JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Preparation of Benzopyrano[2,3-*d*]pyrimidines by using Sulfamic Acid As Heterogeneous Solid Acid Catalyst

[1]Madhukar Gangadhar Kasar Smt. N.N.C. Arts Commerce and Science college Kusumba Tal. And distt Dhule (M.S)
[2] Yogita Yadav Government college for Women Pali, Rewari
[3]Rakesh Vithalrao Patil Arts Commerce and Science college Nagaon Tal. And And distt Dhule (M.S)

Silica-bonded *N*-propyldiethylenetriamine sulfamic acid (SPDTSA) is employed as a recyclable heterogeneous solid acid catalyst for the synthesis of benzopyrano[2,3-*d*]pyrimidines through one-pot condensation reaction of salicylaldehydes, malononitrile and secondary amines at room temperature under solvent-free conditions. SPDTSA showed much the same efficiency when used in consecutive reaction runs.

Keywords: Benzopyrano[2,3-*d*]pyrimidines, Heterogeneous catalysts, Solid acids, Synthesis, Solvent-free conditions

INTRODUCTION

Benzopyranopyrimidines have provided an important pharmacophore synthesized research platform for chemists. This is because of their specific characteristics which consist of anti-inflammatory, analgesic, *in vivo* antitumor, *in vitro* anti-aggregating activities as well as cytotoxic activity against cancer cell lines, and causing significant perturbation in cell cycle kinetics [1-5]. In this respect several pyrimidine derivatives such as compounds **1-2** showed good *in vitro* antiplatelet activity, being able to inhibit AA (Arachidonic Acid), ADP and collagen-induced aggregation, together with a good *in vivo* antithrombotic effect (Fig. 1) [3,6-9]. Some of these compounds were also found to be interesting as analgesic and/or antiphlogistic agents [6]. The basic function in benzopyranopyrimidine scaffold was also investigated and it was concluded that it has a pivotal role in the expression of antiphlogistic/ analgesic activities without adverse gastrolesive effects [10].

In this respect, lots of methods have been developed for the preparation of benzopyranopyrimidine derivatives [1-5,11-13] while none of them contain recyclable and reusable catalysts in their protocols. Bazgir and co-workers for the first time have reported the synthesis of benzopyrano[2,3-*d*]pyrimidines *via* pseudo four-component reaction of salicylic aldehyde, malononitrile and amine in the presence of $LiClO_4$ in EtOH at room temperature for 24 h [14]. Very recently, this multi-component protocol has been developed by ionic liquid $[Bmim]BF_4$ [15], Brønsted acidic ionic liquids [16], $ZrOCl_2.8H_2O$ [17], silica nanoparticles immobilized benzoylthiourea ferrous complex [18], manganese(III) salen complex immobilized on Fe_3O_4 magnetic nanoparticles [19], and choline chloride based deep eutectic solvent [20].

Several types of solid sulfonic acid functionalized silica (both amorphous and ordered) have been synthesized and applied as an alternative to traditional sulfonic acid resins and homogeneous acids in catalyzing chemical transformations [21-41].

Recently, we prepared some silica immobilized sulfonic acids such as; silica-bonded *N*-propyldiethylenetriamine sulfamic acid (SPDTSA) [36,37], silica-bonded *N*-propylsulfamic acid (SBPSA) [25], and silica-bonded *S*-sulfonic acid (SBSSA) [23,24], and investigated their applications as heterogeneous solid acids in organic reactions [26-33,39-41] (Fig. 2).

In continuation our research on the design and

*Corresponding author. E-mail: yadavdryogita@gmail.com

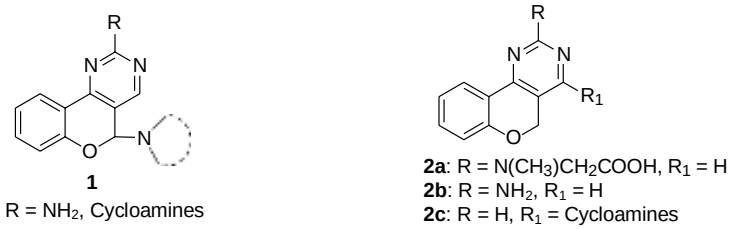


Fig. 1. The structure of some bio-active compounds containing a benzopyrano[2,3-*d*]pyrimidine moiety.

