Res Chem Intermed
DOI 10.1007/s11164-015-2083-5

An efficient four-component domino protocol for the rapid and green synthesis of functionalized benzo[*a*]pyrano[2,3-*c*]phenazine derivatives using caffeine as a homogeneous catalyst

Afshin Yazdani Elah Abadi[1] · Malek-Taher Maghsoodlou[1] · Reza Heydari[1] · Razieh Mohebat[2]

Received: 4 April 2015 / Accepted: 28 April 2015

Abstract A one-pot, two-step procedure has been used to synthesize functionalized benzo[*a*]pyrano[2,3-*c*]phenazine derivatives from a four-component condensation reaction of 2-hydroxynaphthalene-1,4-dione, *o*-phenylenediamine, aldehydes, and malononitrile in the presence of 1,3,7-trimethylpurine-2,6-dione (caffeine) as an expedient and reusable solid base catalyst. This new procedure has the following advantages: operational simplicity, short reaction times, environmentally friendly, easy work-up, and all the products were obtained in excellent yields.

Keywords Multi-component reactions (MCRs) · One-pot synthesis · 1,3,7-Trimethylpurine-2,6-dione (caffeine) · 2-Hydroxynaphthalene-1,4-dione · *o*-Phenylenediamine · Benzo[*a*]pyrano[2,3-*c*]phenazine

Introduction

Multi-component reactions (MCRs) are useful for the synthesis of various groups of compounds [1–7], especially the synthesis of biologically important compounds, because they provide an appropriate method for the preparation of new chemical entities required by pharmaceutical and agrochemical industries [8, 9]. Therefore, in the last few years, MCRs were developed as a fast and convenient way for efficient synthesis of organic compounds [10–17].

Phenazine compounds are nitrogen-containing heterocycles that are found in natural and synthetic products [18–24] showing a diversity of biological functions,

✉ Malek-Taher Maghsoodlou
mt_maghsoodlou@yahoo.com; mt_maghsoodlou@chem.usb.ac.ir

[1] Department of Chemistry, Faculty of Science, University of Sistan and Baluchistan, P. O. Box 98135-674, Zahedan, Iran

[2] Department of Chemistry, Islamic Azad University, Yazd Branch, P. O. Box 89195-155, Yazd, Iran

