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Amino Acid Promoted Ullmann Type Reaction with Low Catalyst Loading *via* Microwave Technology

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This work describes CuBr-catalyzed cross-coupling of sterically hindered phenols with substituted aryl halides and hetero aryl halides under microwave conditions using commercially available amino acids as the reaction promoters and K_3PO_4 as the base. This protocol shown to tolerate sensitive functional groups like CN, CHO *etc*., Especially, in case of 3-bromopyridine coupling with substituted phenols supported this letter in track record of the reactivity.

Keywords: Aryl halide, Phenol, Ligand, Microwave.

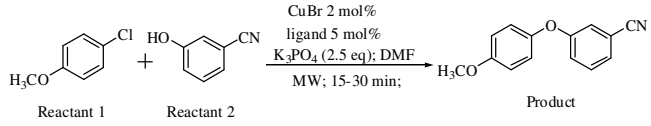
INTRODUCTION

Formation of C-O bond is a key step in synthetic chemistry due to the importance of diaryl ether unit represents a very important class of organic compounds[1,2]. The versatile strategies to access diaryl ethers directly by the reaction of aryl halide with phenols promoted by Cu-reagents[3]. Ullmann discovered copper-catalyzed *O*-arylations of phenols with aryl halides[4]. However, synthetic scope of this reaction conditions are rather limited due to harsh reaction conditions, usually at high temperatures (125-250 °C) in pyridine solvent, greater quantities of the copper catalyst required and the low to moderate yields. In recent modifications reported that the use of catalyst-ligand combinations enhance the reaction rate and allow the couplings to be carried out under milder reaction conditions in the presence of catalytic amount of copper[5-7]. Although several ligands such as 2,2,6,6,-tetramethyl-heptane-3,5-dione (THMD)[7b], N,N-dimethylglycine[8] have been reported as reaction promoters, with different Cu source and ligand combinations[9,10] in the presence of different bases like K_2CO_3, Cs_2CO_3 in polar, non polar solvents, these catalytic systems still suffer from several common problems like stachiometric quantity of ligand loading and high temperature.

Yet, the development of this copper catalyzed Ullmann-type reaction is required all the times most catalytic systems still needed long reaction time (longer than 24 h), relatively high temperature (≥ 120 °C) and high ratios of catalyst loading. We focused on development of cost effective, efficient catalytic system and the lowering the reaction time, temperature by adopting microwave technology[11].

EXPERIMENTAL

General procedure: CuBr (2 mol %), L-proline (5 mol %), aryl halide (1 eq), ArOH (1.05 eq) and K_3PO_4 (2.5 eq) were suspended in DMF (3 mL) in a microwave vial. The tube was then evacuated and backfilled with nitrogen. The vial was sealed and placed in the Dicover-CEM microwave synthesizer; (temperature was controlled using the in-built calibrated IR sensor) and reaction mixture was irradiated at 70 °C in microwave for 15-30 min (time variable for the different reactant). In 2-3 min reaction temperature attained to 70 °C and 3 bar pressure. The reaction mixture was cooled to room temperature and further diluted with water (10 mL) and ethyl acetate (30 mL). The organic layer was separated and back extracted twice with ethyl acetate (20 mL). The combined organic layers were dried over anhyd. Na_2SO_4 and concentrated *via* rota evaporator. The residue was purified through silica gel (60-120 mesh) column chromatography to afford diaryl ether product **Scheme-I**.



Scheme 1: Copper-catalyzed coupling of 4-chloroanisole with 3-hydroxy benzonitrile

3-(4-Methoxyphenoxy)benzonitrile (1c): Pale white colour solid, m.p. 106-108 °C; ^{1}H NMR (400 MHz, DMSOd_6: δ (ppm) 7.38 (t, *J* = 8.0 Hz, 1H), 7.30 (d, *J* = 7.6 Hz, 1H), 7.19-7.13 (m, 2H), 7.00-6.92 (m, 4H), 3.82 (s, 3H); ^{13}C NMR

(100 MHz, $CDCl_3$): δ (ppm) 159.2, 156.8, 148.4, 130.5, 125.7, 121.7, 121.4, 119.9, 118.3, 115.2, 113.4, 55.6; MS (ESI) *m/z* $(M + H)^+$: 226.0; Anal. calcd. for $C_{14}H_{11}NO_2$: C, 74.65; H, 4.92; N, 6.22; O, 14.21. Found: C, 74.75; H, 5.28.

