalyst will accompanied the organic synthesis may be whispered as environmentally benign. There is need for achieving great goals through green chemistry in the field of organic synthesis by building useful organic cores for bulky drug molecules that are presently synthesised by disadvantageous methodology. Naturally abundant available materials like clays[i], enzymes[ii] and surfactants[iii] are extensively applied for different routes of synthesis of organic targets. These naturally occurring materials are promising substitutes for the hazardous organic solvents and catalysts that are presently practised in organic synthesis. Presently used solvents and catalysts in the organic conversions are with disadvantages like expensiveness, short of biodegrability, tedious work-up procedures, use of halogenated organic solvents, use high temperature to get required yield organic compound etc. There are

also some different naturally occurring biochemicals giving distinctive classified active biocatalyst used in organic procedures[iv-vi]. These biocatalyst have gained much more attention of current researcher in the field of organic chemistry through pollution free and eco-friendly protocols[vii] as per the Green Chemistry principles. In this perspective, the plant cell culture of *Daucus carota* root[viii-xiii], soaked *Phaseolus Aureus* (green grams)[xiv], coconut juice (*Cocos Nucifera*)[xv] has been effectively used as catalysts for selective reduction of ketones, aq. extract of *Acacia concinna* has been utilized as reaction medium for the synthesis of 3-carboxycoumarins and Cinnamic acids[xvi], acylation of amines[xvii] and synthesis of aryl-hydrazones[xviii].

Sulfonamides are useful in the field of medicinal chemistry as its core is utilized in building up bulky drugs. Sulfonamides and their derivatives are widely used for HIV protease inhibitor (A) amprenavir[xix], antibacterial activity[xx], anti-carbonic anhydrase[xxi], hypoglycaemic[xxii] , antitumour[xxiii] , anti-thyroid[xxiv] and diuretic (B) Hydrochlorothiazide, (C) Hydroflumethiazide, (D) Quinethazone and (E) Metolazone[xxv], (Figure 1).

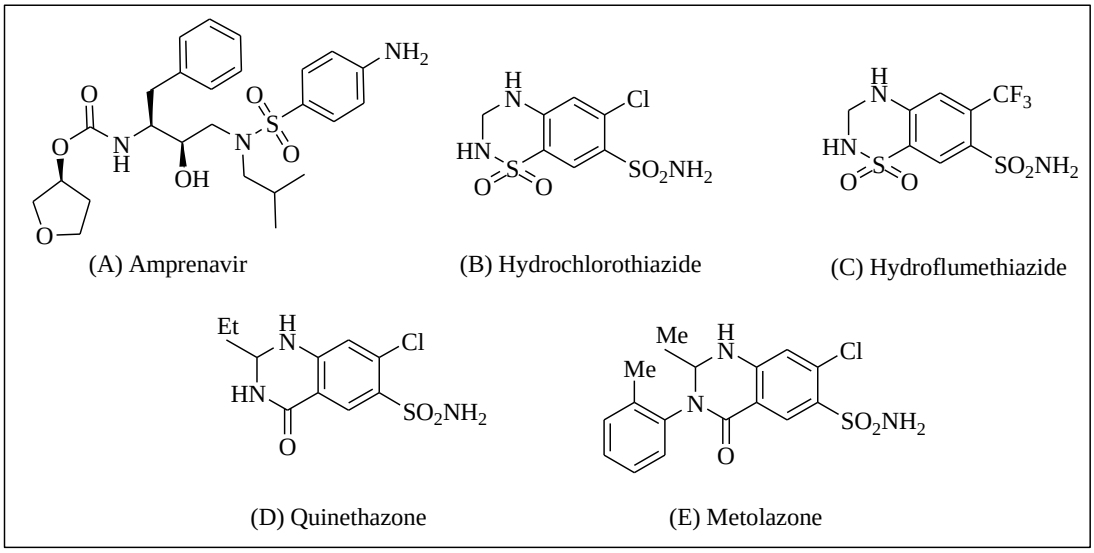


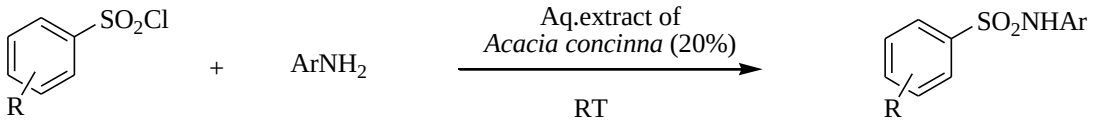
Figure 1. Chemical structure of some pharmacologically active sulfonamide derivatives

Sulfonamides were synthesised from sulfonylbenzotriazoles and different amine was general and efficient procedure[xxvi]. Now a days they are synthesised by oxidation of thiols to sulfonyl chlorides which on further reaction with amines yields sulfonamide is reported[xxvii]. Simply sulfonamides are also synthesised from sulfonic acids[xxviii]. Sulfonic acid on reaction with isocyanate also yields sulfonamides at room temperature[xxix].

