J. Chem. Sci. Vol. 124, No. 4, July 2012, pp. 893–899.

A novel and facile approach for synthesis of 5-amino-7-aryl-6-cyano-4*H*-pyrano[3,2-*b*]pyrroles

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MS received 31 August 2011; revised 25 December 2012; accepted 16 January 2012

Abstract. An efficient and iron-catalysed synthesis of 4*H*-pyrano[3,2-*b*]pyrrole is reported. The reactions proceed through a one-pot, three component cyclocondensation of 3-hydroxypyrrole, malononitrile and various aldehydes to afford 4*H*-pyrano[3,2-*b*]pyrrole derivatives in moderate to good yield using ferric hydrogensulphate, $Fe(HSO_4)_3$, as the catalyst.

Keywords. Pyranopyrrole; one-pot; catalyst.

1. Introduction

In the realm of organic synthesis, it would be desirable to perform a series of simple steps in one pot,[1,2] which would minimize the chemicals used and waste produced, as well as the reaction time consumed. As a result, great attention has been paid to the development of cascade reactions. Multicomponent reactions (MCRs) involving a cascade process with at least three different substrates to generate complex molecular frameworks have emerged as a powerful synthetic strategy.[3,4] Because the combination of three components to generate new products in a single step is extremely economical, among the multi-component reactions.[5]

It is well-known that pyrans are important core units in a number of natural products[6,7] and photochromic materials.[8] Compounds with pyran ring system have many pharmacological properties and play important roles in biochemical process.[9] Therefore, preparation of this heterocyclic nucleus has gained more importance in organic synthesis.

The 4*H*-pyran derivatives are of the immense interests in the area of synthesizing various drugs due to their pharmacological and biological activities, such as antimicrobial,[10] mutagenicity,[11,12] antiproliferative,[13] sex pheromone,[14] antitumour[15] and central nervous system activity.[16] Therefore, the synthesis of such compounds is an interesting challenge.

Many efforts have recently been undertaken by the preparation of various pyran derivatives with the aim of obtaining more biologically potent heterocyclic systems.[17–22] However, to the best of our knowledge, synthesis of 5-amino-7-aryl-6-cyano-4*H*-pyrano[3,2-*b*]pyrrole derivatives has never been communicated up to now. In this study, in continuation of our interest in MCRs,[23,24] the one-pot synthesis of 5-amino-7-aryl-6-cyano-4*H*-pyrano[3,2-*b*]pyrroles by cyclocondensation reaction of 3-hydroxypyrrole, substituted benzaldehydes and malononitrile in the presence of ferric hydrogensulphate, $Fe(HSO_4)_3$, is described here (figure 1).

2. Experimental

2.1 *General*

All chemicals were purchased from Merck, Fluka and Aldrich Chemical Companies. All yields refer to isolated products. The products were characterized by their spectral data. IR spectra were recorded on a Shimadzu-IR 470 spectrophotometer. ^{1}H NMR, ^{13}CNMR and DEPT ^{13}CNMR spectra were recorded on a Bruker 100-MHz spectrometer in chloroform as the solvent and TMS as internal standard. Elemental analysis (C, H, N%) was carried out by Perkin-Elmer 2400 series-II elemental analyzer. Flash column chromatography was performed with 300 and 400 meshes silica gel and analytical thin-layer chromatography (TLC) was performed on pre-coated silica gel plates (60F-254).

*For correspondence

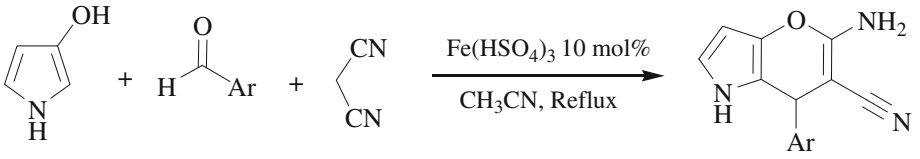


Figure 1. One-pot synthesis of pyranopyrroles.

