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Research Note

BF_3/nano-sawdust as a green, biodegradable, and inexpensive promoter for one-pot synthesis of tri-substituted imidazoles under solvent free conditions

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KEYWORDS
Sawdust;
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Tri-substituted imidazoles;
Solid acid;
Biodegradable catalyst.

Abstract. BF_3/nano-sawdust as a green, inexpensive, natural, biodegradable, and readily available biopolymer solid acid catalyst was synthesized and characterized. This catalyst was used successfully for the synthesis of various tri-substituted imidazoles in high yields under solvent free conditions.

1. Introduction

Tri-substituted imidazoles exhibit a wide range of biological properties such as antitumor, antioxidant [1], antibacterial [2], and anti-inflammatory [3] characteristics and are found in many biologically active substances (Scheme 1).

Various methods for the synthesis of 2,4,5-tri-substitutedimidazoles have been reported [4-8]. The majority of synthetic routes rely on one-pot condensation of diketones or β-hydroxyketones with an aldehyde and ammonium acetate in the presence of catalysts such as silica gel or zeolite [9], alumina [10], molecular iodine [11], neutral ionic liquid [12], L-Proline [13], nano-crystalline Sulfated Zirconia (SZ) [14], DABCO [15], AcOH [16], zeolite-supported reagents [17], silica sulfuric acid [18], PEG-400 [19], InF_3 [20], nanocrystalline magnesium oxide [21], $NiCl_2.6H_2O/Al_2O_3$ [22], $InCl_3.3H_2O$ [23], trichloroisocyanuric acid [24], and bioglycerol-based carbon catalyst [25]. Some of these catalysts are ideal choices for the synthesis of 2,4,5-tri-substituted imidazoles and are often used for this purpose. However, a topic of current interest in this area is the synthesis of new solid acids with numerous advantages such as cost-effectiveness, high catalytic activity, easy workup, and good stability. In this regard, the purpose of this study is to develop cheap and biomaterial catalysts.

Recently, special attention has been paid to carbon based materials, consisting of flexible polycyclic carbon fiber sheets for the preparation of various solid acids. Previously, BF_3/nano-sawdust was synthesized and applied for preparation of highly substituted dihydro-2-oxopyrroles [26]. In this study, BF_3/nano-sawdust was examined for the cost-effective and facile one pot cascade synthesis of tri-substituted imidazolesviaone-pot condensation of benzil with aldehyde and ammonium acetate under thermal conditions.

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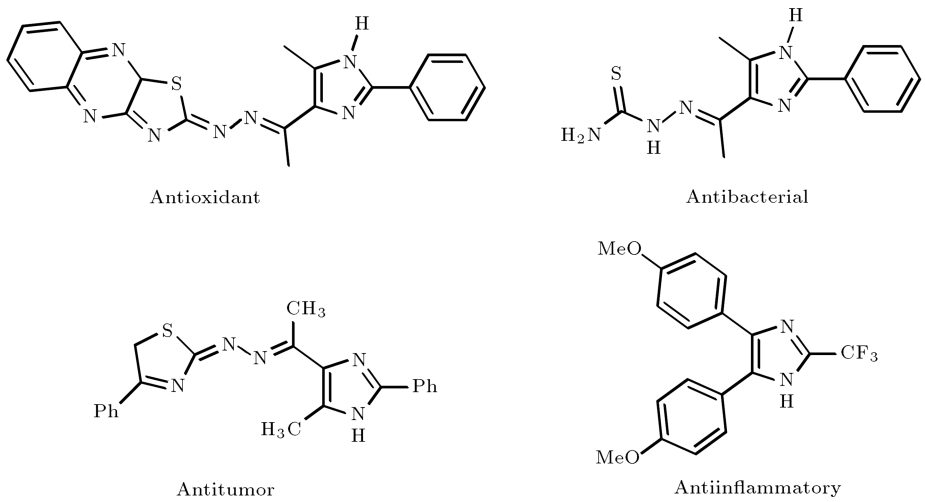


Scheme 1. Biologically active compounds containing tri-substituted imidazole framework.

2. Experimental section

2.1. Materials and methods

All chemicals and solvents were purchased from Merck and Fluka Chemical Companies in high purity. Materials were used from the commercial reagent grade. FT-IR spectra were recorded on an attenuated total reflectance-Fourier transforms infrared (ATR-FTIR) spectrophotometer (Bruker, Eqinox 55). ^{1}H NMR and ^{13}C NMR spectra were recorded at 400 MHz and 100 MHz, respectively, on a Bruker DXR-400 spectrometer using $CDCl_3$ as solvent and tetramethylsilane as internal standard. Melting points were obtained with a Buchi melting point B-540 B.V.CHI apparatus.

