Synthesis of 2,4-diarylquinolines: nickel-catalysed ligand-free cross-couplings of 4-chloro-2-arylquinolines with arylmagnesium halides in 2-methyltetrahydrofuran

Zhenhua Li, Lingmin Xu and Weike Su*

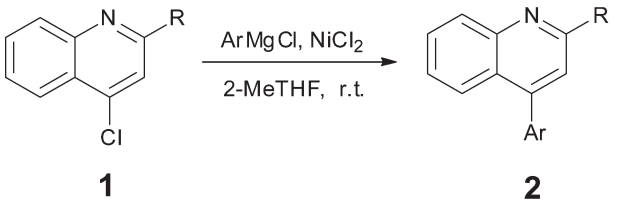
Key Laboratory of Pharmaceutical Engineering of Ministry of Education, College of Pharmaceutical Sciences, Zhejiang University of Technology, Hangzhou 310014, P. R.China

A ligand-free and room temperature protocol for the synthesis of 2,4-diarylquinolines is described. Treatment of 4-chloro-2-arylquinolines with arylmagnesium halides in the presence of a catalytic amount of nickel(II) chloride without ligands in 2-methyltetrahydrofuran (2-MeTHF) afforded the corresponding cross-coupling products in good yields.

Keywords: nickel-catalysis, cross-coupling, Grignard reagents, organomagnesium reagents, 2,4-diarylquinolines

Compounds containing the quinoline scaffold in the structural framework are expected to have wide-spectrum biological activity. Among their various applications,[1–3] functionalised quinolines are in widespread use as a result of their anti-malarial,[4–6] anti-inflammatory,[7,8] anti-asthmatic,[9,10] anti-bacterial[11,12] and anti-hypersensitive activities.[13,14]

Transition metal-catalysed cross-coupling has proved to be efficient in forming new C–C bonds. This methodology plays an important role in the synthesis of 4-substituted quinolines. Usually, palladium-[15], iron-[16,17] or cobalt-[18] catalysed cross-coupling required the use of phosphine or other ligands. Korn *et al*.[19] and Rueping and Teawsuwan[20] later independently discovered that Kumada-type coupling also could generate 4-substituted quinolines by cobalt and manganese catalysis without any ligands. However, the majority of the reactions required low temperatures and, after reactions were quenched, a large amount of toluene or other solvent was needed to extract the products. With 2-MeTHF, which provides very clean organic-water phase separations, the product can be conveniently isolated without adding another solvent. Furthermore, 2-MeTHF has proved to be a greener and more environmentally friendly solvent due to its specific characteristics such as high temperature for the preparation of chloro-Grignard reagents, ready availability from renewable resources, and being readily recoverable.[21] We now report a practical, ligand-free arylation of 4-chloro-2-arylquinolines by treatment with organomagnesium reagents and catalytic amounts of nickel(II) chloride in 2-MeTHF with convenient extraction at room temperature in good to excellent yields (Scheme 1).