2.2 *General procedure for synthesis of pyranopyrrole derivatives* ***5a–l***

A mixture of aldehyde (1 mmol), 3-hydroxypyrrole (1 mmol), malononitrile (1.1 mmol) and ionic liquid catalyst (0.1 mmol) in CH_3CN (4 mml) was stirred at 50°C for the appropriate time. The reaction was monitored by TLC and after completion of the reaction; the catalyst was simply recovered by filtration and washed by dichloromethane. The residue was concentrated *in vacuo* and the crude product was purified by column chromatography on silica gel.

2.2a *5-Amino-1,7-dihydro-7-(4-methoxyphenyl)pyrano[3,2-b]pyrrole-6-carbonitrile* ***(5a)***: Anal Calcd. for $C_{15}H_{13}N_3O_2$ (267.28): C, 67.40; H, 4.90; N, 15.72%. Found: C, 66.22; H, 4.78; N, 15.59%. IR (KBr, ν_{max}, cm^{-1}): 3411 and 3279 (asym. and sym. str. of -NH_2), 3400 (NH), 2160 (-CN str.), 1251 (asym. str. of cyclic ArC-O-C ether). ^{1}H NMR (400 MHz, CDCl3) δ_H (ppm): 3.37 (s, 3H, OCH_3), 5.43 (s, 1H, pyran H_4), 6.11 (d, 1H, pyrrole H_3), 6.63 (d, 2H, Ar-H), 6.68 (d, 1H, pyrrole H_2), 6.89 (s, 2H, D_2O exch., NH2), 7.05 (d, 2H, Ar-H), 7.54 (s, 1H, pyrrole NH). ^{13}C NMR (250 MHz, CDCl3) δ_C (ppm): 28.6 (pyran C_4, CH, CH), 55.23 (O-CH_3, CH_3), 59.5 (pyran C_3), 101.5 (pyran C_6), 104.9 (pyrrole C_3, CH), 119.3 (pyrrole, C_1, CH), 122.0 (CN), 126.1 (pyran C_5), 119.2, 127.4, 130.3, 154.6 (Ar-C), 171.4 (pyran C_2).

2.2b *5-Amino-1,7-dihydro-7-phenylpyrano[3,2-b]pyrrole-6-carbonitrile* ***(5b)***: Anal Calcd. for $C_{14}H_{11}N_3O$ (237.26): C, 70.87; H, 4.67; N, 17.71%. Found: C, 68.59; H, 4.62; N, 16.97%. IR (KBr, ν_{max}, cm^{-1}): 3405 and 3283 (asym. and sym. str. of -NH_2), 3405 (NH), 2157 (-CN str.), 1247 (asym. str. of cyclic ArC-O-C ether). ^{1}H NMR (400 MHz, CDCl3) δ_H (ppm): 5.51 (s, 1H, pyran H_4), 6.25 (d, 1H, pyrrole H_3), 6.73 (d, 1H, pyrrole H_2), 6.75 (s, 2H, D_2O exch., NH2), 7.09–7.15 (m, 5H, Ar-H), 7.50 (s, 1H, pyrrole NH). ^{13}C NMR (250 MHz, CDCl3) δ_C (ppm): 30.6 (pyran C_4, CH), 55.8 (pyran C_3), 101.6 (pyran C_6), 106.4 (pyrrole C_3, CH), 117.9 (pyrrole, C_1, CH), 123.5 (CN), 129.7 (pyran C_5), 122.8, 129.1, 127.9, 130.8 (Ar-C), 173.7 (pyran C_2).