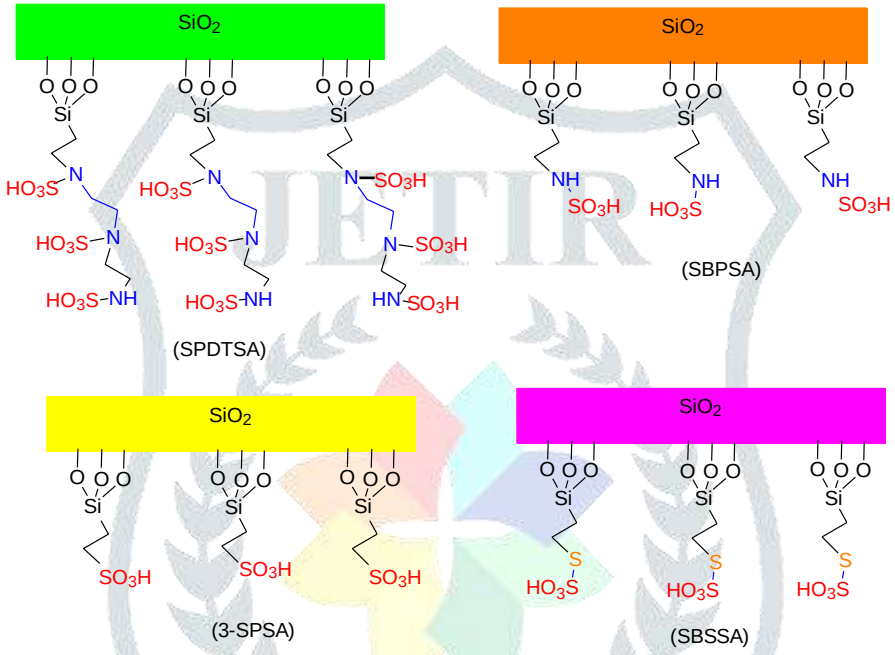


Fig. 2. The structure of used solid acids.

application of silica functionalized solid acids as heterogeneous catalysts in organic transformations [23-41], we describe the application of silica-bonded *N*-propyldiethylenetriamine sulfamic acid (SPDTSA) in the synthesis of benzopyrano[2,3-*d*]pyrimidine derivatives *via* pseudo four-component condensation of salicylaldehydes, malononitrile and secondary amine at room temperature and solvent-free conditions.

EXPERIMENTAL

General

Chemicals were purchased from Merck and Aldrich chemical companies. For recording ^{1}H NMR spectra we used Bruker Ultrashield (400 MHz) in pure deuterated DMSO-d_6 solvent with tetramethylsilane (TMS) as internal standard. Melting points were determined in open capillary tubes in a Barnstead Electrothermal 9100 BZ circulating oil melting point apparatus. The reaction monitoring was accomplished by TLC on silica gel Poly Gram SILG/UV254 plates. All the products are known compounds and were characterized by comparison of their IR, ^{1}H NMR and ^{13}C NMR spectroscopic data and their melting points with reported values [13-20]. Solid acids such as 3-silica propylsulfonic acid [21,22], silica-bonded *S*-sulfonic acid (SBSSA) [23,24], silica-bonded *N*-

propylsulfamic acid (SBPSA) [25] and silica-bonded *N*-propyldiethylenetriamine sulfamic acid (SPDTSA) [36,37] were prepared according to our previously reported procedure.

General Procedure for the Synthesis of Benzopyranopyrimidines

A mixture of 2-hydroxy-benzaldehyde derivative (2 mmol), malononitrile (1 mmol), secondary aliphatic amine (1 mmol), SPDTSA (0.03 g, 2.96 mol%) [37], under solvent-free conditions were stirred at room temperature for 6 h (the progress of the reaction was monitored by TLC). After completion, warm ethanol (10 ml) was added and filtered. The remaining was washed with warm ethanol (2 × 5 ml) to separate catalyst. After cooling the organic phase the crude was precipitated and filtered to obtain products. For further purification the crude was recrystallized from ethanol (95%). The recovered catalyst was dried and reused for the subsequent runs.

2-(4-Morpholino-5H-chromeno[2,3-*d*]pyrimidin-2-yl) phenol (6a). M.p.: 197-199 °C (Lit. [15] 196-197 °C); IR (KBr): 3407, 2920, 2858, 1603, 1491, 1436, 1246, 1117 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) 3.52-3.53 (m, 4H, $2CH_2$), 3.92-3.94 (m, 6H, $3CH_2$), 6.94 (t, 1H, ^3J = 7.4 Hz, Ar), 7.00 (d, 1H, ^3J = 8.4 Hz, Ar), 7.14 (t, 1H, ^3J = 7.2 Hz, Ar), 7.19-7.23 (m, 2H, Ar), 7.26-7.30 (m, 1H, Ar); 7.38 (t, 1H, ^3J = 7.0, Ar), 8.41 (d, 1H, ^3J = 7.6 Hz, Ar), 13.02 (brs, 1H, OH). ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 25.6, 48.6, 66.7, 97.7, 117.1, 117.6, 118.3, 118.9, 119.0, 124.6, 128.4, 128.6, 129.2, 133.1, 150.4, 160.3, 162.0, 164.2, 164.7.

