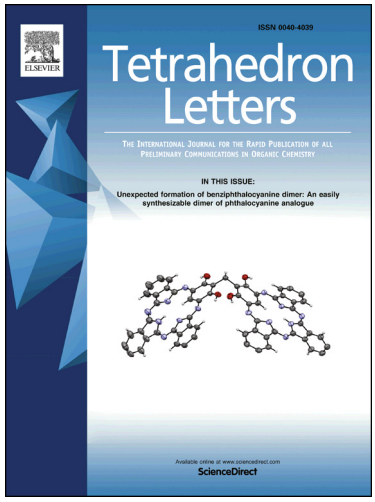


Synthesis of functionalized chromene and spirochromenes using L-Proline-melamine as highly efficient and recyclable homogeneous catalyst at room temperature

Sakkani Nagaraju, Banoth Paplal, Kota Sathish, Santanab Giri, Dhurke Kashinath

PII: S0040-4039(17)31196-6
DOI: https://doi.org/10.1016/j.tetlet.2017.09.060
Reference: TETL 49330

To appear in: *Tetrahedron Letters*

Received Date: 19 August 2017
Revised Date: 19 September 2017
Accepted Date: 20 September 2017

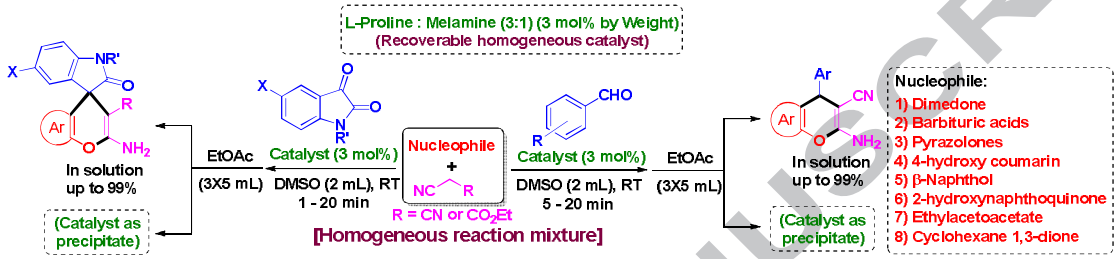
Please cite this article as: Nagaraju, S., Paplal, B., Sathish, K., Giri, S., Kashinath, D., Synthesis of functionalized chromene and spirochromenes using L-Proline-melamine as highly efficient and recyclable homogeneous catalyst at room temperature, *Tetrahedron Letters* (2017), doi: https://doi.org/10.1016/j.tetlet.2017.09.060

Graphical Abstract

Synthesis of functionalized chromene and spirochromenes using L-Proline-melamine as highly efficient and recyclable homogeneous catalyst at room temperature

Leave this area blank for abstract info.

Sakkani Nagaraju,[a] Banoth Paplal,[a] Kota Sathish,[a] Santanab Giri,[b] and Dhurke Kashinath[a*]



Tetrahedron Letters
journal homepage: www.elsevier.com

Synthesis of functionalized chromene and spirochromenes using L-Proline-melamine as highly efficient and recyclable homogeneous catalyst at room temperature

Sakkani Nagaraju,[a] Banoth Paplal,[a] Kota Sathish,[a] Santanab Giri,[b] and Dhurke Kashinath[a*]

[a]*Department of Chemistry, National Institute of Technology, Warangal-506 004, India*
[b]*Department of Chemistry, National Institute of Technology, Rourkela-769 008, India*

ARTICLE INFO

Article history:
Received
Received in revised form
Accepted
Available online

Keywords:
L-proline
Melamine
Recyclable catalyst
Homogeneous catalysis
Spirooxindole
4H-chromene

ABSTRACT

An efficient and recyclable homogeneous catalyst is developed using commercially cheap L-proline and melamine for the synthesis of chromenes and spirochromenes (spirooxindoles) *via* multicomponent reactions at room temperature. Systematic studies were conducted in order to achieve desired reactivity and recyclability of the catalyst using various α-amino acids and aromatic amines as donor-acceptor pairs. Among the screened combinations, L-proline and melamine (3:1 ratio; 3 mol% on total weight) was found to be best catalyst to give the desired products with excellent yields (up to 99%) in very short times (1 to 15 min) at room temperature in DMSO as solvent. The catalyst was recovered by adding EtOAc and reused up to 5 cycles without losing the catalytic activity.

Homogeneous catalysis enjoys the advantage of product selectivity and yields over heterogeneous catalysis depending on the number of active sites in the catalyst. However, the separation of the product, loss of the catalyst and regeneration of the catalyst from the reaction mixture (which require tedious processes, thus may not be suitable for sensitive products) is the main limitation of homogeneous catalysis.[1a-c] Because of this, designing the recyclable homogeneous catalysts with high activity, selectivity and easy separation from the products is always a challenge. In this regard, different approaches were adopted for the development of recyclable homogeneous catalysts. The use of homogeneous catalyst with covalently, non-covalently bonded or immobilized silica or insoluble polymer/resin is most common method for this purpose.[1a,2a] Along with these, the use of organometallic complex and metallodendrimes,[2b-c] transforming a homogeneous catalyst in to heterogeneous catalyst using nanoparticles,[2d] solvent/temperature dependent solubility of the catalyst during and after the reaction, (thermomorphic solvent systems),[1a,2e] precipitation of the catalyst after completion of the reaction,[2f] exposure to UV radiation,[2g] metals complexed with macromolecules (self supported),[2h] tagged catalyst with ionic liquids,[2i] are known in the literature.