2.2c *5-Amino-1,7-dihydro-7-p-tolylpyrano[3,2-b]pyrrole-6-carbonitrile* ***(5c)***: Anal Calcd. for $C_{15}H_{13}N_3O$ (251.28): C, 71.70; H, 5.21; N, 16.72%. Found: C, 70.93; H, 5.08; N, 16.14%. IR (KBr, ν_{max}, cm^{-1}): 3422 and 3272 (asym. and sym. str. of -NH_2), 3419 (NH), 2189 (-CN str.), 1252 (asym. str. of cyclic ArC-O-C ether). ^{1}H NMR (400 MHz, CDCl3) δ_H (ppm): 2.31 (s, 3H, Ar-CH_3), 5.60 (s, 1H, pyran H_4), 6.18 (d, 1H, pyrrole H_3), 6.80 (s, 2H, D_2O exch., NH2), 6.89 (d, 1H, pyrrole H_2), 6.98–7.07 (m, 4H, Ar-H), 7.38 (s, 1H, pyrrole NH). ^{13}C NMR (250 MHz, CDCl3) δ_C (ppm): 24.7 (-CH_3), 29.21 (pyran C_4, CH), 54.6 (pyran C_3), 100.1 (pyran C_6), 107.3 (pyrrole C_3, CH), 115.7 (pyrrole C_1, CH), 126.5 (CN), 131.4 (pyran C_5), 128.3, 129.1, 133.6, 137.9 (Ar-C), 169.1 (pyran C_2).

2.2d *5-Amino-7-(4-bromophenyl)-1,7-dihydropyrano[3,2-b]pyrrole-6-carbonitrile* ***(5d)***: Anal Calcd. for $C_{14}H_{10}BrN_3O$ (316.15): C, 53.19; H, 3.19; N, 13.29%. Found: C, 52.79; H, 3.14; N, 12.64%. IR (KBr, ν, cm^{-1}): 3425 and 3269 (asym. and sym. str. of -NH_2), 3434 (NH), 2201 (-CN str.), 1242 (asym. str. of cyclic ArC-O-C ether). ^{1}H NMR (400 MHz, CDCl3) δ_H (ppm): 5.40 (s, 1H, pyran H_4), 6.11 (d, 1H, pyrrole H_3), 6.49 (s, 2H, D_2O exch., NH2), 7.06 (d, 2H, Ar-H), 6.70 (d, 1H, pyrrole H_2), 7.25 (d, 2H, Ar-H), 7.39 (s, 1H, pyrrole NH). ^{13}C NMR (250 MHz, CDCl3) δ_C (ppm): 31.4 (pyran C_4, CH), 64.9 (pyran C_3), 100.5 (pyran C_6), 109.5 (pyrrole C_3, CH), 117.3 (pyrrole, C_1, CH), 127.2 (CN), 130.3 (pyran C_5), 123.6, 129.4, 130.9, 138.4 (Ar-C), 179.7 (pyran C_2).

2.2e *5-Amino-7-(2-bromophenyl)-1,7-dihydropyrano[3,2-b]pyrrole-6-carbonitrile* ***(5e)***: Anal Calcd. for $C_{14}H_{10}BrN_3O$ (316.15): C, 53.19; H, 3.19; N, 13.29%. Found: C, 51.98; H, 3.16; N, 13.14%. IR (KBr, ν_{max}, cm^{-1}): 3415 and 3298 (asym. and sym. str. of -NH_2), 3411 (NH), 2187 (-CN str.), 1257 (asym. str. of cyclic ArC-O-C ether). ^{1}H NMR (400 MHz, CDCl3) δ_H (ppm): 5.58 (s, 1H, pyran H_4), 6.19 (d, 1H, pyrrole H_3),

6.73 (d, 1H, pyrrole H_2), 6.79 (s, 2H, D_2O exch., NH2), 6.97–7.11 (m, 4H, Ar-H), 7.58 (s, 1H, pyrrole NH). ^{13}C NMR (250 MHz, CDCl3) δ_C (ppm): 28.3 (pyran C_4, CH), 57.5 (pyran C_3), 108.6 (pyran C_6), 108.9 (pyrrole C_3, CH), 121.6 (pyrrole, C_1, CH), 127.5 (CN), 131.5 (pyran C_5), 122.8, 122.4, 128.9, 132.7, 133.0, 141.6 (Ar-C), 179.0 (pyran C_2).