3-(4-Methoxyphenoxy)benzaldehyde (2c): Colour less syrup, ^{1}H NMR (400 MHz, DMSOd_6): δ (ppm) 9.95 (s, 1H), 7.63-7.59 (m, 2H), 7.32-7.30 (m, 2H), 7.08 (d, *J* = 6.8, 2H), 7.01 (d, *J* = 6.8, 2H), 3.77 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 191.7, 159.2, 156.5, 149.1, 130.3, 124.1, 123.5, 121.2, 119.5, 116.8, 115.1, 55.6; MS (ESI) *m/z* (M + H): 229.04; Anal. calcd. for $C_{14}H_{12}O_3$: C, 73.67; H, 5.30; O, 21.03. Found: C, 73.73; H, 5.41; Anal. calcd. for $C_{14}H_{12}O_3$: C, 73.67; H, 5.30; O, 21.03. Found: C, 73.72; H, 5.40.

4-(4-Methoxyphenoxy)benzaldehyde (3c): Pale white colour solid; m.p. 57-62 °C; ^{1}H NMR (400 MHz, DMSOd_6): δ (ppm) 9.90 (s, 1H), 7.89 (d, *J* = 6.8 Hz, 2H), 7.11 (d, *J* = 6.8 Hz, 2H), 7.06-7.02 (m, 4H), 3.78 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 190.7, 164.1, 156.9, 148.2, 131.9, 130.9, 121.8, 116.7, 115.1, 55.6; MS (ESI) *m/z* $(M + H)^+$: 229.04; Anal. calcd. for $C_{14}H_{12}O_3$: C, 73.67; H, 5.30; O, 21.03. Found: C, 73.73; H, 5.41.

2-(4-Methoxyphenoxy)-5-(benzyloxy)benzaldehyde (4c): Pale light colour solid, m.p. 121-125 °C; ^{1}H NMR (400 MHz, DMSOd_6): δ (ppm)10.33 (s, 1H), 7.47-7.31 (m, 7H), 7.05-6.89 (m, 5H), 5.15 (s, 2H), 3.75 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 189.2, 156.1, 155.0, 154.4, 150.6, 136.4, 128.6, 128.1, 127.6, 127.0, 124.3, 120.0, 119.9, 115.6, 111.0, 70.6, 55.7; MS (ESI) *m/z* $(M + H)^+$: 335.1; Anal. calcd. for $C_{21}H_{18}O_4$: C, 75.43; H, 5.43; O, 19.14. Found: C, 75.52; H, 5.51.

1-[4-(2-Methoxyphenoxy)phenyl]ethanone (5c): Colour less syrup, ^{1}H NMR (400 MHz, DMSOd_6): δ (ppm) 7.93 (d, *J* = 9.6 Hz 2H), 7.31-7.15 (m, 3H), 7.03 (t, *J* = 7.6 Hz 1H), 6.88 (d, *J* = 9.6 Hz, 2H), 3.73 (s, 3H), 2.51(s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 196.7, 162.4, 151.7, 143.2, 131.4, 130.4, 126.1, 122.4, 121.3, 115.7, 113.0, 55.8, 26 ppm. MS (ESI) *m/z* $(M + H)^+$: 243.05; Anal. calcd. for $C_{15}H_{14}O_3$: C, 74.36; H, 5.82; O, 19.81. Found: C, 74.45; H, 5.93.

3-(2-Formylphenoxy)benzonitrile (6c): Pale white colour solid, m.p. 80- 84 °C; ^{1}H NMR (400 MHz, DMSOd_6): δ (ppm) 10.32 (s, 1H), 7.91 (d, *J* = 1.2 Hz, 1H), 7.89-7.62 (m, 4H), 7.48 (t, *J* = 1.2 Hz, 1H), 7.41 (t, *J* = 7.6 Hz, 1H), 7.08 (d, *J* = 8.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 189.4, 158.1, 157.2, 136.9, 132.1, 129.5, 128.4, 127.4, 125.2, 124.4, 122.8, 120.1, 118.4, 113.3; MS (ESI) *m/z* $(M + H)^+$: 224.03; Anal. calcd. for $C_{14}H_9NO_2$: C, 75.33; H, 4.06; N, 6.27; O, 14.33. Found: C, 75.71; H, 4.12.

