ISSN 1070-3632, Russian Journal of General Chemistry, 2016, Vol. 86, No. 12, pp. 2732–2736. © Pleiades Publishing, Ltd., 2016.

A New Strategy for Synthesis of 9-Benzoyl-4-methylpyrano[2,3-*f*]chromene-2,8-dione Using L-Proline as a Novel and Efficient Catalyst[1]

E. Y. Goud[a], Y. J. Rao[a,b]*, Y. Hemasri[c], and G. Thirupathi[a]

[a] *Department of Chemistry, Osmania University, Hyderabad, Telangana, 500007 India*
**e-mail: erukalayadaiahgoud@gmail.com*

[b] *Department of Chemistry, Telangana University, Nizamabad, 503322 India*

[c] *Department of Chemistry, Nizam College, Osmania University, 500001 India*

Received November 10, 2015

Abstract—We report the high yield synthesis of novel 9-benzoyl-4-methylpyrano[2,3-*f*]chromene-2,8-dione derivatives obtained by the reaction of 8-formyl-7-hydroxy-4-methylcoumarin with various active methylene compounds. A mechanism of the tandem Knoevenagel condensation and cyclisation reaction is proposed. Structures of all compounds were elucidated on the basis of ^{1}H and ^{13}C NMR, and mass spectrometry, and elemental analysis.

Keywords: substituted 3-oxo-3-phenylpropanenitrile, L-proline, coumarin derivatives

DOI: 10.1134/S1070363216120331

INTRODUCTION

Various synthetic coumarin derivatives constitute a widely used group of anti-HIV [1], anti-inflammatory [2–4], and antioxidant [5, 6] agents. They have been studied as potential anticancer [7–10] and antiviral [11] agents. A broad number of coumarin derivatives have been synthesized mostly on the basis of Perkin or Knoevenagel reactions [12–18]. Further development of synthesis of novel coumarin based scaffolds is of high demand.

RESULTS AND DISCUSSION

Herein we report synthesis of some novel coumarin derivatives **8a–8j** (Schemes 1–3). Resorcinol **1** reacted with ethylacetoacetate in presence of sulfuric acid and gave 7-hydroxy-4-methyl coumarin (**2**). Refluxing of **2** and hexamethylenetetramine in glacial acetic acid for 6 h afforded 8-formyl-4-methyl-7-hydroxy coumarin **3**. Refluxing of substituted benzoates **5** with acetonitrile in the presence of NaOH provided 3-oxo-3-phenyl-propanenitrile derivatives **6**. Condensation of **3** and **6** in ethanol using catalytic amount of L-proline gave corresponding coumarin derivatives **8a–8j** in 2–3 h with 75–90% yield (see table).

A possible mechanistic pathway of the process can be presented as follows (Scheme 4). Initially L-proline in its zwitterionic form reacts with **6** to form a corresponding iminium intermediate followed by proton abstraction from benzoyl acetonitrile with formation of the corresponding carbanion. The latter attacks the iminium intermediate and the following elimination of proline produces the cyano intermediate. This intermediate undergoes rearrangement with formation of the imine intermediate, which upon acidic hydrolysis at 60°C gives a corresponding 9-benzoyl-4-methyl-pyrano[2,3-*f*]chromene-2,8-dione (**8a–8j**).

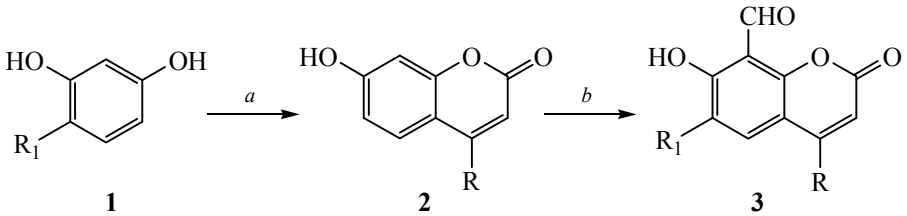
EXPERIMENTAL

All chemicals were purchased from Aldrich and Merk. Melting points were measured in open capillary tubes. IR spectra were recorded as KBr pellets on a Shimadzu FT-IR 8400s spectrophotometer. ^{1}H NMR (400 MHz) and ^{13}C NMR (100 MHz) spectra were measured on a Bruker Avance II 400 spectrometer in $CHCl_3$ using TMS as the internal standard. Mass spectra were measured on a Hewlett-Packard 1100 LC/MSD spectrometer.