2.2f *5-Amino-7-(4-chlorophenyl)-1,7-dihydropyrano [3,2-b]pyrrole-6-carbonitrile* ***(5f)***: Anal Calcd. for $C_{14}H_{10}ClN_3O$ (271.7): C, 61.89; H, 3.71; N, 15.47%. Found: C, 61.34; H, 3.69; N, 15.43%. IR (KBr, ν_{max}, cm^{-1}): 3414 and 3259 (asym. and sym. str. of -NH_2), 3415 (NH), 2156 (-CN str.), 1256 (asym. str. of cyclic ArC-O-C ether). ^1H NMR (400 MHz, CDCl3) δ_H (ppm): 5.48 (s, 1H, pyran H_4), 6.16 (d, 1H, pyrrole H_3), 6.42 (s, 2H, D_2O exch., NH2), 6.64 (d, 1H, pyrrole H_2), 7.06 (d, 2H, Ar-H), 7.21 (d, 2H, Ar-H), 7.29 (s, 1H, pyrrole NH). ^{13}C NMR (250 MHz, CDCl3) δ_C (ppm): 30.7 (pyran C_4, CH), 60.23 (pyran C_3), 106.5 (pyran C_6), 108.4 (pyrrole C_3, CH), 119.0 (pyrrole, C_1, CH), 124.8 (CN), 136.1 (pyran C_5), 129.5, 129.4, 130.5, 132.8 (Ar-C), 179.7 (pyran C_2).

2.2g *5-Amino-7-(2-chlorophenyl)-1,7-dihydropyrano [3,2-b]pyrrole-6-carbonitrile* ***(5g)***: Anal Calcd. for $C_{14}H_{10}ClN_3O$ (271.7): C, 61.89; H, 3.71; N, 15.47%. Found: C, 61.23; H, 3.66; N, 15.18%. IR (KBr, ν_{max}, cm^{-1}): 3458 and 3256 (asym. and sym. str. of -NH_2), 3397 (NH), 2167 (-CN str.), 1248 (asym. str. of cyclic ArC-O-C ether). ^1H NMR (400 MHz, CDCl3) δ_H (ppm): 5.51 (s, 1H, pyran H_4), 6.28 (d, 1H, pyrrole H_3), 6.64 (d, 1H, pyrrole H_2), 6.84 (s, 2H, D_2O exch., NH2), 7.09–7.19 (m, 4H, Ar-H), 7.43 (s, 1H, pyrrole NH). ^{13}C NMR (250 MHz, CDCl3) δ_C (ppm): 26.2 (pyran C_4, CH), 55.6 (pyran C_3), 113.9 (pyran C_6), 114.2 (pyrrole C_3, CH), 118.6 (pyrrole, C_1, CH), 129.1 (CN), 137.2 (pyran C_5), 125.4, 127.3, 128.9, 132.7, 133.0, 139.6 (Ar-C), 173.7 (pyran C_2).

2.2h *5-Amino-7-(4-cyanophenyl)-1,7-dihydropyrano [3,2-b]pyrrole-6-carbonitrile* ***(5h)***: Anal Calcd. for $C_{15}H_{10}N_4O$ (262.09): C, 68.69; H, 3.84; N, 21.36%. Found: C, 67.84; H, 3.75; N, 20.90%. IR (KBr, ν_{max}, cm^{-1}): 3401 and 3248 (asym. and sym. str. of -NH_2), 3418 (NH), 2210 (-CN str.), 2181 (-CN str.), 1257 (asym. str. of cyclic ArC-O-C ether). ^1H NMR (400 MHz, CDCl3) δ_H (ppm): 5.51 (s, 1H, pyran H_4), 6.10 (d, 1H, pyrrole H_3), 6.48 (s, 2H, D_2O exch., NH2), 6.60 (d, 1H, pyrrole H_2), 7.24 (s, 1H, pyrrole NH), 7.26 (d, 2H, Ar-H), 7.38 (d, 2H, Ar-H). ^{13}C NMR (250 MHz, CDCl3) δ_C (ppm): 34.6 (pyran C_4, CH), 62.78 (pyran C_3), 111.7 (pyran C_6), 114.5 (pyrrole C_3, CH), 122.4 (pyrrole, C_1, CH), 124.8 (CN), 126.5 (CN), 139.4 (pyran C_5), 114.8, 129.9, 133.5, 139.5 (Ar-C), 176.3 (pyran C_2).