L-proline mediated reactions often take more time for completion and give poor stereoselectivity. These limitations have been addressed by using additives,[3a] co-catalysts,[3b] incorporating covalently bonded functional groups,[3c] host-guest complexes, and by modular designed organocatalysts.[3d] As a result, last couple of decades have witnessed the use of L-Proline and its derivatives as organocatalysts for different types of reactions[4a,b] and synthesis complex products/biologically important compounds.[4c,d] Along with these, L-proline has been used for multicomponent reactions (MCRs) for the preparation of functionalized pyrans, dihydropyridiines, pyridones, pyrazolo[3,4-b]quinolines, 4H-pyrano[2,3-c]pyrazoles, naphtharidines, dicoumarols etc.[5]

2-Amino-4H-chromene-3-carbonitriles (chromenes)[6] and 2'-amino-2-oxospiro[indoline-3,4'-pyran]-3'-carbonitrile (spiro chromenes/spirooxindoles)[7] are known to show many biological properties including anticancer, antioxidant and antimicrobial, inhibitors of excitatory amino acid transporters etc. Currently, these compounds are prepared by MCR approach using different catalysts like urea,[8a] potassium phthalimide,[8q] organic bases (TEA, DBU, DABCO, DMAP),[8b-e] inorganic salts ($CaCl_2$,[8h] NH_4Cl,[8j] tungstic acid,[8l] cellulose–$HClO_4$,[8i] $NbCl_5$), alternative reaction media (chitosan/ionic liquid,[8k] $BnN(Et)_3Cl$ surfactant,[8n] sulfated choline based heteropolyanion salt,[8o] micellar media[8p]), nanomaterials (nano-organocatalyst,[8f,g] γ-Fe_2O_3 nano particles[8m]) amino acids (cysteine,[8r]) and catalyst free[8s,t] conditions. Along with these methods, L-proline and supported proline derivatives[9] also been used for the synthesis of purpose (**Figure-1**). However, many of these methods (including L-proline) involve the use of temperature, require more time for completion of reaction and

∗ Corresponding author. Tel. +91-870- 246-2677; FAX No. +91-870-245-9547;
e-mail: kashinath@nitw.ac.in; kashinath.dhurke@gmail.com;

limit to three or four types of nucleophiles in both simple chemomene and spirooxindole case.

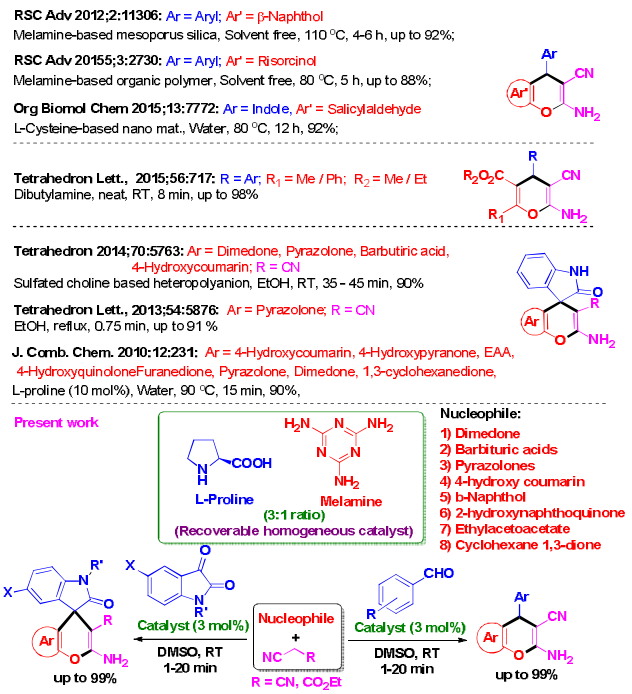


Figure-1. Closely related literature methods for the synthesis of chromenes and spirochromenes and present study