2-(4-(Dimethylamino)-5*H*-chromeno[2,3-*d*] pyrimidin-2-yl)phenol (6b). M.p.: 179-181 °C, (Lit. [14] 177-179 °C); IR (KBr): 3443, 3050, 2894, 1604, 1490, 1453, 1267 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) 3.24 (s, 6H, $N(CH_3)_2$), 4.11 (s, 2H, CH_2), 6.94 (t, 1H, ^3J = 7.6 Hz, Ar), 7.01 (d, 1H, ^3J = 7.6 Hz, Ar), 7.12 (t, 1H, ^3J = 7.2 Hz, Ar), 7.19-7.21 (m, 2H, Ar), 7.26 (d, 1H, ^3J = 8.0 Hz, Ar), 7.36-7.40 (m, 1H, Ar); 8.44 (dd, 1H, ^3J = 8.0, ^4J = 1.6 Hz, Ar), 13.50 (brs, 1H, OH); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 26.0, 41.1, 94.5, 117.0, 117.5, 118.5, 118.8, 119.3, 124.3, 128.2, 128.5, 129.2, 132.8, 150.4, 160.4, 161.5, 164.4.

2-(4-(Piperidin-1-yl)-5H-chromeno[2,3-*d*]pyrimidin-2-yl)phenol (6c). M.P.: 170-172 °C, (Lit. [14] 168-170 °C); IR (KBr): 3442, 2938, 2852, 1601, 1490, 1454, 1257 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) 1.77-1.82 (m, 6H, $3CH_2$), 3.34-3.47 (m, 4H, $N(CH_2)_2$), 3.95 (s, 2H, CH_2), 6.96 (t, 1H, ^3J = 7.2 Hz, Ar), 7.02 (d, 1H, ^3J = 8.0 Hz, Ar), 7.13 (t, 1H, ^3J = 7.4 Hz, Ar), 7.21-7.27 (m, 3H, Ar), 7.36-7.40 (m, 1H, Ar), 8.45 (dd, 1H, ^3J = 8.0 Hz, ^4J = 1.6 Hz, Ar), 13.38 (brs, 1H, OH); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 24.3, 25.6, 25.9, 49.5, 50.5, 97.4, 117.1, 117.5, 118.4, 118.8, 119.5, 124.4, 128.2, 128.5, 129.2, 132.9, 150.6, 160.4, 161.8, 165.1.

2-(4-(Pyrrolidin-1-yl)-5H-chromeno[2,3-*d*]pyrimidin-2-yl)phenol (6d). M.p.: 211-213 °C (Lit. [18] 235-237 °C); IR (KBr): 3465, 3053, 2971, 2871, 1603, 1490, 1451, 1261 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ (ppm) 1.97-2.00 (m, 4H, $2CH_2$), 3.84-3.86 (m, 4H, $N(CH_2)_2$), 4.34 (s, 2H, CH_2), 6.89-6.92 (m, 2H, Ar), 7.12-7.15 (m, 2H, Ar), 7.25-7.36 (m, 3H, Ar), 8.26-8.28 (m, 1H, Ar), 13.36 (brs, 1H, OH). ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 24.2, 24.6, 49.1, 91.6, 115.7, 116.8, 118.1, 119.7, 123.8, 127.6, 128.3, 128.8, 132.0, 149.4, 159.7, 159.9, 160.2, 162.3.

4-Bromo-2-(7-bromo-4-morpholino-5H-chromeno[2, 3-*d*]pyrimidin-2-yl)phenol (6e). M.p.: 204-206 °C (Lit. [17] 198-200 °C); IR (KBr): 3446, 3050, 2970, 2893, 2851, 1594, 1482, 1431, 1273, 1118 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ (ppm) 3.52 (t, 4H, ^3J = 4.6 Hz, $2CH_2$), 3.80 (t, 4H, ^3J = 4.5 Hz, $2CH_2$), 4.05 (s, 2H, CH_2) 6.92 (d, 1H, ^3J = 8.7 Hz, Ar), 7.18 (d, 1H, ^3J = 8.7 Hz, Ar), 7.46 (dd, 1H, ^3J = 8.6, ^4J = 2.3 Hz, Ar), 7.53 (dd, 1H, ^3J = 8.6, ^4J = 2.6 Hz, Ar), 7.61 (d, 1H, ^3J = 2.2 Hz, Ar), 8.32 (d, 1H, ^3J = 2.5 Hz, Ar), 13.15 (brs, 1H, OH). ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 24.2, 47.8, 65.6, 97.1, 109.6, 115.7, 118.1, 119.4, 119.7, 122.3, 130.2, 130.5, 131.1, 134.8, 148.8, 158.6, 159.0, 162.7, 163.7.

4-Bromo-2-(7-bromo-4-(dimethylamino)-5H-chromeno[2,3-*d*]pyrimidin-2-yl)phenol (6f). M.P.: 194-196 °C, (Lit. [16] 200-201 °C); IR (KBr): 3456, 3060, 2923, 1596, 1438, 1457, 1264 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ (ppm) 3.09 (s, 6H, $N(CH_3)_2$), 4.22 (s, 2H, CH_2), 6.90 (d, 1H, ^3J = 6.7 Hz, Ar), 7.13 (d, 1H, ^3J = 7.0 Hz, Ar), 7.43 (dd, 1H, ^3J = 7.0, ^4J = 2.0 Hz, Ar), 7.49 (dd, 1H, ^3J = 7.0, ^4J = 2.2 Hz, Ar), 7.55 (d, 1H, ^3J = 2.0 Hz, Ar), 8.34 (d, 1H, ^3J = 2.2 Hz, Ar), 13.26 (brs, 1H, OH). ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 24.5, 40.4, 93.9, 109.4, 115.5, 117.9,

119.4, 119.8, 122.4, 130.2, 130.4, 131.1, 134.6, 148.7, 158.6, 158.7, 162.3, 163.1.

