Simple and Efficient Method for the Synthesis of Highly Substituted Imidazoles Catalyzed by Benzotriazole

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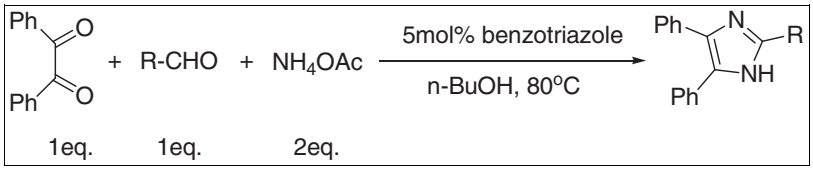

Benzotriazole is an efficient, readily available, and simple catalyst for the synthesis of 2,4,5-trisubstituted imidazoles in high yields from 1,2-diketones and aldehydes in the presence of NH_4OAc via multi-components reaction. The significant features of this one-pot procedure are very simple operation, easy work-up and purification of products.

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INTRODUCTION

Imidazole ring system is one of the most important substructure found in a large number of natural products and pharmacologically active compounds.[1–5] The potency and wide applicability of the imidazole pharmacophore can be attributed to its hydrogen bond donor-acceptor capability as well as affinity for metals (e.g., Zn, Fe, and Mg), which are present in many protein active sites[6]. Various substituted imidazole act as inhibitor of p38 MAP kinase,[7] glucagon receptors,[8] plant growth regulators,[9] therapeutic agents,[10] antibacterial,[11] and also antitumor.[12] Recent advances in green chemistry and organometallic chemistry have extended the boundary of imidazole to the synthesis and application of a large class of imidazoles as ionic liquids and imidazole related N-heterocyclic carbenes.[13,14] In addition, the optical properties (fluorescence[15] and chemiluminescence) of imidazole derivatives are of particular concern for material scientists. Because of their wide range of biological, synthetic, and potential industrial applications, synthesis imidazoles, especially high substituted imidazoles, have received a great deal of attention.

Accordingly, a number of synthetic methods have been reported for synthesis imidazoles and its derivates. Among these method, multicomponent reactions are very smart and convenient method with unique merit.[16] Multicomponent condensation of 1,2-diketones, aromatic aldehydes, and ammonium acetate can be carried out in the presence of several catalysts systems, which include microwaves radiation,[17] molecular iodine,[18] $HClO_4$-SiO_2,[19] heteropolyacid,[20] silica gel/$NaHSO_4$,[21] L-proline,[22] $FeCl_3$·$6H_2O$,[23] BF_3·SiO_2,[24] $K_5CoW_{12}O_{40}$-$3H_2O$,[20b], and silica-supported Wells-Dawson acid.[25] They can also be accessed by refluxing in acetic acid,[26] silica sulfuric acid[27] and catalyzed by $NiCl_2$·$6H_2O$/Al_2O_3,[28] $ZrCl_4$,[29] ionic liquids,[30] ceric ammonium nitrate,[31] $InCl_3$·$3H_2O$,[32] and DABCO[33].

Moreover, some of these synthetic protocols suffer from one or more serious drawbacks, such as longer reaction times, large amount of catalyst loadings, significant amounts of waste materials, low selectivity or low yields, and the use of expensive reagents. Simple efficient and flexible protocol for the synthesis of imidazoles still needs to be pursued for further improvement towards milder reaction conditions, development of simple and inexpensive reagents, convenient procedures, and higher product yields. However, despite intensive effort, only a handful of general methodologies exist for the direct construction of highly substituted imidazoles.

Replacement of conventional toxic and pollutant Bronsted and metal Lewis acid catalysts with environmentally benign organic molecular catalysts is an active area of current research. The use of organic molecules as catalysts has provided attractive alternatives to the more traditional metal-catalyzed. In recent years, benzotriazole has wide application as a synthetic auxiliary in a multitude of synthetic endeavors [34], such as nitrogen ligand[35], reactive promotion reagents[36], or catalyst[37]. But it has not been studied as a catalyst in the synthesis of imidazoles until now. In continuation of our efforts toward the development of organic molecules, catalyst using organic synthesis, herein, we report a mild, efficient, and facile one-pot synthesis of highly substituted imidazole derivatives by the multi-component reaction of 1,2-diketone, amine source, and aldehyde using benzotriazole as the catalyst.

