Synthesis of 2-Amino-4,6-diaryl nicotinonitriles Using Silica-Bound *N*-Propyl Triethylenetetramine Sulfamic Acid as a Recyclable Solid Acid Catalyst

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Abstract: A simple and efficient procedure for the preparation of silica-bound *N*-propyl triethylenetetramine sulfamic acid (SBPTETSA) by the reaction of silica-bound *N*-propyl triethylenetetramine (SBPTET) with chlorosulfonic acid in chloroform is described. Silica-bound *N*-propyl triethylenetetramine sulfamic acid was employed as a recyclable catalyst for the synthesis of 2-amino-4,6-diaryl nicotinonitriles from the multi-component reaction of an acetophenone derivative, an aromatic aldehyde, malononitrile, and ammonium acetate under solvent-free conditions at 100 °C. The heterogeneous catalyst was recycled for five consecutive runs in the optimized multi-component reaction of 4-chloroacetophenone, 4-chlorobenzaldehyde, malononitrile, and ammonium acetate without significant losses to its catalytic activity.

Key words: silica-bonded *N*-propyl triethylenetetramine sulfamic acid; 2-amino-4,6-diaryl nicotinonitrile; pyridine; aldehyde; solvent-free

CLC number: O643

Document code: A

Received 6 March 2012. Accepted 3 May 2012.

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This work was supported by Persian Gulf University Research Council (PGU/FS/6-1/1390/705).

English edition available online at Elsevier ScienceDirect (<http://www.sciencedirect.com/science/journal/18722067>).

Pyridine and its derivatives are important structural motifs and are present in a great number of pharmaceutical compounds and natural products [1–6]. The unique structural arrays and highly pronounced biological and physiological activities [1–6] displayed by such compounds have made them attractive synthetic targets, with 2-amino-4,6-diaryl nicotinonitriles being especially considered as an important class of bio-active compounds [4–6]. For example, 2-aminopyridine derivatives have recently been identified as anti-microbial agents [7], IKK- β inhibitors [8], and potent inhibitors of HIV-1 integrase [9]. Although there are multiple reports in the literature describing the synthesis of 2-amino-3-cyanopyridines, the majority of these procedures require multiple steps [10], long reaction times, toxic solvents such as benzene [11], high temperatures or microwave assistance [12], resulting in disappointingly low yields. In contrast, straight-forward and efficient one-pot catalytic procedures for the synthesis of 2-amino-3-cyanopyridines under mild conditions are still limited. Most recently, there have been reports describing the synthesis of 2-amino-3-cyanopyridines according to a two step synthesis [13] using either a Brønsted acidic ionic liquid at 150 °C [14] or Yb(PFO)₃ in refluxing ethanol [15].

Several types of solid sulfonic acid functionalized silica (both amorphous and ordered) have been synthesized and applied as alternatives to the traditional sulfonic acid resins and homogeneous acids in catalyzing chemical transforma-

tions [16–24]. In a continuation of our own studies on the design and application of solid acid catalysts in organic transformations [17–24], we herein describe the preparation of silica-bound *N*-propyl triethylenetetramine sulfamic acid (SBPTETSA) and its application as a catalyst for the synthesis of 2-amino-4,6-diaryl nicotinonitriles.

SBPTETSA was prepared by the reaction of 3-triethylenetetramine-*N*-propylsilica (3-PNPS) with chlorosulfonic acid in chloroform (Scheme 1).

1 Experimental

1.1 Catalyst preparation

Chemicals were purchased from Fluka, Merck, and Aldrich. Fourier transform infrared (FT-IR) spectra were run on a Shimadzu Infrared spectroscopy FT-IR-8000 and a Bruker spectrum X. The ¹H and ¹³C NMR was run on Bruker Avance (400 MHz) instruments in CDCl₃. Melting points were recorded on a SMP1 melting point apparatus in open capillary tubes and are uncorrected. Reaction progress was followed by TLC using silica gel SILG/UV 254 plates. Chloropropyl silica was prepared according to a previously reported procedure [23]. All of the products were characterized by comparison of their IR, ¹H, and ¹³C NMR spectroscopic data and their melting points with the reported values [7–15].

Scheme 1. Preparation of SBPTETSA.