4-Bromo-2-(7-bromo-4-(piperidin-1-yl)-5H-chromeno[2,3-*d*]pyrimidin-2-yl)phenol (6g). M.p.: 189-193 °C (Lit. [17] 187-189 °C); IR (KBr): 3433, 3080, 2937, 2849, 1599, 1483, 1433, 1255 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ (ppm) 1.65-1.78 (m, 6H, $3CH_2$), 3.48-3.53 [m, 4H, $N(CH_2)_2$], 4.03 (s, 2H, CH_2), 6.90 (d, 1H, J = 6.8 Hz, Ar), 7.15 (d, 1H, ^3J = 6.8 Hz, Ar), 7.44 (d, 1H, ^3J = 7.1 Hz, Ar), 7.50 (d, 1H, ^3J = 7.1 Hz, Ar), 7.60 (s, 1H, Ar), 8.34 (s, 1H, Ar), 13.17 (brs, 1H, OH). ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 23.3, 24.3, 25.1, 48.5, 96.7, 109.5, 115.6, 118.0, 119.4, 119.8, 122.5, 130.1, 130.4, 131.1, 134.7, 148.9, 158.6, 159.0, 162.8, 163.9.

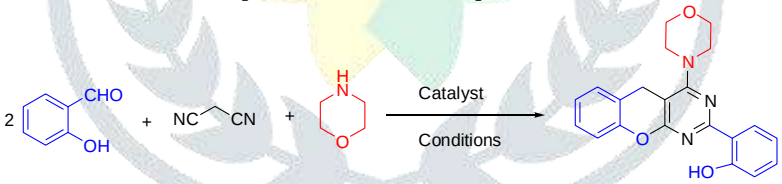
5-Methoxy-2-(8-methoxy-4-morpholino-5H-chromeno[2,3-*d*]pyrimidin-2-yl)phenol (6h). M.P.: 227-230 °C, (Lit. [18] 225-226 °C); IR (KBr): 3444, 3060, 2966, 2891, 2833, 1603, 1508, 1430, 1262, 1103 cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6): δ (ppm) 3.53 [t, 4H, ^3J = 3.6 Hz, $N(CH_2)_2$], 3.78 (s, 3H, OCH_3), 3, 79-3.82 (m, 7H, $O(CH_2)_2$ & OCH_3), 3.93 (s, 2H, CH_2), 6.45 (d, 1H, ^3J = 1.7 Hz, Ar), 6.52-6.54 (m, 1H, Ar), 6.74-6.78 (m, 2H, Ar), 7.24 (d, 1H, ^3J = 6.8 Hz, Ar), 8.18 (d, 1H, ^3J = 7.0 Hz, Ar), 13.05 (brs, 1H, OH). ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 23.8, 47.9, 55.0, 55.2, 65.7, 96.4, 101.1, 101.4, 106.2, 110.8, 111.2, 111.3, 129.2, 129.7, 150.2, 159.0, 160.3, 161.2, 162.9, 163.0, 163.9.

5-Methoxy-2-(8-methoxy-4-(dimethylamino)-5H-chromeno[2,3-*d*]pyrimidin-2-yl)phenol (6i). M.P.: 180-182 °C, (Lit. [17] 174-176 °C); IR (KBr): 3450, 3060, 2920, 1595, 1437, 1456, 1260 cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6): δ (ppm) 3.21 (s, 6H, $N(CH_3)_2$), 3.78 (s, 3H, OCH_3), 3.80 (s, 3H, OCH_3), 4.07 (s, 2H, CH_2), 6.43-6.45 (m, 1H, Ar), 6.52 (dd, 1H, ^3J = 7.1 Hz, ^4J = 1.9 Hz, Ar), 6.71-6.75 (m, 2H, Ar), 7.20 (d, 1H, ^3J = 6.6 Hz, Ar), 8.17 (d, 1H, ^3J = 7.1 Hz, Ar), 13.35 (brs, 1H, OH). ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 24.2, 40.3, 54.9, 55.1, 93.3, 101.0, 101.2, 105.9, 110.6, 111.3, 111.5, 129.2, 129.6, 150.2, 159.0, 159.9, 161.3, 162.5, 162.8, 163.4.

RESULTS AND DISCUSSION

The catalytic activity of silica immobilized acids (SPDTSA, SBPSA, SBSSA and 3-SPSA) was investigated as heterogeneous solid acid catalysts in one-pot synthesis of benzopyranopyrimidines through *pseudo* four-component reaction of salicylaldehyde, malononitrile, secondary amine and the results are summarized in Table 1.