Though the use of small molecules as additives or co-catalysts is known concept,[3b] the use of commercially available small organic molecules (other than L-proline) as recyclable homogeneous catalysts is rare.[10] Thus, considering the biological importance chromenes, recyclable homogeneous catalysis and in continuation with our efforts in developing simple synthetic methods,[11] here in we report L-proline-melamine combination as highly efficient recyclable homogeneous catalyst for the synthesis of chromenes and spirochromenes *via* MCR approach. Towards this, we envisaged the use of commercially available small organic molecules with hydrogen bonding donor-donor and donor-acceptor sites as additives in combination with α-amino acid derivatives.[3,12] In order to achieve the desired reactivity, active catalyst systems, initially the catalyst systems were prepared by mixing L-proline (**1a**) with different aromatic and heteroaromatic amines (**2a**-**2e**) in MeOH (RT, overnight). Evaporation of the solvent gave active catalysts as white powder (see ESI for detailed procedure) which were used (3 mol%) for multicomponent reaction of isatin (**3a**) with dimedone (**4a**) and malononitrile (**5a**) to desired spirochromene (**6a**) in 50-70% yield (**Scheme 1**;**Table-1**; entries 1-10). It is interesting to note that all the catalyst systems are giving the desired product with moderate yields compare to the reaction of L-proline (30 mmol) (**Table-1;** entry 1). Also, entry 4 indicate that the structural features (1,3-relationship of the nitrogen; charged species of pyridinium ion) of the aromatic amines are important for faster kinetics of the reaction. Considering this, further investigation was continued using different heteroaromatic amines (**2f**-**2h**) and guanidine (**2i**). Among these, the combination of L-proline (**1a**) and 2-aminopyrazine (**2f**)/guanidine (**2i**) are slightly better in terms of reactivity which may be due to distant donor-acceptor atoms and their ratio/increased pKa values of catalyst system because of the presence of extra nitrogen.

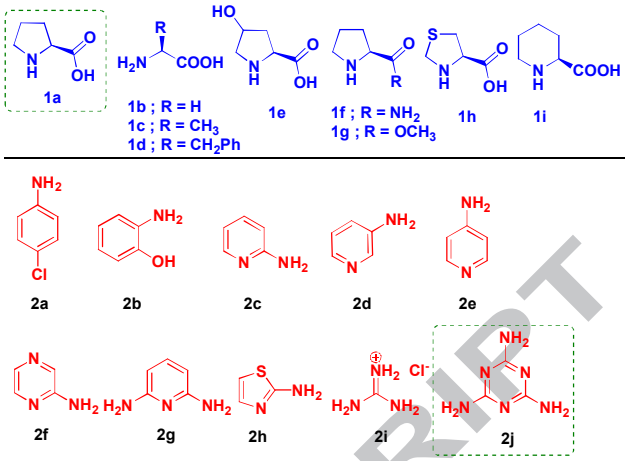
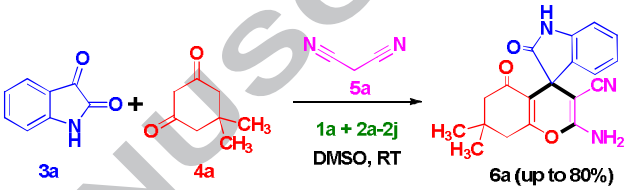


Figure 2. Different α-amino acids and aromatic amines used in the present study for the development of recyclable homogeneous catalyst



Scheme 1. Catalyst screening for the multicomponent reaction of isatin (**3a**), dimedone (**4a**) and malononitrile (**5a**)

Melamine **2j** (1,3,5-Triazine-2,4,6-triamine) with pKa 5 and 66% nitrogen content is a unique molecule that has hydrogen donor-acceptor-donor sites (donor to donor distance of 4.8 A° units) to form self-assembly supramolecular networks *via* inter-molecular non-covalent interactions [hydrogen bonding, aromatic (π-π)] etc.[12,13] Melamine unit has been extensively used for the preparation of functional materials, nano-structures, liquid crystals and biologically active products.[14] However, limited reports are available for its applications in organic synthesis for MCRs and other reactions.[15]

Keeping in view of the above results and considering the structural features of melamine **2j** (with respect to 2-aminopyridine, 2-aminopiperazine and guanidine) and with the intension of improving the reaction conditions further, melamine **2j** was selected for present study. Thus, the catalyst system was prepared using similar procedure with melamine:L-proline (1:1, 1:2 and 1:3 ratios) as white powder. The resulting catalysts were used (3 mol% by weight) for the multicomponent reaction as shown in **Scheme-1**. Surprisingly this combination of L-proline and melamine combination [**1a** + **2j**] gave better yields (85%, 90% and 99% respectively) (**Table-1**; entries 11, 12 and 13) compare to all the screened combinations described above.

After successfully obtaining the expected reactivity, efforts were made to characterize catalyst system (for IR, mass spectra, see ESI) and study its stability using computational methods. All the studied molecules were optimized using B3LYP[16a,b] functional with 6-311+G(d,p) in the form of basis set. Vibrational frequency were also analyzed at the same level of theory and basis set to ensure ground state geometries. Positive vibrational frequencies for all of our catalyst systems indicate that all of them are on the local minimum of their respective potential energy surfaces. The optimized geometries along with their Cartesian coordinates are given in supporting information (see ESI). To find the stability of 1:1, 1:2 and 1:3 (melamine:L-Proline catalyst systems) we have calculated the formation