4-Methyl-7-hydroxy coumarin (2) [19]. Concentrated sulfuric acid (20 mL) was added to a 100 mL round bottom flask and cooled down to 0–5°C in an

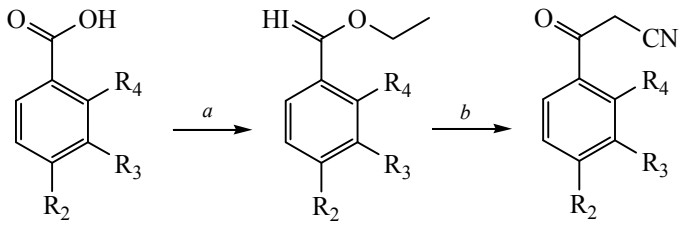
[1] The text was submitted by the authors in English.

Scheme 1. Synthesis of 4-methyl-7-hydroxy-8-formyl coumarin.



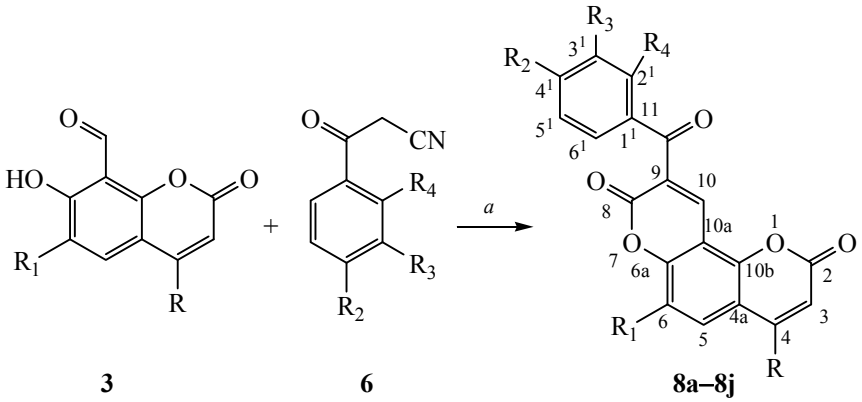
a: H_2SO_4, ethylacetoacetate, 15 min; *b*: hexamethylenetetramine, AcOH, 6 h, HCl, 30 min, 80–85°C.

Scheme 2. Synthesis of 3-oxo-3-phenylpropanenitrile derivatives.



a: H_2SO_4, EtOH, 15 min; *b*: CH_3CN, NaH, THF, room temperature, 40–80%.

Scheme 3. Synthesis of **8a–8j** by the Knoevengel condensation of **3** and **6a–6j.**