2-(*O*-tolyloxy)naphthalene (7c): Colourless syrup; ^{1}H NMR (400 MHz, DMSOd_6): δ (ppm) 7.95 (d, *J* = 9.2 Hz, 1H), 7.90 (d, *J* = 8.0 Hz, 1H), 7.76 (d, *J* = 8.0 Hz, 1H), 7.48-7.37 (m, 3H) 7.29-7.25 (m, 2H), 7.19-7.14 (m, 2H), 7.00 (d, *J* = 8.0 Hz, 1H), 2.21 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 155.8, 154.3, 134.4, 131.5, 130.2, 129.8, 129.7, 127.7, 127.2, 126.4, 124.2, 120.1, 119.1, 111.6, 16.2; MS (ESI) *m/z* $(M + H)^+$: 235.01; Anal. calcd. for $C_{17}H_{14}O$: C, C, 87.15; H, 6.02; O, 6.83. Found: C, 87.23; H, 6.12.

5-(2-Isopropylphenoxy)pyridine-2-carbonitrile (8c): Pale yellow syrup, ^{1}H NMR (400 MHz, DMSOd_6): δ (ppm) 8.50 (d, *J* = 2.4 Hz, 1H), 8.01 (d, *J* = 8.0 Hz, 1H), 7.50 (d, *J* = 4.0, 1H), 7.37-7.31 (m, 3H), 7.10 (dd, *J* = 3.4 Hz, 6.0 Hz, 1H), 3.09-3.02 (m, 1H), 1.16 (d, *J* = 6.8 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 157.5, 150.8, 141.3, 140.7, 129.5, 127.8, 127.6, 126.5, 122.5, 120.6, 117.2, 27.1, 23.02; MS (ESI) *m/z* $(M + H)^+$: 239.02; Anal. calcd. for $C_{15}H_{14}N_2O$: C, 75.61; H, 5.92; N, 11.76; O, 6.71. Found: C, 75.74; H, 5.99.

4-(2-Isopropylphenoxy)isoquinoline (9c): Pale brown syrup, ^{1}H NMR (400 MHz, DMSOd_6): δ (ppm) 9.11 (s, 1H), 8.22 (d, *J* = 8.4 Hz, 1H), 8.16 (d, *J* = 8.4, 1H), 7.90-7.77 (m, 3H), 7.48 (q, 1H), 7.24-7.22 (m, 2H) 6.92-6.90 (m, 1H), 3.28 (m, 1H), 1.25 (d, *J* = 7.2 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 153.4, 149.5, 146.7, 139.7, 130.1, 129.5, 128.9, 127.8, 127.2, 127.2, 127.1, 127.7, 121.1, 119.3, 27.3, 23.0; MS (ESI) *m/z* $(M + H)^+$: 264.01; $C_{18}H_{17}NO$ Anal. calcd. for $C_{15}H_{14}N_2O$: C, 82.10; H, 6.51; N, 5.32; O, 6.08. Found: C, 82.24; H, 6.45.

2-(Pyridin-3-yloxy)benzaldehyde (10c): Yellow crystalline solid; m.p. 75-79 °C; ^{1}H NMR (400 MHz, DMSOd_6): δ (ppm) 10.41 (s, 1H), 8.50 (d, *J* = 2.8 Hz, 1H), 8.45 (dd, *J* = 1.2 Hz, 4.4 Hz, 1H), 7.89 (dd, *J* = 2.0 Hz, 8.0 Hz, 1H), 7.70 (d, *J* = 7.6 Hz, 1H), 7.60-7.57 (m, 1H), 7.50-7.47 (m, 1H), 7.36 (t, *J* = 7.6 Hz, 1H), 7.03 (d, *J* = 8.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 186.6, 158.8, 153.1, 145.3, 141.5, 135.9, 129.0, 127.1, 126.3, 124.4, 124.3, 118.4; MS (ESI) *m/z* $(M + H)^+$: 200.2; Anal. calcd. for $C_{12}H_9NO_2$: C, 72.35; H, 4.55; N, 7.03; O, 16.06. Found: C, 72.45; H, 4.64.