RESULTS AND DISCUSSION

Three component condensation reactions of benzaldehyde (1.0 mmol) with ammonium acetate (2.0 mmol) and benzil

(1.0 mmol) for the synthesis of imidazole were used as a model reaction (Scheme 1).

Initially, in continuation of our previous work on the applications of Ph_3P, PPh_3 (10 mol%) was used as a catalyst for model reaction in *n*-butanol solvent at 80°C, which led to the 2,4,5-trisubstituted imidazole in 80% yield for 24 h. But the reaction time is long, and catalyst loadings is also large, even the yield is good. Encouraged by this result, we moved our attention to nitrogen containing organic molecules that have great choice spaces and belong to the same group with phosphorus. First object is 4-dimethylaminopyridine (DMAP), it also works for the model reaction and gives the desire product in 76% yield when 5 mol% DMAP was used in *n*-butanol solvent at 80°C for 12 h (Table 1, entry 4). When increased the catalyst loading to 10 mol%, the yield of the desired product showed a slight increase to 80% (Table 1, entry 2). The temperature effect of this model reaction also was evaluated by using 5 mol% DMAP as catalyst in *n*-butanol solvent at 50, 80°C and reflux (118°C). The experiment results that exhibit the yields of product are 62, 76 and 55%, respectively (Table 1, entries 3–5). Reaction solvent also was a very crucial factor for this reaction. In order to determine the most appropriate solvent system for this DMAP-catalyzed synthesis of substituted imidazoles, the model reaction was tested in a variety of protic and aprotic solvents, such as EtOH, MeOH *i*-PrOH, *t*-BuOH, CH_3CN, CH_2Cl_2, $CHCl_3$, and toluene. But none of the above solvent was found to be effective than *n*-butanol for this reaction (Table 1). Considering the initial experimental outcomes, it was worthwhile to investigate the other nitrogen containing organic molecules. We screen the catalyzed performance of several commercially available nitrogen organic molecules for model reaction in *n*-butanol solvent at 80°C. The results are shown in Table 2. To our surprise, benzotriazole gave excellent yield to 88% among the selected catalyst for this model reaction. Then, benzotriazole was selected as the best candidate for 2,4,5-trisubstituded imidazole by 5 mol% catalyst loading at 80°C in *n*-butanol solvent.

After optimizing the best reaction conditions for the synthesis 2,4,5-trisubstituded imidazole, the scope and efficiency of the process was explored under the optimized conditions. For this purpose, a broad range of structurally diverse aromatic aldehydes as well as aliphatic aldehydes was condensed with 1,2-diketones and ammonium acetate under the best conditions (Scheme 2). *Ortho*-substituted, *meta*-substituted, and *para*-substituted aromatic aldehydes, including electron-donating or electron-withdrawing groups, undergo this one-pot multicomponent process to afford 2,4,5-trisubstituded imidazoles in good yields (Table 3). Aliphatic aldehydes afforded the corresponding imidazoles in moderate yields (Table 3, entries 15 and 16). And the yield of furaldehyde to a corresponding imidazole was very good. But the results of salicylaldehyde (Table 3, entry 5) and *o*-hydroxybenzaldehyde (Table 3, entry 8) did not satisfy us. The reason is may be that they have acidity of hydroxyl group, but catalyst is alkaline, thus both of them affecting the catalytic activity, thereby affecting the yields. Various functional groups were found to be compatible under the optimum reaction conditions. In general, the reactions were clean, easy to purify, and tolerate the different functional groups.

Table 1

DMAP catalyzed-condensation of 1,2-diketone, benzaldehyde, and ammonium acetate in different solvents and with different catalyst loadings.

