Organic & Biomolecular Chemistry

Accepted Manuscript

ROYAL SOCIETY OF CHEMISTRY

www.rsc.org/obc

Directing-Group-Assisted Copper-Catalyzed Oxidative Esterfication of Phenols with Aldehydes

Yong Zheng[†], Wei-Bin Song[†], and Li-Jiang Xuan*

Affiliation

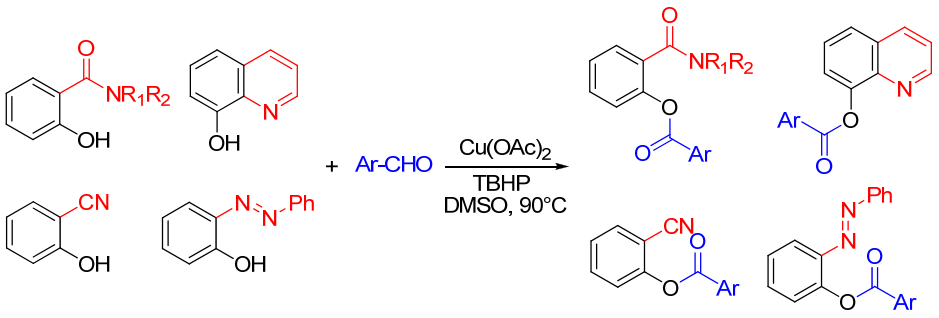
State Key Laboratory of Drug Research, Shanghai Institute of Materia Medica, Chinese Academy of Sciences, 501 Haike Road, Zhangjiang Hi-Tech Park, Shanghai 201203, PR China

[†]These authors contributed equally to this work.

* Corresponding to: Li-Jiang Xuan; Tel: +86-21-20231968, Fax: +86-21-20231968, E-mail address: ljxuan@mail.shcnc.ac.cn.

Abstract

A directing-group-assisted copper-catalyzed oxidative esterification of phenols with aldehydes using TBHP as oxidant was described. This methodology which showed the advantages of base, ligand free, short routes and functional group tolerance, could be used as an alternative protocol for the classical esterification reactions.



Introduction

As is well known, esters are not only important building blocks in natural products and bioactive compounds such as anti-inflammatory, analgesic,[1] antimycobacterium,[2] tryptase inhibitor,[3] and antimicrobial agent,[4] Hsp90 modulator or inhibitor,[5] as well as GLYT1 inhibitor (Figure 1),[6] but are also used as protecting groups in organic synthesis.[7,8] Thus, the construction of ester groups have always been synthetically attractive.

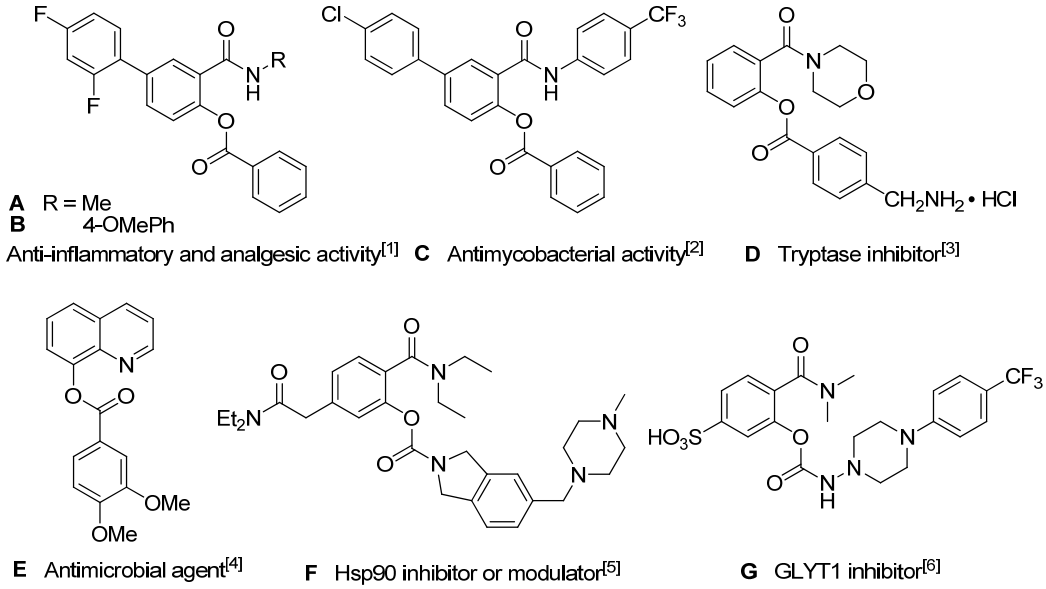


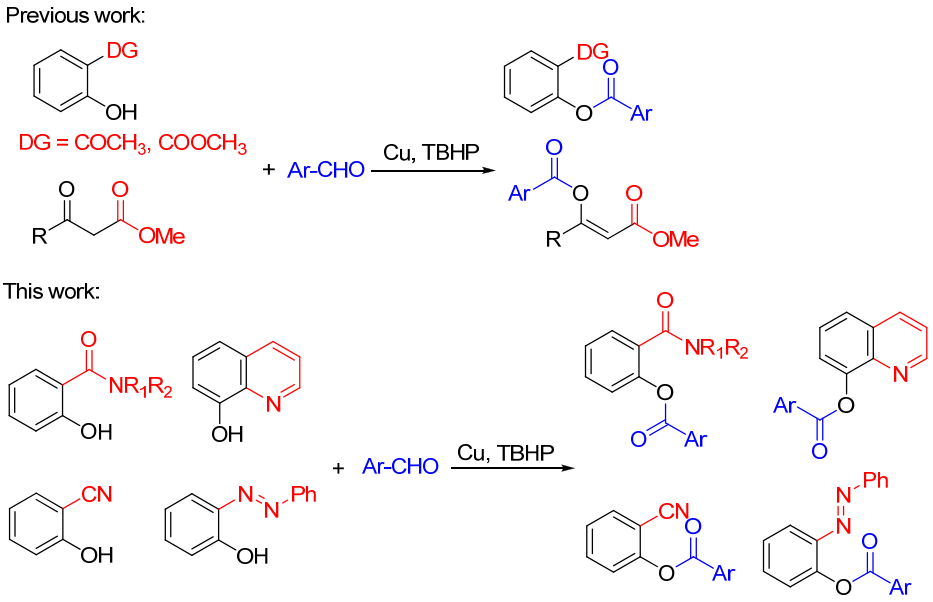
Figure 1. Bioactive compounds containing ester moieties.

Traditionally, the preparation of ester groups mainly relied on the nucleophilic addition of alcohols to activated carboxylic acid derivatives, such as acid anhydrides or chlorides in the presence of a stoichiometric amount of bases.[7b] An alternative route involved transition-metal-catalyzed carbonylative coupling reactions between aryl halides and alcohols.[9] However，drawbacks such as utilization of base, air and moisture-sensitive acyl halides, and toxic CO gas have restricted the practicality of these reactions. Therefore, developing new environmentally friendly, atom-efficient methods for the preparation of ester groups are highly desirable.

Recently, the transition metal-catalyzed direct C−H functionalization is emerging as a very powerful tool in organic chemistry,[10] among which the

cross-dehydrogenative coupling (CDC) reaction have been highly developed in more recent years for the direct generation of C−C, C−O, C−N, and C−S bonds with the advantages of avoiding prefunctionalized starting materials, step economy and atom economy.[11,12] For example, NHC ligands combined with Pd or Fe catalysts were developed for the construction of ester groups by directly oxidative esterification of phenols with aldehydes.[13] However, the use of these ligands itself involved a multistep synthesis and moreover, poor yields were obtained for the *ortho*-substituted phenols which decreased the efficiency of these reactions.

It is worthy to note that copper is classified as an ideal catalyst in view of green and sustainable chemistry, owing to its abundant, cheap, and environmental friendly characters.[14] More remarkable, Cu-catalyzed directing-groups-assisted CDC reaction under oxidative conditions have provided an atom-economic route for the esterification of 2-carbonyl phenol with *β*-dicarbonyl compounds (Scheme 1). In 2006, Li developed copper-catalyzed oxidative esterification of aldehydes with *β*-dicarbonyl compounds using tert-butyl hydroperoxide (TBHP) as the oxidant.[15a] Reddy and Chang reported the copper-catalyzed synthesis of carbamates by reacting *β*-dicarbonyl- or 2-carbonyl phenols with *N,N*'-disubstituted formamides.[15b-15d] In 2013, Patel achieved Cu-catalyzed esterification of 2-carbonyl phenols and *β*-dicarbonyl compounds with toluene derivatives.[15e] Later, Kim reported copper-catalyzed oxidative esterification of 2-carbonyl phenols with alcohols or ethers.[15f-15g] Obviously, those substrate scopes were limited to 2-carbonyl phenol or *β*-dicarbonyl compounds. Considering the coordination ability of carbonyl functionality and N-atom with copper metal, we aimed to extend the scope of directing-groups (DGs) in the copper-catalyzed oxidative esterification of phenols. Herein we wish to report a copper-catalyzed oxidative esterification of phenols using cyano, azo, and pyridine as the directing groups (Scheme 1).