Acacia concinna is generally known as Shikakai which has family Leguminosae and originates in tropical region of southern Asia. The fruits of *Acacia concinna* have cleansing property due to the presence of saponins that are foaming agents. These saponis produces leather when shaken in aqueous solutions. The fruit is known to have 10-11.5% saponins and their structure has been reported.[xxx,xxxi] These saponins resolves similar surfactant properties as that of dodecyl benzene sulphonates.[xxxii] The aqueous extract of these pods of *Acacia concinna* shows acidic pH which is due to the 'acacic acid' found in the solution.[xxxiii] Encapsulation of the reactants in micellar cages drives the equilibrium toward the product side by giving out the water molecule out of its interior yields of products (Figure 2). The action of micellar cages in formation of product excited us to use aqueous Acacia concinna solutions as an efficient and eco-friendly acidic surfactant catalyst for the synthesis of sulfonamide derivatives.

RESULT AND DISCUSSION:

Current methodology presents economical, simple and greener pathway for synthesis of sulfonamide catalyzed by aq. extract of *Acacia concinna* pods which in continuation of our ongoing research on development of newer synthetic method for bioactive compounds.[xxxiv-xxxix] Different sulfonamides (**3**) were synthesised using various aromatic sulfonyl chlorides (**1**) and aromatic amines (**2**) (Scheme 1). Synthesis of sulfonamides by current approach does not involve use hazardous organic solvents, and no tedious reaction workup. Green chemistry principles are followed in the current methodology.[xl-xli]



1 **2** **3**

Scheme 1. Natural surfactant catalyzed synthesis of sulfonamide derivatives

Reaction of benzene sulfonyl chloride (1mmol) and aniline (1mmol) in 10 mL aqueous extract of *Acacia concinna* pods (10% w/v) at room temperature was carried out in order to ensure the catalytic effectiveness of present natural surfactant and we are good yield of product **3a.** The result encouraged us for optimisation of concentration of aqueous solutions of *acacia concinna* pods. Optimisation study concluded that that 20% of the catalyst was sufficient to get highest yield of the product **3a** (>95%). Increasing concentration of *Acacia concinna* pods (25%, 30%, 35% and 40%) did not affect the yield of the final product. Hence, 20% (w/v) aqueous extract of *Acacia concinna* pods and 10 mL volume was selected as optimized to drive the reaction (Table 1). Different sulfonamide derivatives are synthesis at reaction time and in good yields as in Table 2.

Table 1. Optimization of catalyst concentration.

Entry	Catalyst concentration %(w/v)	Time (hr)	Yield(%)[a]
1.	10	2.5	92
2.	20	1.5	97
3.	25	1.5	95
4.	30	2	95
5.	40	2	92
6.	--	12	NR[b]

[a]Isolated yield of **3**. [b]No Reaction

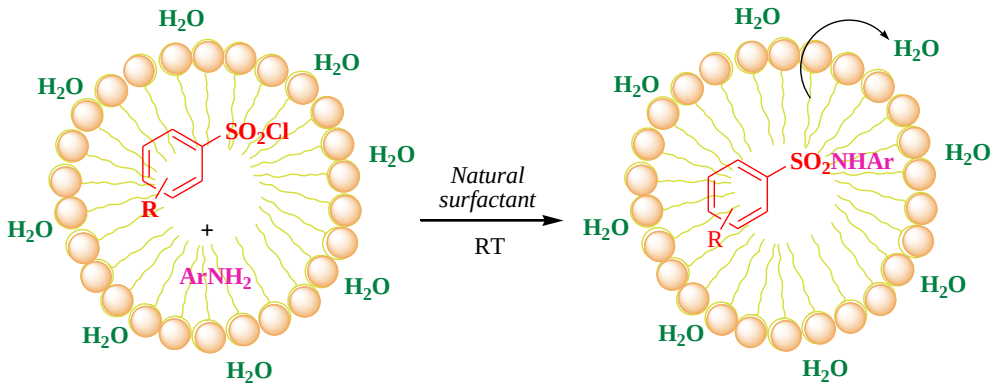
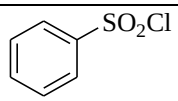
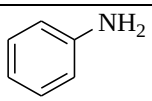
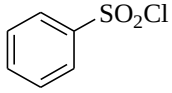
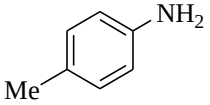
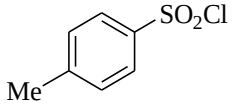
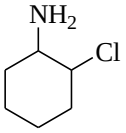
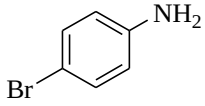
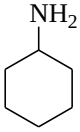
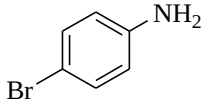
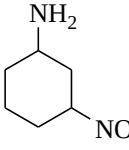
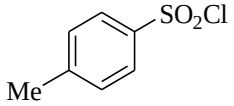
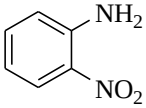
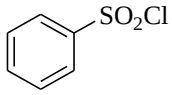
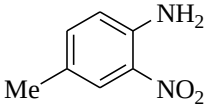
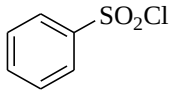
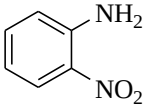
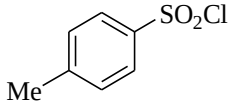
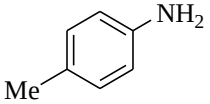
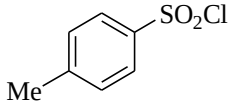
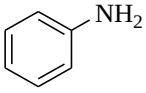
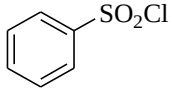
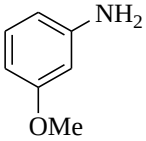