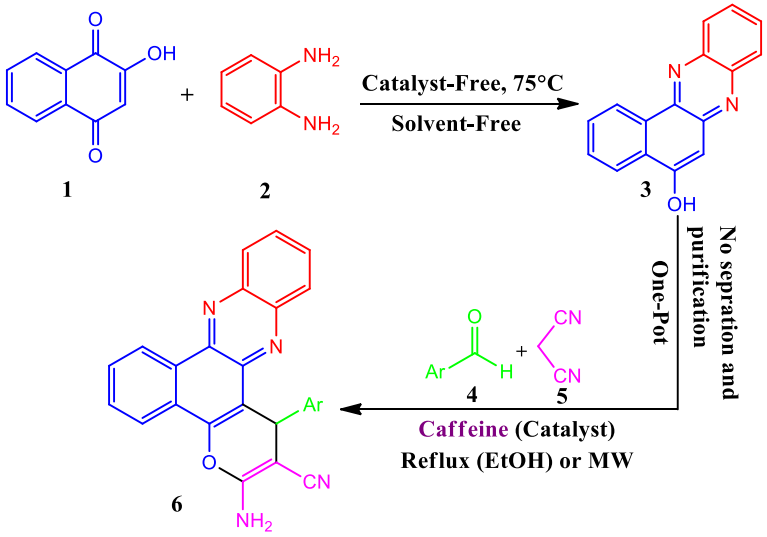
Published online: 09 May 2015

including antimalarial [25, 26], trypanocidal [27], fungicidal [28, 29], antiplatelet [30], and antitumor [31] activities. Benzo[*a*]phenazines that have been formed from a naphthoquinone and phenazin show high activity as dual inhibitors of topoisomerase I and II and are useful as antitumor agents [32]. In addition, chromenes have shown remarkable effects as pharmaceuticals [33, 34], including antifungal [35, 36] and antimicrobial activities [37]. Moieties of molecules with phenazines [24] and chromenes [38] have attracted great attention in drug discovery. Functionalized benzo[*a*]pyrano[2,3-*c*]phenazine derivatives have these moieties. We herein report a very green synthesis of functionalized benzo[*a*]pyrano[2,3-*c*]phenazine derivatives catalyzed by caffeine (Scheme 1; Fig. 1).

Experimental

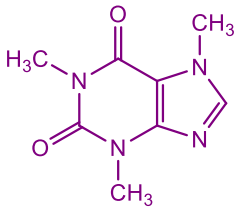
General

All melting points were determined on an Electrothermal 9100 apparatus and are uncorrected. IR spectra were recorded on a Shimadzu IR-470 spectrometer. Mass spectra were recorded on a FINNIGAN-MAT 8430 mass spectrometer operating at an ionization potential of 70 eV. The ^{1}H nuclear magnetic resonance (NMR) and ^{13}C NMR spectra were recorded on Bruker DRX-400 Avance instruments with dimethyl sulfoxide (DMSO) as solvent. Thin-layer chromatography (TLC) was performed on silica-gel Polygram SILG/UV 254 plates. All reagents were purchased from Merck and Aldrich and used without further purification.



Scheme 1 Synthesis of 3-amino-2-cyano-1-aryl-1*H*-benzo[*a*]pyrano[2,3-*c*]phenazines derivatives

Fig. 1 The structure of caffeine



General procedure for the synthesis of benzo[*a*]pyrano[2,3-*c*]phenazine derivatives using the conventional heating method (method A)

At first, 2-hydroxynaphthalene-1,4-dione **1** (1 mmol) and *o*-phenylenediamine **2** (1 mmol) were mixed at 75 °C (solvent free) for <5 min until an orange solid of benzo[*a*]phenazine **3** was formed. Then, aryl aldehydes **4** (1 mmol), and malononitrile **5** (1 mmol), and caffeine (30 mol %) were added, the flask was fitted with a condenser, and the resulting mixture in ethanol (10 mL) was heated to reflux under stirring. The reaction was monitored by TLC, and after the required time and completion of the reaction, the reaction mixture was cooled to room temperature. The resulting solid product was filtered and was washed twice with water (2 × 5 mL), then dried and subsequently recrystallized from hot ethanol. In order to recover the catalyst, since caffeine is soluble in water, the water including caffeine was evaporated under reduced pressure and caffeine was recovered and reused.

General procedure for the synthesis of benzo[*a*]pyrano[2,3-*c*]phenazine derivatives using the microwave heating method (method B)

In this method, at first, accordance with the procedures A, made an orange solid of benzo[*a*]phenazine **3**. Then, aryl aldehydes **4** (1 mmol), malononitrile **5** (1 mmol), and caffeine (20 mol %) were added and this mixture was transferred to a microwave oven and irradiated under 180 W. The reaction was monitored by TLC, and upon completion, the reaction mixture was allowed to cool to room temperature. Then, 5 mL of water was added to the mixture. The caffeine was dissolved in water, and filtered for separation of the crude product. The separated product was washed twice with water (2 × 5 mL). The solid crude product subsequently recrystallized from hot ethanol to give the pure solid. Finally, the water including caffeine was evaporated under reduced pressure and caffeine was recovered and reused.