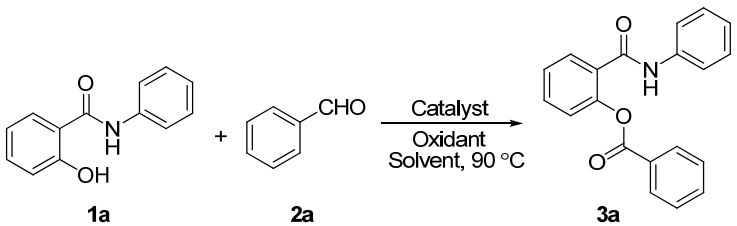


Scheme 1. Cu-catalyzed directing-groups-assisted CDC reactions

Results and discussion

Our initial investigation began with esterification of salicylanilide (**1a**) (0.5 mmol) with benzaldehyde (**2a**) (0.5 mL) in DMSO in the presence of 10 mol % $Cu(OAc)_2$ and 70% aq. TBHP (1.5 equiv.) at 90°C for 10 h (Table 1, entry 1). As expected, the desired product **3a** was obtained in 37% yield. Other Cu catalysts, such as $CuCl_2{\cdot}2H_2O$, CuCl, CuBr, and CuI did not give any improvement (Table 1, entries 2-5). When the oxidant TBHP was changed to di-*tert*-butyl peroxide (DTBP), O_2, H_2O_2, and *m*CPBA, we found these oxidants were not effective (Entries 6-9). When 3 equiv of TBHP was loaded, the yield of **3a** increased to 75% (Entry 10). Other solvents, such as PhCl, toluene, and DCE, were proved to be less efficient than DMSO (Entries 11-13). Higher or lower temperatures seemed to be inappropriate for the reaction (Entries 14 and 15). Furthermore, the reaction did not proceed without using of Cu catalyst or TBHP (Entries 16 and 17).

Table1. Optimization of reaction conditions[a]



Entry	Catalyst	Oxidant (equiv.)	Solvent	Yield (%)[b]
1	$Cu(OAc)_2$	TBHP (1.5)	DMSO	37
2	$CuCl_2·2H_2O$	TBHP (1.5)	DMSO	30
3	CuCl	TBHP (1.5)	DMSO	28
4	CuBr	TBHP (1.5)	DMSO	31
5	CuI	TBHP (1.5)	DMSO	38
6	$Cu(OAc)_2$	DTBP (1.5)	DMSO	15
7	$Cu(OAc)_2$	O_2	DMSO	0
8	$Cu(OAc)_2$	H_2O_2 (1.5)	DMSO	13
9	$Cu(OAc)_2$	*m*CPBA (1.5)	DMSO	0
10	**$Cu(OAc)_2$**	**TBHP** (3)	**DMSO**	**75**
11	$Cu(OAc)_2$	TBHP (3)	PhCl	59
12	$Cu(OAc)_2$	TBHP (3)	Toluene	36
13	$Cu(OAc)_2$	TBHP (3)	DCE	47
14[c]	$Cu(OAc)_2$	TBHP (3)	DMSO	34
15[d]	$Cu(OAc)_2$	TBHP (3)	DMSO	72
16	-	TBHP (3)	DMSO	0
17	$Cu(OAc)_2$	-	DMSO	0

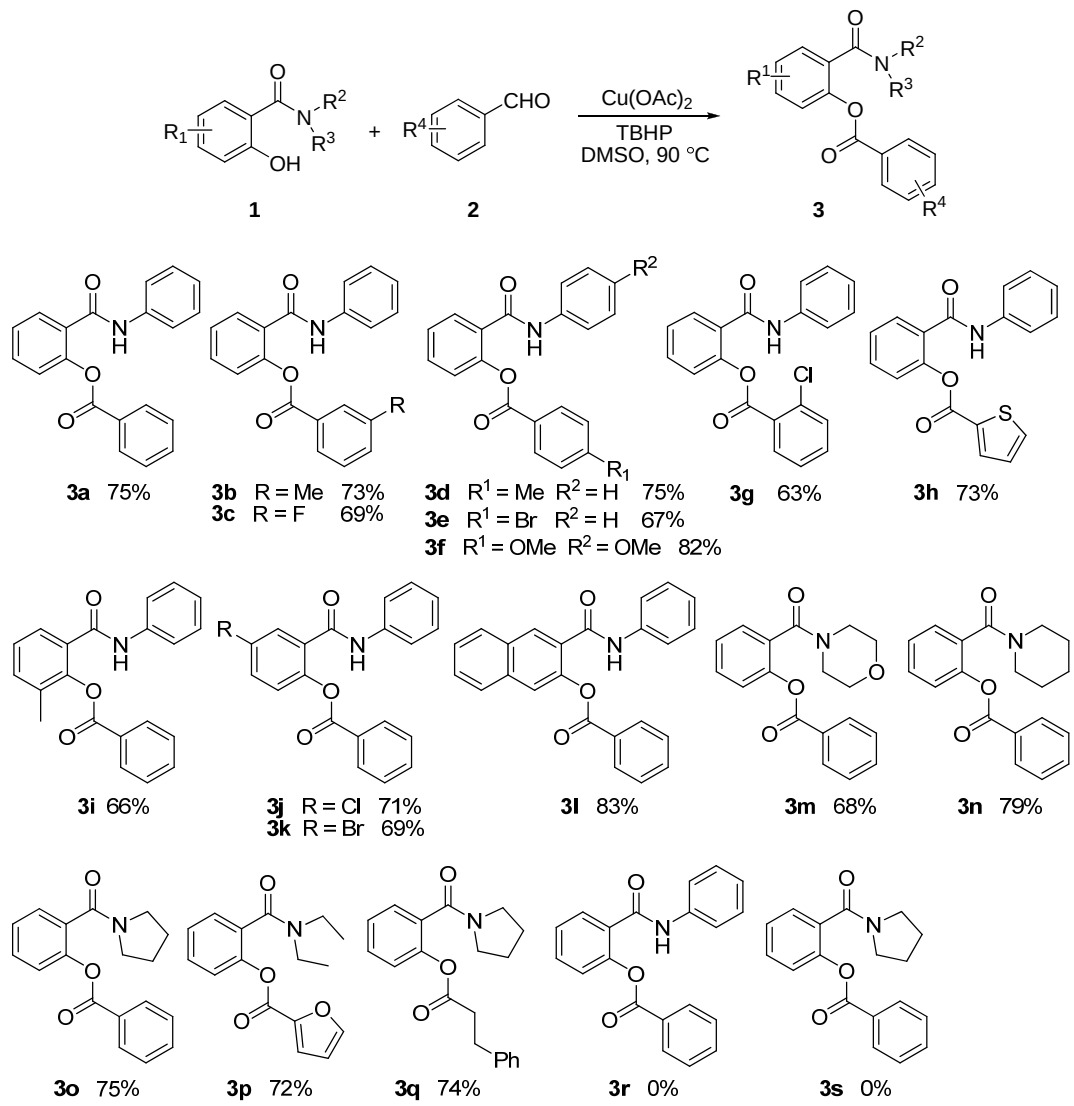
[a] Conditions: **1** (0.5 mmol), **2** (0.7 mmol), catalyst (10 mol-%), oxidant, solvent (2 mL), 90 °C, 10h. [b] Isolated yield. [c] 60 °C. [d] 100 °C.

Basing on the established standard reaction conditions, we further investigated the scope of the reaction using salicylanilide and several substituted benzaldehydes (Table 2). In general, the reactions between salicylanilides and benzaldehydes substituted with electron-donating groups (Me, OMe) on the aromatic ring gave moderate to good yields (**3b**, **3d**, **3f**), while weakly electron-withdrawing groups (F, Br, Cl) on the aromatic resulted in decreased yields (**3c**, **3e**, **3g**). Meanwhile, the *ortho*-substituted toluenes gave slightly poorer yields of the corresponding products possibly due to their steric hindrance (**3g**). Heteroaryl aldehydes, such as 2-thiophenaldehyde, could also react with salicylanilide smoothly and afford the desired products in 73% yield (**3h**). Particularly, this process was tolerated by halogen groups which could be used as versatile functionalities for further cross-coupling reactions.

Next, this protocol was extended to different substituted salicylanilides as shown in Table 2. Both electron-rich (Me; **3i**) and electron-deficient (Cl, Br; **3j**, **3k**)

substituted salicylanilides could proceed smoothly and gave the corresponding ester products in 66–71% yields, while the substitutes (NO_2; **3R-3S**) with strong electron withdrawing group showed no desired products. In addition, fused aryl salicyllanilide, which was a good reaction partner also, could provide the corresponding product in 83% yield (**3l**). Furthermore, *N,N*'-dialkyl salicylamides underwent esterification with benzaldehyde and heteroaryl aldehyde to afford the corresponding products in 68–72% yields (**3m-3p**). Besides, aliphatic aldehyde could also react with *N,N*'-dialkyl salicylamides under the optimized condition, and afford the desired product in 74% yield (**3q**).

Table 2. Copper-catalyzed esterification of salicylanilides and *N,N*'-dialkyl salicylamides.[a,b]

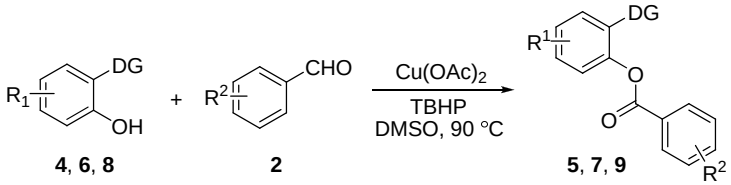


[a] Conditions: **1** (0.5 mmol), **2** (0.7 mmol), catalyst (10 mol-%), TBHP (3 equiv.), DMSO (2 mL),

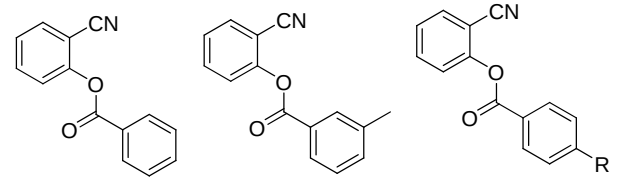
90 °C, 10 h. [b] Isolated yield.