4-Methoxy-3-(pyridin-3-yloxy)benzaldehyde (11c): Pale yellow syrup, ^{1}H NMR (400 MHz, DMSOd_6): δ (ppm) 9.84 (s, 1 H), 8.35 (s, 2H), 7.72 (dd, *J* = 2.0, 8.4 Hz, 1H), 7.52 (d, *J* = 1.6 Hz, 1H), 7.25-7.32 (m, 2H), 7.12 (d, *J* = 8.4 Hz, 1H), 3.92 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 190.0, 156.3, 153.7, 144.9, 144.3, 140.1, 130.3, 129.0, 124.2, 120.5, 112.3, 56.2 ppm; MS (ESI) *m/z* $(M + H)^+$: 230.1; Anal. calcd. for $C_{13}H_{11}NO_3$: C, 68.11; H, 4.84; N, 6.11; O, 20.94. Found: C, 68.23; H, 4.95.

1-(4-(Thiazol-2-yloxy)phenyl)ethanone (12c): Pale brown semisolid; ^{1}H NMR (400 MHz, DMSOd_6): δ (ppm) 8.06 (d, *J* = 6.8 Hz, 2H), 7.46 (d, *J* = 6.8 Hz, 2H), 7.35 (d, *J* = 6.4 Hz, 2H), 2.60 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 196.6, 172.0, 158.9, 137.6, 134.2, 130.4, 119.4, 113.9, 26.5 ppm. MS (ESI) *m/z* $(M + H)^+$: 220; Anal. calcd. for $C_{11}H_9NO_2S$: C, 60.26; H, 4.14; N, 6.39; O, 14.59; S, 14.62. Found: C, 60.35; H,4.22.

6-(Pyridin-3-yloxy)pyridine-3-carbonitrile (13c): Pale yellow gummy solid; ^{1}H NMR (400 MHz, DMSOd_6): δ (ppm) 8.66 (d, *J* = 2.4 Hz, 1H), 8.53-8.50 (m, 2H), 8.38 (d, *J* = 8.8 Hz, 1H), 7.74 (d, *J* = 8.4 Hz, 1H), 7.54-7.51 (m, 1H), 7.37 (d, *J* = 8.8 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 164.7, 162.5, 151.7, 149.2, 146.7, 143.6, 142.5, 129.1, 127.1, 116.4, 112.3, 104.8. MS (ESI) *m/z* $(M + H)^+$: 198.2; Anal. calcd. for $C_{11}H_7N_3O$:C, 67.00; H, 3.58; N, 21.31; O, 8.11. Found: C, 67.23; H, 3.95.

5-(Quinolin-3-yloxy)pyridine-3-carbaldehyde(14c): pale yellow syrup, ^{1}H NMR (400 MHz, DMSOd_6): δ (ppm) 10.12 (s, 1H), 8.93 (d, *J* = 1.6 Hz, 1H), 8.89 (dd, *J* = 1.6 Hz, 4.0 Hz, 1H), 8.81(d, *J* = 2.8 Hz, 1H), 8.32 (dd, *J* = 1.2 Hz, *J* = 8.4 Hz, 1H), 8.12 (d, *J* = 8.4 Hz, 1H), 7.88-7.87 (m, 1H), 7.67 (d, *J* = 2.8 Hz, 1H), 7.64 (s, 1H), 7.57-7.59 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 191.9, 153.5, 153.3, 149.8, 146.3, 146.1, 145.0, 135.4, 132.2, 131.5, 128.7, 124.3, 122.9, 122.0,

114.5; MS (ESI) *m/z* (M + H)$^+$: 251.5; Anal. calcd. for $C_{15}H_{10}N_2O_2$: C, 71.99; H, 4.03; N, 11.19; O, 12.79 Found: C, 72.08; H, 4.14.

RESULTS AND DISCUSSION

In preliminary studies, reaction of 4-chloroanisole with 3-hydroxy benzonitrile in DMF at 110 °C in the presence of K_3PO_4 using 5 mol % of CuBr without using additives the reaction was examined subsequent conventional heating and microwave reaction. Conventional heating resulted 55 % of product selectivity in 22 h at 110 °C, where 72 % product selectivity was detected under microwave heating in 20 min. By comparison, reaction completed in 15 min in the presence of 10 mol % of L-proline under microwave heating (CEM synthesizer) and product selectivity also increased to 95 %. It has been suggested that such additives would increase the solubility of copper salts by preventing their aggregation and they could also enhance the reactivity. The reaction screened with using commercially available amino acids such as L-proline, N-methyl proline, pyrrole-2-carboxilic acid and 2-picolinic acid, in DMF and K_3PO_4 as base and results are summarized in Table-1.