Entry	Catalyst (%)	Solvent	Temp (°C)	Time (h)	Yield (%)
1	10	EtOH	RT	48	10
2	10	*n*-BuOH	50	12	80
3	5	*n*-BuOH	50	12	62
4	5	*n*-BuOH	80	12	76
5	5	*n*-BuOH	Reflux	12	55
6	5	CH_3CN	RT	24	No product
7	5	CH_3CN	Reflux	24	14
8	5	CH_2Cl_2	Reflux	24	Race
9	5	$CHCl_3$	Reflux	24	Race
10	5	Toluene	80	24	23
11	5	*i*-PrOH	80	9	62
12	5	MeOH	Reflux	15	72
13	5	*t*-BuOH	80	9	27
14	5	EtOH	Reflux	13	58

In order to explore the applicability of this method, the same reaction conditions were applied for the synthesis of 1,2,4,5-tetrasubstituted imidazoles via the one-pot, four-component condensation of 1,2-diketone (1 mmol), aldehydes (1 mmol), primary amine (1 mmol), and ammonium acetate (1 mmol) as depicted in Scheme 3.

The substrate scope of the reaction was then evaluated using a variety of structurally diverse aldehydes, primary amines, and 1,2-diketone. The 1,2,4,5- tetrasubstituted imidazoles were obtained in moderate yields (Table 4).

Scheme 1. Three component condensation for synthesis 2,4,5-trisubstituded imidazoles.

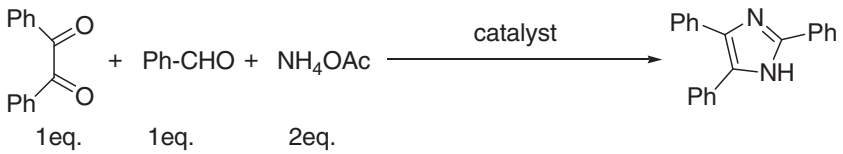


Table 2

Condensation of 1,2-diketone, benzaldehyde, and ammonium acetate using different catalyst in *n*-buOH.

Entry	Catalyst	Catalyst (%)	Temp.(°C)	Solvent	Time (h)	Yield (%)
1	PPh_3	10	80	*n*-Butanol	24	80
2	DMAP	10	50	*n*-Butanol	24	81
3	DMAP	5	80	*n*-Butanol	12	76
4	Hexamethylenetramine	5	80	*n*-Butanol	12	68
5	Benzotriazole	5	80	*n*-Butanol	12	88
6	Diphenylguanidine	5	80	*n*-Butanol	12	69
7	Benzimidazole	5	80	*n*-Butanol	12	61

Scheme 2. Benzotriazole-catalyzed synthesis of 2,4,5-trisubstituted imidazoles.

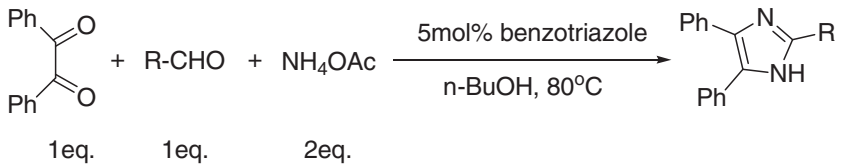
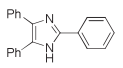
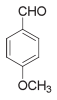
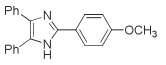
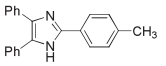
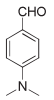
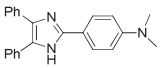
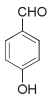
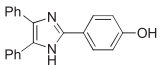
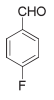
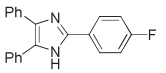
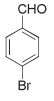
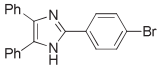


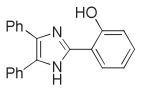
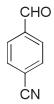
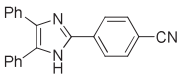
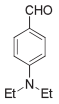
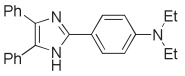
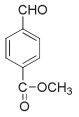
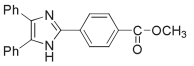
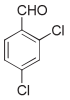
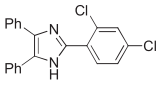
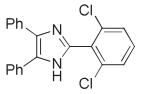
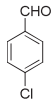
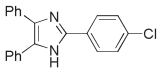
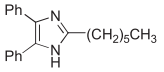
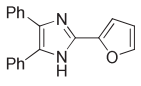
Table 3

Synthesis of 2,4,5-trisubstituted imidazoles.