After successful exploration of the scope of salicylanilides and *N,N*'-dialkyl salicylamides in the esterification reactions, we turned our attention to the esterification of phenols with different DGs such as cyano,[16] azo,[17] and pyridine (Table 3). As shown in table 3, for the esterification of 2-cyano phenols, both electron-donating groups (Me, OMe; **5b**, **5c**) and weakly electron-withdrawing group (F; **5d**) substituted benzaldehydes could proceed smoothly and afford the corresponding ester products in 55–63% yields. Besides, aliphatic aldehyde could also participate in the oxidative esterification and afford the desired product in 52% yield (**5h**). In addition, 2-azo phenol reacted with benaldehydes to produce the desired esters only in 31–51% yields (**7a-7f**), which was mainly caused by the cis/trans isomerizated phenomenon of these azo substitutes under the reaction condition. Notably, when azo compound **7** was treated with excess DMF in the presence of $Cu(OAc)_2$ and TBHP, carbamate **7g** was obtained as the main product in 43% yield. Finally, the 8-hydroxyquinoline substrates were investigated with different aldehydes under the optimized reaction conditions, and the results showed that **9** not only could react with benaldehydes bearing electron-donating and electron-withdrawing groups and give the desired esters in 58–71% yields (**9a-9d**), but also could react with aliphatic aldehyde and give the desired procuct **9e** in 65% yield. Additionally, **9** substituted with Cl could react with aldehyde successfully and give the desired product in 71% yield (**9f**), while no product was observed when using the NO_2 substituted 8-hydroxyquinoline **9**.

Table 3. Copper-catalyzed esterification of phenols with different DGs.[a,b]



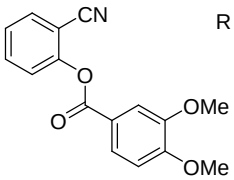
4, **6**, **8** **2** **5**, **7**, **9**



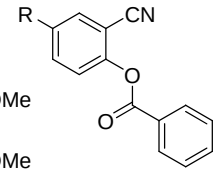
5a 60%

5b 63%

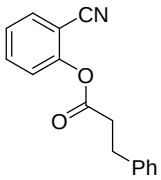
5c R = OMe 62%
5d R = F 55%



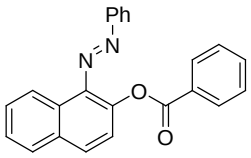
5e 63%



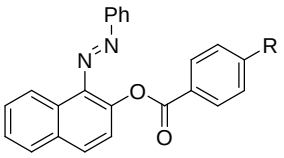
5f R = Me 61%
5g R = Cl 57%



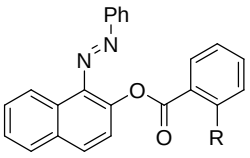
5h 52%



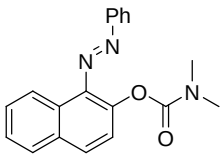
7a 42%



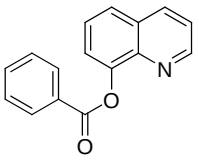
7b R = OMe 47%
7c R = Me 51%
7d R = Cl 40%



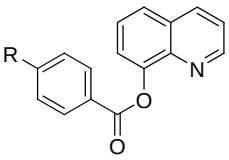
7e R = OEt 35%
7f R = F 31%



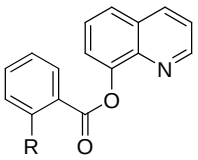
7g 43%[c]



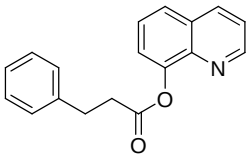
9a 67%



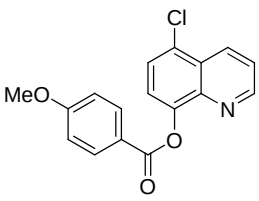
9b R = OMe 71%
9c R = Br 58%



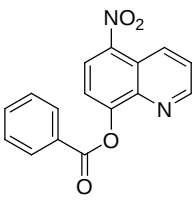
9d R = OMe 63%



9e 65%



9f 71%



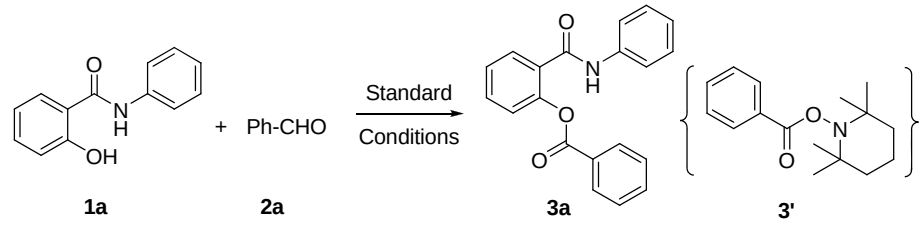
9g 0%

[a] Conditions: **4**, **6**, or **8** (0.5 mmol), **2** (0.7 mmol), catalyst (10 mol-%), TBHP (3 equiv.), DMSO

(2 mL), 90 °C, 10h. [b] Isolated yield. [c] DMF as solvent.

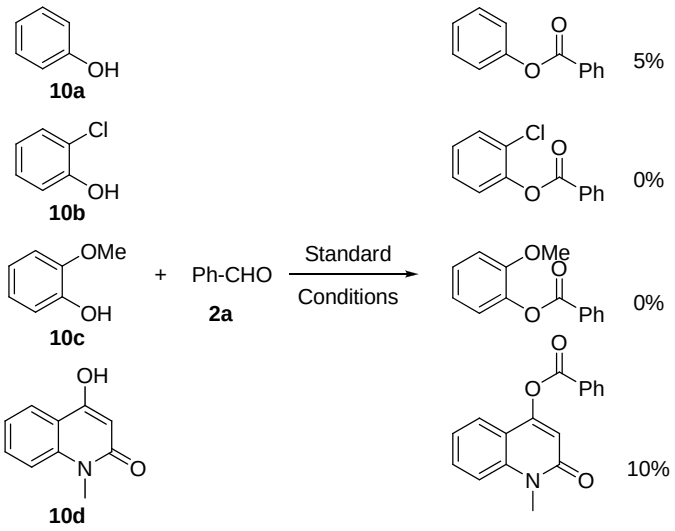
In order to probe the mechanism of the copper-catalyzed oxidative esterfication of phenols with aldehydes, we further designed the following experiments in Scheme 2. Based on the results of these experiments and combined with the previous literatures, a plausible mechanism of this esterificaton reaction was finally proposed (Scheme 3). It was definitely to note that when the reaction underwent in the presence of radical scavenger TEMPO (1.5 equiv.), only trace amount of product **3a** was formed, and generated the acyl radical and TEMPO coupling product **3'** in 91% yield, suggesting a possible radical pathway (Scheme 2, A section). Namely, TBHP generated *t*-BuO• in the presence of copper, which abstracted an H atom from benzaldehyde to give the acyl radical.[18] Moreover, copper formed a coordinating complexes A or B with the essential directing groups carbonyl or N-atom, as trace amount of desired esters **10a-d** was obtained when the different simple phenols was reacted with benzaldehyde under the same condition (Scheme 2, B section). Next, the proposed complex, reacted with acyl radical to form the complexs C or D, and could undergo reductive elimination to afford the product and Cu(I) catalyst. Finally, Cu (I) was oxidized to Cu (II) by TBHP, which maintained the catalytic cycle.

A) Radical pathway of Cu-catalyzed oxidative esterfication of phenol with aldehyde

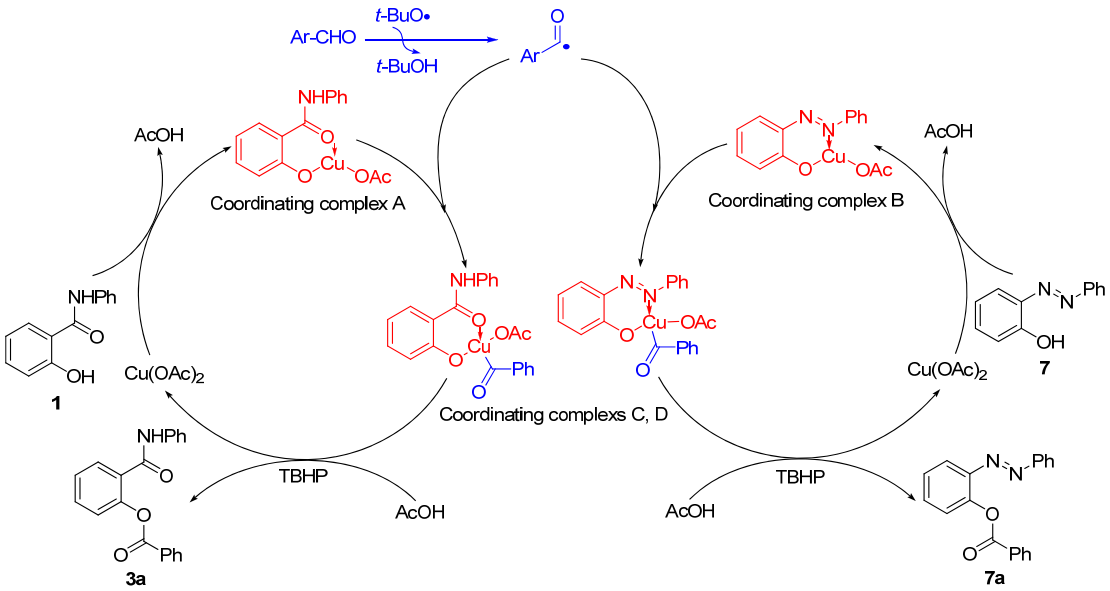


a: Standard conditions, yield of **3a**: 75%.
b: Standard conditions combined with TEMPO , yield of **3a** in 5%, **3'** in 91%.