The analytical and spectroscopic data for the unknown compounds are as follows:

3-Amino-2-cyano-1-(2,4-dichlorophenyl)-1*H*-benzo[*a*]pyrano[2,3-*c*]phenazine (Table 2, entry 1): yield of method A: 0.435 g (93 %), method B: 0.444 g (95 %), brown solid, m.p.: 308–310 °C; IR (KBr): ν_{max} = 3457, 3376, 3170, 2185, 1653, 1620, 1589, 1492, 1464, 1401, 1390, 1347, 1326, 1288, 1220, 1160, 1097, 1050, 843, 753 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ = 9.18 (d, 1H, J = 7.2 Hz,

Ar–H), 8.41 (d, 1H, $J = 7.6$ Hz, Ar–H), 8.23–8.20 (m, 1H, Ar–H), 8.02–7.98 (m, 1H, Ar–H), 7.96–7.90 (m, 2H, Ar–H), 7.90–7.88 (m, 2H, Ar–H), 7.55 (d, 1H, $J = 2$ Hz, Ar–H), 7.40 (s, 2H, NH_2), 7.20 (d, 1H, $J = 8.8$, Ar–H), 7.15 (dd, 1H, $J_1 = 2$ Hz, $J_2 = 8.4$ Hz, Ar–H), 5.83 (s, 1H, CH) ppm; ^{13}C NMR (100 MHz, DMSO-d_6): $\delta = 159.8$, 147.0, 142.5, 141.9, 140.9, 140.5, 140.1, 133.7, 132.0, 131.9, 131.2, 131.0, 130.7, 130.6, 129.7, 129.5, 128.9, 128.8, 128.1, 125.9, 125.2, 122.6, 119.9, 112.6, 56.8, 34.6 ppm; MS (*m*/*z*, %): 468 (M^+, 6).

3-Amino-2-cyano-1-(3-methoxyphenyl)-1*H*-benzo[*a*]pyrano[2,3-*c*]phenazine (Table 2, entry 2): yield of method A: 0.374 g (87 %), method B: 0.387 g (90 %), yellow solid, m.p.: 240–242 °C; IR (KBr): $\nu_{max} = 3449$, 3300, 3165, 2175, 1663, 1599, 1595, 1485, 1449, 1428, 1398, 1385, 1347, 1314, 1288, 1261, 1163, 1103, 1048, 1025, 992, 947, 871, 752 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): $\delta = 9.16$ (d, 1H, $J = 8$ Hz, Ar–H), 8.40 (d, 1H, $J = 8$ Hz, Ar–H), 8.23–8.21 (m, 1H, Ar–H), 8.13–8.10 (m, 1H, Ar–H), 7.98–7.93 (m, 1H, Ar–H), 7.91–7.88 (m, 3H, Ar–H), 7.39 (s, 2H, NH_2), 7.12 (t, 1H, $J = 8$ Hz, Ar–H), 7.00 (t, 1H, $J = 2$ Hz, Ar–H), 6.90 (d, 1H, $J = 8$ Hz, Ar–H), 6.67 (dd, 1H, $J_1 = 2$ Hz, $J_2 = 7.6$ Hz, Ar–H), 5.43 (s, 1H, CH), 3.67 (s, 3H, OCH_3) ppm; ^{13}C NMR (100 MHz, DMSO-d_6): $\delta = 160.4$, 159.5, 147.2, 146.5, 141.9, 141.0, 140.4, 140.1, 131.2, 130.9, 130.6, 130.3, 129.9, 129.5, 129.4, 129.1, 126.0, 125.2, 122.5, 120.7, 120.1, 114.3, 114.2, 111.9, 58.2, 55.3, 37.7 ppm; MS (*m*/*z*, %): 430 (M^+, 33).