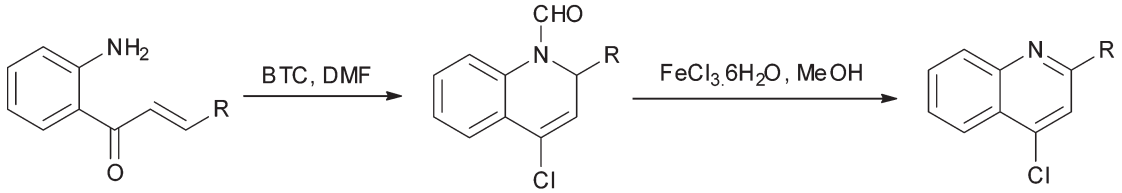
1 **2**

Scheme 1

Firstly, the starting materials, 4-chloro-2-arylquinolines **1**, were prepared by treatment of the 2′-aminochalcones with the novel Vilsmeier–type reagent derived from bis(trichloromethyl) carbonate (BTC) and DMF, followed by oxidative deformylation with $FeCl_3.6H_2O$ in refluxing methanol (Scheme 2).[22] We initially chose 4-chloro-2-phenylquinoline **1a** as a model to test this reaction. Treatment of **1a** (1.0 mmol) with *p*-tolylmagnesium chloride (4.0 mmol) in 2-MeTHF in the presence of nickel(II) chloride (0.1 mmol) for 1 h at room temperature afforded 2-phenyl-4-(*p*-tolyl)quinoline **2a** in 81% yield. We re-examined the reaction conditions in order to improve the yield, and the results are summarised in Table 1. It was found that inexpensive $NiCl_2$ was a good coupling catalyst to give 2-phenyl-4-(*p*-tolyl)quinoline **2a** in good yield at room temperature (entry **1**). Other metal salts such as $CoCl_2$, $FeCl_3$ and $MnCl_2$ (entries **2**-**4**) also catalysed the reaction, but the yields were lower under the same conditions. When 0.05 mmol catalyst was used, the reaction gave 71% yield of **2a** (entry **5**). Under the catalyst-free conditions, the yield of **2a** was sharply reduced to 15% (entry **6**). Parallel experiments using 3.0, 4.0 and 5.0 mmol of *p*-tolylmagnesium chloride indicated that 4.0 mmol of Grignard reagent was optimal for the conversion of **1a** into **2a** and that more Grignard reagent did not afford the product in significantly increased yield (entries **1**, **7** and **8**). Neither lower nor higher temperatures improved the yield of **2a** (entries **9–11**).

To extend the scope of this reaction, a wide range of substituted and structurally diverse 4-chloro-2-arylquinolines were subjected to this reaction and the corresponding substituted 2,4-diarylquinolines were obtained. The results are summarised in Table 2.

As can be seen from Table 2, with some variations in detail this method was successful in all cases except 4-chloro-2-(4-nitrophenyl)quinoline (entry **1m**). To our delight, we found that using 9-chloro-1,2,3,4-tetrahydroacridine **1n** also afforded the corresponding product in 65% yield (Scheme 3). The electronic effect of substituted groups in the 4-chloro-2-arylquinolines was obvious and the substrates with electron-donating groups (entries **1c–f**, **1j**) were more active and



Scheme 2

* Correspondent. E-mail: pharmlab@zjut.edu.cn

Table 1 Addition of *p*-tolylMgCl to 4-chloro-2-phenylquinoline **1a** to afford 2-phenyl-4-(*p*-tolyl)quinoline **2a**

Entry	Cat. /mol%	Ratio : **1a**:*p*-tolylMgCl	Temp. /°C	Yield[a] /%
1	$NiCl_2$(10)	1:4	r.t.	81
2	$CoCl_2$(10)	1:4	r.t.	73
3	$FeCl_3$(10)	1:4	r.t.	35
4	$MnCl_2$(10)	1:4	r.t.	76
5	$NiCl_2$(5)	1:4	r.t.	71
6	$NiCl_2$(0)	1:4	r.t.	15
7	$NiCl_2$(10)	1:3	r.t.	68
8	$NiCl_2$(10)	1:5	r.t.	82
9	$NiCl_2$(10)	1:4	0	43
10	$NiCl_2$(10)	1:4	–10	39
11	$NiCl_2$(10)	1:4	40	68

[a]Isolated yields based on 4-chloro-2-phenylquinoline **1a**

efficient in providing the products in higher yields than those with the electron-withdrawing groups (entries **1g**, **1m**). On the other hand, while the use of electron-rich substituted aryl magnesium halides (entry 1) was successful, the use of electron deficient substituents or of heterocyclic magnesium halides gave the corresponding desired products in rather diminished yields (entries **1k**, **1l**).