Table 1. Investigation the Effect of Catalysts and Solvents on the Reaction of Salicylaldehyde, Malononitrile and Morpholine at Room Temperature[a]



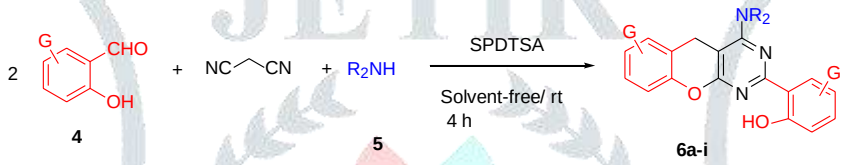
Entry	Catalyst	Catalyst loading (g)	Conditions	Time (h)	Yield (%)[b]
1	3-SPSA	0.03	Solvent-free	4	82
2	SBSSA	0.03	Solvent-free	5	80
3	SBPSA	0.03	Solvent-free	5	80
4	SPDTSA	0.03	Solvent-free	4	90
5	SPDTSA	0.01	Solvent-free	6	78
6	SPDTSA	0.05	Solvent-free	3.5	90
7	SPDTSA	0.03	Ethanol	8	80
8	SPDTSA	0.03	Water	8	N.R.
9	SPDTSA	0.03	Acetonitrile	6	48

[a]Reaction conditions; salicylaldehyde (2 mmol), and malononitrile (1 mmol) at room temperature (in the case of solvent (3 ml). [b]Isolated yield.

For this purpose, the reaction between salicylaldehyde (2 mmol), malononitrile (1 mmol) and morpholine (1 mmol) was selected as a model reaction at room temperature in order to establish the feasibility of the strategy and optimize the reaction conditions. As shown in Table 1, the catalytic effect of solid acids SPDTSA, SBPSA, SBSSA and 3-SPSA was studied as heterogeneous acid catalysts. All of these silica immobilized propyl sulfonic acids accomplished this *pseudo* four-component condensation reaction at room temperature under solvent-free conditions. The model reaction was converted into the corresponding product in a higher yield using solid acid SPDTSA as catalyst (Table 1, entry 4). The lower amounts of SPDTSA (0.01 g) was converted the model reaction in longer reaction time and lower yield (Table 1, entry 5) and using higher amounts of the catalyst (0.05 g) did not improve the result to an appreciable extent (Table 1, entry 6). The model reaction was treated in solvents such as ethanol, water, and acetonitrile in the presence of SPDTSA (0.03 g) as catalyst at room temperature (Table 1, entries 7-9), but the best result was under solvent-free conditions. The optimum conditions was α-hydroxybenzaldehyde (2 mmol), malononitrile (1 mmol), secondary amine (1 mmol) and SPDTSA (0.03 g, 2.96 mol%) at room temperature under solvent-free conditions.

The reaction can tolerate α-hydroxybenzaldehydes and some of its derivatives carrying either electron-donating or halogen and the results were reasonable (Table 2). Aliphatic

Table 2. Synthesis of Benzopyranopyrimidines Using SPDTSA as Catalyst at Room Temperature and under Solvent-Free Conditions for 4 h