Entry	Aldehyde	Product	Time (h)	Yield (%)
1			12	88
2			12	76
3			12	82
4			12	75
5			12	70
6			12	75
7			12	81

(*Continued*)

Table 3
(Continued)

Entry	Aldehyde	Product	Time (h)	Yield (%)
8			12	63
9			12	83
10			12	80
11			12	83
12			12	79
13			14	83
14			13	82
15			12	76
16	$CH_3(CH_2)_5CHO$		12	75
17			10	81

Scheme 3. Benzotriazole-catalyzed synthesis of 1,2,4,5-tetrasubstituted imidazoles.

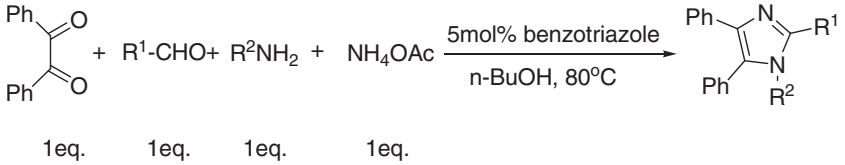


Table 4

Synthesis of 1,2,4,5-tetrasubstituted imidazoles catalyzed by benzotriazole.

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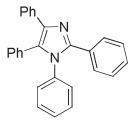
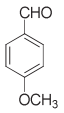
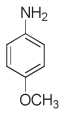
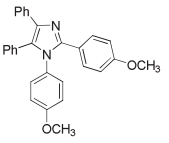
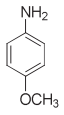
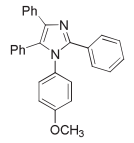
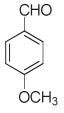
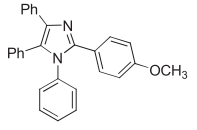
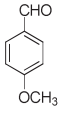
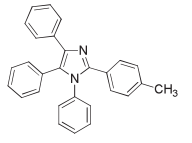
1				13	60
2				15	62
3				15	64
4				15	58
5				14	56

A plausible mechanism for the benzotriazole catalyzed synthesis of substituted imidazoles (Scheme 4) has been proposed. In the case of 2,4,5-trisubstituted imidazoles, the reaction proceeds through diamine intermediate **A**, which may form by two different pathways (pathway I or pathway II). **Path I** involves the reaction of benzotriazole that has rich electron pair with aldehyde leading to the formation of intermediate and subsequent condensation with two molecules of ammonia to form diamine intermediate **A**. **Path II** provides diamine intermediate **A** via inimium catalyst. Intermediate **A** condenses with carbonyl carbons of the 1,2-diketone followed by dehydration to afford the imino **B**, which rearranges to the desired trisubstituted imidazoles.

CONCLUSION

In summary, we have identified a one-pot synthesis of highly functionalized trisubstituted and tetrasubstituted imidazoles from readily available starting materials utilizing benzotriazole as the catalyst. This one-pot procedure is very simple, easy work-up and purification of product.

EXPERIMENTAL

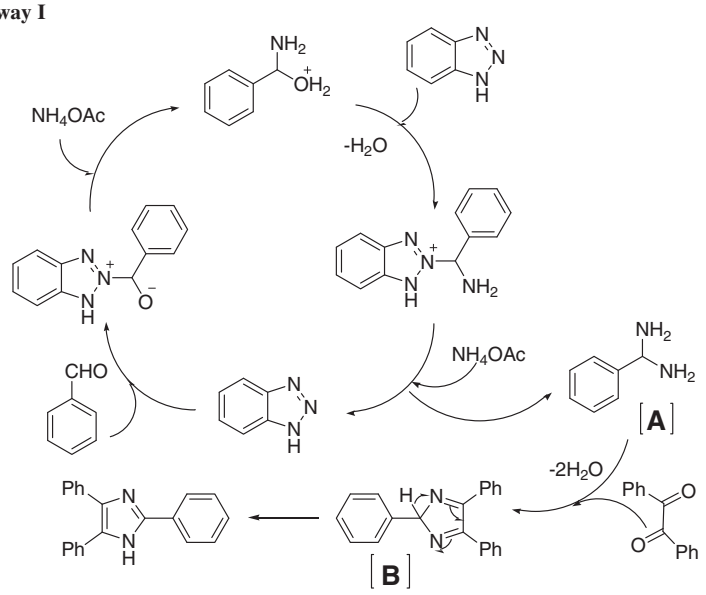
All solvents and reagents were used as obtained from commercial sources. 1,2-Diketones were prepared according to standard methods and their purities were established before utilization by melting point. ^{1}H NMR spectra were recorded at 300 MHz, from $CDCl_3$ and CD_3SOCD_3 solutions. Ultra-high resolution MS was obtained on MaXis UHR-TOP (Bruker Daltonic Corporation, Germany). The IR spectra were recorded on Fourier transform infrared spectrometer EQUINX55 (Brucher Corporation, Germany). All runs were conducted at least in duplicate. The substituted imidazoles were identified by comparison with samples prepared according to known procedures.