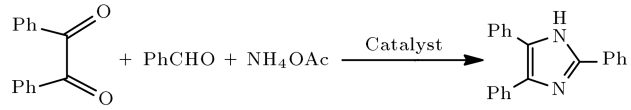
2.2. Typical procedure for synthesis of tri-substituted imidazoles

To a mixture of benzil (0.21 g, 1 mmol), benzaldehyde (0.12 g, 1.1 mmol), and NH_4OAc (0.23 g, 3 mmol), BF_3/nano-sawdust (0.06 g) was added. The reaction mixture was heated at 110°C and the progress of the reaction was monitored by TLC. After completion of reaction (200 min), the mixture was cooled to room temperature, dissolved in acetone, and filtered for the catalyst to be separated. After adding water to the concentrated filtrate, the solid product appeared. The product was re-crystallized in ethanol to obtain pure product as a white solid (0.278 g, 94%); mp 272-273°C. FT-IR: $\bar{\nu}$ (KBr) = 3443 (N-H), 3038, 1602, 1504, 1461, 766, 697 cm^{-1}. ^{1}H NMR (500 MHz, DMSO-d$_6$): δ = 12.68 (s, 1H, N-H), 8.09 (d, ^3J = 7.5 Hz, 2H, ArH), 7.38 (t, ^3J = 7.2 Hz, 2H, ArH), 7.31 (brs, 2H, ArH), 7.23 (brs, 1H, ArH), 7.45-7.55 (m, 8H, ArH) ppm.

Spectral data for the selected compounds:

2-(4-Chlorophenyl)-4,5-diphenyl-1*H*-imidazole (Table 1, entry 2). FT-IR: $\bar{\nu}$ (KBr) = 3026, 1600, 1482, 1069, 826, 766, 695 cm^{-1}, ^{1}H NMR (400 MHz, DMSO-d$_6$): δ=12.8(s, 1H, N-H), 8.14(s, 1H, C-H), 8.04 (d, 1H, ^3J=7 Hz), 7.25-7.55 (m, 12H, ArH).

Table 1. BF_3/nano-sawdust promoted synthesis of 2,4,5-trisubstituted imidazoles.[a]



Entry	*R*	Yield (%)[b]	M.P.°C	Ref.
1	C_6H_5	94	272-273	[21]
2	4-ClC_6H_4	92	262-264	[21]
3	2, 4-$MeO_2C_6H_3$	95	213-216	[21]
4	2, 4-$Cl_2C_6H_3$	84	174-176	[13]
5	4-IsopropylC_6H_4	86	253-255	[17]
6	2-OHC_6H_4	83	203-205	[21]
8	2-$MeOC_6H_4$	82	212-214	[16]
9	2-ClC_6H_4	90	199-201	[21]
10	4-MeC_6H_4	88	232-235	[21]
11	1-Naphthyl	85	273-276	[21]
12	3-$NO_2C_6H_4$	71	265-267	[13]
13	4-$NO_2C_6H_4$	75	236-238	[24]
14	2-$NO_2C_6H_4$	72	230-231	[16]
15	$(CH_3)_2CH$	68	298-230	[13]

[a]: The amounts of aldehyde (mmol): benzil (mmol): NH_4OAc (mmol): BF_{3-n}/nano-sawdust (g) are 1.1:1:3:0.06

[b]: Isolated yield.

2-(4-Isopropyl phenyl)-4,5-diphenyl-1H-imidazole (Table 1, entry 5). FT-IR: $\bar{\nu}$ (KBr)=3029, 2961, 1602, 1490, 837,765, 696 cm^{-1}. ^{1}H NMR (400 MHz, DMSO-d$_6$): δ=12.60 (s, 1H, N-H), 8.01 (d, ^3J=8.2 Hz, 2 H, ArH), 7.35 (d, ^3J=8.2 Hz, 2H, ArH), 7.38-7.52 (m, 10H, ArH), 2.94 (sep, ^3J=6.9 Hz, 1H, C-H), 1.25 (d,

^3J=6.9 Hz, 6H, $2CH_3$); Elemental analysis. Found, %: C 85.03; H 6.61; N 8.36. $C_{24}H_{22}N_2$. Calculated, %: C 85.17; H 6.55; N 8.28.