Results and discussion

First, to find optimization conditions, the one-pot four-component reaction of 2-hydroxynaphthalene-1,4-dione, *o*-phenylenediamine, 2,4-dichlorobenzaldehyde, and malononitrile in the presence of caffeine as catalyst was selected as model. So, 2-hydroxynaphthalene-1,4-dione (1 mmol) and *o*-phenylenediamine (1 mmol) were mixed at 75 °C for <5 min until an orange solid of benzo[*a*]phenazine was formed without using any catalyst under solvent-free conditions. Then, in method A, 2,4-dichlorobenzaldehyde (1 mmol), malononitrile (1 mmol), and caffeine as catalyst were added, the flask was fitted with a condenser, and the resulting mixture in ethanol (10 mL) was heated to reflux under stirring. The use of different amounts of catalyst (20, 25, 30, 35 mol %) at different temperatures (25, 50, 75 °C) were investigated (Table 1). The best result was obtained with 30 mol % of caffeine as catalyst at 75 °C in ethanol under reflux conditions and afforded 3-amino-2-cyano-1-(2,4-dichlorophenyl)-1*H*-benzo[*a*]pyrano[2,3-*c*]phenazine in 30 min with 93 % of yield.

Then, optimization conditions for method B, the same as above model using different amounts of catalyst (10, 20, 30 mol %) at various powers (100, 180, 300 W) was investigated (Table 1). The best result was obtained with 20 mol % of caffeine as catalyst at 180 W afforded 3-amino-2-cyano-1-(2,4-dichlorophenyl)-1*H*-benzo[*a*]pyrano[2,3-*c*]phenazine in 7 min with 95 % of yield.

Using these optimized reaction conditions, the scope and efficiency of the reaction were explored for the synthesis of a wide variety of substituted benzo[*a*]pyrano[2,3-*c*]phenazine derivatives. The results are summarized in

Table 1 Optimization of the reaction conditions for the synthesis of 3-amino-2-cyano-1-(2,4-dichlorophenyl)-1*H*-benzo[*a*]pyrano[2,3-*c*]phenazine from 2-hydroxynaphthalene-1,4-dione, *o*-phenylenediamine, 2,4-dichlorobenzaldehyde, and malononitrile in the presence of different amount of caffeine as catalyst in varieties temperature and power

Entry	Conventional heating (method A)				Microwave irradiation (method B)			
	Cat (mol %)	*T* (°C)	Time (min)	Yield (%)	Cat (mol %)	Power (W)	Time (min)	Yield (%)
1	20	25	60	Trace	10	100	10	Trace
2	20	50	60	85	20	180	10	95
3	30	50	45	92	30	180	10	94
4	25	50	45	87	30	180	7	94
5	30	75	30	93	20	180	7	95
6	35	50	45	93	10	180	7	82
7	30	75	20	90	20	300	5	91

Table 2 Synthesis of 3-amino-2-cyano-1-aryl-1*H*-benzo[*a*]pyrano[2,3-*c*]phenazine derivatives from the reaction of 2-hydroxynaphthalene-1,4-dione, *o*-phenylenediamine, malononitrile, and aldehydes in the presence of caffeine as catalyst

Entry	Aldehydes	Method A (cat. 30 mol %), (*T*. 75 °C)		Method B (cat. 20 mol %), (power. 180 W)		Melting point m.p. (°C)/Lit. m.p. (°C) [References]
		Time (min)	Yield (%)	Time (min)	Yield (%)	
1	$2,4\text{-}(Cl)_2C_6H_3$	30	93	7	95	308–310/this work
2	$3\text{-}CH_3OC_6H_4$	75	87	10	90	240–242/this work
3	$4\text{-}NO_2C_6H_4$	30	95	7	96	283/(281–283) [39]
4	$4\text{-}BrC_6H_4$	60	87	7	87	282–285/(283–285) [39]
5	$4\text{-}FC_6H_4$	60	90	8	91	275/(274–276) [39]
6	$4\text{-}ClC_6H_4$	60	90	10	90	288–290/(288–291) [39]
7	$2\text{-}CH_3OC_6H_4$	75	85	10	87	268–271/(270–272) [39]
8	$2,3\text{-}(CH_3O)_2C_6H_3$	90	85	10	85	292/(292–294) [39]
9	$4\text{-}OH\text{-}3\text{-}NO_2C_6H_3$	90	88	10	90	291/(290–291) [39]
10	$4\text{-}OH\text{-}3\text{-}CH_3OC_6H_3$	100	87	12	90	246–249/(247–248) [39]
11	$3,4,5\text{-}(CH_3O)_3C_6H_2$	120	86	12	87	252–256/(252–254) [39]
12	C_6H_5	50	90	10	92	300/(298–300) [39]
13	$4\text{-}CH_3C_6H_4$	60	91	12	92	292–294/(293–294) [39]
14	$3\text{-}NO_2C_6H_4$	75	89	8	90	276–280/(278–279) [39]