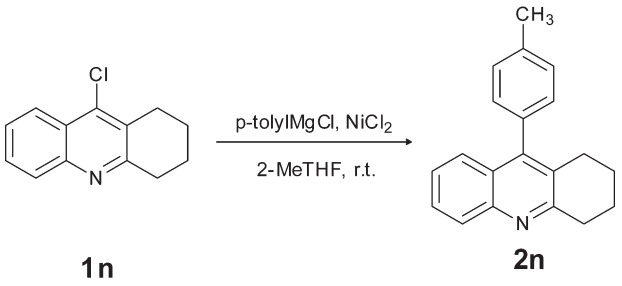
In summary, ligand-free nickel catalysed cross-coupling of 4-chloro-2-arylquinolines with arylmagnesium halides to prepare a range of 2,4-diarylquinolines in 2-MeTHF was developed. Furthermore, the reaction products can be directly extracted and no additional solvents were needed. We believe that this protocol will be a useful alternative for the synthesis of 2,4-disubstituted quinolines from readily available precursors.

Experimental

^{1}H NMR and ^{13}C NMR spectra were recorded on a Varian 400 MHz or Bruker Avance III (500 MHz) instrument in $CDCl_3$ as the solvent, and chemical shifts were expressed in parts per million (ppm) using TMS as an internal standard. IR spectra (KBr) were recorded on an AVATAR-370 instrument. Mass spectra were measured with a Trace Finnigan DSQ instrument. Melting points were measured on a Büchi B-540 apparatus and are uncorrected.

Preparation of 4-methylphenylmagnesium chloride

A solution of 4-chlorotoluene (4.0 mmol) in 2-MeTHF (5.0 mL) was added dropwise to a three-necked flask, charged with activated magnesium (4.8 mmol), 2-MeTHF (1.0 mL) and nitrogen atmosphere. The mixtures were refluxed for 6 h. The flask was then cooled to room temperature and the Grignard reagent was used directly in the following experiment.



1n **2n**

Scheme 3

Preparation of 2,4-diarylquinolines

A 25-mL Schlenk tube, equipped with a magnetic stirring bar and a septum, was charged with the appropriate 4-chloro-2-arylquinoline (1.0 mmol), $NiCl_2$ (0.10 mmol) and 2-MeTHF (5.0 mL). The corresponding arylmagnesium halide (4.0 mmol) was added dropwise at room temperature. The reaction mixture was stirred at the temperature stated in each experiment until the cross-coupling reaction was complete (0.5–1 h, monitored by TLC). The suspension was quenched with HCl (5.0 mL) and the organic phase was dried with anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure to yield the corresponding crude product, which was purified by silica gel chromatography using 2% ethyl acetate/petroleum ether as eluent.

2,4-Diphenylquinoline (**2a**): White solid; m.p. 113–114 °C (lit.[23] 111–112 °C); ^{1}H NMR δ: 8.23 (1H, d, *J* = 8.4 Hz), 8.19–8.14 (2H, m), 7.89 (1H, d, *J* = 8.4 Hz), 7.80 (1H, s), 7.72 (1H, td, *J* = 8.4, 1.4 Hz), 7.58–7.44 (9H, m); ^{13}C NMR δ: 119.3, 124.5, 125.5, 125.6, 126.2, 127.5 (2C), 128.3, 128.5 (2C), 128.7 (2C), 129.2, 129.4 (2C), 129.9, 138.2, 139.5, 148.6, 149.0, 156.7; MS (EI): *m/z* (%) = 281 (M^+, 75), 204 (30), 77 (20).

2-Phenyl-4-(p-tolyl)quinoline (**2b**): White solid; m.p. 101–102 °C (lit.[24] 100–100.5 °C); ^{1}H NMR δ: 8.21 (1H, d, *J* = 8.4 Hz), 8.16 (2H, d, *J* = 7.2 Hz), 7.90 (1H, d, *J* = 8.4 Hz), 7.77 (1H, s), 7.69 (1H, t, *J* = 7.6 Hz), 7.49 (2H, t, *J* = 6.8 Hz), 7.43 (4H, d, *J* = 8.0 Hz), 7.32 (2H, d, *J* = 7.6 Hz), 2.46 (3H, s); ^{13}C NMR δ: 21.8, 119.6, 125.9, 126.0, 126.4, 127.8 (2C), 129.0 (2C), 129.5 (3C), 129.6 (3C), 130.2, 135.6, 138.5, 139.8, 148.8, 149.4, 157.0; MS (EI): *m/z* (%) = 295 (M^+, 35), 280 (20), 205 (100).