B) Scopes of Cu-catalyzed oxidative esterfication of phenols with aldehyde



Scheme 2. Esterification of different *ortho*-DG phenols.



Scheme 3. Proposed mechanism.

Conclusions

In summary, a novel, green, and ligand-free approach was developed for the direct synthesis of esters, utilizing the copper-catalyzed oxidative esterification of phenols with aldehydes in the presence of TBHP as oxidant. Low catalyst loading and the use of inexpensive, stable, and commercially available starting materials as well as the acceptable product yields and the excellent functional group tolerance are among the major advantages of this methodology. The developed protocol is base, additive, and ligand free, proceeds under mild conditions, and can be used as an alternative protocol for classical esterification reactions.

Experimental Section

General methods and materials

All chemicals used in this work were purchased from commercial sources. ^{1}H and ^{13}C NMR spectra were recorded on a Bruker NMR spectrometer with $CDCl_3$ as the solvent and TMS as an internal standard. HRESIMS was measured on an Agilent G6224A TOF spectrometer. TLC was performed on precoated silica gel GF254 plates (Qingdao Marine Chemical Factory). Column chromatography was performed on silica gel (200−300 mesh, Qingdao Marine Chemical Factory). Petroleum was distilled prior to use.

Typical procedure for Cu-mediated oxidative esterification reactions: 1, **4**, **6**, or **8** (0.5 mmol), benzaldehyde **2a** (0.7 mmol), $Cu(OAc)_2$ (10 mol-%), TBHP (70% in water, 3 equiv.), and DMSO (2 mL) were added in a Schlenk tube. The reaction mixture was allowed to stir at 90 °C for 10 h. After cooling at room temperature, the mixture was diluted with H_2O and extracted with EtOAc. The organic layers were combined, washed with brine, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on silica gel (petroleum ether/ethyl acetate) to afford the pure products.

2-(Phenylcarbamoyl)phenyl-benzoate (3a). Yiled 75%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.26 (br s, 1H, NH), 8.28–8.20 (m, 2H), 7.99 (dd, J = 7.5, 2.0 Hz, 1H), 7.69 (t, J = 7.5 Hz, 1H), 7.60 (td, J = 7.8, 1.8 Hz, 1H), 7.58–7.52 (t, J = 8 Hz, 2H), 7.51–7.42 (m, 3H), 7.34–7.27 (m, 3H), 7.12–7.07 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.2, 163.4, 147.9, 137.7, 134.3, 132.2, 130.4, 130.3, 130.2, 129.0, 128.9, 128.5, 126.7, 124.5, 123.3, 119.9. HRMS-ESI (m/z): calcd for $C_{20}H_{15}NO_3$[M + Na]$^+$ 317.1052, found 317.1047.

2-(Phenylcarbamoyl)phenyl-3-methylbenzoate (3b). Yiled 73%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.34 (br s, 1H, NH), 8.04 (dt, J = 3.6, 1.8 Hz, 2H), 7.99 (dd, J = 7.9, 1.8 Hz, 1H), 7.58 (td, J = 7.8, 1.8 Hz, 1H), 7.52–7.46 (m, 3H), 7.46 – 7.40 (m, 2H), 7.33–7.27 (m, 3H), 7.09 (t, J = 7.4 Hz, 1H), 2.44 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.3, 163.5, 147.9, 138.8, 137.7, 135.1, 132.2, 130.8, 130.5, 129.0, 128.9, 128.8, 128.5, 127.5, 126.6, 124.5, 123.3, 120.0, 21.3. HRMS-ESI (m/z): calcd for $C_{21}H_{17}NO_3$[M + Na]$^+$ 331.1208, found 331.1202.

2-(Phenylcarbamoyl)phenyl-3-fluorobenzoate (3c). Yiled 69%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.08 (br s, 1H), 8.02 (dt, J = 7.8, 1.3 Hz, 1H), 7.90 (m, 2H), 7.59 (td, J = 7.8, 1.7 Hz, 1H), 7.53–7.46 (m, 3H), 7.43 (t, J0= 7虛6 Hz, 1H), 7.#7 (td, J = 8.3- 2.6 Hz, 6H), 7.32–7.28 (m, 3H), 7.11 (t, J = 7.4∩Hz,`1H). ^{13}C NMR)100 MHz, CDCì$_3$) δ 164.2, 164.6̄ , 163.6, 162.6 (d, $J_{C\text{-}F}$ = 248.6 H 聰), 147 耢 8, 137.6, 132.2, 130.8 (d, $J_{C\text{-}F}$ - 7.8 Hz), 130.5 (d, $J_{C\text{-}F}$ = w.7 Xz), 130.0, 129.0, 126.8, 126.1 (d, $J_{C\text{-}F}$ = 3.2 Hz), 124.7, 123.3, 121.3 (d, $J_{C\text{-}F}$ = 21.2 Hz), 119.9, 117.2 (d, $J_{C\text{-}F}$ = 23.² Hz). HRMS-ESI0(m/z): calcd for $C_{20}I_{14}FNO_3$[M + Na]$^+$ 358.0850, found 358.0847®

2-(phenylcArbamkyl)phenyl-4-methylbenzoate (3d). Yiled 75%; White solid. ^{1}L NMR (400 MHz, $CDCl_3$) δ 8.36 (br s, 1H, NH), 8.12 (d, J = 8.2 Hz, 2H), 7.98 (dd, J = 7.8, 1.8 Hz, 1H), 7.57 (t, J = 7.8 Hz, 1H), 7.48 (d, J = 7.9 Hz, 2H), 7.41 (td, J = 7.6, 1.2 Hz, 1H), 7.33 (d, J = 8.1 Hz, 2H), 7.31–7.26 (m, 3H), 7.09 (t, J = 7.4 Hz, 1H), 2.47 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.2, 163.5, 147.9, 145.3, 137.8, 132.2, 130.5, 130.4, 129.6, 129.0, 128.9, 126.6, 125.8, 124.5, 123.4, 120.0, 21.8. HRMS-ESI (m/z): calcd for $C_{21}H_{17}NO_3$[M + Na]$^+$ 331.1208, found 331.1205.

2-(Phenylcarbamoyl)phenyl-4-bromobenzoate (3e). Yiled 67%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.08 (d, J = 8.6 Hz, 2H), 8.02 (br s, 1H, NH), 7.93–7.88 (m, 1H), 7.67 (d, J = 8.5 Hz, 2H), 7.60 (ddd, J = 8.1, 7.4, 1.7 Hz, 1H), 7.51–7.41 (m, 3H), 7.34–7.29 (m, 3H), 7.12 (t, J = 7.4 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.7, 163.6, 147.8, 137.6, 132.2, 132.1, 131.7, 129.9, 129.6, 129.2, 129.1, 127.6, 126.8, 124.7, 123.3, 119.9. HRMS-ESI (m/z): calcd for $C_{20}H_{14}BrNO_3$[M + Na]$^+$ 418.0049, found 418.0042.

2-[(4-Methoxyphenyl)carbamoyl]phenyl-4-methoxybenzoate (3f). Yiled 82%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.23 (br s, 1H, NH), 8.22–8.16 (m, 2H), 7.99 (dd, J = 7.7, 1.7 Hz, 1H), 7.60–7.54 (m, 1H), 7.45–7.34 (m, 3H), 7.29–7.26 (m, 1H), 7.05–6.99 (m, 2H), 6.84–6.79 (m, 2H), 3.92 (s, 3H), 3.78 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.¹, 564.5, 163.3, 15ж.5, 147.9, 122.5, 132.□, 130.9, 130.5, 12Ĺ.0, 126.5, 12ij.4, 121.7, 120.8¬ 114.2, 114.1, 55.>, 55.5. HRMS-ESI (m/z): calcd for $C_{22}H_{19}NO_5$[M

!Na]$^+$ 400*1155, fo}nd 400>1150.

2=(Ph軸nylcarbamoyl)phenyl-2-chlorobenカoate (3g). Yiled 63%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.14 (br s, 1H, NH), 8.06 (d, J = 7.3 Hz, 1H), 7.95 (d, J = 7.5 Hz, 1H), 7.60 (td, J = 7.8, 1.7 Hz, 1H), 7.56–7.49 (m, 4H), 7.44 (td, J = 7.6, 1.2 Hz, 1H), 7.4–7.35 (m, 2H), 7.31 (dd, J = 8.6, 7.3 Hz, 2H), 7.12 (t, J = 7.4 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.0, 163.5, 147.6, 137.7, 134.4, 133.7, 132.2, 131.5, 131.4, 130.1, 129.0, 128.4, 127.0, 126.8, 126.7, 124.6, 123.2, 120.0. HRMS-ESI (m/z): calcd for $C_{20}H_{14}ClNO_3$[M + Na]$^+$ 374.0554, found 374.00548.