Table 2. The desired pure products were characterized by comparison of their physical data (melting points, IR, and ^{1}H NMR) with those of known compounds in the literature. The extensive ranges of substituted and structurally various aldehydes afforded the corresponding products in high to excellent yields using the caffeine as

a green catalyst (Table 2). As shown in Table 2, aromatic aldehydes containing electron-withdrawing groups increased the rate of reaction and gave higher yields than that with electron-donating groups.

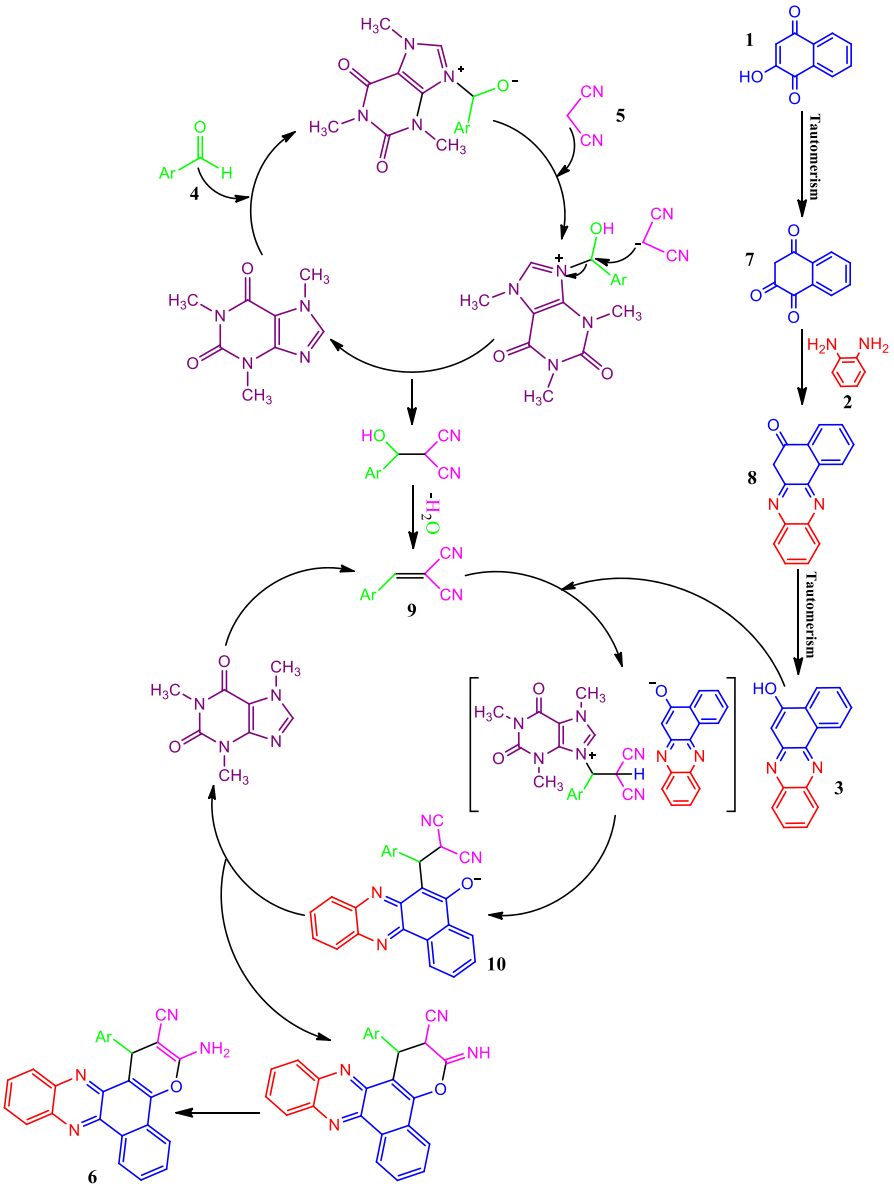
For catalyst recovery, we also investigated recycling of the caffeine using a selected model reaction of 2-hydroxynaphthalene-1,4-dione, *o*-phenylenediamine, 2,4-dichlorobenzaldehyde, and malononitrile in the presence of caffeine (Table 2, entry 1). After completion of the reaction (method B), the reaction mixture was cooled to room temperature. Then, 5 mL of water was added to the mixture. The caffeine was dissolved in water, and filtered for separation of the crude product. The separated product was washed twice with water (2 × 5 mL). The resulting product subsequently recrystallized from hot ethanol to give the pure solid. In order to recover the catalyst, after washing the mixture with water completely, since caffeine is soluble in water, the water including caffeine was evaporated under reduced pressure and caffeine was recovered and reused.