A general procedure for the synthesis of 2,4,5-substituted imidazole derivatives. In a 50 mL round bottom flask, benzotriazole (6 mg) and aldehyde (1.0 mmol) were taken in *n*-butanol (10 mL) to dissolve. Then 1,2-diketone (1.0 mmol) and ammonium acetate (2.0 mmol) were added. After the reaction mixture was heated at 80°C slowly until completion of the determinate time, the reaction mixture was cooled to room temperature and the solvent was removed by rotary evaporator. The crude residue was recrystallized by petroleum ether to obtain the pure corresponding substituted imidazole derivatives.

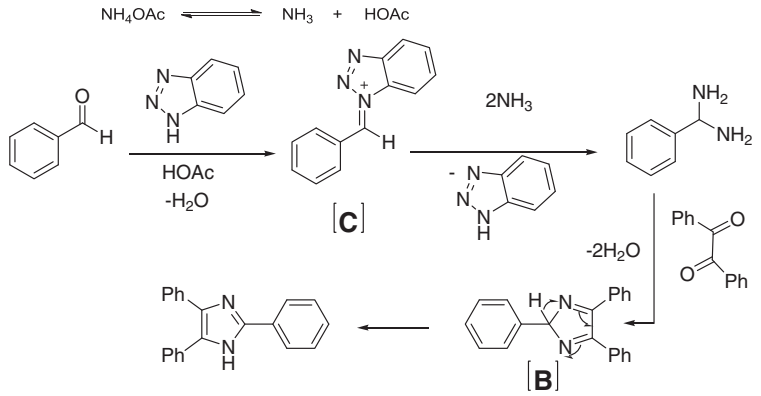
***2,4,5-Triphenyl-1H*-imidazole (3–1).** Mp 270–272°C. ^{1}H NMR(DMSO-d_6): δ12.71(s, 1H), 8.09(d, J = 7.4 Hz, 2H), 7.23–7.56

Scheme 4. A plausible mechanisms for the formation of imidazoles. Pathway I—benzotriazole through electron pair. Pathway II—iminium catalysis.

Pathway I



Pathway II



(m, 13H); FTIR (KBr, cm^{-1}): 3462, 2964, 1599, 1460; HRMS (ESI): *m/z* calcd for $C_{21}H_{16}N_2$ $[M\text{-}H]^+$ 295.1313, found 295.1310.

2-(4-Methoxyphenyl)-4,5-diphenyl-1H-imidazole (3–2). Mp 226–228°C. ^{1}H NMR (DMSO-d_6): δ 7.86(d, J = 8.5 Hz, 2H), 7.57–7.09(m, 10H), 6.88(d, J = 8.6 Hz, 2H), 3.83(s, 3H); FTIR (KBr, cm^{-1}): 3422, 3027, 2953, 1612, 1492, 1249; HR-MS (ESI): *m/z* calcd for $C_{22}H_{18}N_2O$ $[M+H]^+$ 327.1419, found 327.1420.

4,5-Diphenyl-2-p-tolyl-1H-imidazole (3–3). Mp 233–235°C. ^{1}H NMR (DMSO-d_6): δ 12.57 (s, 1H), 7.99 (d, J = 7.8 Hz, 2H), 7.22–7.56(m, 12H), 2.35(s, 3H); FTIR (KBr, cm^{-1}): 3442, 3027, 1599, 1493, 1322; HRMS (ESI): *m/z* calcd for $C_{22}H_{18}N_2$ $[M+H]^+$ 311.1470, found 311.1473.