2,4-Di-p-tolylquinoline (**2c**): Pale yellow solid; m.p. 107–108 °C; IR: ν_{max} 2920, 1592, 1543, 1497, 1357, 818, 764 cm^{-1}; ^{1}H NMR δ: 8.22 (1H, d, *J* = 8.2 Hz), 8.08 (2H, d, *J* = 8.0 Hz), 7.90 (1H, dd, *J* = 8.4, 0.8 Hz), 7.77 (1H, s), 7.70 (1H, td, *J* = 8.2, 1.2 Hz), 7.45–7.41 (3H, m), 7.35–7.30 (4H, m), 2.47 (3H, s), 2.42 (3H, s); ^{13}C NMR δ: 19.8, 20.1, 119.2, 124.9, 125.5, 125.6, 125.9, 128.6, 129.1 (3C), 129.3 (3C), 129.7, 130.0, 135.4, 136.9, 138.0, 138.1, 148.4, 149.0, 156.8; HRMS (ESI): Calcd for $C_{23}H_{20}N$ 310.1596 (M+H) found 310.1582.

2-(4-Methoxyphenyl)-4-(p-tolyl)quinoline (**2d**): Pale yellow solid; m.p. 108–109 °C (lit.[25] 108 °C); ^{1}H NMR δ: 8.21 (1H, d, *J* = 8.6 Hz), 8.14 (2H, d, *J* = 8.8 Hz), 7.88 (1H, dd, *J* = 8.4, 0.8 Hz), 7.74 (1H, s),

Table 2 Nickel(II)-catalysed cross-coupling between 4-chloro-2-arylquinolines and aryl magnesium halides

Entry **1**	Quinoline 2-substituent (R)	Arylmagnesium halide (Ar)	Product **2**	Time /h	Yield/%[a]
1a	Phenyl	*p*-Tolyl	**2a**	1	81
1b	Phenyl	Phenyl	**2b**	1	77
1c	*p*-Tolyl	*p*-Tolyl	**2c**	0.5	85
1d	4-Methoxyphenyl	*p*-Tolyl	**2d**	0.5	93
1e	3,4-Dimethylphenyl	*p*-Tolyl	**2e**	0.5	88
1f	3,4-Dimethoxyphenyl	*p*-Tolyl	**2f**	0.5	95
1g	4-Chlorophenyl	*p*-Tolyl	**2g**	1	50[b]
1h	2-Furyl	Phenyl	**2h**	1	65
1i	2-Thiophenyl	*p*-Tolyl	**2i**	1	70
1j	*p*-Tolyl	1-Naphthyl	**2j**	0.5	80
1k	Phenyl	3,4,5-Trifluorophenyl	**2k**	1	42
1l	Phenyl	1-Thiophenyl	**2l**	1	Trace
1m	4-Nitrophenyl	*p*-Tolyl	**2m**	1	None

[a]Isolated yields based on heteroaryl chloride.
[b]Ratio of **1g** : *p*-tolylMgCl = 1 : 2.5

7.69 (1H, td, *J* = 8.4, 1.2 Hz), 7.46–7.39 (3H, m), 7.34 (2H, d, *J* = 8.0 Hz), 7.03 (2H, d, *J* = 8.6 Hz), 3.88 (3H, s), 2.48 (3H, s); ^{13}C NMR δ: 21.4, 55.4, 114.1, 118.8, 125.5, 125.6, 125.8, 128.8, 129.1, 129.3, 129.6, 129.8, 131.9, 135.3, 138.2, 148.4, 149.0, 156.2, 160.6; MS (EI): *m/z* (%) = 325 (M^+, 100), 310 (41), 281 (22).