2.2i *5-Amino-7-(2-cyanophenyl)-1,7-dihydropyrano [3,2-b]pyrrole-6-carbonitrile* ***(5i)***: Anal Calcd. for $C_{15}H_{10}N_4O$ (262.09): C, 68.69; H, 3.84; N, 21.36%. Found: C, 68.34; H, 3.23; N, 21.20%. IR (KBr, ν_{max}, cm^{-1}): 3421 and 3248 (asym. and sym. str. of -NH_2), 3416 (NH), 2201 (-CN str.), 2190 (-CN str.), 1250 (asym. str. of cyclic ArC-O-C ether). ^1H NMR (400 MHz, CDCl3) δ_H (ppm): 5.59 (s, 1H, pyran H_4), 6.31 (d, 1H, pyrrole H_3), 6.60 (d, 1H, pyrrole H_2), 6.81 (s, 2H, D_2O exch., NH2), 7.23–7.39 (m, 4H, Ar-H), 7.43 (s, 1H, pyrrole NH). ^{13}C NMR (250 MHz, CDCl3) δ_C (ppm): 29.2 (pyran C_4, CH), 59.6 (pyran C_3), 110.3 (pyran C_6), 110.9 (pyrrole C_3, CH), 118.1 (pyrrole, C_1, CH), 120.3 (CN), 121.5 (CN), 134.2 (pyran C_5), 115.0, 128.2, 130.6, 132.5, 133.9, 141.3 (Ar-C), 174.8 (pyran C_2).

2.2j *5-Amino-1,7-dihydro-7-(4-nitrophenyl)pyrano[3, 2-b]pyrrole-6-carbonitrile* ***(5j)***: Anal Calcd. for $C_{14}H_{10}N_4O_3$ (282.25): C, 59.57; H, 3.57; N, 19.85%. Found: C, 59.21; H, 3.52; N, 19.66%. IR (KBr, ν_{max}, cm^{-1}): 3413 and 3240 (asym. and sym. str. of -NH_2), 3414 (NH), 2178 (-CN str.), 1360 and 1548 (asym. and sym. str. of -NO_2), 1249 (asym. str. of cyclic ArC-O-C ether). ^1H NMR (400 MHz, CDCl3) δ_H (ppm): 5.50 (s, 1H, pyran H_4), 6.17 (d, 1H, pyrrole H_3), 6.40 (s, 2H, D_2O exch., NH2), 6.57 (d, 1H, pyrrole H_2), 7.31 (s, 1H, pyrrole NH), 7.37 (d, 2H, Ar-H), 8.03 (d, 2H, Ar-H),. ^{13}C NMR (250 MHz, CDCl3) δ_C (ppm): 30.4 (pyran C_4, CH), 59.70 (pyran C_3), 107.8 (pyran C_6), 108.2 (pyrrole C_3, CH), 120.5 (pyrrole, C_1, CH), 124.3 (CN), 136.8 (pyran C_5), 121.5, 129.1, 141.6, 145.3 (Ar-C), 177.4 (pyran C_2).