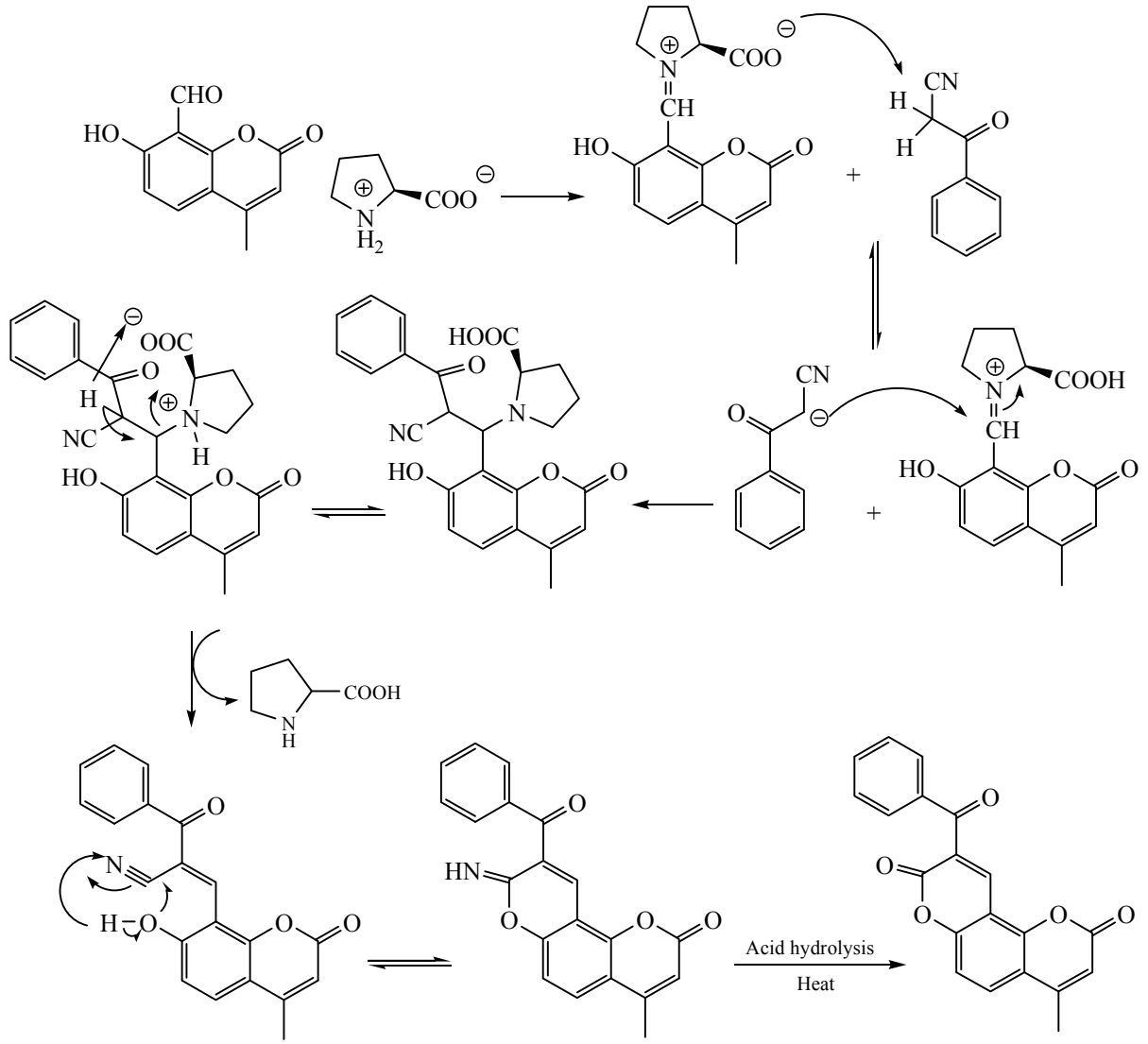


a: L-Proline, EtOH reflux, 2–3 h.

ice bath. A solution of resorcinol **1** (0.001 mol) in ethyl acetoacetate (0.0015 mol) was added to sulfuric acid under constant stirring at 0°C. The reaction mixture was stirred over night at room temperature and poured on to crushed ice with vigorous stirring. An off-white solid obtained was filtered off and recrystallized from ethanol. mp 180–182°C. IR spectrum, ν, cm^{-1}: 3423 (OH), 1733 (CO), 1555 (C=C). ^1H NMR spectrum, δ, ppm: 2.49 s (3H, C^4CH_3), 6.31 s (1H, C^3H), 6.92 d (1H, C^6H, J = 9.0 Hz), 6.94 s (1H, C^8H), 7.57 d (1H, C^5H, J = 9.0 Hz).