2-(3,4-Dimethylphenyl)-4-(p-tolyl)quinoline (**2e**): Pale yellow solid; m.p. 115–116 °C; IR: ν_{max} 2917, 1589, 1543, 1494, 823, 761 cm^{-1}; ^{1}H NMR δ: 8.23 (1H, d, *J* = 8.4 Hz), 7.98 (1H, s), 7.88 (2H, t, *J* = 8.4 Hz), 7.77 (1H, s), 7.69(1H, td, *J* = 8.4, 1.2 Hz), 7.48–7.39 (3H, m), 7.34 (2H, d, *J* = 7.6 Hz), 7.25 (1H, t, *J* = 7.6 Hz), 2.47 (3H, s), 2.38 (3H, s), 2.33 (3H, s); ^{13}C NMR δ: 19.8, 20.1, 21.4, 29.8, 119.2, 124.9, 125.5, 125.6, 125.9, 128.6, 129.1 (2C), 129.3 (3C), 129.7, 130.0, 135.3, 136.9, 138.0, 138.1, 148.4, 149.0, 156.8; HRMS (ESI): Calcd for $C_{24}H_{22}N$ 324.1752 (M+H) found 324.1740.

2-(3,4-Dimethoxyphenyl)-4-(p-tolyl)quinoline (**2f**): Pale yellow solid; m.p. 120–121 °C; IR: ν_{max} 2930, 1590, 1517, 1498, 1263, 1024, 765 cm^{-1}; ^{1}H NMR δ: 8.22 (1H, d, *J* = 8.4 Hz), 7.88 (2H, m), 7.75 (1H, s), 7.73–7.65 (2H, m), 7.46–7.41 (3H, m), 7.35 (2H, d, *J* = 8.0 Hz), 6.97 (1H, d, *J* = 8.4 Hz), 4.04 (3H, s), 3.95 (3H, s), 2.48 (3H, s); ^{13}C NMR δ: 21.4, 56.0, 56.1, 110.3, 110.9, 118.8, 120.2, 125.5, 125.8, 129.1 (2C), 129.3 (2C), 129.5, 129.6, 132.2, 135.3, 136.5, 138.2, 148.4, 149.0, 149.1, 150.1, 156.1; HRMS(ESI): Calcd for $C_{24}H_{22}NO_2$ 356.1651 (M+H) found 356.1644.

2-(4-Chlorophenyl)-4-(p-tolyl)quinoline (**2g**): white solid; m.p. 91–92 °C; IR: ν_{max} 2917, 1592, 1491, 1091, 814, 756 cm^{-1}; ^{1}H NMR δ: 8.19 (1H, dd, *J* = 8.4, 0.4 Hz), 8.13–8.07 (2H, m), 7.89 (1H, dd, *J* = 8.4, 0.8 Hz), 7.72 (1H, s), 7.69 (1H, td, *J* = 8.4, 1.6 Hz), 7.47–7.38 (5H, m), 7.32 (2H, d, *J* = 8.0 Hz), 2.46 (3H, s); ^{13}C NMR δ: 30.1, 119.1, 125.9, 126.1, 126.6, 129.0 (2C), 129.2 (2C), 129.5 (2C), 129.6 (2C), 129.8, 130.2, 135.4, 135.7, 138.2, 138.6, 148.9, 149.6, 155.6; HRMS (ESI): Calcd for $C_{22}H_{17}{}^{35}ClN$ 330.1050 (M+H) found 330.1033.

2-(Furan-2-yl)-4-phenylquinoline (**2h**): White solid; m.p. 91–92 °C (lit.[26] 90–92 °C); ^{1}H NMR δ: 8.19 (1H, d, *J* = 8.4 Hz), 7.84 (1H, dd, *J* = 8.4, 1.2 Hz), 7.76 (1H, s), 7.69 (1H, ddd, *J* = 8.4, 6.8, 1.2 Hz), 7.60 (1H, dd, *J* = 1.6, 0.8 Hz), 7.56–7.46 (6H, m), 7.43 (1H, td, *J* = 8.4, 1.2 Hz), 6.57 (1H, dd, *J* = 3.6, 2.0 Hz); ^{13}C NMR δ: 110.5, 112.2, 115.3, 117.6, 120.2, 125.6, 126.2, 128.4, 128.5 (2C), 129.3 (3C), 129.4, 129.7, 137.8, 144.1, 148.2, 149.2; MS (EI): *m/z* (%) = 271 (M^+, 23), 195 (13), 183 (100), 77 (75).