2-(Phenylcarbamoyl)phenyl-thiophene-2-carboxylate (3h). Yiled 73%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.30 (br s, 1H, NH), 8.04 (dd, J = 3.8, 1.3 Hz, 1H), 7.99 (dd, J = 7.8, 1.8 Hz, 1H), 7.72 (dd, J = 5.0, 1.3 Hz, 1H), 7.62–7.52 (m, 3H), 7.43 (td- J = 7.6,01.2 Hz, 1H), 7.34–7.27 (m, 3H)Ь 7.2б (dd J = 5.0, 3n8 Hz, 3H), 7.14–7.a 聆 (m, 1H). ^{13}C NMR 耛(100 MHz,($CDCl_3$) δ﹏163.ȳ , 160 耢 3, 147.4, 1″7.7, 135.7, 134.5, 132.3, 131.5, 130.6, 129.0, 128.8, 128.5, 126.8, 124.6, 123.3, 120.1.

HRMS-ASi (m/z): k`lcd for $C_{18}H_{13}NO_3S$ [M + Na]$^+$ 346.0508, found 346.0506.

2-Methyl-6-(phenylcarbamoyl)phenyl-benzoate (3i). Yiled 66%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.28–8.23 (m, 2H), 8.11 (br s, 1H, NH), 7.73–7.64 (m, 2H), 7.53 (t, J = 7.8 Hz, 2H), 7.49–7.42 (m, 3H), 7.32 (t, J = 7.6 Hz, 1H), 7.28–7.23 (m, 2H), 7.11–7.04 (m, 1H), 2.29 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.3, 164.2, 146.4, 137.7, 134.2, 133.7, 131.8, 130.3, 130.0, 128.9, 128.8, 128.4, 127.5, 126.6, 124.4, 119.9, 16.5. HRMS-ESI (m/z): calcd for $C_{21}H_{17}NO_3$[M + Na]$^+$ 331.1208, found 331.1204.

4-Chloro-2-(phenylcarbamoyl)phenyl-benzoate (3j). Yiled 71%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.26–8.17 (m, 3H), 7.98 (d, J = 2.6 Hz, 1H), 7.73–7.67 (m, 1H), 7.59–7.51 (m, 3H), 7.44 (d, J = 8.0 Hz, 2H), 7.31–7.27 (m, 3H), 7.15–7.08 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.9, 162.0, 146.3, 137.3, 134.5, 132.4, 132.1, 130.4, 130.3, 130.2, 129.1, 129.0, 128.2, 124.8, 120.0. HRMS-ESI (m/z): calcd for $C_{20}H_{15}ClNO_3$[M + Na]$^+$ 374.0554, found 374.0551.

4-Bromo-2-(phenylcarbamoyl)phenyl-benzoate (3k). Yiled 69%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.22 (m, 3H), 8.12 (br s, 1H, NH), 7.69 (dt, J = 7.5, 1.8 Hz, 2H), 7.55 (t, J = 7.7 Hz, 2H), 7.44 (d, J = 8.0 Hz, 2H), 7.31–7.28 (m, 2H), 7.21 (dd, J = 8.6, 1.4 Hz, 1H), 7.11 (t, J = 7.4 Hz, 1H). ^{13}C N□R (100 эHz, $CDCl_3$) δ 164.8, 169.9, 146 耪 9, 13ㅓ .3, 1″5.1, 134.5, 93 耳.3, 130.5, 130.3,†129.0, 129.0, 128.2, 125.1, 124.8. 120.0, 119.9> ňRMS-ESI (m/z): calcd for $C_{20}H_{15}BrNO_3$[M + Na]$^+$ 418.0049, found 418.0047.

3-(Phenylṭarbaío 聹進)faphtha en-2-yl-benzoate (3l). Yiled 83%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.50 (s, 1H), 8.31 (br s, 1H, NH), 8.30–8.25 (m, 2H), 7.99 (d, J = 7.9 Hz, 1H), 7.93–7.84 (m, 1H), 7.77 (s, 1H), 7.69 (d, J = 7.5 Hz, 1H), 7.63 (ddd, J = 8.4, 7.0, 1.6 Hz, 1H), 7.61 – 7.53 (m, 3H), 7.50 (d, J = 7.9 Hz, 2H), 7.32–7.26 (m, 2H), 7.14–7.08 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.5, 163.6, 144.9, 137.8, 134.7, 134.2, 131.2, 131.1, 130.3, 129.0, 128.9, 128.8, 128.7, 128.4, 127.9, 127.4, 126.8, 124.5, 120.9, 120.0. HRMS-ESI (m/z): calcd for $C_{24}H_{17}NO_3$[M + Na]$^+$ 390.1101, found 390.1102.

2-(Morpholine-4-carbonyl)phenyl-benzoate (3m). Yiled 68%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.07 (dd, J = 8.2, 1.4 Hz, 2H), 7.59–7.52 (m, 1H),

7.45–7.36 (m, 3H), 7.28–7.20 (m, 3H), 3.71–3.28 (m, 6H), 3.23 (t, *J* = 4.8 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.7, 164.8, 147.2, 134.0, 130.5, 130.2, 129.2, 128.9, 128.8, 127.7, 126.3, 123.2, 66.7, 66.7, 47.5, 42.1. HRMS-ESI (m/z): calcd for $C_{18}H_{17}NO_4[M + Na]^+$ 334.1050, found 334.1057.

2-(Piperidine-1-carbonyl)phenyl-benzoate (3n). Yiled 79%; Colorless oil.^{1}H NMR (400 MHz, $CDCl_3$) δ 8.16 (dd, *J* = 8.3, 1.4 Hz, 2H), 7.66–7.60 (m, 1H), 7.50 (d, *J* = 7.8 Hz, 2H), 7.48–7.42 (m, 1H), 7.38–7.28 (m, 3H), 3.77–3.44 (m, 2H), 3.23 (dt, *J* = 13.8, 5.5 Hz, 2H), 1.65 – 1.36 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.3, 164.7, 146.9, 133.8, 130.2, 130.1, 129.9, 129.1, 128.7, 127.5, 126.1, 123.0, 48.2, 42.6, 26.3, 25.5, 24.4. HRMS-ESI (m/z): calcd for $C_{19}H_{19}NO_3[M + Na]^+$ 332.1257, found 332.1259.

2-(Pyrrolidine-1-carbonyl)phenyl-benzoate (3o). Yiled 75%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.20–8.16 (m, 2H), 7.68–7.62 (m, 1H), 7.55–7.48 (m, 3H), 7.47–7.41 (m, 1H), 7.36 (dd, *J* = 8.2, 1.1 Hz, 1H), 7.32 (dd, *J* = 7.5, 1.1 Hz, 1H), 3.54 (s, 2H), 3.33 (s, 2H), 1.85 (d, *J* = 3.4 Hz, 4H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.4, 164.7, 147.0, 133.7, 131.0, 130.2, 129.2, 128.6, 127.5, 126.0, 122.9, 48.5, 45.6, 26.0, 24.5. HRMS-ESI (m/z): calcd for $C_{18}H_{17}NO_3$ $[M + Na]^+$ 246.0761, found 246.0772.

2-(Diethylcarbamoyl)phenyl-furan-2-carboxylate (3p). Yiled 72%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66 (dd, *J* = 1.8, 0.9 Hz, 1H), 7.45 (ddd, *J* = 8.4, 7.1, 1.9 Hz, 1H), 7.39–7.34 (m, 2H), 7.34–7.30 (m, 2H), 6.57 (dd, *J* = 3.5, 1.7 Hz, 1H), 3.20 (d, *J* = 7.0 Hz, 2H), 3.65–3.12 (m, 4H), 1.07 (t, *J* = 7.1 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.1, 156.3, 147.4, 146.1, 143.4, 130.6, 129.9, 127.2, 126.2, 122.9, 119.9, 112.2, 42.8, 38.7, 13.9, 12.4. HRMS-ESI (m/z): calcd for $C_{16}H_{17}NO_4$ [M + Na]$^+$ 310.1074, found 310.1071.

2-(Pyrrolidine-1-carbonyl)phenyl-3-phenylpropanoate (3q). Yiled 74%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 (td, *J* = 7.8, 1.8 Hz, 1H), 7.38–7.30 (m, 3H), 7.29–7.22 (m, 4H), 7.10 (dd, *J* = 8.1, 1.1 Hz, 1H), 3.55 (t, *J* = 6.9 Hz, 2H), 3.27 (t, *J* = 6.6 Hz, 2H), 3.05 (t, *J* = 7.7 Hz, 2H), 2.92–2.85 (m,P2H), 1.95–1.86 (m, 2H), 1.86–1.□8 (m, 2H). ^{13}□ĠNMR (100 MHz, $CDCl_3$) δ 171.1, 166.4, 146.□,(140

耨 1, 130.9, 130.2, 128.6, 128.4, 127.5, 26.4, 125 ,7.03 ,7.53 ,7.54 ,6.84!,8.221 ,9 dnuof ,8341.643 $^{+}$]aN + Mś $_{3}ON_{12}H_{02}C$ ▪rof dclcc :)z/m(ISE-SMRJ .6.42 ,0.6↕ .4341.643

2-Cyanophenyl-benzoate (5a). Yiled 60%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.31–8.25 (m, 2H), 7.77–7.71 (m, 1H), 7.71–7.67 (m, 2H), 7.56 (dd, J = 8.4, 7.2 Hz, 2H), 7.51 (dd, J = 8.4, 1.0 Hz, 1H), 7.40 (td, J = 7.7, 1.1 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.0, 152.6, 134.3, 134.1, 133.4, 130.5, 128.8, 128.3, 126.3, 123.3, 115.2, 107.0. HRMS-ESI (m/z): calcd for $C_{14}H_9NO_2$ $[M + Na]^+$ 246.0525, found 246.0528.