As shown in Table 3, we studied the reusability of the caffeine as a green catalyst for the same reactants. It was observed that the recovered catalyst works with the same performance up to 2nd run, (Table 3, entries 1 and 2), while in the 3rd and 4th runs (Table 3, entries 3 and 4) the product yield is reduced slightly, which may be due to some weight loss of catalyst during each recovery process.

The mechanism for the formation of the products has been proposed in Scheme 2 according to the literature [39]. On the basis of this mechanism, at first, 2-hydroxynaphthalene-1,4-dione **1** tautomrizes to intermediate **7**. The primary condensation of **7** with *o*-phenylenediamine **2** obtain 6*H*-benzo[*a*]phenazin-5-one **8**, which in tautomerism equilibrium reasons to prepare benzo[*a*]phenazin-5-ol **3**. On this mechanism, caffeine is an impressive catalyst to form the olefin **9**, which easily prepares in situ from Knoevenagel condensation of aldehyde **4** with malononitrile **5**. The Michael addition of 6*H*-benzo[*a*]phenazin-5-ol **3** with benzylidenemalononitrile **9** in the presence of caffeine finally give intermediate **10**, which then causes the inner molecular ring to be formed after a tautomeric proton shift to produce 3-amino-2-cyano-1-aryl-1*H*-benzo[*a*]pyrano[2,3-*c*]phenazines **6** (Scheme 2).

Table 3 Recycling and reusability of the catalyst (100 mg) for the synthesis of 3-amino-2-cyano-1-(2,4-dichlorophenyl)-1*H*-benzo[*a*]pyrano[2,3-*c*]phenazine from 2-hydroxynaphthalene-1,4-dione (1 mmol), *o*-phenylenediamine (1 mmol), 2,4-dichlorobenzaldehyde (1 mmol), and malononitrile (1 mmol)

Entry	Run	Method A		Method B	
		Time (min)	Yield (%)	Time (min)	Yield (%)
1	1st	30	93	7	95
2	2nd	30	93	7	95
3	3rd	30	90	7	92
4	4th	30	87	7	90



Scheme 2 Proposed mechanism for the synthesis of 3-amino-2-cyano-1-aryl-1*H*-benzo[*a*]pyrano[2,3-*c*]phenazines