energies (ΔE_f) by using the expression $\Delta E_f = E_{M\text{-}P} - (E_M + E_P)$. For all the cases, we have found that the formation energy is negative. For 1:1 complex the formation energy is found to be -14.85 kcal/mol. For 1:2 and 1:3 complexes, two types of formation energy can be possible. The stepwise and direct. If we look at the direct complex formation for 1:2 (-29.49 kcal/mol) and 1:3 (-44.55 kcal/mol), we have found that the formation energy gradually increases from 1:1 complex. This suggest that 1:3 complex formation is preferable among the other two. The stability can also be analyzed in view of the number of H-bonds present in the complex. Optimized geometries of the catalyst complexes reveals that there exist H- bond between melamine and Proline as shown in **Figures 3** and **4**. We have found that the H bond distances ranges from 1.6 to 1.9 Å depending on the centers involve for H-bond formation. More number of H-bonds makes 1:3 complex superior than other two complexes. All the computational work has been performed in G09W suits program.[16c]

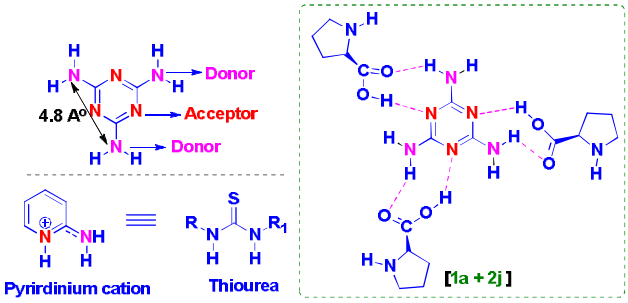
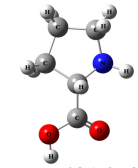
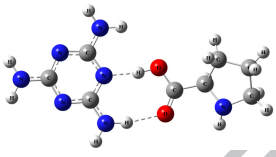


Figure-3. Possible interactions of L-proline (**1a**) with melamine (**2j**) to give stable catalyst

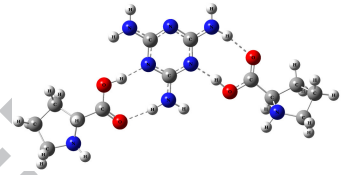


E= -401.27804454 a.u

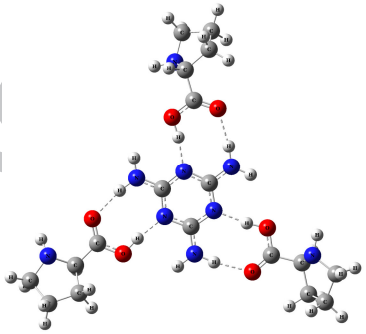
E= -446.63887465 a.u



E = -847.94060246 a.u



E = -1249.24227537 a.u



E = -1650.54373801 a.u

H-bond distances in Å: 1:N-H 1.66; O-H 1.93 2. N-H 1.67; O-H 1.91 3: N-H: 1.69; O-H: 1.90

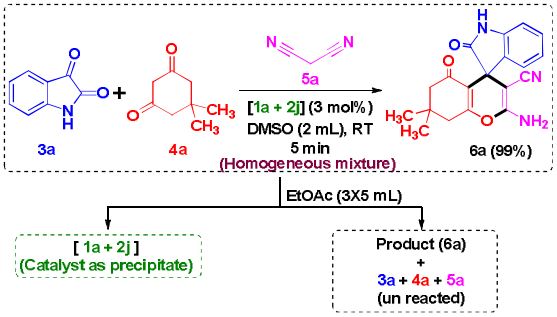
Figure-4. Optimized geometries of the catalyst complexes (which reveals that there exist H- bond between melamine and L-proline)

Table-1. Screening of the catalysts for the MCR of isatin (**3a**) dimedone (**4a**), and malononitrile (**5a**)

S. No.	Catalyst combination	Reaction time (h)	Isolated Yield (%)[a]
1	1a (30 mol%) + no additive	24	25
2	1a + 2a (1:1)	5	60
3	1a + 2b (1:1)	4	65
4	1a + 2c (1:1)	4	70
5	1a + 2d (1:1)	5	60
6	1a + 2e (1:1)	6	50
7	1a + 2f (1:1)	3	80
8	1a + 2g (1:1)	8	60
9	1a + 2h (1:1)	5	75
10	1a + 2i (1:1)	3	80
11	**1a + 2j (1:1)**	**40 min**	**85**
12	**1a + 2j (2:1)**	**25 min**	**90**
13	**1a + 2j (3:1) (3 mol%)**	**5 min**	**99**
14	Only 2j	24	ND
15	2b + 2j	6	70
16	2c + 2j	24	30
17	2d + 2j	24	35
18	2e + 2j	24	20
19	2f + 2j	24	Trace
20	2g + 2j	24	ND
21	2h + 2j	24	ND
22	2i + 2j	24	ND
23	1a + 2j (in water)		Trace

Reaction conditions.[a]All the reactions were performed at 1 mmol scale using 3 mol% of the catalyst in DMSO solvent at RT and given as isolated yields.