1.1.1 Synthesis of 3-triethylenetetramine-*N*-propylsilica (3-TETANPS)

To a mixture of chloropropyl silica (25 g) in anhydrous xylene (250 ml), an excess of triethylenetetramine (25 ml) was added. The resulting mixture was refluxed with stirring for 24 h. The reaction mixture was then cooled to room temperature and filtered through a vacuum glass filter. The filter-cake was washed sequentially with xylene and a large excess of ethanol and dried under vacuum overnight at 80 °C to give the desired product 3-TETANPS (26.4 g).

1.1.2 Synthesis of SBPTETSA

To a magnetically stirred mixture of 3-TETANPS (26.4 g) in CHCl_3 (50 ml) was added chlorosulfonic acid (25 ml) in a drop-wise manner at 0 °C over a period of 2 h. Upon completion of the reaction, the mixture was stirred for a further 2 h and then filtered. The filter-cake was washed with ethanol (50 ml) and dried at room temperature to afford the desired product, SBPTETSA, as a cream powder (27.5 g).

Elemental analysis found: S, 1.04%; C, 10.05%; H, 2.15%; N, 2.54%. The number of H^+ sites on the SBPTETSA was determined by pH-ISE conductivity titration (Denver Instrument Model 270) and found to be 0.6 mmol of H^+ sites per 1 g of solid acid at 25 °C (pH = 2.62).

1.2 General procedure for the synthesis of 2-amino-4,6-diarylnicotinonitrile derivatives

To a mixture of an acetophenone derivative (1.0 mmol), an aromatic aldehyde (1.0 mmol), malononitrile (1.0 mmol), and ammonium acetate (1.5 mmol) was added SBPTETSA (0.07 g, equivalent to 0.042 mmol of H^+) and the resulting mixture was heated at 100 °C under solvent-free conditions. Upon completion of the reaction (monitored by TLC),

ethanol (5 ml) was added and the resulting mixture was filtered. The filter-cake was washed with warm ethanol (5 ml $\times$ 3) to effectively clean the catalyst. The filtrates were subsequently combined and provided the products were recrystallized from ethanol. The recovered catalyst was dried and reused in the subsequent runs.

2-Amino-6-(4-chlorophenyl)-4-phenyl-nicotinonitrile (**1a**). IR (neat, cm^{-1}): 3494.74, 3391.15, 2207.42, 1607.03, 1568.35, 1546.79, 1422.39, 1364.52, 1259.13, 1084.75, 1009.35, 829.34, 760.49, 693.35. ^1H NMR (400 MHz, CDCl_3): δ 5.29 (s, 2H), 7.11 (s, 1H), 7.38 (d, 2H, J = 8.8 Hz), 7.45–7.47 (m, 3H), 7.55–7.57 (m, 2H), 7.89 (d, 2H, J = 8.8 Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 109.95, 117.23, 127.12, 127.58, 127.96, 127.99, 131.77, 135.40, 139.69, 154.73, 157.42.

2-Amino-4,6-bis-(4-chlorophenyl)-nicotinonitrile (**1b**). IR (neat, cm^{-1}): 3498.89, 3393.13, 2204.81, 1607.13, 1579.10, 1543.75, 1492.07, 1431.94, 1396.80, 1365.73, 1258.38, 1091.86, 1011.82, 821.13, 773.54. ^1H NMR (400 MHz, CDCl_3): δ 5.30 (s, 2H), 7.07 (s, 1H), 7.38 (d, 2H, J = 8.0 Hz), 7.44 (d, 2H, J = 8.0 Hz), 7.50 (d, 2H, J = 8.0 Hz), 7.88 (d, 2H, J = 8.0 Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 110.68, 116.79, 122.17, 128.62, 129.07, 129.31, 129.51, 154.99, 160.32.

2-Amino-6-(4-chlorophenyl)-4-(4-methoxyphenyl)-nicotinonitrile (**1c**). IR (neat, cm^{-1}): 3458.62, 3365.89, 2917.65, 2206.41, 1582.36, 1544.06, 1515.45, 1454.96, 1427.14, 1367.80, 1297.85, 1254.62, 1183.98, 1012.28, 821.40. ^1H NMR (400 MHz, CDCl_3): δ 3.82 (s, 3H), 5.25 (s, 2H), 6.97 (d, 2H, J = 8.0 Hz), 7.09 (s, 1H), 7.37 (d, 2H, J = 8.0 Hz), 7.54 (d, 2H, J = 8.0 Hz), 7.88 (d, 2H, J = 8.0 Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 65.36, 109.71, 127.55, 127.96, 128.59, 132.37, 135.29, 138.39, 154.36, 159.78.