4-(4,5-Diphenyl-1H-imidazole-2-yl)-phenyl-dimethylamine (3–4). Mp 250–252°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.77 (d, J = 8.6 Hz, 2H), 7.53(d, J = 6.1 Hz, 4H), 7.40–7.17(m, 6H), 6.73(d, J = 8.6 Hz, 2H), 3.00(s, 6H); FTIR (KBr, cm^{-1}): 3473, 3035, 1615, 1508; HRMS (ESI): *m/z* calcd for $C_{23}H_{21}N_3$ $[M+H]^+$ 340.1735, found 340.1733.

4-(4,5-Diphenyl-1H-imidazol-2-yl)phenol (3–5). Mp 253–256°C. ^{1}H NMR (300 MHz, DMSO-d_6): δ 12.40(s, 1H), 9.62(s, 1H), 7.90(d, J = 8.4 Hz, 2H), 7.23–7.52(m, 10 H), 6.86(d, J = 8.2 Hz, 2H); FTIR (KBr, cm^{-1}): 3455, 3283, 1701, 1284; HRMS (ESI): *m/z* calcd for $C_{21}H_{16}N_2O$ $[M+H]^+$ 313.1263, found 313.1266.

2-(4-Fluorophenyl)-4,5-diphenyl-1H-imidazole (3–6). Mp 253–253.5°C. ^{1}H NMR (DMSO-d_6): δ 12.71(s, 1H), 8.14 (d, J = 8.4 Hz, 2H), 7.91–6.95(m, 12H); FTIR (KBr, cm^{-1}): 3428, 3028, 1607, 1492; HRMS (ESI): *m/z* calcd for $C_{21}H_{15}N_2F$ $[M+H]^+$ 315.1219, found 315.1217.

2-(4-Bromophenyl)-4,5-diphenyl-1H-imidazole (3–7). Mp 259–261°C. ^{1}H NMR (DMSO-d_6): δ 12.80(s, 1H), 8.04(d, J = 8.4 Hz, 2H), 7.69(d, J = 8.4 Hz, 2H), 7.55–7.12(m, 10H); FTIR (KBr, cm^{-1}): 3430, 3029, 1600, 1483; HRMS (ESI): *m/z* calcd for $C_{21}H_{15}N_2Br$ $[M+H]^+$ 375.0419, found 375.0418.

2-(4,5-Diphenyl-1H-imidazol-2-yl)-phenol (3–8). Mp 209.5–211°C. ^{1}H NMR (DMSO-d_6): δ 13.10 (br, s, 1H), 8.05 (d, J = 7.8, 1H), 7.26–7.52(m, 11H), 6.97(m, 2H); FTIR (KBr, cm^{-1}): 3447, 3192, 3057, 1601; HRMS (ESI): *m/z* calcd for $C_{21}H_{16}N_2O$ $[M+H]^+$ 313.1263, found 313.1262.

2-(4,5-Diphenyl-1H-imidazol-2-yl)-benzonitrile (3–9). Mp 274–276°C. ^{1}H NMR (DMSO-d_6): δ 13.10(s, 1H), 8.26

(d, $J = 8.1$ Hz, 2H), 7.95(d, $J = 8.1$ Hz, 2H), 727–754(m, 10H); FTIR (KBr, cm^{-1}): 3460, 3052, 2226, 1609, 1489; HRMS (ESI): *m/z* calcd for $C_{22}H_{15}N_3$ $[M + H]^+$ 322.1266, found 322.1264.

4-(4,5-Diphenyl-1H-imidazole-2-yl)-phenyl-diethylamine (3–10). Mp 221–223°C. ^1H NMR ($CDCl_3$): δ 7.72(d, $J = 8.5$ Hz, 2H), 7.50(d, $J = 6.3$ Hz, 4H), 7.35–7.15(m, 6H), 6.66(d, $J = 8.4$ Hz, 2H), 3.40–3.33(m, 4H), 1.17(t, 6H); FTIR (KBr, cm^{-1}): 3468, 3029, 2969, 2932, 1616; HRMS (ESI): *m/z* calcd for $C_{25}H_{25}N_3$ $[M + H]^+$ 368.2048, found 368.2045.