Meanwhile, simultaneous attempts were made to simplify the reaction protocol and recovery of the catalyst as precipitate. Thus, different combinations of solvents were added to the reaction mixture in order to get the products and catalyst separately. Among all, addition of EtOAc was found to be best solvent system to give the product in solution and catalyst as precipitate as shown in **Scheme-2**. Further, to find the reactivity of the regenerated catalyst, the precipitate (catalyst system) obtained from above reaction was washed with EtOAc (in order to remove impurity traces), air dried to get the catalyst as fine powder. This regenerated catalyst system (**1a + 2j**) was used (3 mol%) for above reaction up to 5 cycles to give the desired products in good yields (**Table-2**).



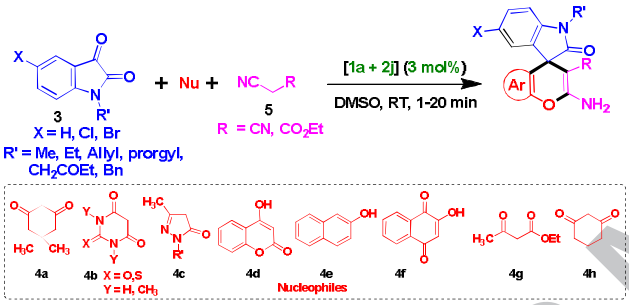
Scheme 2. Schematic representation for the catalyst recovery after the multicomponent reaction

Table-2. Recyclability studies of the catalyst system

S. No.	Cycle No.	Reaction time (min)	Isolated yield (%)[a]
1	Cycle-1	5 min	99
2	Cycle-2	5 min	99
3	Cycle-3	5 min	99
4	Cycle-4	8 min	98
5	Cycle-5	10	98

[a]Reactions were performed at 1 mmol of isatin as control in DMSO solvent using 3 mol% of the catalyst [**1a + 2j**]

Having successfully demonstrating the regeneration and recyclability of the catalyst after the above reaction, nucleophiles (**4b**-**4h**) with variable ring systems were reacted with isatins **3a** (Scheme 3) using DMSO as reaction medium. It is noteworthy to mention all the nucleophiles are equally reactive giving the desired products (**6a**-**6h**) within short period of time (1-15 min) with excellent yields (up to 99%) and catalyst recovery as described above in every case (Model study; see ESI).[18] Later, many functionalized (aromatic ring and N-substituted) isatins were treated with malononitrile/ethylcyanoacetate and nucleophiles to give library of chromene-spirooxindole derivatives as shown in **Scheme-3**; **Figure-5**. In the similar lines, different nucleophiles were reacted with *p*-nitrobenzaldehyde and malononitrile as model study to give desired products in short reactions times with excellent yields (Model study; See ESI). In this case, the reactions of 4-hydroxy coumarin and 2-hydroxy naphthoquinone and EAA required more time (20 min) for the completion with the aromatic aldehydes with electron withdrawing groups as substituents. Subsequently, same protocol was extended for the generation of library of compounds under optimized conditions (**Scheme-4**), (**Figure-6**). Here also the catalyst was recovered in all cases by adding EtOAc to the reaction mixture as described above.



Scheme-3. MCRs of isatin and malononitrile with different nucleophiles in presence of [**1a** + **2j**] (3 mol%) in DMSO at RT).

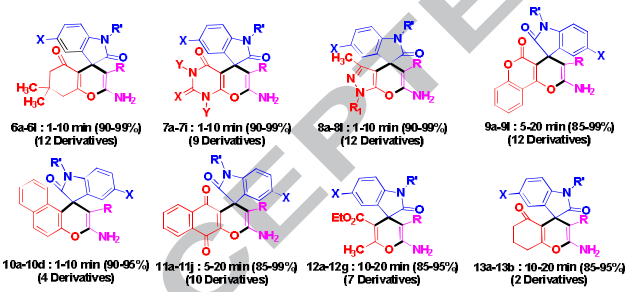
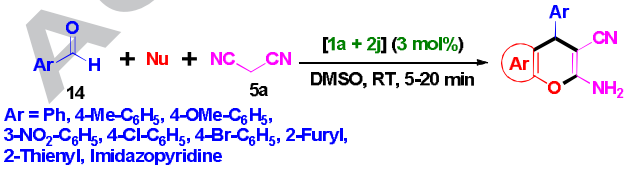


Figure-5. Various spirooxindole derivatives prepared under optimized conditions (the physical and spectral data (^{1}H- , ^{13}C-NMR and Mass) is given in ESI



Scheme-4. MCRs of aromatic aldehydes and malononitrile with different nucleophiles in presence of [**1a** + **2j**] (3 mol%) in DMSO at RT).