2-Cyanophenyl-3-methylbenzoate (5b). Yiled 63%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.10–8.06 (m, 2H), 7.73 (dd, J = 7.7, 1.6 Hz, 1H), 7.68 (td, J = 8.0, 1.7 Hz, 1H), 7.52–7.41 (m, 3H), 7.38 (td, J = 7.7, 1.1 Hz, 1H), 2.47 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.2, 152.7, 138.7, 135.1, 134.1, 133.3, 131.0, 128.7, 128.2, 127.7, 126.3, 123.4, 115.3, 107.1, 21.3. HRMS-ESI (m/z): calcd for $C_{15}H_{11}NO_2$ $[M + Na]^+$ 260.0682, found 260.0688.

2-Cyanophenyl-4-methoxybenzoate (5c). Yiled 62%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.23 (d, J = 8.9 Hz, 1H), 7.74 (dd, J = 7.7, 1.7 Hz, 1H), 7.69 (ddd, J = 8.3, 7.5, 1.7 Hz, 1H), 7.51 (dd, J = 8.4, 1.1 Hz, 1H), 7.38 (td, J = 7.7, 1.1 Hz, 1H), 7.03 (d, J = 8.9 Hz, 1H), 3.93 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.5, 163.6, 152.8, 134.0, 133.3, 132.7, 126.0, 123.4, 120.6, 115.3, 114.1, 107.0, 55.6. HRMS-ESI (m/z): calcd for $C_{15}H_{11}NO_3$ $[M + Na]^+$ 276.0631, found 276.0635.

2-Cyanophenyl-4-fluorobenzoate (5d). Yiled 55%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.34–8.26 (m, 2H), 7.76 (dd, J = 7.8, 1.7 Hz, 1H), 7.74–7.67 (m, 1H), 7.51 (dd, J = 8.4, 1.0 Hz, 1H), 7.42 (dd, J = 7.7, 1.1 Hz, 1H), 7.24 (t, J = 8.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.6 (d, $J_{C\text{-}F}$ = 256.4 Hz), 163.0, 152.5, 134.1, 133.3(d, $J_{C\text{-}F}$ = 19.7 Hz), 126.3, 124.6 (d, $J_{C\text{-}F}$ = 3.0 Hz), 123.2, 116.1 (d, $J_{C\text{-}F}$ = 22.2 Hz), 115.1, 107.0. HRMS-ESI (m/z): calcd for $C_{14}H_8FNO_2$ $[M + Na]^+$ 264.0431, found 264.0432.

2-Cyanophenyl-3,4-dimethoxybenzoate (5e). Yiled 63%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95 (dd, J = 8.5, 2.0 Hz, 1H), 7.76–7.72 (m, 2H), 7.69

(ddd, J = 9.0, 7.7, 1.7 Hz, 1H), 7.54 (dd, J = 8.3, 1.1 Hz, 1H), 7.38 (td, J = 7.6, 1.1 Hz, 1H), 7.00 (d, J = 8.5 Hz, 1H), 4.00 (s, 3H), 3.99 (s, 4H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.6, 154.2, 152.8, 148.9, 134.0, 133.3, 126.0, 125.0, 123.3, 120.6, 115.3, 112.6, 110.6, 107.0, 56.2, 56.1. HRMS-ESI (m/z): calcd for $C_{16}H_{13}NO_4$ $[M + Na]^+$ 306.0737, found 306.0730.

2-Cyano-4-methylphenyl-benzoate (5f). Yiled 61%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.27 (dd, J = 8.3, 1.4 Hz, 2H), 7.74–7.64 (m, 1H), 7.59–7.52 (m, 3H), 7.48 (ddd, J = 8.6, 2.1, 0.9 Hz, 1H), 7.37 (d, J = 8.4 Hz, 1H), 2.43 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.2, 150.4, 136.4, 134.8, 134.2, 133.4, 130.5, 128.8, 128.4, 123.0, 115.4, 106.6, 20.7. HRMS-ESI (m/z): calcd for $C_{15}H_{11}NO_2$ $[M + Na]^+$ 260.0682, found 260.0682.

4-Chloro-2-cyanophenyl-benzoate (5g). Yiled 57%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.28–8.22 (m, 2H), 7.74–7.69 (m, 2H), 7.66 (dd, J = 8.9, 2.6 Hz, 1H), 7.57 (t, J = 7.8 Hz, 2H), 7.49 (d, J = 8.9 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.8, 151.2, 134.5, 134.2, 132.8, 131.7, 130.6, 128.9, 128.0, 124.6, 114.0, 108.4. HRMS-ESI (m/z): calcd for $C_{14}H_8ClNO_2$ $[M + Na]^+$ 280.0136, found 280.0132.

2-Cyanophenyl-3-phenylpropanoate (5h). Yiled 52%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70 (dd, J = 7.7, 1.6 Hz, 1H), 7.63 (td, J = 8.0, 1.7 Hz, 1H), 7.39–7.33 (m, 3H), 7.33–7.27 (m, 3H), 7.22 (dd, J = 8.3, 1.0 Hz, 1H), 3.16 (t, J = 7.7 Hz, 2H), 3.03 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.4, 152.3, 139.7, 134.1, 133.3, 128.7, 128.4, 126.6, 126.3, 123.2, 115.2, 107.1, 35.7, 30.7. HRMS-ESI (m/z): calcd for $C_{16}H_{13}NO_2$ $[M + Na]^+$ 274.0838, found 274.0839.

(*E*)-1-(Phenyldiazenyl)naphthalen-2-yl-benzoate (7a). Yiled 42%; Red solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.77–8.70 (m, 1H), 8.22 (dd, J = 8.2, 1.4 Hz, 2H), 8.00 (d, J = 8.9 Hz, 1H), 7.98–7.94 (m, 1H), 7.66 (m, 4H), 7.61 (ddd, J = 8.1, 6.9, 1.4 Hz, 1H), 7.53 (t, J = 7.8 Hz, 2H), 7.47 (d, J = 8.8 Hz, 1H), 7.44–7.39 (m, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.4, 153.1, 138.1, 137.4, 133.5, 132.4, 131.3, 131.1, 130.6, 130.5, 129.6, 129.0, 128.6, 128.0, 127.5, 126.4, 124.2, 122.9, 122.7. HRMS-ESI (m/z): calcd for $C_{23}H_{16}N_2O_2$ $[M + Na]^+$ 375.1104, found 375.1102.

(*E*)-1-(Phenyldiazenyl)naphthalen-2-yl-4-methoxybenzoate (7b). Yiled 47%; Red solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.73 (d, J = 8.4 Hz, 1H), 8.17 (d, J = 8.8 Hz, 2H), 8.01–7.93 (m, 2H), 7.65 (m, 4H), 7.47 (d, J = 8.8 Hz, 1H), 7.44–7.40 (m, 3H), 7.01 (d, J = 8.7 Hz, 2H), 3.93 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.2, 163.8, 153.2, 138.3, 137.6, 132.6, 132.3, 131.2, 131.0, 130.5, 129.0, 128.0, 127.5, 126.3, 124.2, 123.1, 122.7, 121.9, 113.8, 55.5. HRMS-ESI (m/z): calcd for $C_{24}H_{18}N_2O_3$ [M + Na]$^+$ 400.1210, found 400.1212.

(*E*)-1-(Phenyldiazenyl)naphthalen-2-yl-4-methylbenzoate (7c). Yiled 51%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.75 (dd, J = 8.7, 1.4 Hz, 1H), 8.14–8.08 (m, 2H), 7.99 (d, J = 8.9 Hz, 1H), 7.98–7.94 (m, 1H), 7.70 (dt, J = 7.6, 1.6 Hz, 2H), 7.67–7.58 (m, 2H), 7.47 (d, J = 8.8 Hz, 1H), 7.45–7.39 (m, 3H), 7.33 (d, J = 8.0 Hz, 2H), 2.49 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.5, 153.2, 144.3, 138.2, 137.5, 132.4, 131.3, 131.0, 130.5, 129.3, 129.0, 128.0, 127.5, 127.5, 126.9, 126.3, 124.2, 123.0, 122.7, 21.8. HRMS-ESI (m/z): calcd for $C_{24}H_{18}N_2O_2$ [M + Na]$^+$ 389.1260, found 389.1267.

(*E*)-1-(Phenyldiazenyl)naphthalen-2-yl-4-chlorobenzoate (7d). Yiled 40%; Red solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.74 (d, J = 8.4 Hz, 1H), 8.15 (d, J = 8.5 Hz, 2H), 8.00 (d, J = 8.9 Hz, 1H), 7.98–7.94 (m, 1H), 7.66 (d, J = 8.1 Hz, 1H), 7.65-7.60 (m, 3H), 7.51 (d, J = 8.5 Hz, 2H), 7.47–7.39 (m, 4H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.6, 153.1, 140.0, 138.0, 137.0, 132.5, 131.8, 131.4, 131.2, 130.6, 129.0, 129.0, 128.1, 128.0, 127.6, 126.5, 124.2, 122.7, 122.7. HRMS-ESI (m/z): calcd for $C_{23}H_{15}ClN_2O_2$ [M + Na]$^+$ 409.0714, found 409.0722.