4-Methyl-7-hydroxy-8-formyl coumarin (3) [20]. To a solution of 7-hydroxy-4-methyl-coumarin **2** (0.001 mol) in glacial acetic acid (20 mL) hexamethylenetetramine (0.003 mol) was added. The mixture was heated at 80–85°C in a water bath for 6 h. A hot solution of 5 mL water and 30 mL hydrochloric acid was added to the reaction mixture, stored for 30 min and cooled down to room temperature. It was extracted with diethyl ether, the solvent evaporated to give a pale yellow solid. Yield 22%, mp 176–178°C. IR spectrum, ν, cm^{-1}: 3442 (OH), 1742 (CO), 1644

Scheme 4. A possible mechanism for formation of 9-benzoyl-4-methylpyrano[2, 3-*f*]chromene-2,8-dione (**8a–8j**).



(CHO), 1594 (C=C). ^{1}H NMR spectrum, δ, ppm: 2.44 s (3H, C^4CH_3), 6.22 s (1H, C^3H), 6.90–6.93 d (1H, C^6H, J = 9Hz), 7.73–7.76 d (1H, C^5H, J = 9 Hz), 10.63 s (1H, HCO), 12.28 s (1H, OH).

Synthesis of 8a–8j by the Knoevengel condensation of 3 with 6a–6j [21, 22]. 8-Formyl-4-methyl-7-hydroxy coumarin **3** (0.001 mol) was dissolved in 10 mL of ethanol solution of a derivative of 3-oxo-3-phenylpropanenitrile **6a–6j** (0.001 mol) and catalytic amount of L-proline. Upon refluxing for 2–3 h the mixture was cooled down to 0–5°C and filtered off (see table).

9-Benzoyl-4-methylpyrano[2,3-*f*]chromene-2,8-dione (8a). mp 174°C. IR spectrum, ν, cm^{-1}: 3442 (OH), 1765.0 and 1716.0 (C=O), 1742 (CO), 1644 (CHO), 1594 (C=C). ^{1}H NMR spectrum, δ, ppm: 2.51 d (3H, CH_3, J = 1.255 Hz), 6.35 d (1H, 3-H, J = 1.255 Hz), 7.35 d (1H, 6-H, J = 9.035, 0.502 Hz), 7.51 m (2H, 3^1,5^1-H,), 7.65 t.t.t (1H, 4^1-H), 7.860 d (1H, 5-H, J = 8.784 Hz), 7.89 d (1H, 6^1-H, J = 1.506 Hz), 7.89 d (1H, 1^1-H, J = 1.255 Hz,), 8.62 s (1H, 10-H). ^{13}C NMR spectrum, δ_C, ppm: 19, 108, 112.9, 114.4, 116.2, 127.1, 128.8, 129, 129.7, 134.2, 135.5, 138.4, 150.8, 152.2, 156.3, 157.2, 159, 190.8. DIPMS [M + H]: m/z 333.07603. Found, %: C 72.25, H 3.62. $C_{20}H_{12}O_5$. Calculated, %: C 72.29, H 3.64.

9-(*p*-Chlorobenzoyl)-4-methylpyrano[2,3-*f*]chromene-2,8-dione (8b). mp 232–233°C. IR spectrum, ν, cm^{-1}: 3442 (OH), 1755.0 and 1716.0 (C=O), 1742 (CO), 1644 (CHO), 1615 (C=C), 1594 (C=C). ^{1}H NMR spectrum, δ, ppm: 2.51 d (3H, CH_3, J = 1.255 Hz),

6.35 d (1H, 3-H, J = 1.255 Hz), 6.93 d (1H, 6-H, J = 9.035 Hz), 7.16 d (1H, 5-H, J = 8.784 Hz, 7.45 d (2H, 3^1,5^1-H, J = 1.506 Hz), 7.72 d (1H, 6^1,2^1-H, J = 1.506 Hz), 8.62 s (1H, 10-H). ^{13}C NMR spectrum, δ_C, ppm: 19, 108, 112.9, 114.4, 118.3, 127.1, 128.8, 129, 129.7, 134.2, 135.5, 140, 150.8, 152.2, 156.3, 157.2, 159, 190.8. Mass spectrum: m/z 367 $[M + H]^+$. Found, %: C 65.44, H 3.0. $C_{20}H_{11}ClO_5$. Calculated, %: C 65.50, H 3.02. M 366.75.