Figure 2. Micelle-promoted synthesis of sulfonamides

Table 2. Synthesis of sulfonamide derivatives (3a-k)

Entry	Sulfonyl chloride	Amine	Product	Time (hrs)	Yield (%)	M.P.(°C) Ref.
1.			**3a**	1.5	97	59-60[xlii]
2.			**3b**	1.2	92	118-119[xlii]
3.			**3c**	1.2	90	105-107[xliii]
4.			**3d**	1.5	88	100-102[xliii]
5.			**3e**	2.2	86	116-118[xliii]
6.			**3f**	2.2	92	112-113[xlii]
7.			**3g**	2.5	90	100-102[xlii]
8.			**3h**	2.5	96	101-103[xlii]
9.			**3i**	2.1	88	114-115[xlii]
10.			**3j**	1.5	90	95-97[xlii]
11.			**3k**	1.2	92	87-88[xliv]

CONCLUSION:

From the current methodology, we are able to describe an environmental friendly, efficient and economical catalyst for the synthesis of derivatives in aqueous extract of *Acacia concinna* pods medium. The application of biocatalyst in field of organic synthesis, water as medium, medium reaction condition and easy reaction workup are some of the advantages of present methodology.

EXPERIMENTAL SECTION:

General Remarks. All chemicals were obtained commercially from suppliers and were used without purification. Melting points were recorded on Digital Electro thermal Melting point apparatus and are uncorrected. Reaction monitoring was conducted using Thin Layer Chromatography (TLC) using pre-coated Silica gel 60 F_{254} plates with layer thickness 0.25nm purchased from Merck Ltd. TLC plates were visualized under ultraviolet light at 254 nm wavelength.

General procedure for the preparation of catalyst

A fine powder of *Acacia concinna* pods (20 g) in water (100 mL) was heated in a 250 mL conical flask at 100^{o}C for 20 min. The solid material was filtered and the aqueous extract was collected. The prepared extract has concentration 20% w/v.

General procedure for the synthesis of sulfonamide derivatives

A mixture of aromatic sulfonyl chloride (1mmol), and amine (1 mmol) in catalyst solution (20%, 10 mL) was stirred at room temperature for specified time (Table 2). After completion of the reaction (as indicated by TLC), a separated solid was filtered on Buchner funnel, washed with water and dried to obtain pure products in excellent yields.

Spectral data of representative compounds:

Phenyl(phenylsulfonyl)amine (3a)- White solid; Yield 80 %; mp: 59-60 ^{0}C;
^{1}HNMR (400MHz, DMSO-d^{6}): δ 4.39 (1H, bs, -NH), 7.01-7.02 (1H, d, Ar-H), 7.06-7.08 (2H, d, Ar-H), 7.19-7.23 (2H, m, Ar-H), 7.53-7.55 (2H, d, Ar-H), 7.58-7.59 (1H, d, Ar-H),7.73-7.75 (2H, d, Ar-H). **LCMS (ESI):** m/z 233

(4-Methylphenyl)(phenylsulfonyl)amine (3b)- White solid; Yield 80 %; mp: 118-119 ^{0}C;
^{1}H NMR (400MHz, DMSO-d^{6}): δ 2.17 (3H, s, CH_3), 4.57 (1H, bs, -NH), 6.94-6.96 (1H, d, Ar-H), 7.00-7.02 (1H, d, Ar-H), 7.50-7.60 (2H, m, Ar-H), 7.70-7.72 (1H, d, Ar-H). **LCMS (ESI):** m/z 247

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