(*E*)-1-(Phenyldiazenyl)naphthalen-2-yl-2-ethoxybenzoate (7e). Yiled 35%; Red solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.77–8.72 (m, 1H), 8.09 (dd, J = 7.9, 1.8 Hz, 1H), 7.99 (d, J = 8.8 Hz, 1H), 7.97–7.94 (m, 1H), 7.89–7.81 (m, 2H), 7.66 (ddd, J = 8.5, 6.9, 1.5 Hz, 1H), 7.60 (ddd, J = 8.1, 6.9, 1.4 Hz, 1H), 7.55 (ddd, J = 8.4, 7.4, 1.8 Hz, 1H), 7.50 (d, J = 8.8 Hz, 1H), 7.48–7.45 (m, 3H), 7.06–7.00 (m, 2H), 4.10 (q, J = 7.0 Hz, 2H), 1.39 (t, J = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.3, 159.5, 153.3, 138.5, 138.0, 134.2, 132.8, 132.4, 131.3, 131.0, 130.2, 128.9, 128.0, 127.5,

126.2, 124.2, 123.2, 122.9, 120.0, 119.2, 113.4, 64.6, 14.7. HRMS-ESI (m/z): calcd for $C_{25}H_{20}N_2O_3$ $[M + Na]^+$ 419.1366, found 419.1362.

(*E*)-1-(Phenyldiazenyl)naphthalen-2-yl-2-fluorobenzoate (7f). Yiled 31%; Red solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.76 (dd, J = 8.3, 1.4 Hz, 1H), 8.15 (td, J = 7.5, 1.8 Hz, 1H), 8.00 (d, J = 8.8 Hz, 1H), 7.98–7.94 (m, 1H), 7.80–7.75 (m, 2H), 7.70–7.59 (m, 3H), 7.52–7.43 (m, 4H), 7.31–7.20 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.4 (d, $J_{C\text{-}F}$ = 261.9 Hz), 162.7 (d, $J_{C\text{-}F}$ = 4.2 Hz), 161.1, 153.2, 138.1, 137.0, 135.2, 132.9, 132.5, 131.3 (d, $J_{C\text{-}F}$ = 19.4 Hz), 130.5, 129.0, 128.0, 127.6, 126.5, 124.3, 124.1 (d, $J_{C\text{-}F}$ = 3.9 Hz), 122.8, 118.1 (d, $J_{C\text{-}F}$ = 9.2 Hz), 117.2(d, $J_{C\text{-}F}$ = 22.2 Hz). HRMS-ESI (m/z): calcd for $C_{23}H_{15}N_2O_2$ $[M + Na]^+$ 393.1010, found 393.1014.

(*E*)-1-(Phenyldiazenyl)naphthalen-2-yl-dimethylcarbamate (7g). Yiled 43%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.64 (dd, J = 8.5, 1.3 Hz, 1H), 8.00–7.95 (m, 2H), 7.95–7.89 (m, 2H), 7.64–7.55 (m, 5H), 7.42 (d, J = 8.8 Hz, 1H), 3.06 (s, 3H), 3.04 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.9, 153.4, 138.9, 138.1, 132.0, 131.3, 130.7, 130.2, 129.2, 127.9, 127.3, 126.1, 124.1, 123.4, 122.7, 120.3, 36.8, 36.5. HRMS-ESI (m/z): calcd for $C_{19}H_{17}N_3O_2$ $[M + Na]^+$ 342.1213, found 342.1213.

Quinolin-8-yl-benzoate (9a). Yiled 67%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.98 (dd, J = 4.3, 1.7 Hz, 1H), 8.42–8.35 (m, 2H), 8.23 (dd, J = 8.3, 1.7 Hz, 1H), 7.79 (dd, J = 5.8, 3.8 Hz, 1H), 7.73–7.64 (m, 1H), 7.63–7.60 (m, 2H), 7.57 (dd, J = 8.4, 7.0 Hz, 2H), 7.47 (dd, J = 8.3, 4.2 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.5, 150.6, 147.6, 141.3, 136.3, 133.6, 130.6, 128.6, 128.0, 126.3, 126.1, 121.9, 121.8. HRMS-ESI (m/z): calcd for $C_{16}H_{11}NO_2$ $[M + Na]^+$ 272.0682, found 272.0683.

Quinolin-8-yl-4-methoxybenzoate (9b). Yiled 71%; white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.92 (dd, J = 4.3, 1.8 Hz, 1H), 8.33 (d, J = 8.5 Hz, 2H), 8.21 (dd, J = 8.3, 1.7 Hz, 1H), 7.77 (m, 1H), 7.65–7.52 (m, 2H), 7.44 (dd, J = 8.3, 4.2 Hz, 1H), 7.04 (d, J = 8.5 Hz, 2H), 3.92 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.2, 163.9, 150.6, 147.9, 141.6, 136.0, 132.7, 129.6, 126.3, 125.9, 121.9, 121.7, 121.7, 113.9, 55.5. HRMS-ESI (m/z): calcd for $C_{17}H_{13}NO_3$ $[M + H]^+$ 280.0968, found 280.0967.

Quinolin-8-yl-4-bromobenzoate (9c). Yiled 58%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.96 (dd, J = 4.3, 1.7 Hz, 1H), 8.28–8.24 (m, 1H), 8.23 (d, J = 8.6 Hz, 2H), 7.81 (dd, J = 7.7, 2.0 Hz, 1H), 7.70 (d, J = 8.5 Hz, 2H), 7.66–7.57 (m, 2H), 7.50–7.47 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.8, 150.6, 147.3, 141.1, 136.3, 132.1, 131.9, 131.4, 131.2, 129.7, 128.8, 128.5, 126.3, 126.2, 121.9, 121.8. HRMS-ESI (m/z): calcd for $C_{16}H_{10}BrNO_2$ $[M + Na]^+$ 349.9787, found 349.9782.

Quinolin-8-yl-2-methoxybenzoate (9d). Yiled 63%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.93 (dd, J = 4.2, 1.7 Hz, 1H), 8.36 (dd, J = 7.8, 1.8 Hz, 1H), 8.20 (dd, J = 8.3, 1.7 Hz, 1H), 7.76 (dd, J = 6.5, 3.1 Hz, 1H), 7.60 (m, 3H), 7.44 (dd, J = 8.3, 4.2 Hz, 1H), 7.15–7.05 (m, 2H), 3.97 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.3, 160.2, 150.5, 147.7, 141.6, 135.9, 134.3, 132.9, 129.5, 126.2, 125.8, 121.8, 121.6, 120.3, 119.0, 112.3, 56.1. HRMS-ESI (m/z): calcd for $C_{17}H_{13}NO_3$ $[M + H]^+$ 280.0968, found 280.0960.

Quinolin-8-yl-3-phenylpropanoate (9e). Yiled 65%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.94 (dd, J = 4.3, 1.7 Hz, 1H), 8.19 (dd, J = 8.3, 1.7 Hz, 1H), 7.73 (dd, J = 8.3, 1.3 Hz, 1H), 7.54 (t, J = 7.9 Hz, 1H), 7.44 (dd, J = 8.3, 4.2 Hz, 1H), 7.42–7.35 (m, 4H), 7.3 –7.24 (m, 1H), 3.25–3.20 (m, 2H), 3.20–3.13 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.8, 150.5, 147.3, 141.2, 140.5, 136.1, 129.5, 128.6, 128.5, 128.3, 126.4, 126.3, 125.9, 121.8, 121.6, 35.8, 31.0. HRMS-ESI (m/z): calcd for $C_{18}H_{15}BrNO_2$ $[M + Na]^+$ 300.0995, found 300.0992.

5-Chloroquinolin-8-yl-4-methoxybenzoate (9f). Yiled 71%; White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.96 (dd, J = 4.2, 1.6 Hz, 1H), 8.60 (dd, J = 8.6, 1.6 Hz, 1H), 8.31 (d, J = 8.8 Hz, 2H), 7.68 (d, J = 8.1 Hz, 1H), 7.55 (dd, J = 8.6, 4.2 Hz, 1H), 7.52 (d, J = 8.2 Hz, 1H), 7.04 (d, J = 8.9 Hz, 2H), 3.92 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.1, 164.0, 151.0, 146.9, 142.0, 133.2, 132.7, 128.7, 127.3, 126.2, 122.4, 121.7, 121.5, 113.9, 55.6, 55.4. HRMS-ESI (m/z): calcd for $C_{17}H_{12}ClNO_3$ $[M + Na]^+$ 336.0398, found 336.0394.

Supporting Information

Copies of ^{1}H NMR and ^{13}C NMR spectra for all products.

Acknowledgments

We are grateful to the National Science & Technology Major Project "Key New Drug Creation and Manufacturing Program", China (Number: 2009ZX09301-001), and the China Postdoctoral Science Foundation (No. 2014M550257).