4-(4,5-Diphenyl-1H-imidazole-2-yl)-phenyl-methyl (3–11). Mp 240.5–242°C. ^1H NMR (300 MHz, DMSO-d_6): δ 12.85(s,1H), 8.24 (d, $J = 7.9$ Hz, 2H), 8.07(d, $J = 7.9$ Hz, 2H), 7.83–6.80(m, 10H), 3.88 (s, 3H); FTIR (KBr, cm^{-1}): 3348, 3055, 1649, 1609, 1438; HRMS (ESI): *m/z* calcd for $C_{23}H_{18}N_2O_2$ $[M + H]^+$ 355.1368, found 354.1365.

2-(2,4-Dichloropheny)-4,5-dipenyl-1H-imidazole (3–12). Mp 174.5–175.5°C. ^1H NMR ($CDCl_3$): δ 10.22(s, 1H), 8.41(d, $J = 8.6$ Hz, 1H), 7.22–7.56(m, 12H); FTIR (KBr, cm^{-1}): 3066, 2928, 1594, 1476, HRMS (ESI): *m/z* calc. for $C_{21}H_{14}N_2Cl_2$ $[M + H]^+$ 365.0534, found 365.0535.

2-(2,6-Dichloropheny)-4,5-dipenyl-1H-imidazole (3–13). Mp 229–230°C. ^1H NMR ($CDCl_3$): δ 9.42(s, 1H), 7.66 (d, $J = 7.0$ Hz, 2H), 7.17–7.57 (m, 11H); FTIR (KBr, cm^{-1}): 3055, 1599, 1447; 1194; HRMS (ESI): *m/z* calcd for $C_{22}H_{18}N_2O$ $[M + H]^+$ 327.1419, found 327.1416.

2-(4-Chlorophenyl)-4,5-diphenyl-1H-imidazole (3–14). Mp 265.5–266.5°C. ^1H NMR (300 MHz, DMSO-d_6): δ 12.71(s, 1H), 8.10(d, $J = 8.2$ Hz, 2H), 7.77–7.09(m, 12H); FTIR (KBr, cm^{-1}): 3430, 3055, 1602, 1433; HRMS (ESI): *m/z* calcd for $C_{21}H_{15}N_2Cl$ $[M + H]^+$ 331.0924, found 331.1927.

4,5-Diphenyl-1H-imidazole (3–15). Mp 230–231.5°C. ^1H NMR (DMSO-d_6): δ 12.45 (s, 1H), 7.77 (s, 1H), 7.33–7.44(m, 10H); FT–IR (KBr, cm^{-1}): 3059, 2990, 1602, 1513; HRMS (ESI): *m/z* calcd for $C_{15}H_{12}N_2$ $[M + H]^+$ 221.1000, found 221.1008.

***2-Hexyl-4,5-diphenyl-1H*-imidazole (3–16).** Mp 129–130°C. ^1H NMR ($CDCl_3$): δ 11.26(s, 1H), 7.44(d, $J = 6.2$ Hz, 4H), 7.22(d, $J = 6.1$ Hz, 6H), 2.63–2.27(m, 2H), 1.54(dd, $J = 15.2$, 7.5 Hz, 2H), 1.35–1.00(m, 6H), 0.92–0.64(m, 3H); FTIR (KBr, cm^{-1}): 3031, 2953, 2924, 2854, 1602; HRMS (ESI): *m/z* calcd for $C_{21}H_{24}N_2$ $[M + H]^+$ 305.1935, found 305.1932.

2-Furan-2-yl-4,5-diphenyl-1H-imidazole (3–17). Mp 231–232°C. ^1H NMR ($CDCl_3$): δ 9.84(s, 1H), 7.47(d, $J = 18.7$ Hz, 5H), 7.29(s, 6H), 6.95(s, 1H), 6.50(s, 1H); FTIR (KBr, cm^{-1}): 3056, 1601, 1525, 1425; HRMS (ESI): *m/z* calcd for $C_{19}H_{14}N_2O$ $[M + H]^+$ 287.1106, found 287.1108.