2-(Thiophen-2-yl)-4-(p-tolyl)quinoline (**2i**): White solid; m.p. 95–96 °C; IR: ν_{max} 2923, 1592, 1547, 1498, 1428, 1082, 821 cm^{-1}; ^{1}H NMR δ: 8.13 (1H, d, *J* = 8.4 Hz), 7.84 (1H, d, *J* = 8.4 Hz), 7.77–7.59 (3H, m), 7.57–7.28 (5H, m), 7.13 (1H, dd, *J* = 4.8, 3.6 Hz), 2.47 (3H, s); ^{13}C NMR δ: 21.1, 117.5, 125.3, 125.4, 125.6, 127.6, 128.0, 128.3, 128.9 (2C), 129.0 (2C), 129.1, 129.2, 134.8, 137.9, 145.0, 148.2, 148.7, 151.4. HRMS (ESI): Calcd for $C_{20}H_{16}NS$ 302.1003 $(M+H)^+$ found 302.1004.

4-(Naphthalen-1-yl)-2-(p-tolyl)quinoline (**2j**): White solid; m.p. 135–136 °C; IR: ν_{max} 2919, 1594, 1542, 782, 767 cm^{-1}; ^{1}H NMR δ: 8.33 (1H, s), 8.11 (2H, d, *J* = 8.0 Hz), 7.98 (2H, dd, *J* =15.6, 8.0 Hz), 7.90 (1H, s), 7.71 (1H, t, *J* = 7.6 Hz), 7.62 (1H, t, *J* = 7.2 Hz), 7.54–7.46 (2H, m), 7.45–7.37 (2H, m), 7.33–7.26(4H, m), 2.43 (3H, s); ^{13}C NMR δ: 21.5, 120.3, 125.2, 125.9, 126.0 (2C), 126.1, 126.4, 126.8, 127.3, 127.4 (2C), 128.2, 128.6, 129.5 (4C), 129.6, 131.8, 133.3, 135.8, 136.2, 139.5, 147.9, 156.5; HRMS (ESI): Calcd for $C_{26}H_{20}N$ 346.1596 $(M+H)^+$ found 346.1596.

2-Phenyl-4-(3,4,5-trifluorophenyl)quinoline (**2k**): Pale yellow solid; m.p. 146–147 °C; IR: ν_{max} 3060, 1527, 1405, 1043, 772 cm^{-1}; ^{1}H NMR δ: 8.29 (1H, s), 8.17 (2H, d, *J* = 7.2 Hz), 7.83–7.71 (3H, m), 7.58–7.42 (4H, m), 7.23–7.15 (2H, m); ^{13}C NMR δ: 114.1 (*J* = 6.0 Hz), 114.2 (*J* = 6.0 Hz), 119.4, 124.9, 125.1, 127.2, 127.7 (2C), 129.1 (2C), 129.9, 130.2, 130.5, 134.4 (*J* = 6.0 Hz), 139.2 (*J* = 35 Hz), 141.5 (*J* = 35 Hz), 146.1, 148.8, 150.1 (*J* = 6.0 Hz), 152.6 (*J* = 6.0 Hz), 156.9; HRMS (ESI): Calcd for $C_{21}H_{13}F_3N$ 336.1000 $(M+H)^+$ found 336.0990.

9-(p-Tolyl)-1,2,3,4-tetrahydroacridine (**2n**): Yellow solid; m.p. 135–136 °C (lit.[27] 145–146 °C); ^{1}H NMR δ: 8.01 (1H, d, *J* = 8.4 Hz), 7.62–7.55 (1H, m), 7.36–7.26 (4H, m), 7.10 (2H, d, *J* = 8.0 Hz), 3.20 (2H, t, *J* = 6.6 Hz), 2.61 (2 H, t, *J* = 6.4 Hz), 2.46 (3H, s), 2.00–1.92 (2H, m), 1.79 (2H, m). ^{13}C NMR δ: 21.2, 22.7, 22.9, 27.9, 33.9, 125.0, 125.5, 126.5, 127.7, 128.0, 128.2, 128.6 (2C), 128.9 (2C), 133.6, 137.1, 145.5, 146.6, 158.5; MS (ESI): *m/z* = 274.4 $(M+1)^+$.