9-(*p*-Nitrobenzoyl)-4-methyl-pyrano[2,3-*f*]chromene-2,8-dione (8c). mp 232–234°C. IR spectrum, ν, cm^{-1}: 1765.0 and 1716.0 (C=O), 1613 (C=C). ^{1}H NMR spectrum, δ, ppm: 2.51 d (3H, CH_3, J = 1.25 Hz), 6.35 d (1H, 3-H, J = 1.25 Hz), 7.35 d (1H, 6-H, J = 9.03 Hz), 7.86 d (1H, 5-H, J = 8.78 Hz), 8.96 d (2H, 6^1,2^1-H, J = 1.25 Hz), 8.30 d (2H, 3^1,5^1-H, J = 8.784 Hz), 8.62 s (1H, 10-H). ^{13}C NMR spectrum, δ_C, ppm: 19, 108, 112.9, 114.4, 118.2, 125.1, 127.8, 129, 129.7, 134.2, 135.5, 140.4, 150.8, 152.2, 156.3, 159.5, 160, 191.2. Mass spectrum: m/z 378 $[M + H]^+$. Found, %: C 63.63, H 2.98, N 3.69. $C_{20}H_{11}NO_7$. Calculated, %: C 63.67, H 3.02, N 3.71. M 377.30.

9-(*o*-Methylbenzoyl)-4-methyl-pyrano[2,3-*f*]chromene-2,8-dione (8d). mp 190–192°C. IR spectrum, ν, cm^{-1}: 2925 (C–H), 1765.0 and 1716.0 (C=O), 1613 (C=C). ^{1}H NMR spectrum, δ, ppm: 2.51 d (3H, CH_3, J = 1.255 Hz), 2.6 s (o-CH_3), 6.35 d (1H, 3-H, J = 1.255 Hz), 7.35 d (1H, 6-H, J = 9.035 Hz), 7. 60 d (1H, 5-H, J = 8.784 Hz), 7.51, 7.65 m (4H, 4^1 3^1,5^1, 6^1-H), 8.62 s (1H, 10-H). ^{13}C NMR spectrum, δ_C, ppm: 19, 21, 110, 112.9, 117.4, 1187.2, 127.1, 128.8, 129, 129.7, 134.2, 135.5, 138.4, 150.8, 152.2, 156.3, 159.2, 160.5, 190.8. Mass spectrum: m/z 348 $[M + H]^+$. Found, %: C 72.80, H 4.02. $C_{21}H_{14}O_5$. Calculated, %: C 72.83, H 4.07. M 346.33.

9-Benzoyl-6-chloro-4-methylpyrano[2,3-*f*]chromene-2,8-dione (8e). mp 162–164°C. IR spectrum, ν, cm^{-1}: 1765.0 and 1716.0 (C=O), 1613 (C=C). ^{1}H NMR spectrum, δ, ppm: 2.51 d (3H, CH_3, J = 1.255 Hz), 6.35 d (1H, 3-H, J = 1.255 Hz), 7.860 s (1H, 5-H), 7.51 m (2H, 3^1,4^1-H), 7.65 t.t.t (1H, 4^1-H), 7.89 d (1H, 6^1-H, J = 1.506 Hz), 7.89 d (1H, 2^1-H, J = 1.255 Hz), 8.62 s (1H, 10-H). ^{13}C NMR spectrum, δ_C, ppm: 19, 108, 112.9, 114.4, 116.2, 127.1, 128.8, 129, 129.7, 134.2, 135.5, 138.4, 150.8, 152.2, 156.3, 157.2, 159, 190.8. Mass spectrum: m/z 332.31 $[M + H]^+$. Found, %: C 65.46, H 3.01. $C_{20}H_{12}O_5$. Calculated, %: C 65.50, H 3.02. M 366.75.