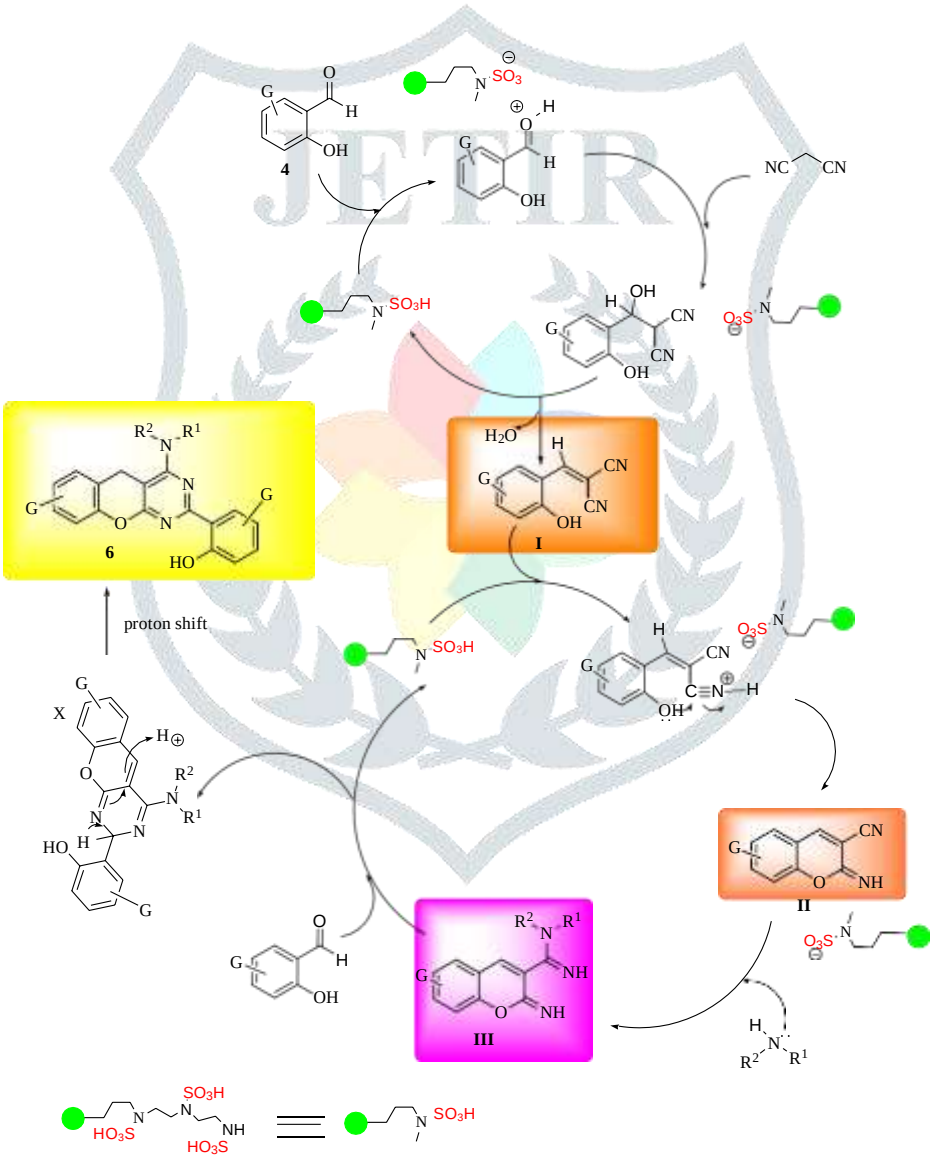


Entry	Amine	Aldehyde	Product	Yeild (%)[a]	M.p. (°C)	Lit. M.p. (°C)
1	Morpholine	2-Hydroxy-benzaldehyde	**6a**	90	197-199	196-197 [15]
2	Dimethyl amine	2-Hydroxy-benzaldehyde	**6b**	85	179-181	177-179 [14]
3	Piperidine	2-Hydroxy-benzaldehyde	**6c**	88	170-172	168-170 [14]
4	Pyrrolidine	2-Hydroxy-benzaldehyde	**6d**	82	211-213	235-237 [18]
5	Morpholine	5-Bromo-2-hydroxy-benzaldehyde	**6e**	78	204-206	198-200 [17]
6	Dimethyl amine	5-Bromo-2-hydroxy-benzaldehyde	**6f**	75	194-196	200-201 [16]
7	Piperidine	5-Bromo-2-hydroxy-benzaldehyde	**6g**	73	189-193	187-189 [17]
8	Morpholine	4-Methoxy-2-hydroxy-benzaldehyde	**6h**	75	227-230	225-226 [18]
9	Dimethyl amine	4-Methoxy-2-hydroxy-benzaldehyde	**6i**	88	180-182	174-176 [17]
10	Diethyl amine	2-Hydroxy-benzaldehyde	-	N.R.	-	-
11	Dibutyl amine	2-Hydroxy-benzaldehyde	-	N.R.	-	-

amines such as diethyl amine and dibutyl amine did not react while the best results were achieved with cyclic secondary amines such as morpholine, piperidine and pyrrolidine.

Proposed mechanism for the synthesis of benzopyranopyrimidine derivative **6** is described in Scheme 1 [18,19]. The process represents a typical cascade reaction in which the catalyst facilitates the Knoevenagel condensation reaction through activate salicylic aldehyde for nucleophilic attack of the malononitrile. The catalyst can activate O-H groups, such that the Pinner reaction occurs and intermediate **II** is formed. Next, the cyano group of intermediate **II** can be attacked by the amine to produce intermediate **III**. Finally, intermediate **III** reacts with another molecule of salicylic aldehyde followed by proton transfer to afford the final benzopyranopyrimidine **6**.

The possibility of recycling the catalyst SPDTSA was examined using by the reaction of salicylaldehyde, malononitrile, and morpholine under the optimized conditions. Upon completion, ethanol (10 ml) was added



Scheme 1. Proposed mechanism for the synthesis of benzopyranopyrimidine

[a]Isolated yield.

and filtered. The remaining was washed with warm ethanol (2 × 5 ml). The separated catalyst was dried and reused for the subsequent experiments under similar reaction conditions. The results showed that the catalyst could be effectively used for at least four consecutive cycles without much appreciable loss in its catalytic activity (Fig. 3).