We are grateful to the National Natural Science Foundation of China (No. 20876147) for financial support.

Received 16 February 2011; 31 March 2011
Paper 1100576 doi: 10.3184/174751911X13026226423986
Published online: 3 May 2011

References

1 M.E. Doyle and J.M. Egan, *Pharmacol. Rev.*, 2003, **55**, 105.
2 R. Benigni, *Chem. Rev.*, 2005, **105**, 1767.
3 J.P. Michael, *Nat. Prod. Rep.*, 2005, **22**, 627.
4 R.G. Ridley, *Nature,* 2002, **415**, 686.
5 P.L. Olliaro and W.R.J. Taylor, *J. Exp. Biol.*, 2003, **206**, 3753.
6 R. Klingenstein, P. Melnyk, S.R. Leliveld, A. Rycke-Busch and C. Korth, *J. Med. Chem.*, 2006, **49**, 5300.
7 B. Lal, N.B. Bhise, R.M. Gidwani, A.D. Lakdawala, K. Joshi and S. Parvardhan, *ARKIVOC,* 2005, **ii**, 77.
8 Y.L. Chen, Y.L. Zhao, C.M. Lu, C.C. Tzeng and J.P. Wang, *Bioorg. Med. Chem.*, 2006, **14**, 4373.
9 M. Ishiwara, Y. Aoki, H. Takagaki, M. Ui and F. Okajima, *J. Pharmacol. Exp. Ther.*, 2003, **307**, 583.
10 P. Benedetti, R. Mannhold, G. Cruciani and G. Ottaviani, *Bioorg. Med. Chem.*, 2004, **12**, 3607.
11 P.C. Appelbaum and M.R. Jacobs, *Curr. Opin. Microbiol.*, 2005, **8**, 510.
12 P. Narender, U. Srinivas, M. Ravinder, B.A. Rao, C. Ramesh, K. Harakishore, B. Gan-gadasu, U.S.N. Murthy and V.J. Rao, *Bioorg. Med. Chem.*, 2006, **14**, 4600.
13 T. Staalhandske and T. Kalland, *Immunopharmacology*, 1986, **11**, 87.
14 T.H. Thatcher, I. Luzina, R. Fishelevich, M.A. Tomai, R.L. Miller and A.A. Gaspari, *J. Invest. Dermatol.*, 2006, **126**, 821.
15 V. Bonnet, F. Mongin and F. Trecourt, *Tetrahedron*, 2002, **58**, 4429.
16 J. Quintin, X. Franck and R. Hocquemiller, *Tetrahedron Lett.*, 2002, **43**, 3547.
17 A. Furstner, A. Leitner and M. Mendze, *J. Am. Chem. Soc.*, 2002, **124**, 13856.
18 T.J. Korn, M.A. Schade and M.N. Cheemala, *Synthesis*, 2006, **21**, 3547.
19 T.J. Korn, G. Cahiez and P. Knochel, *Synlett,* 2003, **12**, 1892.
20 M. Rueping and W. Ieawsuwan, *Synlett*, 2007, **2**, 0247.
21 D.F. Aycock, *Org. Process Res. Dev.*, 2007, 11, 156.
22 K.H. Kumar and P.T. Perumal, *J. Heterocyclic Chem.,* 2008, **45**, 597.
23 R. Martinez, D.J. Ramon and M. Yus, *Eur. J. Org. Chem.*, 2007, 1599.
24 M. Shingo, I. Kunio and K. Isao, *Nippon Kagaku Kaishi*, 1979, **11**, 1514.
25 J. Horn, S.P. Marsden and A. Nelson, *Org. Lett.*, 2008, **10**, 4117.
26 R.S. Hou, J.L. Wu and H.T. Cheng, *J. Chi. Chem. Soc.*, 2008, **55**, 915–918.
27 Y.K. Agrawal and H.M. Joshipura, *Indian J. Chem.*, 2005, **44B**, 1649.