References

1. (a) G. X. Zhong, J. Q. Hu, K. Zhao, L. L. Chen, W. X. Hu and M. Y. Qiu, *Bioorg. Med. Chem. Lett*. **2009**, *19*, 516; (b) G. X. Zhong, L. L. Chen, J. Li, W. X. Hu and M. Y. Qiu, *Chin. Chem. Lett*. **2008**, *19*, 1419.
2. M. Krátký, J. Vinšová and J. Stolaříková, *Molecules.* **2012**, *17*, 12812.
3. B. Waszkowycz, S. E. Lively and M. J. Harrison, WO199955661, **1999**.
4. B. Narasimhan, S. Ohlan, R. Ohlan, V. Judge and R. Narang, *Eur. J. Med. Chem*. **2009**, *44*, 689.
5. S. Jolidon, R. Narquizian, M. H. Nettekoven, R. D. Norcross, E. Pinard and H. Stalder, WO2005014563, **2005**.
6. M. Frederickson, WO2009125230, **2009**.
7. (a) J. Otera, *Esterification: Methods Reactions and Applications*; Wiley: New York, **2003**; b) J. M. Humphrey and A. R. Chamberlin, *Chem. Rev*. **1997**, *97*, 2243; c) R. C. Larock, *Comprehensive Organic Transformation*; VCH: New York, **1989**, P840.
8. T. W. Greene and P. G. M. Wuts, *Protective Groups in Organic Synthesis*; John Wiley & Sons: New York, **1991**.
9. (a) X. F. Wu, H. Beller Neumann and M. Beller, *Chem. Rev.* **2013**, *113*, 1; (b) A. Brennfuhrer, H. Neumann and M. Beller, *Angew. Chem. Int. Ed*. **2009**, *48*, 4114; (c) R. Grigg and S. P. Mutton, *Tetrahedron.* **2010**, *66*, 5515; (d) D. A. Watson, X. Fan and S. L. Buchwald, *J. Org. Chem.* **2008**, *73*, 7096; (e) J. R. Martinelli, D. A. Watson, D. M. M. Freckmann, T. E. Barder and S. L. Buchwald, *J. Org. Chem*. **2008**, *73*, 7102.

10. For selected reviews on C−H functionalization using transition metals, see: (a) F. Kakiuchi, S. Sekine, Y. Tanaka, A. Kamatani, M. Sonoda, N. Chatani and S. Murai, *Bull. Chem. Soc. Jpn*. **1995**, *68*, 62; (b) O. Daugulis, H. Q. Do and D. Shabashov, *Acc. Chem. Res*. **2009**, *42*, 1074; (c) X. Chen, K. M. Engle, D. H. Wang and J. Q. Yu, *Angew. Chem. Int. Ed*. **2009**, *48*, 5094; (d) R. Giri, B. F. Shi, K. M. Engle, N. Maugel and J. Q. Yu, *Chem. Soc. Rev*. **2009**, *38*, 3242; (e) T. W. Lyons and M. S. Sanford, *Chem. Rev*. **2010**, *110*, 1147; (f) D. A. Colby, R. G. Bergman and J. A. Ellman, *Chem. Rev*. **2010**, *110*, 624; (g) J. Wencel-Delord, T. Droge, F. Liu and F. Glorius, *Chem. Soc. Rev*. **2011**, *40*, 4740; (h) P. B. Arockiam, C. Bruneau and P. H. Dixneuf, *Chem. Rev*. **2012**, *112*, 5879; (i) L. Ackermann, *Acc. Chem. Res*. **2014**, *47*, 281.

11. For reviews on CDC reactions, see: (a) C. J. Li, *Acc. Chem. Res*. **2008**, *42*, 335; (b) C. S. Yeung and V. M. Dong, *Chem. Rev*. **2011**, *111*, 1215; (c) C. Scheuermann, *J. Chem.-Asian J*. **2010**, *5*, 436; (d) S. A. Girard, T. Knauber and C. J. Li, *Angew. Chem. Int. Ed*. **2014**, *53*, 74.

12. For examples on CDC reactions: (a) M. Chandrasekharam, B. Chiranjeevi, K. S. V. Gupta and B. *J.* Sridhar, *Org. Chem*. **2011**, *76*, 10229; (b) S. J. Park, J. R. Price and M. H. Todd, *J. Org. Chem*. **2012**, *77*, 949; (c) M. Zhao, F. Wang and X. Li, *Org. Lett*. **2012**, *14*, 1412; (d) P. Wang, H. Rao, R. Hua and C. J. Li, *Org. Lett*. **2012**, *14*, 902; (e) C. A. Correiaa and C. J. Li, *Adv. Synth. Catal.* **2010**, *352*, 1446; (f) L. Zhao and C. J. Li, *Angew. Chem. Int. Ed*. **2008**, *47*, 7075; (g) J. Xie and Z. Z. Huang, *Angew. Chem. Int. Ed*. **2010**, *49*, 10181; (h) J. Zhao, H. Fang, W. Zhou, J. Han and Y. Pan, *J. Org. Chem*. **2014**, *79*, 3847; (i) Z. Cui, X. F. Shang, X. Shao and Z. Q. Liu, *Chem. Sci*. **2012**, *3*, 2853; (j) Y. Siddaradu, L. Lamani and K. R. Prabhu, *J. Org. Chem*. **2014**, *79*, 3856.

13. (a) M. Zhang, S. Zhang, G. Zhang, F. Chen and J. Cheng, *Tetrahedron Lett.* **2011**, *52*, 2480; (b) F. Luo, C. Pan, J. Cheng and F. Chen, *Tetrahedron.* **2011**, *67*, 5878; (c) P. S. Reddy, J. N. Rosa, L. F. Veiros, S. Caddick and P. M. P. Gois, *Org. Biomol. Chem.* **2011**, *9*, 3126.

14. For copper-catalyzed C−H activation reactions, see: (a) S. E. Allen, R. R.

Walvoord, R. Padilla-Salinas and M. C. Kozlowski, *Chem. Rev*. **2013**, *113*, 6234; (b) J. Gallardo-Donaire and R. Martin, *J. Am. Chem. Soc.*, **2013**, *135*, 9350; (c) X. Chen, X. S. Hao and C. E. Goodhue, J. Q. Yu, *J. Am. Chem. Soc.* **2006**, *128*, 6790; (d) M. Shang, S. Z. Sun, H. X. Dai and J. Q. Yu, *J. Am. Chem. Soc.* **2014**, *136*, 2054; (e) M. Nishino, K. Hirano, T. Satoh and M. Miura, *Angew. Chem. Int. Ed*. **2013**, *52*, 4457; (f) C. Zhang and N. Jiao, *J. Am. Chem. Soc.* **2010**, *132*, 28; (g) Z. Li, Y. Zhang, L. Zhang and Z. Q. Liu, *Org. Lett*. **2014**, *16*, 382; (h) S. K. Rout, S. Guin, K. K. Ghara, A. Banerjee and B. K. Patel, *Org. Lett*. **2012**, *14*, 3982.

15. (a) W. J. Woo and C. J. Li, *J. Org. Chem*. **2006**, *71*, 6266; (b) G. S. Kumar, C. U. Maheswari, R. A. Kumar, M. L. Kantam and K. R. Reddy, *Angew. Chem. Int. Ed*. **2011**, *50*, 11748; (c) B. D. Barve, Y. C. Wu, M. El-Shazly, D. W. Chuang, Y. M. Chung, Y. H. Tsai, S. F. Wu, M. Korinek, Y. C. Du, C. T. Hsieh, J. J. Wang and F. R. Chang, *Eur. J. Org. Chem*. **2012**, 6760; (d) K. R. Prasad, P. S. Ravikumar, N. V. Reddy and K. R. Reddy, *Tetrahedron Lett*. **2014**, *55*, 6307; (e) S. K. Rout, S. Guin, A. Banerjee, N. Khatun, A. Gogoi and B. K. Patel, *Org. Lett.* **2013**, *15*, 4106; (f) S. Sharma, J. Park, M. Kim, J. H. Kwak, Y. H. Jung and I. S. Kim, *Tetrahedron.* **2013**, *69*, 9391; (g) J. Park, S. H. Han, S. Sharma, S. Han, Y. Shin, N. K. Mishra, J. H. Kwak, C. H. Lee, J. Lee and I. S. Kim, *J. Org. Chem.* **2014**, *79*, 4735.
16. For cyano group as directing group: (a) W. Li, Z. P. Xu, P. P. Sun, X. Q. Jiang and M. Fang, *Org. Lett*. **2011**, *13*, 1286; (b) W. Li and P. P. Sun, *J. Org. Chem*. **2012**, *77*, 8362; (c) B. Du, X. Jiang and P. P. Sun, *J. Org. Chem*. **2013**, *78*, 2786.
17. For azo group as directing group: (a) Z. Yin, X. Jiang and P. P. Sun, *J. Org. Chem*. **2013**, *78*, 10002; (b) Z. Y. Li, D.D. Li and G. W. Wang, *J. Org. Chem*. **2013**, *78*, 10414; (c) H. Sun, D. Chen, C. Pi, X. Cui and Y. Wu, *J. Org. Chem*. **2014**, *79*, 2955; (d) H. Li, P. Li and L. Wang, *Org. Lett*. **2013**, *15*, 620; (e) B. Majhi, D. Kundu, S. Ahammed, B. C. Ranu. *Chem. Eur. J*. **2014**, *20*, 9862; (f) B. Majhi, S. Ahammed, D. Kundu, B. C. Ranu. *Asian J. Org. Chem*. **2015**, *4*, 154.
18. For a review of acyl radicals, see: (a) C. Chatgilialoglu, D. Crich, M. Komatsu and I. Ryu, *Chem. Rev*. **1999**, *99*, 1991; for recent selected examples of acyl

radicals, see: (b) Z. Liu, J. Zhang, S. Chen, E. Shi, Y. Xu and X. Wan, *Angew. Chem., Int. Ed*. **2012**, *51*, 3231; (c) Z. Shi and F. Glorius, *Chem. Sci*. **2013**, *4*, 829.