To show the advantages of these solid acids (3-SPSA, SBPSA, SBSSA and SPDTSA) as catalysts in *pseudo*-four component reaction, our results and reaction conditions for synthesis of 2-(4-morpholino-5H-chromeno[2,3-*d*] pyrimidin-2-yl)phenol (**6a**) are compared with previously reported data in Table 3. The results show that our method

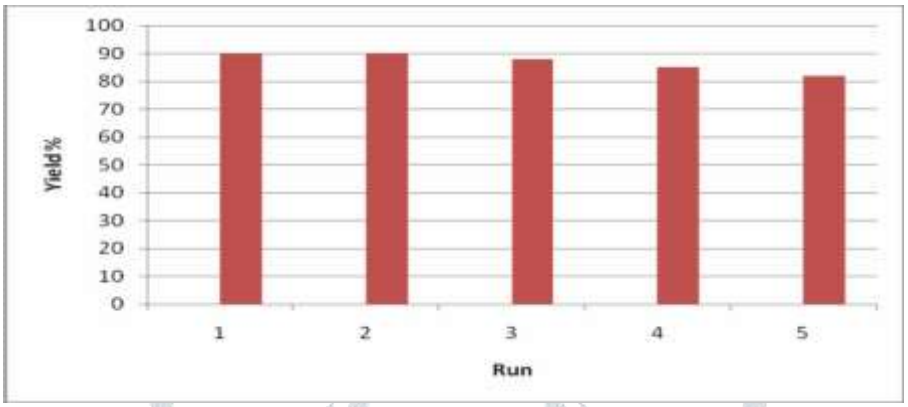


Fig. 3. Investigation of catalyst reusability in the reaction of salicylaldehyde (2 mmol), malononitrile (1 mmol), and morpholine (1 mmol) in the presence of 0.03 g of SPDTSA at room temperature under solvent-free conditions. Reaction time = 4 h.

Table 3. Comparison the Results of SPDTSA, SBSSA, SBPSA and 3-SPSA with other Catalysts Reported in Literature for the Synthesis of **6a**

Entry	Catalyst	Conditions	Time (h)	Yield (%)[a]	Ref.
1	$LiClO_4$ (20 mol%)	Ethanol, r.t.	24	95	[11]
2	$[Bmim]BF_4$ (5 mol%)	Solvent-free, r.t.	0.33	76	[12]
3	$[Hnhp][HSO_4]$ (5 mol%)	Solvent-free, r.t.	0.2	87	[13]
4	Piperidine (20 mol%)	Solvent-free, 100 °C	11	78	[10]
5	Piperidine (20 mol%)	MW (180 W), 100 °C	0.1	92	[10]
6	$ZrOCl_2.8H_2O$ (30 mol%)	Solvent-free, rt.	15	88	[14]
7	Fe(II)-BTU-SNPs (15 mg)	Ethanol, r.t.	4	93	[15]
8	Fe_3O_4\SiO_2\Salen\Mn MNP (0.0008 g)	Solvent-free, r.t.	0.83	96	[16]
9	-	Choline chloride-urea (0.5 ml), r.t.	1	75	[17]
10	3-SPSA (0.03 g)	Solvent-free, r.t.	4	82	This work
11	SBPSA (0.03 g)	Solvent-free, r.t.	5	80	This work
12	SBSSA (0.03 g)	Solvent-free, r.t.	5	80	This work
13	SPDTSA (0.03 g)	Solvent-free, r.t.	4	90	This work

is quite comparable with the former methods in yields and reaction times.

CONCLUSIONS

In conclusion, this work shows that silica-bonded solid acids which can be prepared by simple operation from commercially available and relative cheap starting materials, efficiently catalyze the synthesis of benzopyranopyrimidines. It could also be recovered and reused for several times without noticeable loss of reactivity.

ACKNOWLEDGEMENTS

We are thankful to the Persian Gulf University Research Council for the partial support of this work. Also, we are thankful to the School of Chemistry, Manchester University for running NMRs.

REFERENCES

[1] C.N. O'Callagan, J. Chem. Soc. Perkin Trans. I (1980) 1335.

[2] O. Bruno, S. Schenone, A. Ranise, F. Bondavalli, E. Barocelli, V. Ballabeni, M. Chiavarini, S. Bertoni, Bioorg. Med. Chem. 9 (2001) 629.

[3] O. Bruno, C. Brullo, A. Ranise, S. Schenone, F. Bondavalli, E. Barocelli, V. Ballabeni, M. Chiavarini, M. Tognolini, M. Impicciatore, Bioorg. Med. Chem. Lett. 11 (2001) 1397.

[4] O. Bruno, C. Brullo, S. Schenone, A. Ranise, F. Bondavalli, E. Barocelli, F. Magnanini, V. Ballabeni, Farmaco 57 (2002) 753.

[5] O. Bruno, C. Brullo, S. Schenone, F. Bondavalli, A. Ranise, M. Tognolini, V. Ballabeni, E. Barocelli, Bioorg. Med. Chem. 12 (2004) 553.

[6] O. Bruno, S. Schenone, A. Ranise, E. Barocelli, M. Chiavarini, V. Ballabeni, S. Bretoni, Arzn. Forsch. 50 (2000) 140.

[7] V. Ballabeni, F. Calcina, M. Tognolini, O. Bruno, C. Manotti, E. Barocelli, Life Sci. 74 (2004) 1851.