After screening of above four ligands, L-proline was found to be a superior ligand combination with CuBr to serve as better ligand-catalytic system to make diaryl ethers at lower temperature in very shorter reaction time under microwave conditions. After optimizing the reaction conditions, we subsequently extended the scope of Ullmann-type coupling reaction using 5 mol % of L-proline without affecting the product selectivity. All the reactions performed efficiently using 2 mol % of CuBr, 5 mol % of ligand under microwave conditions in DMF and K_3PO_4 as base at 70 °C. To the best of our knowledge, most of the diaryl ether formation reactions reported with highly reactive aryl iodides with phenols, few reports have been found with less reactive aryl chloride and moderate reactive aryl bromides and very few reports on hetero aromatic halides. We report here, CuBr and L-proline is the best combination for the C-O bond formation of less reactive aryl/hetero-aryl chlorides and also moderate reactive aryl/hetero-aryl bromides with sterically hindered phenols and hetero-aryl alcohols with excellent yields using low catalyst-ligand loading under microwave irradiation. During recent years, microwaves have been extensively used for carrying out chemical reactions and have become a useful non-conventional energy source for performing organic synthesis[12,13]. This protocol mainly refer the ligand loading, solvent ratio, time, temperature and yields. And also observed stability in the presence of sensitive functional groups. The isolated yields compared with conventional heating and results are summarized in Table-2.

We were curious about effect of substituent on the rate of the coupling reaction. Generally, *ortho*-substituted phenol coupling partners are often challenging due to steric hindrance. By using the optimized conditions *ortho*-substituted halides could be coupled with a variety of phenols (entriy 6). Electron-donating groups on the phenol and electron-withdrawing groups on the aryl halides make the reaction favourable. Electron withdrawing group of *ortho*-substituted phenols effectively formed ethers with hetero-aryl halides (entries 7-11) gave above 85 % yields. The steric hindrance of phenols usually slightly disfavoured for the reaction. 4-Chloro-acetophenone was used as the substrate and reacted with 2-methoxyphenol resulted in 90 %, where considerably lower yield in conventional heating. Spectacular electronic effects were observed when 2-Isoproylphenol was submitted to coupling with het hetero-aryl chlorides (entries 8, 9) more than 80 % yield. Only slight decrease in the reaction rate was noted with electron rich and electron withdrawing substituted 2-chloro-5-cyanopyridine (entry 9) here -CN group was well tolerated on the aryl chloride. We please to note that we could quantitatively couple 2-bromo napthalene with the sterically hindered *ortho*-cresol under these conditions (entry 7) with 91 % yield.