2-Amino-6-(4-chlorophenyl)-4-(4-methylsulfanyphenyl)-nicotinonitrile (**1d**). IR (neat, cm^{-1}): 3494.70, 3392.31, 2919.98, 2206.92, 1608.73, 1572.57, 1539.05, 1493.20,

1435.71, 1364.39, 1259.07, 1087.49, 1011.87, 806.21. ^1H NMR (400 MHz, CDCl_3): δ 2.47 (s, 3H), 5.28 (s, 2H), 7.08 (s, 1H), 7.30 (d, 2H, $J = 8.0$ Hz), 7.37 (d, 2H, $J = 8.0$ Hz), 7.49 (d, 2H, $J = 8.0$ Hz), 7.88 (d, 2H, $J = 8.0$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 14.22, 109.63, 125.15, 127.45, 127.56, 127.99, 131.94, 135.26, 140.63, 153.62, 157.43, 159.20. Anal calcd for $\text{C}_{19}\text{H}_{14}\text{ClN}_3\text{S}$: C, 64.86; H, 4.01; N, 11.94; Found: C, 64.67; H, 4.10; N, 11.78.

2-Amino-6-(4-chlorophenyl)-4-*p*-tolyl-nicotinonitrile (**1e**). IR (neat, cm^{-1}): 3493.41, 3389.76, 2919.01, 2204.78, 1606.55, 1578.89, 1543.48, 1366.12, 1257.48, 1048.54, 811.25. ^1H NMR (400 MHz, CDCl_3): δ 2.37 (s, 3H), 5.27 (s, 2H), 7.09 (s, 1H), 7.26 (d, 2H, $J = 7.8$ Hz), 7.37 (d, 2H, $J = 8.8$ Hz), 7.46 (d, 2H, $J = 10.1$ Hz), 7.88 (d, 2H, $J = 8.8$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 20.36, 109.84, 127.01, 127.55, 127.96, 128.65, 132.84, 135.31, 139.19, 154.31, 159.15. Anal calcd for $\text{C}_{19}\text{H}_{14}\text{ClN}_3$: C, 71.36; H, 4.41; N, 11.09; Found: C, 71.18; H, 4.52; N, 10.94.

2-Amino-6-(4-fluorophenyl)-4-*p*-tolyl-nicotinonitrile (**1f**). IR (neat, cm^{-1}): 3491.85, 3391.49, 2908.20, 2206.03, 1606.46, 1581.58, 1546.75, 1508.21, 1427.95, 1368.11, 1302.75, 1259.52, 1217.55, 1158.98, 837.04, 817.49, 773.16. ^1H NMR (400 MHz, CDCl_3): δ 2.37 (s, 3H), 5.26 (s, 2H), 7.06–7.10 (m, 3H), 7.26 (d, 2H, $J = 7.8$ Hz), 7.46 (dt, 2H, $J_1 = 8.0$ Hz, $J_2 = 2.0$ Hz), 7.91–7.95 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.41, 110.80, 115.70, 115.91, 128.06, 129.26, 129.34, 129.69, 133.94, 140.19, 160.19. Anal calcd for $\text{C}_{19}\text{H}_{14}\text{FN}_3$: C, 75.23; H, 4.65; N, 13.85; Found: C, 75.04; H, 4.58; N, 13.78.

2-Amino-6-(4-fluorophenyl)-4-(4-methoxyphenyl)-nicotinonitrile (**1g**). IR (neat, cm^{-1}): 3449.08, 3322.16, 2906.23, 2210.69, 1600.97, 1573.26, 1546.15, 1511.12, 1441.74, 1372.80, 1296.30, 1255.32, 1226.99, 1177.52, 1027.28, 857.28, 838.65, 817.59. ^1H NMR (400 MHz, CDCl_3): δ 3.81 (s, 3H), 5.25 (s, 2H), 6.97 (dt, 2H, $J_1 = 8.8$ Hz, $J_2 = 2.5$ Hz), 7.06–7.11 (m, 3H), 7.53 (dt, 2H, $J_1 = 9.1$ Hz, $J_2 = 2.7$ Hz), 7.90–7.95 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 55.46, 110.65, 114.40, 115.69, 115.90, 129.25, 129.33, 129.62, 154.85, 158.51, 160.64 ($J_{\text{C-F}} = 194.73$). Anal calcd for $\text{C}_{19}\text{H}_{14}\text{FN}_3\text{O}$: C, 71.46; H, 4.42; N, 13.16; Found: C, 71.28; H, 4.40; N, 13.02.