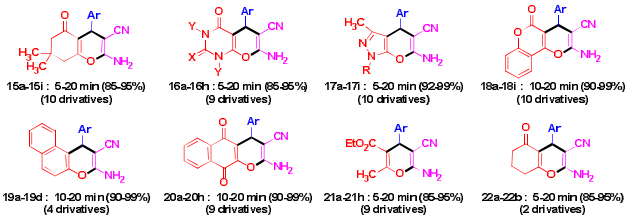
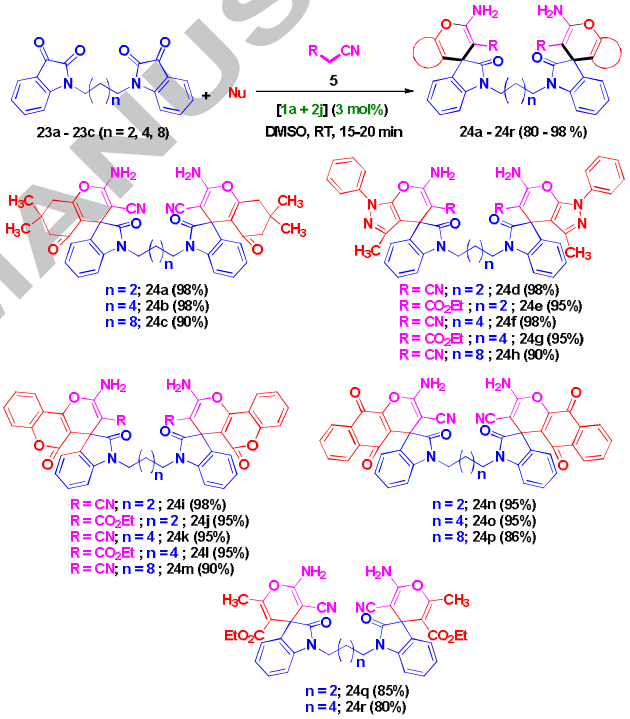


Figure-6. Various chromene derivatives prepared under optimized conditions (the physical and spectral data (^{1}H- , ^{13}C-NMR and Mass) is given in ESI

In continuation with above, with the intension of generating more structural variation and testing the ability of the catalyst for more complex systems, the *bis*-isatins were prepared from simple alkylation of isatin and corresponding dibromides. Then the resulting *bis*-isatins (**23a**-**23c**) were treated with different nucleophiles and malononitrile / ethylcyanoacetate (under optimized conditions) to give the expected *bis*-spirooxindole-chromenes (**24a**-**24r**) in good yields (80-98%) (**Scheme-5**)



Scheme-5. Preparation of *bis*-spirooxindole derivatives (**24a**-**24r**) using the optimized reaction conditions.

Conclusion

In conclusion, we have developed a simple method for recyclable homogeneous catalysis using commercially cheap L-proline (**1a**) and melamine (**2j**) as donor-acceptor pair. This is the first example for recyclable homogeneous catalyst without any support for the materials used as catalyst. Also this is first examples for fast multicomponent reactions without heating under simple experimental procedures (with broad substrate scope, excellent yields). Further this catalyst system is working well for other reactions which will be reported in due course of time.

Acknowledgments

SN thanks, UGC-New Delhi for the fellowship. SG thanks DST (IFA 14-CH-151) and NIT Rourkela for financial support and computational facilities. DK thanks, DST (SERB), New Delhi for the financial support (SB/FT/CS-136/2012 and SB/EMEQ-103/2014).