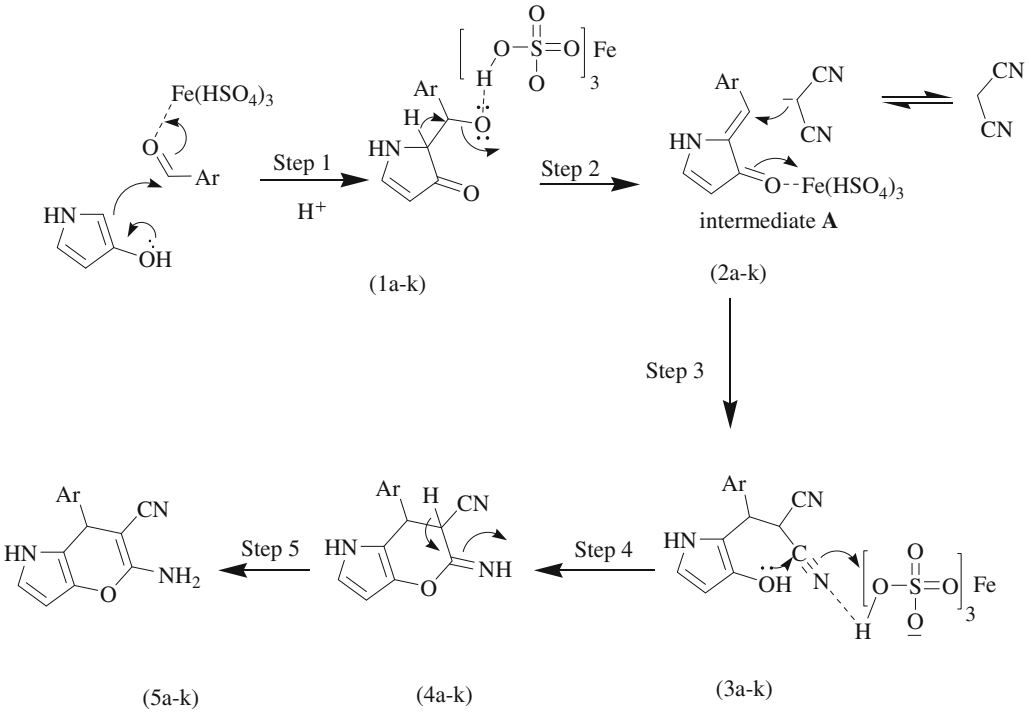
2.2k *5-Amino-1,7-dihydro-7-(2-nitrophenyl)pyrano[3, 2-b]pyrrole-6-carbonitrile* ***(5k)***: Anal Calcd. for $C_{14}H_{10}N_4O_3$ (282.2): C, 59.57; H, 3.57; N, 19.85%. Found: C, 59.03; H, 3.48; N, 19.57%. IR (KBr, ν_{max}, cm^{-1}): 3410 and 3195 (asym. and sym. str. of -NH_2), 3365 (NH), 2167 (-CN str.), 1381 and 1547 (asym. and sym. str. of -NO_2), 1253 (asym. str. of cyclic ArC-O-C ether). ^1H NMR (400 MHz, CDCl3) δ_H (ppm): 5.51 (s, 1H, pyran H_4), 6.28 (d, 1H, pyrrole H_3), 6.48 (d, 1H, pyrrole H_2), 6.86 (s, 2H, D_2O exch., NH2), 7.33–7.39 (m, 2H, Ar-H), 7.44 (s, 1H, pyrrole NH),

Table 1. Effect of solvents on the synthesis of pyrano[3,2-*b*]pyrrole derivatives.[a]

Entry	Solvent	Time (h)	Yield (%)[b]
1	Benzene	8	40
2	CH_3CN	6	86
3	MeOH	7	30
4	EtOH	7	38
5	Toluene	5	63

[a]Reaction conditions: 1.0 equiv. of 3-hydroxypyrrole, 1.0 equiv. of benzaldehyde, 1.1 equiv. of malonoitrile, 10 mol% of $Fe(HSO_4)_3$, 4 mL of CH_3CN and at reflux condition.
[b]Isolated yields

7.56 (dd, 1H, Ar-H), 8.01 (d, 1H, Ar-H). ^{13}C NMR (250 MHz, CDCl3) δ_C (ppm): 26.0 (pyran C_4, CH), 54.3 (pyran C_3), 110.9 (pyran C_6), 112.2 (pyrrole C_3, CH), 121.2 (pyrrole, C_1, CH), 121.9 (CN), 137.7 (pyran C_5), 122.0, 128.4, 133.5, 134.9, 136.0, 148.8 (Ar-C), 177.0 (pyran C_2).