A general procedure for the synthesis of 1,2,4,5-substituted imidazole derivatives. In a 50 mL round bottom flask, benzotriazole (6 mg) and aldehyde were taken in *n*-butanol (10 mL) and dissolved. Then 1,2-diketone (1.0 mmol), ammonium acetate (1.0 mmol), and primary amine (1.0 mmol) were added, after which the reaction mixture was heated at 80°C slowly until the determinate time. The reaction mixture was cooled to room temperature, and the solvent was removed by rotary evaporator. The crude residue was purified by column chromatography using ethyl acetate and petroleum ether (1:7) as eluent to give the corresponding substituted imidazole derivatives.

1,2,4,5-Tetraphenylimidazole (4–1). Mp 216–217°C. ^1H NMR ($CDCl_3$): δ 7.60(d, $J = 7.3$ Hz, 2H), 7.43(d, $J = 5.1$ Hz, 2H), 7.25(s, 12H), 7.14(s, 2H), 7.03(d, $J = 6.0$ Hz, 2H); FTIR (KBr, cm^{-1}):3057, 1595, 1494; HRMS (ESI): *m/z* calcd for $C_{27}H_{20}N_2$ $[M + H]^+$ 373.1626, found 373.1627.

1,2-Bis(4-methoxypheyl)-45-diphenyl-1H-imidazole (4–2). Mp 197–199°C. ^1H NMR ($CDCl_3$): δ 7.59(s, 2H), 7.37(d, $J = 8.6$ Hz, 2H), 7.10–7.39(m, 8H), 6.93(d, $J = 8.6$ Hz, 2H), 6.76(d, $J = 7.8$ Hz, 4H), 3.77(s, 3H), 3.74(s, 3H); FTIR (KBr, cm^{-1}): 3012, 2932, 1608, 1514; HRMS (ESI): *m/z* calcd for $C_{29}H_{24}N_2O_2$ $[M + H]^+$ 433.1838, found 433.1839.

1-(4-Methoxyphenyl)-2,4,5-triphenyl-1H-imidazole (4–3). Mp 167–169°C. ^1H NMR (300 MHz, $CDCl_3$): δ 7.60(d, $J = 7.2$ Hz, 2H), 7.46(d, $J = 3.6$ Hz, 2H), 7.35–7.06(m, 10H), 6.95(d, $J = 8.7$ Hz, 2H), 6.73(d, $J = 8.7$ Hz, 2H), 3.73(s, 3H); FTIR (KBr, cm^{-1}): 3051, 2960, 1601, 1510; HRMS (ESI): *m/z* calcd for $C_{28}H_{22}N_2O$ $[M + H]^+$ 403.1732, found 403.1734.

1-(4-Methoxyphenyl)-2,4,5-triphenyl-1H-imidazole (4–4). Mp 163–165°C. ^1H NMR ($CDCl_3$): δ 7.55(d, $J = 7.1$ Hz, 2H), 7.32 (d, $J = 8.5$ Hz, 2H), 7.25–7.07(m, 9H), 7.04(d, $J = 6.4$ Hz, 2H), 6.97 (d, $J = 5.9$ Hz, 2H), 6.71(d, $J = 8.6$ Hz, 2H), 3.70(s, 3H); FTIR (KBr, cm^{-1}): 3660, 2956, 1607, 1481; HRMS (ESI): *m/z* calcd for $C_{28}H_{22}N_2O$ $[M + H]^+$ 403.1732, found 403.1730.

2-(4-Methylphenyl)-1,4,5-triphenylimidazole (4–5). Mp 180–182°C. ^1H NMR (300 MHz, $CDCl_3$): δ 7.60 (d, $J = 7.0$ Hz, 3H), 7.01–7.40(m, 16H), 2.30(s, 3H); FTIR (KBr, cm^{-1}): 3042, 1595, 1493; HRMS (ESI): *m/z* calcd for $C_{28}H_{22}N_2$ $[M + H]^+$ 387.1783, found 387.1786.

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