References and notes

1. (a) *Recoverable and Recyclable Catalysts*, Benaglia M, Ed 2009 John Wiley & Sons, Ltd, (b) Cole-Hamilton DJ. *Homogeneous Catalysis-New Approaches to Catalyst Separation, Recovery, and Recycling*. Science. 2003;299:1702. (c) Astruc D, Lu F, Aranzaes JR. *Angew Chem Int Ed.* 2005;44:7852; (d) Gladysz JA. *Chem Rev*. 2002;102:3215; (e) Trindade AF, Gois PMP, Afonso CAM. *Chem Rev*. 2009;109:418.
2. (a) Corma A, Garcia H. *Adv Synth Catal.* 2006;348:1391; (b) Cornils B, Herrmann WA, Beller M, Paciello R, Eds. *Applied Homogeneous Catalysis with Organometallic Compounds: A*, VCH, Germany, 2017; (c) Van Klink GPM, Dijkstra HP, Van Koten G*CR. Chimie.* 2003;6:1079; (d) Gladysz JA. Curran DP. *Fluorous Chemistry: From biphasic catalysis to a parallel chemical universe and beyond. Tetrahedron.* 2002;58:3823; (e) Färber T, Riechert O, Zeiner T, Sadowski G, Behr A, Vorholt AJ. *Chemical Engg Research and Design.* 2016:12:263; (f) Dioumaev VK, Bullock RM. *NATURE.* 2000;424:530; (g) Zhang G, Lang R, Wang W, Lv H, Zhao L, Xia C, Lia F. *Adv Synth Catal.* 2015;5:917; (h) Bissessar D; Achard T; Bellemin-Laponnaza S. *Adv Synth Catal.* 2016;358:1982; (i) Sebesta R, Kmentova´b I, Toma S. *Green Chem.* 2008;10:484.
3. (a) Yu L, Luan J, Xu L, Ding Y, Xu Q. *Tetrahedron Lett.* 2015;56: 6116; (b) Xu L, Wang F, Huang J, Yang C, Yu L, Fan Y. *Tetrahedron.* 2016;72:4076; (c) Chen H, Wang Y, Weia S; Sun J. *Tetrahedron: Asymmetry*. 2007;18:1308; (d) Cobb AJA, Shaw DM, Longbottom DA, Gold JB, Ley SV. *Org Biomol Chem.* 2005;3:84; (e) Reis O, Eymur S, Reis B, Demir AS. *Chem Commun*. 2009;0:1088; (f) Martinez-Castaneda A, Kedziora K, Lavandera I, Rodriguez-Solla H, Concellon C, Amo VD. *Chem Commun.* 2014;50:2598; (g) Perera S, Sinha D, Rana NK, Trieu-Do V, Zhao JCG. *J Org Chem.* 2013;78:10947; (h) Rana NK, Huang H, Zhao J CG. *Angew Chemie*. 2014;53:7619.
4. (a) Herna´ ndez JG, Juaristi E. *Chem Commun.* 2012;48:5396; (b) Gruttadauria M, Giacalone F, Noto R. *Chem Soc Rev.* 2008; 37:1666; (c) Raja M, Singh VK. *Chem Commun*. 2009;0:6687 (d) Marqués-López E, Herrera RP, In *Comprehensive Enantioselective Organocatalysis: Catalysts, Reactions, and Applications,* Ed. Dalko PI, Wiley-VCH Verlag GmbH & Co. KGaA, 2013; (e) Sun BF. *Tetrahedron Lett.* 2015;56:2133.
5. (a) Sarita K, Yogesh KT, Mahendra K. *Current Organocatalysis.* 2016;3:176; (b) Mecadon H, Rohman MdR, Kharbangar I, Laloo BM, Kharkongor I, Rajbangshi M, Myrboh B. *Tetrahedron Lett.* 2011;52:3228; (c) Li M, Zhanga B, Gu Y. *Green Chem.* 2012;14:2421.
6. (a) Doshi JM, Tian D, Xing C. *J Med Chem.* 2006;49:7731; (b) Aridoss G, Zhou B, Hermanson DL, Bleeker NP, Xing C. *J Med Chem*. 2012;55:5566
7. (a) Pavloyska TL, Redkin RG, Lipson VV, Atamanuk DV. *Mol Diversity.* 2016;20:299; (b) Hostetler G, Dunn D, McKenna B. A, Kopec K, Chatterjee S. *Chem Biol Drug Des.*2014;83:149; (c) Vintonyak VV, Warburg K, Kruse H, Grimme S, Hübel K, Rauh D,Waldmann H. *Angew Chem Int Ed.* 2010;49:5902
8. (a) Brahmachari G, Banerjee B. *ACS Sustainable Chem Eng.* 2014;2:411; (b) Dekamin MG, Eslami M. *Green Chem.* 2014;16:4914; (c) Khurana JM, Nand B, Saluja P. *Tetrahedron.* 2010;6:5637; (d) Davarpanah J, Kiasat AR. *RSC Adv.* 2014;4:4403; (e) Feng J, Ablajan K, Sali A. *Tetrahedron.* 2014;70:484; (f) Litvinov YM, Mortikov VY, Shestopalov AM. *J Comb Chem.* 2008;10:741; (g) Safaei HR, Shekouhy M, Shirinfeshan A, Rahmanpur S. *Mole Diversity.* 2012;16:669; (h) Dabiri M, Bahramnejad M, Baghbanzadeh M. *Tetrahedron.* 2009;65:9443; (i) Khalafi-Nezhad A, Divar M, Panahi F. *RSC Adv*. 2015;5:2223; (j) Khan T, Siddiqui ZN. *New J Chem.* 2014;38:4847; (k) Rai P, Srivastava M, Singh J, Singh J. *New J Chem.* 2014;38:3181; (l) Zhu SL, Jia SJ, Zhang Y. *Tetrahedron.* 2007;63:9365; (m) Satasia SP, Kalaria PN, Avalani JR, Raval DK. *Tetrahedron.* 2014;70:5763 (n) Wang LM, Jiao N, Qiu J, Yu JJ, Liu JQ, Guo FL, Liu Y. *Tetrahedron*. 2010;66:339; (o) Rostamnia S, Nuri A, Xin H, Pourjavadi A, Hosseini SH. *Tetrahedron Lett.* 2013;54:3344; (p) Baghernejad M, Khodabakhshi S, Tajik S. *New J Chem.* 2016;40:2704; (q) Gupta A, Jamatia R, Pal AK. *New J Chem.* 2015;39:5636; (r) Khalafi-Nezhad A, Nourisefat M, Panahi F. *Org Biomol Chem.* 2015;13:7772; (s) Zhang M, Fu QY, Gao G, He HY, Zhang Y, Wu YS, Zhang ZH. *ACS Sustainable Chem Eng*. 2017;5:6175 (t) Satasia SP, Kalaria PN, Avalani JR, Raval DK. *Tetrahedron*. 2014;70:5763.