[8] C. Brullo, M. Rocca, P. Fossa, E. Cichero, E. Barocelli, V. Ballabeni, L. Flammini, C. Giorgio, F.

[9] Saccani, G. Domenichini, O. Bruno, Bioorg. Med. Chem. Lett. 22 (2012) 1125.

[a]Isolated yield.

[10] K. Chinnakali, D. Sudha, M. Jayagobi, R. Raghunathan, H.K. Fun, Acta Cryst. E65 (2009) o2907.

[11] O. Bruno, C. Brullo, F. Bondavalli, A. Ranise, S. Schenone, M. Tognolini, V. Ballabeni, E. Barocelli, Med. Chem. 3 (2007) 127.

[12] O. Bruno, C. Brullo, S. Schenone, F. Bondavalli, A. Ranise, M. Tognolini, M. Impicciatore, V. Ballabeni, E. Barocelli, Bioorg. Med. Chem. 14 (2006) 121.

[13] A.V. Borisov, S.G. Dzhavakhishvili, I.O. Zhuravel, S.M. Kovalenko, V.M. Nikitchenko, J. Comb. Chem. 9 (2007) 5.

[14] A. Zonouzi, M. Biniaz, R. Mirzazadeh, M. Talebi, S.W. Ng, Heterocycles 81 (2010) 1271.

[15] R. Ghahremanzadeh, T. Amanpour, A. Bazgir, Tetrahedron Lett. 51 (2010) 4202.

[16] A.K. Gupta, K. Kumari, N. Singh, D.S. Raghuvanshi, K.N. Singh, Tetrahedron Lett. 53 (2012) 650.

[17] H.R. Shaterian, M. Aghakhanizadeh, Res. Chem. Intermed. 39 (2013) 3877.

[18] H.R. Tavakoli, S.M. Moosavi, A. Bazgir, J. Korean Chem. Soc. 57 (2013) 260.

[19] S. Amirnejat, F. Movahedi, H. Masrouri, M. Mohadesi, M.Z. Kassaee, J. Mol. Catal. A Chem. 378 (2013) 135.

[20] S.M. Sadeghzadeh, F. Daneshfar, M. Malekzadeh, Chin. J. Chem. 32 (2014) 349.

[21] N. Azizi, M. Mariami, M. Edrisi, Dyes Pigments 100 (2014) 215.

[22] D. Zareyee, B. Karimi, Tetrahedron Lett. 48 (2007) 1277.

[23] B. Karimi, M. Khalkhali, J. Mol. Catal. A Chem. 271 (2007) 75.

[24] K. Niknam, D. Saberi, M. Nouri Sefat, Tetrahedron Lett. 50 (2009) 4058.

[25] K. Niknam, D. Saberi, M. Mohagheghnejad, Molecules 14 (2009) 1915.

[26] K. Niknam, D. Saberi, Tetrahedron Lett. 50 (2009) 5210.

[27] K. Niknam, D. Saberi, Appl. Catal. A Gen. 366 (2009) 220.

[28] K. Niknam, D. Saberi, M. Baghernejad, Phosphorus, Sulfur, and Silicon 185 (2010) 875.

[29] K. Niknam, M.R. Mohammadizadeh, S. Mirzaee, D. Saberi, Chin. J. Chem. 28 (2010) 663.

[30] K. Niknam, D. Saberi, M. Nouri Sefat, Tetrahedron Lett. 51 (2010) 2959.

[31] K. Niknam, F. Panahi, D. Saberi, M. Mohagheghnejad, J. Heterocycl. Chem. 47 (2010) 292.

[32] K. Niknam, D. Saberi, H. Molaee, M.A. Zolfigol, Can.

J. Chem. 88 (2010) 164.
[33] S. Tayebi, M. Baghernejad, D. Saberi, K. Niknam, Chin. J. Catal. 32 (2011) 1477.
[34] K. Niknam, M.R. Mohammadizadeh, S. Mirzaee, Chin. J. Chem. 29 (2011) 1417.
[35] K. Niknam, A. Deris, F. Naeimi, F. Majleci,
[36] Tetrahedron Lett. 52 (2011) 4642.
[37] M. Nouri Sefat, D. Saberi, K. Niknam, Catal. Lett.141 (2011) 1713.
[38] M. Nouri Sefat, A. Deris, K. Niknam, Chin. J. Chem.29 (2011) 2361.
[39] T. Rahi, M. Baghernejad, K. Niknam, Chin. J. Catal.33 (2012) 1095.
[40] K. Niknam, A. Jamali, M. Tajaddod, A. Deris, Chin.J. Catal. 33 (2012) 1312.
[41] S.M.G. Ahmadi-Ana, M. Baghernejad, K. Niknam, Chin. J. Chem. 30 (2012) 517.
[42] S.P. Brojeni, M. Baghernejad, D. Saberi, K. Niknam,Green Chem. Lett. Rev. 6 (2013) 69.
[43] K. Niknam, S.A. Sajadi, R. Hosseini, M. Baghernejad,Iran. J. Catal. 4 (2014) 163.