9-Benzoyl-6-chloro-4-(chloromethyl)pyrano[2,3-*f*]-chromene-2,8-dione (8f). mp 182-184°C. IR spectrum, ν, cm^{-1}: 1765.0 and 1710.0 (C=O), 1613 (C=C). ^{1}H NMR spectrum, δ, ppm: 4.51 s (2H, CH_2), 6.35 s (1H, 3-H), 7.51 m (2H, 3^1,5^1-H), 7.65 t.t.t (1H, 4^1-H), 7.860 s (1H, 5-H), 7.89 d (1H, 6^1-H, J = 1.506 Hz), 7.89 d (1H, 2^1-H, J = 1.255 Hz), 8.62 s (1H, 10-H). ^{13}C NMR spectrum, δ_C, ppm: 19, 112, 119.9, 125.4, 126.2, 127.1, 129.1, 129.5, 129.7, 134.2, 135.5, 140.4, 150.8, 152.2, 156.3, 157.2, 159, 190.8. Mass spectrum: m/z 367 $[M + H]^+$. Found, %: C 59.81, H 2.48. $C_{20}H_{10}Cl_2O_5$. Calculated, %: C 59.87, H 2.51. M 401.20.

Synthetic data for 9-benzoyl-4-methylpyrano[2,3-*f*]-chromene-2,8-diones (**8a–8j**)

Entry	R	R_1	R_2	R_3	R_4	Time, h	Yield, %
8a	CH_3	H	H	H	H	2	90
8b	CH_3	H	Cl	H	H	2	87
8c	CH_3	H	NO_2	H	H	2	85
8d	CH_3	H	H	H	CH_3	3	80
8e	CH3	Cl	H	H	H	3	85
8f	CH_2Cl	Cl	H	H	H	3	78
8g	CH_2Cl	H	H	H	H	2	87
8h	CH_2Cl	H	Cl	H	H	2	80
8i	CH_3	Cl	H	H	CH_3	3	85
8j	CH_3	Cl	NO_2	H	H	3	75

9-Benzoyl-4-(chloromethyl)pyrano[2,3-*f*]chromene-2,8-dione (8g). mp 170°C. IR spectrum, ν, cm^{-1}: 1765.0 and 1716.0 (C=O), 1613 (C=C). ^{1}H NMR spectrum, δ, ppm: 4.51 s (2H, CH_2), 6.35 d (1H, 3-H, J = 1.255 Hz), 7.35 d (1H, 6-H, J = 9.035 Hz, J = 0.502 Hz), 7.51 m (2H, 3^1,5^1-H), 7.65 t.t.t (1H, 4^1-H), 7.860 d (1H, 5-H, J = 8.784 Hz, 7.89 d (1H, 6^1-H, J = 1.506 Hz), 7.89 d (1H, 2^1-H, J = 1.255 Hz), 8.62 s (1H, 10-H). ^{13}C NMR spectrum, δ_C, ppm: 19, 110.8, 112.9, 114.4, 116.2, 127.1, 128.8, 129, 129.7, 134.2, 135.5, 138.4, 150.8, 152.2, 156.3, 159.2, 160.2, 190.8. Mass spectrum: m/z 367 $[M + H]^+$. Found, %: C 65.49, H 2.98. $C_{20}H_{11}ClO_5$. Calculated, %: C 65.50, H 3.02. M 366.50.

9-(*p*-Chlorobenzoyl)-4-(chloromethyl)pyrano[2,3-*f*]-chromene-2,8-dione (8h). mp 228°C. IR spectrum, ν, cm^{-1}: 1765.0 and 1716.0 (C=O), 1613 (C=C). ^{1}H NMR spectrum, δ, ppm: 4.51 s (2H, CH_2), 6.35 d (1H, 3-H, J = 1.255 Hz), 7.35 d (1H, 6-H, J = 9.035 Hz), 7.51 m (2H, 3^1,5^1-H), 7.860 d (1H, 5-H, J = 8.784 Hz, 7.89 d

(1H, 2^1,6^1-H, J = 1.506 Hz), 8.62 s (1H, 10-H). ^{13}C NMR spectrum, δ_C, ppm: 19, 110.5, 112.9, 114.4, 116.2, 127.1, 128.8, 129, 129.7, 134.2, 135.5, 138.4, 150.8, 152.2, 156.3, 159.2, 160.2, 190.8. Mass spectrum: *m*/*z* 401. Found, %: C 59.84, H 2.49. $C_{20}H_{10}Cl_2O_5$. Calculated, %: C 59.87, H 2.51.