9. (a) Li Y, Chen H, Shi C, Shi D, Ji S. *J Comb Chem.* 2010;2:231; (b) Karamthulla S, Pal S, Parvinb T, Choudhury LH. *RS Adv*. 2014;4:15319.
10. Zolfigol MA, Tavasoli M, Moosavi-Zare AR, Moosavi P, Kruger HG, Shirid M, Khakyzadeha V. *RSC Adv*. 2013;3:25681.
11. (a) Nagaraju S, Sathish K, Paplal B, Kashinath D. *Tetrahedron Lett.* 2017;58:2865; (b) Paplal B, Nagaraju S, Sridhar B, Kashinath D. *Catal Commun*. 2017;99:115; (c) Paplal B. Nagaraju S, Palakollu V, Kanvah S, Kumar B.V, Kashinath D. *RSC Adv*. 2015;5:57842; (d) Paplal B, Nagaraju S, Palakollu V, Sujatha K, Kanvah S, Kumar B.V, Kashinath D. *RSC Adv*. 2014;4: 54168; (e) Nagaraju S, Satyanarayana N, Paplal B, Vasu AK, Kanvah S, Kashinath D. *RSC Adv*. 2015;5:81768; (f) Nagaraju S. Satyanarayana N, Paplal B, Vasu AK, Kanvah S, Sridhar B, Prabhakar S, Kashinath D. *RSC Adv*. 2015;5:94474; (g) Nagaraju S, Perumal P. O, Divakar K, Paplal B, Kashinath D. New J Chem. 2017;41:8993 (a) Arduini M, Crego-Calama M, Timmerman P, Reinhoudt DN. *J Org Chem.* 2003;68:1097; (b) Leung FKC, Cui JF, Hui TW, Zhou ZY, Wong MK. *RSC Adv.* 2014;4:26748.
12. (a) Russell KC, Lehn JM, Kyritsakas N, DeCian A, Fischer J. *New J Chem.*1998;22:123; (b) Ikonen S, Nonappa, Kolehmainen E. *Cryst Eng Comm.* 2010;12:4304; (c) Saha A, Roy B, Garai A, Nandi AK. *Langmuir*. 2009;25:8457; (d) Seetha Lekshmi S, Guru Row TN. *Cryst Eng Comm.* 2011;13:4886.
13. (a) Roy B, Bairia P, Nandi AK. *RSC Adv*. 2014;4:1708; (b) Bretterbauer K, Schwarzinger C. *Curr Org Synth.* 2012;9:342; (c) Bucos M, Sierra T, Golemme A, Termine R, Barber J, Giménez R, Serrano JL, Romero P, Marcos M. Chem Eur J. 2014;20:10027.
14. (a) Kundu SK, Bhaumik A. *RSC Adv*. 2015;5:32730; (b) Mondal J, Modak A, Nandi M, Uyama H, Bhaumik A. *RSC Adv*. 2012;2: 11306; (c) Tan MX, Gu L, Li N, Ying JY, Zhang Y. *Green Chem.* 2013;15;1127; (d) Ghorbani-Choghamarani A, Rashidimoghadam S. *Chin J Cat.* 2014;35:1024; (e) Mansoor SS, Aswin K, Logaiya K, Sudhan SPN. *J King Saud Uni. Science*. 2013;25:191.
15. (a) Lee C, Yang W, Parr GR. *Phys Rev B*. 1988;37:785; (b) Becke AD. *Phys Rev A*. 1988;38:3098; (c) Frisch MJ. Trucks GW, Schlegel HB, Scuseria GE, Robb MA, et.al. Gaussian 09, *Revision* A.02 Gaussian, Inc., Wallingford CT, 2016.
16. *General procedure for the multicomponent reaction using L-proline-melamine catalyst system:* To a solution of L-proline-melamine complex (3 mol%) in DMSO (2 mL) was added Dimedone 0.025 mg (0.178 mmol), malononitrile (1 equiv) and benzaldehyde / isatin (1 equiv) and stirred at room temperature for 1-20 min. After completion of the reaction (monitored by TLC), ethyl acetate was added stirring and continued for another 5 min. The precipitate formed was filtered. Evaporation of solvent gave the crude product which was recrystallized using ethanol to give the pure compound.

Supplementary Material

Electronic supplementary information (^{1}H- ^{13}C-NMR and Mass spectral data and spectra) can be found for this article.

Synthesis of functionalized chromene and spirochromenes using L-Proline-melamine as highly efficient and recyclable homogeneous catalyst at room temperature

Sakkani Nagaraju,[a] Banoth Paplal,[a] Kota Sathish,[a] Santanab Giri,[b] and Dhurke Kashinath[a*]

[a]*Department of Chemistry, National Institute of Technology, Warangal-506 004, India*
[b]*Department of Chemistry, National Institute of Technology, Rourkela-769 008, India*

Highlights:

1. Highly efficient and recyclable homogeneous catalyst
2. α-amino acids and aromatic amines as donor-acceptor pairs
3. Catalyst recovery and reuse up to 6 cycles
4. Efficient for 8 types of nucleophiles