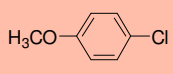
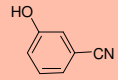
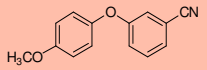
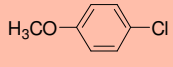
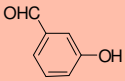
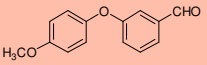
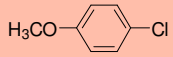
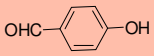
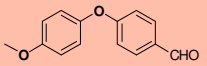
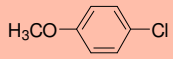
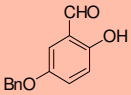
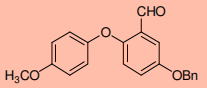
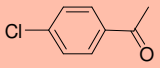
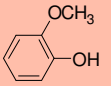
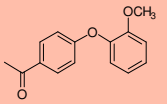
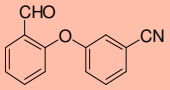
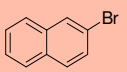
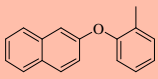
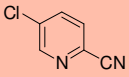
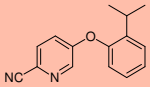
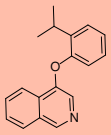
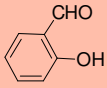
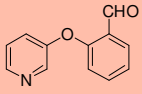
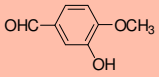
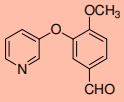
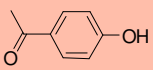
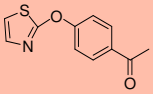
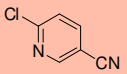
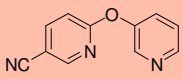
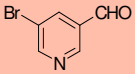
Next, the cross-coupling reaction between hetero-aryl halides with substituted phenols (entries 8-12) and hetero-aryl alcohols were examined (entries 13 and 14). The one, we identified the substituted phenols coupling with 3-halopyridine case is much differential. Where the much difference observed in yield while comparing with the conventional and microwave technologies. The earlier literature, failed to provide coupling reaction of 3-halopyridines[12] because less reactive than 2-halopyridine. This letter strongly, supported here in getting extreme reactivity observed in microwave condition (entries 10, 11, 14). The other substituted phenols possessing sensitive functional groups are well tolerated during coupling under microwave and also afforded reasonable yields (entries 1, 2, 8, 11, 13, 14). Hetero-aryl halides such as 3-chloro pyridine (entries 10, 11), 3-Cyano-5-chloropyridines, 4-Chloroisoquinoline, 2-bromothiazole (entry 12), 5-bromonicotinaldehyde (entry 14) could be coupled with electro-deficient, electron-neutral and hindered phenols. However, 5-membered ring hetero-aryl halides containing two hetero atoms such as 2-bromothiazole (entry 12) also gave product reaction with 3-hydroxypyridine in excellent yields under these reaction conditions. The C-O bond formation of 3-hydroxyquinoline (entry 14) with a substituted pyridine also proceeded smoothly and also gave excellent yield 86 %. Common functional groups, including cyano, aldehydes and ketones were tolerated under the reaction conditions employed.

TABLE-1
COUPLING REACTION OF 4-CHLOROANISOL WITH PHENOL UNDER THE CATALYSIS OF CuBr AND AMINO ACIDS

Entry	Catalyst	Ligand	Conventional (Cal. Yield %)*	MW (Cal. Yield %)*
1	CuBr	L-Proline	61	95
2	CuBr	*N*-Methyl proline	48	86
3	CuBr	2-Picolinic acid	52	82
4	CuBr	Pyrrole-2-carboxilic acid	55	85
5	CuI	L-Proline	53	81

Reaction conditions: CuBr powder (2 mol %), ligand (5 mol %), 4-chloroanisole (1.0 eq), 3-hydroxy benzonitrile (1.05 eq), K_3PO_4 (2.5 eq), DMF MW 15-30 min

TABLE-2
CuBr-CATALYZED DIARYL ETHER FORMATION OF ARYL/HETERO-ARYL HALIDES WITH SELECTED PHENOLS IN THE PRESENCE OF L-PROLINE

Entry	ArX (a)	ArOH (b)	Product (c)	Temp (°C)	Conventional yield (%)	MW yield (%)
1				70	57	95
2				70	59	93
3				70	61	90
4				70	48	86
5				75	67	90
6				70	46	87
7				70	59	91
8				80	55	87
9				90	47	88
10				90	63	90
11				90	49	86
12				80	51	91
13				70	55	90
14				90	38	86

Reaction conditions: Cu Br (2 mol %), L-proline (5 mol %), ArX (1 eq), ArOH (1.05 eq), K_3PO_4 (2.5 eq), DMF (3 V), 70-90 °C, MW 15-25 min. [b] Isolated yields after column chromatography

The best results were observed in microwave irradiation rather thermal heating with remarkable reduction in reaction time because of homogeneous heating throughout the reaction media by microwave irradiation as compared to convection currents in thermal heating. Evidently, the microwave irradiation increased the reaction rate and selectivity rather than conventional method taking much longer reaction time (requires 20-30 h at 110-130 °C).

Conclusion

We have successfully demonstrated economical and operationally simple CuBr-L-proline catalytic synthesis of substituted di aryl, hetero-aryl ethers from the coupling of substituted phenols towards halo pyridines, haloquinolines and bromo benzothiazole in excellent yields with low loading ligands in shorter time under microwave conditions. The best results were observed in microwave irradiation rather than

conventional heating with remarkable reduction in reaction time.

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