Compnd	Ar
a	4-OMe-C6H4
b	C6H6
c	4-Me-C6H4
d	4-Br-C6H4
e	2-Br-C6H4
f	4-Cl-C6H4
g	2-Cl-C6H4
h	4-CN-C6H4
i	2-CN-C6H4
j	4-NO2-C6H4
k	2-NO2-C6H4
l	2-Furyl

Figure 2. Proposed mechanism for one-pot, three-component synthesis of pyrano[3,2-*b*]pyrrole derivatives catalysed by [pmim] $HSO_{4\,SiO2}$.

Table 2. One-pot, three-component synthesis of 5-amino-7-aryl-6-cyano-4*H*-pyrano[3,2-*b*]pyrroles.[a]

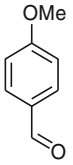
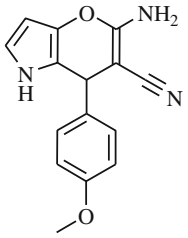
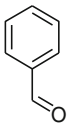
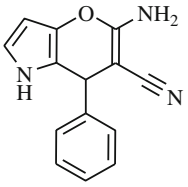
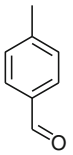
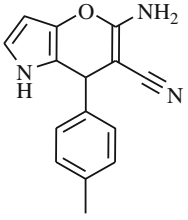
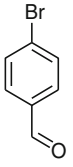
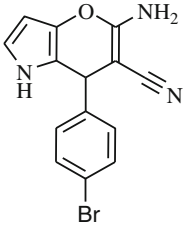
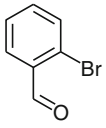
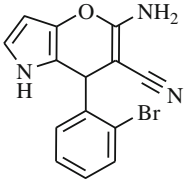
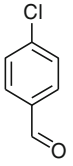
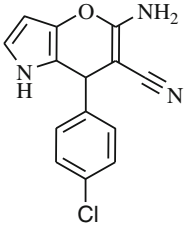
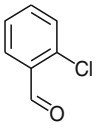
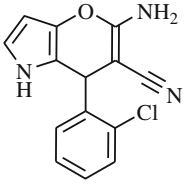
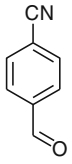
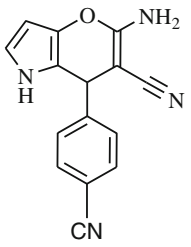
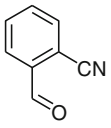
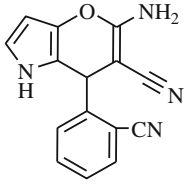
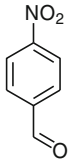
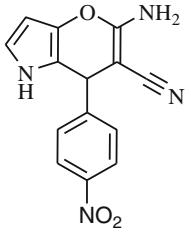
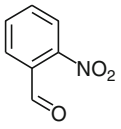
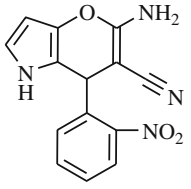
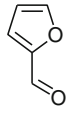
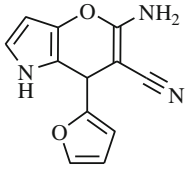
Entry	Aldehyde	Product[b]	Time (h)	Yield (%)[c]
1			7	73
2			6	86
3			6	82
4			5	84
5			6	80
6			5	87
7			5	80

Table 2. *(continued).*

Entry	Aldehyde	Product[b]	Time (h)	Yield (%)[c]
8			6	68
9			6.5	65
10			7	75
11			8	70
12			8	55

[a]Reaction conditions: 1.0 equiv. of 3-hydroxypyrrole, 1.0 equiv. of aldehyde, 1.0 equiv. of malonoitrile, 10 mol% of $Fe(HSO_4)_3$, 4 mL of CH_3CN as solvent and at 50°C.
[b]The products were identified by ^{1}HNMR, ^{13}C NMR and EA analysis.
[c]Isolated yields