9-(*o*-Methylbenzoyl)-6-chloro-4-methylpyrano-[2,3-*f*]chromene-2,8-dione (8i). mp 233°C. IR spectrum, ν, cm^{-1}: 1765.0 and 1716.0 (C=O), 1613 (C=C). ^{1}H NMR spectrum, δ, ppm: 2.51 d (3H, CH_3, J = 1.255 Hz), 6.35 d (1H, 3-H, J = 1.255 Hz), 7.860 s (1H, 5-H), 7.51 m (2H, 3^1,5^1-H), 7.65 t.t.t (1H, 4^1-H), 7.89 d (1H, 6^1-H, J = 1.506 Hz), 7.89 d (1H, 2^1-H, J = 1.255 Hz), 8.62 s (1H, 10-H). ^{13}C NMR spectrum, δ_C, ppm: 19, 21, 110, 112.9, 117.4, 1187.2, 127.1, 128.8, 129, 129.7, 134.2, 135.5, 138.4, 150.8, 152.2, 156.3, 159.2, 160.5, 190.8. Mass spectrum: *m*/*z* 381 $[M + H]^+$. Found, %: C 66.20, H 3.42. $C_{21}H_{13}ClO_5$. Calculated, %: C 66.24, H 3.44. *M* 381.78.

9-(*p*-Nitrobenzoyl)-6-chloro-4-methylpyrano-[2,3-*f*]chromene-2, 8-dione (8j). mp 240°C. IR spectrum, ν, cm^{-1}: 1765.0 and 1716.0 (C=O), 1613 (C=C). ^{1}H NMR spectrum, δ, ppm: 2.51 d (3H, CH_3, J = 1.255 Hz), 6.35 d (1H, 3-H, J = 1.255 Hz), 7.860 s (1H, 5-H),8.96 d (2H, 6^1, 2^1-H, J = 1.255 Hz), 8.30 d (2H, 3^1,5^1-H, J = 8.784 Hz), 8.62 s (1H, 10-H). ^{13}C NMR spectrum, δ_C, ppm: 19, 108, 112.9, 114.4, 118.2, 125.1, 127.8, 129, 129.7, 134.2, 135.5, 140.4, 150.8, 152.2, 156.3, 159.5, 160, 191.2. Mass spectrum: *m*/*z* 412 $[M + H]^+$. Found, %: C 58.30, H 2.43, N 3.37. $C_{20}H_{10}ClNO_7$. Calculated, %: C 58.34, H 2.45, N 3.40. *M* 411.75.

ACKNOWLEDGMENTS

The authors are thankful to the Head, Department of Chemistry, Osmania University, Hyderabad, for providing Laboratory facilities and the Director, CFRD, Osmania University, Hyderabad, for providing spectral analysis facilities. Erukala Yadaiah Goud, is thankful to CSIR, New Delhi, India, for financial support in the form of CSIR-SRF.