Conclusions

In this work, we report an efficient four-component domino protocol for the rapid and green synthesis of functionalized benzo[*a*]pyrano[2,3-*c*]phenazine derivatives in the presence of caffeine. The synthetic procedure offers several advantages,

including operational simplicity, clean reaction conditions, high yields, and no pollution threat to the environment, which together make a useful and attractive process for synthesis of these compounds. In this one-pot, two-step, four component condensation reaction was carried out caffeine as an inexpensive, highly reactive, non-toxic, and reusable and green solid base catalyst (environmentally friendly) under conventional heating or microwave irradiation. Moreover, our work was characterized by the use of microwave irradiation as a partially reproducible energy source and avoidance of hazardous organic solvents. In all these cases, this paper introduced a green and economically cost-effective method.

Acknowledgments We gratefully acknowledge financial support from the Research Council of the University of Sistan and Baluchestan and Islamic Azad University of Yazd.

References

1. M.T. Maghsoodlou, A. Hassankhani, H.R. Shaterian, S.M. Habibi-Khorasani, E. Mosaddegh, Tetrahedron Lett. **48**, 1729 (2007)
2. M.T. Maghsoodlou, N. Hazeri, M. Lashkari, F.N. Shahrokhabadi, B. Naghshbandi, M.S. Kazemidoost, M. Rashidi, F. Mir, M. Kangani, S. Salahi, Res. Chem. Intermed (2014). doi:10.1007/s11164-014-1793-4
3. F.N. Sadeh, M.T. Maghsoodlou, N. Hazeri, M. Kangani, Res. Chem. Intermed. (2014). doi:10.1007/s11164-014-1710-x
4. P.Y. Gu, F. Zhou, J. Gao, G. Li, Ch. Wang, Q.F. Xu, Q. Zhang, J.M. Lu, J. Am. Chem. Soc. **135**, 14086 (2013)
5. G. Li, Y. Wu, J. Gao, J. Li, Y. Zhao, Q. Zhang, Chem. Asian J. **8**, 1574 (2013)
6. V. Polshettiwar, R.S. Varma, Chem. Soc. Rev. **37**, 1546 (2008)
7. B. Ganem, Acc. Chem. Res. **42**, 463 (2009)
8. M.T. Maghsoodlou, S.M. Habibi-Khorasani, A. Moradi, N. Hazeri, A. Davodi, S.S. Sajadikhah, Tetrahedron **67**, 4892 (2011)
9. C. Hulme, V. Gore, Curr. Med. Chem. **10**, 51 (2003)
10. M.T. Maghsoodlou, S.M. Habibi-Khorasani, R. Heydari, F. Rostami-Charati, N. Hazeri, M. Lashkari, M. Rostamizadeh, G. Marandi, A. Sobolev, M. Makha, Tetrahedron Lett. **50**, 4439 (2009)
11. X. Yang, F. Hu, H. Di, X. Cheng, D. Li, X. Kan, X. Zou, Q. Zhang, Org. Biomol. Chem. **12**, 8947 (2014)
12. B. Jiang, S.J. Tu, K. Parminder, W. Walter, G.J. Li, Am. Chem. Soc. **131**, 11660 (2009)
13. D. Bonne, T. Constantieux, Y. Coquerel, J. Rodriguez, Org. Biomol. Chem. **10**, 3969 (2012)
14. B. Jiang, F. Shi, S.J. Tu, Curr. Org. Chem. **14**, 357 (2010)
15. P. Helene, Adv. Synth. Catal. **354**, 237 (2012)
16. J.G. Hernandez, E. Juaristi, Chem. Commun. **48**, 5396 (2012)
17. D. Enders, C. Wang, M. Mukanova, A. Greb, Chem. Commun. **46**, 2447 (2010)
18. N.V. De Witte, A.O. Stoppani, M. Dubin, Arch. Biochem. Biophys. **432**, 129 (2004)
19. L.M. Lopez, A. Pellegrino de Iraldi, P.H. Carrizo, M. Dubin, A.O.M. Stoppani, Biocell. **26**, 237 (2002)
20. A.L.B.S. Barreiros, J.M. David, J.P. David, Quim. Nova **29**, 113 (2006)
21. H.J. Park, K.J. Ahn, S.D. Ahn, E. Choi, S.W. Lee, B. Williams, E.J. Kim, R. Griffin, E.A. Bey, W.G. Bornmann, J. Gao, H.J. Park, D.A. Boothman, C.W. Song, Int. J. Radiat. Oncol. Biol. Phys. **61**, 212 (2005)
22. S.B. Ferreira, K. Salomão, F.C. da Silva, A.V. Pinto, C.R. Kaiser, A.C. Pinto, V.F. Ferreira, S.L. de Castro, Eur. J. Med. Chem. **46**, 3071 (2011)
23. J. Bloxham, C.P. Dell, C. Smith, Heterocycles **38**, 399 (1994)
24. J.B. Laursen, J. Nielsen, Chem. Rev. **104**, 1663 (2004)
25. M. Makgatho, R. Anderson, J. O'Sullivan, T. Egan, J. Freese, N. Cornelius, C. Van Rensburg, Drug Dev. Res. **50**, 195 (2000)