2.2l *5-Amino-7-(furan-2-yl)-1,7-dihydropyrano[3,2-b]pyrrole-6-carbonitrile* ***(5l)***: Anal Calcd. for $C_{12}H_9N_3O_2$ (227.22 gr/mole): C, 63.43; H, 3.99; N, 18.49%. Found: C, 63.04; H, 3.86; N, 18.34%. IR (KBr, ν, cm^{-1}): 3418 and 3234 (asym. and sym. str. of -NH_2), 3419 (NH), 2166(-CN str.), 1252 (asym. str. of cyclic ArC-O-C ether). ^{1}H NMR (400 MHz, CDCl3) δ_H (ppm): 5.47 (s, 1H, pyran H_4), 5.87 (dd, 1H, furan H_3), 6.19 (m, 2H, pyrrole H_3 and furan H_4), 6.59 (d, 1H, pyrrole H_2), 6.78 (s, 2H, D_2O exch., NH2), 7.24 (d, 1H, furan H_2), 7.40 (s, 1H, pyrrole NH). ^{13}C NMR (250 MHz, CDCl3) δ_C (ppm): 29.4 (pyran C_4, CH), 56.4 (pyran C_3), 106.9 (pyran C_6), 107.0 (furan C_3), 110.3 (pyrrole C_3, CH), 110.8 (furan C_4, CH), 119.5 (pyrrole, C_1, CH), 116.4 (CN), 141.9 (furan C_2, CH), 143.2 (pyran C_5), 150.9 (furan C_1, CH), 167.4 (pyran C_2).

3. Results and discussions

A mixture of benzaldehyde, 3-hydroxypyrrole and malononitrile with stoichiometic ratio of 1.0:1.0:1.1 and 10% mol of ferric hydrogensulphate was chosen as the model reaction to check the feasibility of this synthesis. The reaction was carried out in CH_3CN at reflux condition. The corresponding pyrano[3,2-*b*]pyrrole was obtained in good yield. Encouraged by the results, to perceive the effect of solvent on the catalytic efficiency of $Fe(HSO_4)_3$, various solvents were examined for the model reaction (table 1). As a result of this investigation, protic solvents such as ethanol and methanol led to the worst results. Inversely, application of polar aprotic solvent such as acetonitrile significantly improved chemical yields and reaction times. Additionally, using toluene and benzene as apolar media for the model reaction, chemical yields and reaction times became almost better compared with those achieved by protic solvents.

On the basis of recent reports which have proposed *ortho*-quinone methides (OQMs) as *in situ* intermediate in one-pot, three-component synthesis of naphtopyran derivatives,[24] we envisioned a mechanism with similar intermediate (intermediate **A**) for one-pot, three-component synthesis of pyranopyrrole derivatives which have been reported in this research (figure 2). After Michael-type addition of malononitrile to intermediate **A**, the reaction is followed by attack of hydroxyl group on one of two nitrile groups to afford final product.

The model reaction was extended using different derivatives of benzaldehyde. It was revealed that the electronic nature of substituted groups on the aromatic aldehyde could affect the reactions in terms of reaction times and chemical yields. The yield of the reactions was increased with the change of substituent groups on the benzaldehyde from methoxy to Br and then Cl, however, the presence of more electron-withdrawing groups, such as NO_2 and CN adversely affected the results (table 2). The catalyst used is easy to prepare, inexpensive, non-toxic, highly reusable and simultaneously has Lewis and Bronsted acidic characters that make it to act as a bi-functional heterogeneous catalyst. It can be coordinated with carbonyl oxygen increasing the reactivity of the carbonyl compound. Moreover, the catalyst is capable of binding with the nitrogen atom to facilitate heterocyclization to afford the corresponding pyrano[3,2-*b*]pyrrole product.

4. Conclusion

A novel and effective approach for the synthesis of substituted pyrano[3,2-*b*]indole-3-carbonitrile derivatives by one-pot, three-component reactions of 3-hydroxyindole, aromatic aldehydes and malononitrile in the presence of ferric hydrogensulphate was reported.

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