REFERENCES

1. Spino, C., Dodier, M., and Sotheeswaran, S., *Bioorg. Med. Chem. Lett*., 1998, vol. 8, p. 3475. doi 10.1016/S0960-894X(98)00628-3
2. Witaicenis, A., Seito, L.N., and Di Stasi, L.C., *Chem. Biol. Interact,* 2010, vol. 186, p. 211. doi 10.1016/j.cbi.2010.03.045
3. Huang, G.J., Deng, J.S., and Liao, J.C., *J. Agric. Food Chem*., 2012, vol. 60, p. 1673. doi 10.1021/jf204297e
4. Kwon, O.S., Choi, J.S., and Islam, M.N., *Arch. Pharm. Res*., 2011, vol. 34, p. 1561. doi 10.1007/s12272-011-0919-0
5. Basile, A., Sorbo, S., and Spadaro, V., *Molecules*, 2009, vol. 14, p. 939. doi 10.3390/molecules14030939
6. Kim, S.H., Kang, K.A., Zhang, R., Piao, M.J., Ko, D.O., Wang, Z.H., Chae, S.W., Kang, S.S., Lee, K.H., Kang, H.K., Kang, H.W., and Hyun, J.W., *Acta Pharmacol. Sinica,* 2008, vol. 29, p. 1319. doi 10.1111/j.1745-7254.2008.00878.x
7. Luo, K.W., Sun, J.G., Chan, J.Y., Yang, L., Wu, S.H., Fung, K.P., Liu, F.Y., *Chemotherapy*, 2011, vol. 57, p. 449. doi 10.1159/000331641
8. Yang, D., Gu, T., Wang, T., Tang, Q., and Ma, C. *Biosci.: Biotechnol., Biochem*., 2010, vol. 74, p. 1430. doi 10.1271/bbb.100110
9. Yun, E.S., Park, S.S., Shin, H.C., Choi, Y.H., Kim, W.J., and Moon, S.K., *Toxicol. In Vitro*, 2011, vol. 25, p. 1335. doi 10.1016/j.tiv.2011.05.001
10. Lee, C.R., Shin, E.J., Kim, H.C., Choi, Y.S., Shin, T., and Wie, M.B., *Lab. Anim. Res*., 2011, vol. 27, p. 259. doi 10.5625/lar.2011.27.3.259
11. Sancho, R., Marquez, N., Gomez-Gonzalo, M., Calzado, M.A., Bettoni, G., Coiras, M.T., and Munoz, E.J., *Biol. Chem.*, 2004, vol. 279, p. 37349. doi 10.1074/jbc.M401993200
12. Costa, M., Areias, F., Abrunhosa, L., Venâncio, A., and Proença, F., *J. Org. Chem*., 2008, vol. 73, p. 1954. doi 0.1021/jo702552f
13. Proença, F. and Costa, M., *Green Chem*., 2008, vol. 10, p. 995. doi 10.1039/B807892K
14. Fringuelli, F., Piermattti, O., and Pizzo, F.J., *Chem. Educ*., 2004, vol. 81, p. 874. doi 10.1021/ed081p874
15. Vodmajer, J., Toplak, R., Leban, I., and Majcen, Le Marechal, A., *Tetrahedron*, 2005, vol. 61, p. 7012. doi 10.1016/j.tet.2005.05.020
16. Vodmajer, J., Toplak, R., Leban, I., and Majcen Le Marechal, A., *Tetrahedron Lett.,* 2003, vol. 44, p. 2363. doi 10.1016/S0040-4039(03)00249-1
17. Heravi, M.M., Poormohammad, N., Beheshtiha, Y.Sh., Bahernejad, B., and Malakooti, R., *Bull. Chem. Soc. Ethiop*., 2010, vol. 24, p. 273. ISSN 1011-3924.
18. Harishkumar, H.N., Mahadevan, K.M., Kiran Kumar, H.C., and Satyanarayan, N.D., *Org. Commun*., 2011, vol. 4, p. 26. ISSN 1307-6175.
19. Pechmann, H. and Duisberg, C., *Ber. Dtsch. Chem. Ges*., 1883, vol. 16, p. 2119. doi 10.1002/cber.188301602117
20. Patel, A.D., Sharma, M.S., Vohra, J.J., and Joshi, J.D., *J. Indian Chem. Soc*., 1997, vol. 74, p. 287. ISSN 0019-4522.
21. Tamiz, A.P., Cai, S.X., Zhou, Z.L., Yuen, P.W., Schelkun, R.M., Whittemore, E.R., Weber, E., Woodward, R.M. and Keana, J.F.W., *J. Med. Chem*., 1999, vol. 42, p. 3412. doi 10.1021/jm990199u
22. McChuskey, A., Robinson, P.J., Hill, T., Scott, J.L., and Edwards, J.K., *Tettrahedron Lett*., 2002, vol. 43, p. 3117. doi 10.1016/S0040-4039(02)00480-X