2-Amino-6-(4-fluorophenyl)-4-(4-chlorophenyl)-nicotinonitrile (**1h**). IR (neat, cm^{-1}): 3480.19, 3346.41, 2217.26, 1632.44, 1596.41, 1544.46, 1510.16, 1491.50, 1441.34, 1362.47, 1226.12, 1152.51, 1086.58, 1011.67, 808.05. ^1H NMR (400 MHz, CDCl_3): δ 5.30 (s, 2H), 7.05 (s, 1H), 7.09 (t, 2H, $J = 8.7$ Hz), 7.44 (d, 2H, $J = 8.3$ Hz), 7.50 (d, 2H, $J = 8.6$ Hz), 7.92–7.95 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 110.60, 115.78, 115.99, 116.87, 129.30, 129.39, 129.51, 133.87, 135.21, 136.22, 153.98, 159.52 ($J_{\text{C-F}} = 129.21\text{Hz}$). Anal. Calcd for $\text{C}_{18}\text{H}_{11}\text{ClFN}_3$: C, 66.78; H, 3.42; N, 12.98; Found: C, 66.62; H, 3.37; N, 12.81.

2-Amino-6-(4-fluorophenyl)-4-(2-chlorophenyl)-nicotinonitrile (**1i**). IR (neat, cm^{-1}): 3485.17, 3347.14, 2223.97, 1626.98, 1596.59, 1551.96, 1508.63, 1439.86, 1361.06, 1223.80, 1156.26, 1054.21, 852.13, 826.12, 759.32. ^1H NMR (400 MHz, CDCl_3): δ 5.28 (s, 2H), 7.03 (s, 1H), 7.08 (t, 2H, $J = 8.7$ Hz), 7.29–7.38 (m, 3H), 7.47–7.49 (m, 1H), 7.91–7.96 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 111.83, 115.74, 115.95, 116.19, 127.15, 129.45, 130.28, 130.32, 130.75, 132.27, 133.88, 135.77, 153.13, 158.48, 159.57, 164.12 ($J_{\text{C-F}} = 251.03$ Hz). Anal. Calcd for $\text{C}_{18}\text{H}_{11}\text{ClFN}_3$: C, 66.78; H, 3.42; N, 12.98; Found: C, 66.59; H, 3.39; N, 12.75.

2-Amino-4-phenyl-6-*p*-tolyl-nicotinonitrile (**1j**). IR (neat, cm^{-1}): 3491.20, 3392.15, 2918.62, 2204.33, 1627.25, 1574.03, 1542.94, 1425.23, 1369.13, 1257.57, 1018.03, 818.58, 767.55, 704.04. ^1H NMR (400 MHz, CDCl_3): δ 2.35 (s, 3H), 5.31 (s, 2H), 7.11 (s, 1H), 7.25 (d, 2H, $J = 8.0$ Hz), 7.37–7.41 (m, 3H), 7.46 (d, 2H, $J = 8.0$ Hz), 7.90–7.92 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3): δ 20.34, 110.13, 116.31, 126.28, 127.04, 127.77, 128.61, 129.11, 132.99, 136.99, 139.06, 154.11, 158.71, 159.26.

2-Amino-4-(4-nitrophenyl)-6-*p*-tolyl-nicotinonitrile (**1k**). IR (neat, cm^{-1}): 3491.25, 3388.15, 2920.08, 2206.90, 1606.18, 1549.34, 1512.86, 1349.58, 1258.08, 1012.06, 791.23, 699.25. ^1H NMR (400 MHz, CDCl_3): δ 2.35 (s, 3H), 5.34 (s, 2H), 7.11 (s, 1H), 7.23 (d, 2H, $J = 8.0$ Hz), 7.73 (dd, 2H, $J_1 = 9.1$ Hz, $J_2 = 2.2$ Hz), 7.84 (dd, 2H, $J_1 = 8.3$ Hz, $J_2 = 1.8$ Hz), 8.32 (dd, 2H, $J_1 = 9.1$ Hz, $J_2 = 2.0$ Hz). ^{13}C NMR (100 MHz, CDCl_3): δ 28.67, 123.15, 126.25, 128.33, 128.69, 129.21, 164.45. Anal calcd for $\text{C}_{19}\text{H}_{14}\text{N}_4\text{O}_2$: C, 69.08; H, 4.27; N, 16.96; Found: C, 68.91; H, 4.19; N, 16.78.