2-(2-Chlorophenyl)-4,5-diphenyl-1*H*-imidazole (Table 1, entry 9). FT-IR: $\bar{\nu}$ (KBr)=3026, 1600, 1482, 1069, 826, 766, 695 cm^{-1}, ^{1}H NMR (400 MHz, DMSO-d_6): δ=12.5 (s, 1H, N-H), 8.55 (brs, 1H), 7.67 (brs, 2H), 7.49 (brs, 3H), 7.42 (brs, 5H), 7.27 (brs, 3H).

2-(4-Nitrophenyl)-4,5-diphenyl-1H-imidazole (Table 1, entry 13). FT-IR: $\bar{\nu}$ (KBr)=3061, 1599, 1487, 1516, 1339, 1108, 854, 765, 695 cm^{-1}, ^{1}HNMR (400 MHz, DMSO-d_6): δ=11.81 (s, 1H, N-H), 8.07 (m, 2H), 7.67 (d, ^3J=8 Hz, 4H), 7.52 (brs, 2H), 7.40 (brs, 3H), 7.29 (brs, 3H).

3. Results and discussion

In this study, we investigated the catalytic activity of BF_3/nano-sawdust for the synthesis of 2,4,5-tri-substituted imidazole via a three-component reaction of benzil, aldehydes, and ammonium acetate. To optimize the reaction conditions, the synthesis of 2,4,5-tri-phenyl-1*H*-imidazole (1) was used as a model reaction. We performed the three-component reaction in a system consisting of benzil (1 mmol), benzaldehyde (1.1 mmol), and ammonium acetate (3 mmol) under various conditions (Table 2). According to the obtained data, it is revealed that using 0.06 g of catalyst in solvent-free condition at 110°C yields the best results for this transformation (Table 2, entry 9). To examine the reusability of BF_3/nano-sawdust in a solvent-free condition, after each run, the product was dissolved in $CHCl_3$, then filtered and reused. The effect of the reused catalyst on yields is shown in Table 2, entries 12 and 13.

With optimized reaction conditions; the scope of 2,4,5-trisubstituted imidazoles was explored using different aldehydes, benzil, and ammonium acetate (Table 1). Aromatic aldehydes have produced tri-substituted imidazoles in higher yield than that of aliphatic aldehydes. Liquid aromatic aldehydes produced a higher yield of products due to the higher number of collisions in solvent free conditions.

In summary, BF_3/nano-sawdust was prepared, characterized, and applied successfully for the synthesis of various 2,4,5-tri-substituted imidazoles via condensation of benzil with a variety of aldehydes and ammonium acetate. Short reaction times, high yields, easy work-up, no leaching, and biodegradability of catalyst are some of the advantages of this green protocol.

Acknowledgment

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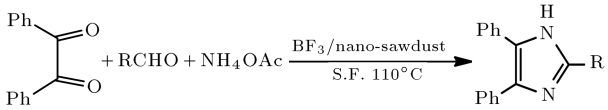
Table 2. BF_3/nano-sawdust promoted synthesis of 2,4,5-triphenyl-1*H*-imidazole[a].



Entry	Cat (g)	Solvent	Temp (°C)/ time (min)	Yield[b] (%)	[Ref.]
1	—	Ethanol	Reflux/80	21	
2	BF_{3-n}/nano-sawdust (0.03)	Ethanol	Reflux/80	38	
3	BF_{3-n}/nano-sawdust (0.04)	Ethanol	Reflux/80	53	
4	BF_{3-n}/nano-sawdust (0.06)	Ethanol	Reflux/80	64	
5	BF_{3-n}/nano-sawdust (0.06)	*n*-Hexane	Reflux/80	35	
6	BF_{3-n}/nano-sawdust (0.06)	THF	Reflux/80	50	
7	BF_{3-n}/nano-sawdust (0.06)	—	100/100	72	
8	BF_{3-n}/nano-sawdust (0.06)	—	110/100	80	
9	BF_{3-n}/nano-sawdust (0.06)	—	110/200	94	
10	BF_{3-n}/nano-sawdust (0.06)	—	120/200	94	
11	BF_{3-n}/nano-sawdust (0.05)	—	110/200	84	
12	BF_{3-n}/nano-sawdust (0.06, 2nd run)	—	110/200	90	
13	BF_{3-n}/nano-sawdust (0.06, 3rd run)	—	110/200	87	
14	Trichloroisocyanuric (20 mol%)	Ethanol	Reflux/12 h	90	[24]
15	Bio-glycerol based Carbon (10%w/w)	CH_3CN	55/7 h	84	[25]
16	L-Proline (15 mol%)[8]	MeOH	60/9 h	90	[13]

[a]: The mmol amount of aldehyde: benzil: NH_4OAc is 1.1:1:3.

[b]: Isolated yield.

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