26. V. Andrade-Nieto, M. Goulart, J.F. da Silva, M.J. da Silva, M. Pinto, A. Pinto, M. Zalis, L. Carvalho, A. Krettli, Bioorg. Med. Chem. Lett. **14**, 1145 (2004)
27. C. Neves-Pinto, V. Malta, M. Pinto, R. Santos, S. Castro, A.J. Pinto, Med. Chem. **45**, 740 (2002)
28. D. Cartwright, W. Chilton, D. Benson, Appl. Microbiol. Biotechnol. **43**, 211 (1995)
29. J. Ligon, S. Dwight, P. Hammer, N. Torkewitz, D. Hofmann, H. Kempf, K. Pee, Pest. Manag. Sci. **56**, 688 (2000)
30. M. Muller, T. Sorrell, Prostaglandins **50**, 301 (1995)
31. H.J. Lee, J.S. Kim, S.Y. Park, M.E. Suh, H.J. Kim, E.K. Seo, C.O. Lee, Bioorg. Med. Chem. **12**, 1623 (2004)
32. N. Vickr, L. Burgess, I.S. Chuckowree, R. Dodd, A.J. Folkes, D.J. Hardick, T.C. Hancox, W.H. Miller, J. Milton, S. Sohal, S. Wang, S.P. Wren, P.A. Charlton, W. Dangerefield, C. Liddle, P. Mistry, A.J. Stewart, W.A.J. Denny, Med. Chem. **45**, 721 (2002)
33. D. Yu, M. Suzuki, L. Xie, S.L. Morris-Natschke, K.H. Lee, Med. Res. Rev. **23**, 322 (2003)
34. F. Borges, F. Roleira, N. Milhazes, L. Santana, E. Uriarte, Curr. Med. Chem. **12**, 887 (2005)
35. J.G. Tangmouo, A.L. Meli, J. Komguem, V. Kuete, F.N. Ngounou, D. Lontsi, V.P. Beng, M.I. Choudhary, B.L. Sondengam, Tetrahedron Lett. **47**, 3067 (2006)
36. A.S.A. El-Aziz, A.M. El-Agrody, A.H. Bedair, T.C. Corkery, A. Ata, Heterocycles **63**, 1793 (2004)
37. R.O.S. Kitamura, P. Romoff, M.C.M. Young, M.J. Kato, J.H.G. Lago, Phytochemistry **67**, 2398 (2006)
38. G.P. Ellis, Chem. Heterocycl. Compd. **31**, 1 (1977)
39. S.L. Wang, F.Y. Wu, C. Cheng, G. Zhang, Y.P. Liu, B. Jiang, F. Shi, S.J. Tu, ACS Comb. Sci. **13**, 135 (2011)