2-Amino-4-(3-nitrophenyl)-6-*p*-tolyl-nicotinonitrile (**1l**). IR (neat, cm^{-1}): 3479.98, 3365.81, 2217.73, 1622.34, 1568.24, 1525.06, 1342.43, 1258.22, 1084.85, 813.11, 743.43. ^1H NMR (400 MHz, CDCl_3): δ 2.35 (s, 3H), 5.34 (s, 2H), 7.13 (s, 1H), 7.23 (d, 2H, $J = 7.8$ Hz), 7.67 (t, 1H, $J = 8.1$ Hz), 7.86 (d, 2H, $J = 8.3$ Hz), 7.92 (d, 1H, $J = 8.1$ Hz), 8.30–8.32 (m, 1H), 8.40–8.41 (m, 1H). ^{13}C NMR (100 MHz, CDCl_3): δ 21.46, 110.61, 123.33, 124.46, 127.32, 129.67, 130.12, 134.19, 138.62, 141.10, 152.28, 160.20. Anal calcd for $\text{C}_{19}\text{H}_{14}\text{N}_4\text{O}_2$: C, 69.08; H, 4.27; N, 16.96; Found: C, 68.89; H, 4.14; N, 16.73.

2 Results and discussion

The thermogravimetric analysis (TGA) curve of SBPTETSA revealed the mass loss of organic materials as they decomposed upon heating (Fig. 1). An initial mass loss from the SBPTETSA up to 120 °C was caused by the removal of physically adsorbed solvent and surface hydroxyl groups. A mass loss accounting for approximately 11.58%

Fig. 1. TGA profile of SBTETASA.

of the initial mass occurred between 220 and 410 °C and was attributed to the thermal decomposition of the organic groups. The covalent chemical bonds within the catalyst bestowed high thermal stability on the structure.

The FT-IR spectrum of SBTETASA is shown in Fig. 2. The major peaks for silica (SiO_2) are the broad anti-symmetric Si–O–Si stretching mode from 1300 to 1000 cm^{-1} and the symmetric Si–O–Si stretching mode near 820–750 cm^{-1} . For sulfamic acid functional group, the FT-IR absorption ranges of the O=S=O asymmetric and symmetric stretching modes were located at 1170 and 1060 cm^{-1} , respectively. The FT-IR spectrum revealed an overlap in the asymmetric and symmetric stretching bands of SO_2 with the Si–O–Si stretching bands in the silica functionalized alkyl-sulfamic acid. The spectrum also contained a broad OH stretching absorption from 3600 to 3200 cm^{-1} . NH stretching and bending occurred at 3420 and 1650 cm^{-1} , respectively.

Fig. 2. FT-IR spectrum of SBTETASA.

The one-pot synthesis of **1b** was selected as a model reaction for our study. A mixture of 4-chlorobenzaldehyde (1 mmol), 4-chloroacetophenone (1 mmol), malononitrile (1 mmol), ammonium acetate (1.5 mmol), and different catalytic loading of SBTETASA was stirred under solvent-free

conditions at 100 °C (Table 1). It is clear from the results that SBTETASA performed as an effective catalyst in this four-component condensation reaction. The best catalytic loading of SBTETASA from the experiments conducted was 0.07 g in terms of reaction time and isolated yield. The application of a lower temperature gave the corresponding product in lower yield, with an extended reaction time being required to drive the reaction to higher levels of conversion (Table 1, entry 6). The reaction conditions outlined in entry 3 of Table 1 were subsequently identified as the optimized conditions, involving the heating of a mixture of an acetophenone derivative (1 mmol), an aldehyde (1 mmol), malononitrile (1 mmol), ammonium acetate (1.5 mmol), and SBTETASA (0.07 g, equal to 0.04 mmol of H^+) at 100 °C under solvent-free conditions.

Table 1 Condensation reaction of 4-chloroacetophenone, 4-chlorobenzaldehyde, malononitrile, and ammonium acetate in the presence of different loading of the catalyst under solvent-free conditions at different temperatures

Entry	Catalyst	Catalyst loading (g)	Temperature (°C)	Yield* (%)
1	SBTETASA	0.01	100	65
2	SBTETASA	0.03	100	75
3	SBTETASA	0.07	100	90
4	SBTETASA	0.1	100	91
5	SBTETASA	0.07	120	90
6	SBTETASA	0.07	90	80
7	H_2SO_4	0.1 (1 mmol)	100	trace
8	CH_3COOH	0.1 (1.67 mmol)	100	40
9	$\text{H}_2\text{NSO}_3\text{H}$	0.07 (0.72 mmol)	100	70

Reaction conditions: 4-chlorobenzaldehyde 1 mmol, 4-chloroacetophenone 1 mmol, malononitrile 1 mmol, ammonium acetate 1.5 mmol, 10 min. *Isolated yield.

With the optimized reaction conditions in hand, we proceeded to investigate the scope of the reaction by employing a wide range of aromatic aldehydes in the process (Table 2). The reaction performed well, providing the corresponding 2-amino-3-cyanopyridines in good to high yields, demonstrating the generality of the method and its good tolerance of both electron-withdrawing and electron-donating substituents on the aromatic ring of the aldehyde. For example, aromatic aldehydes containing electron-donating substituents, including 4-OMe, 4-SMe, and 4-Me, reacted with acetophenone derivatives, including 4-chloro- and 4-fluoroacetophenone under the optimized conditions, to provide the corresponding products in good to high yields (Table 2, entries 3–7).

Furthermore, aromatic aldehydes containing electron-withdrawing substituents, including 4- NO_2 and 3- NO_2 reacted with 4-methylacetophenone and malononitrile under the optimized conditions to afford the corresponding

Table 2 Synthesis of various 2-amino-4,6-diaryl nicotinonitriles in the presence of SBPTETSA under solvent-free conditions

Entry	R ¹	R ²	Product	Yield* (%)	Melting point (°C)
1	H	4-Cl	1a	85	240–242 (240–241 [13])
2	4-Cl	4-Cl	1b	90	230–231 (228–229 [13])
3	4-MeO	4-Cl	1c	75	204–205
4	4-MeS	4-Cl	1d	65	202–203
5	4-Me	4-Cl	1e	85	215–217
6	4-Me	4-F	1f	80	203–204
7	4-MeO	4-F	1g	85	194–196
8	4-Cl	4-F	1h	90	204–206
9	2-Cl	4-F	1i	87	202–203
10	H	4-Me	1j	80	182–183
11	4-O ₂ N	4-Me	1k	65	201–203 (180–182 [13])
12	3-O ₂ N	4-Me	1l	67	188–190

Reaction conditions: aldehyde 1 mmol, acetophenone derivative 1 mmol, malononitrile 1 mmol, ammonium acetate 1.5 mmol, SBPTETSA 0.07 g (equal to 0.042 mmol of H⁺), 100 °C, 10 min. *Isolated yield.

products in high yield (Table 2, entries 11 and 12). *Ortho*-substituted aromatic aldehydes also reacted successfully in this four component condensation (Table 2, entry 9). It is worthy of note that this method not only affords the products in good to high yields but also effectively avoids problems associated with catalyst cost, handling, safety, and pollution.

The possibility of recycling the catalyst was examined using the reaction of 4-chlorobenzaldehyde, 4-chloroacetophenone, malononitrile, and ammonium acetate under the optimized conditions (Fig. 3). Upon completion of the reaction, the mixture was filtered and the filter-cake was washed

Fig. 3. Recyclability of the SBPTETSA catalyst. Reaction conditions: 4-chloroacetophenone 1 mmol, 4-chlorobenzaldehyde 1 mmol, malononitrile 1 mmol, ammonium acetate 1.5 mmol, catalyst 0.07 g, 100 °C, 10 min.

with ethanol. The filter-cake of solid catalyst was then collected and stored ahead of the next reaction. The recycled catalyst could be reused five times without any further treatment. Furthermore, no appreciable loss was observed in the catalytic activity of the SBPTETSA catalysts over the five recycling runs.

3 Conclusions

Silica-bound propyl triethylenetetramine sulfamic acid efficiently catalyzed the synthesis of 2-amino-4,6-diaryl nicotinonitriles via a four component condensation reaction. The simplicity of this procedure, together with the eco-friendly, non-volatile, easy-to-handle, non-hazardous, and recyclable nature of catalyst, represents the main advantages of this method.

Acknowledgments

We are thankful to the School of Chemistry, Manchester University for running NMR, CHN, and TGA.

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