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Article

Microwave-Assisted Rapid and Green Synthesis of Schiff Bases Using Cashew Shell Extract as a Natural Acid Catalyst

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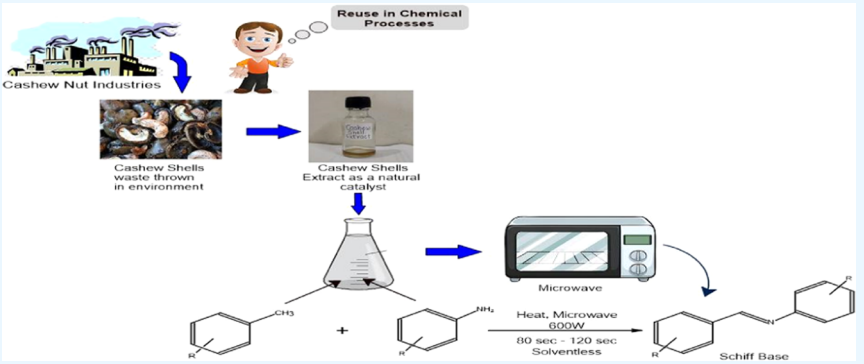

ABSTRACT: The Schiff bases were prepared with aromatic aldehyde and aromatic amine using cashew shell extract as a catalyst under microwave irradiation. This reaction is rapid, efficient, and solvent-free and involves the one-pot synthesis of Schiff bases under microwave irradiation. The synthesized Schiff bases were characterized by Fourier transform infrared (FTIR) spectroscopy, ^{1}H nuclear magnetic resonance (NMR) spectroscopy, ^{13}C NMR spectroscopy, and gas chromatography−mass spectrometry (GC−MS). The advantages of the preparation of Schiff bases under microwave irradiation are high yield, shorter reaction time, easy, elimination of side products, and quick product isolation. The synthesized Schiff base derivatives are well known for their biological activity like antibacterial and antifungal activity.

1. INTRODUCTION

Green chemistry is the global term for the development and modification of chemical processes.[1] This may help chemists to initiate a revolution in the principles and practices of various industries by designing chemical products and methods for the elimination of pollution.[2]

The chemical products are prepared using conventional and nonconventional synthesis processes. In conventional organic synthesis processes, it takes a longer time, resulting in a higher cost. These processes require some hazardous solvents and reagents.[3] To overcome these drawbacks of conventional processes, the nonconventional processes are the best alternative to perform organic transformations. In nonconventional processes, microwave-assisted synthesis has become an interesting method for researchers in the past few decades. The synthesis of organic molecules using microwaves has proven to be economical, clean, and environmentally friendly with a shorter reaction time.[4,5]

Schiff bases are imine compounds with a −C═N bond linkage.[6] Schiff base derivatives play an important role in the field of inorganic medicinal chemistry. In this connection, Schiff base derivatives show diversified applications in antimicrobial activity[2,7] and antitumor activity and have excellent chelating ability.[8−12] The literature review study reveals that free Schiff base derivatives show no cytotoxic behavior compared to their metal complexes.[13] The novel application of Schiff bases with metal complexes is the successive cleavage of DNA molecule bonding via a non-oxidative mechanism.[14] Schiff bases are well known for their use in rubber additives[15] and the pharmaceutical industry.[16] Various literature reports about the synthesis of Schiff bases are available. These reports show that the transition-metal complexes of Cu(II), Co(II), Fe(II), Ni(II), and V(II) were produced from bidentate Schiff bases, which exhibit good antibacterial activity.[17,18] The various organic transformations using a microwave-assisted reaction[19−21] are reported. In this work, we report a microwave-assisted synthesis of Schiff bases using anacardic acid present in cashew shell extract, which acts as an acid catalyst. The cashew nut is native to Central America and India, mostly in the Konkan region of Maharashtra.[22]

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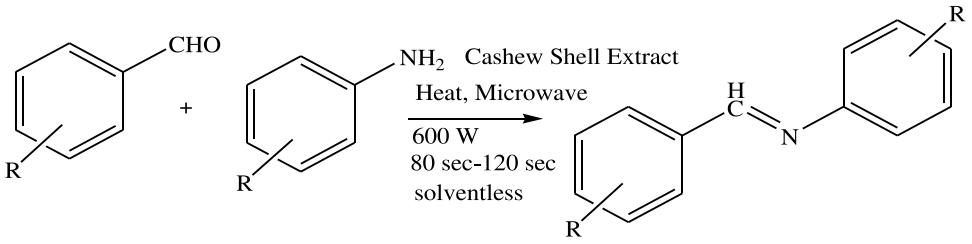
Scheme 1. Schiff Base Derivatives Prepared under a Microwave Irradiation Mechanism



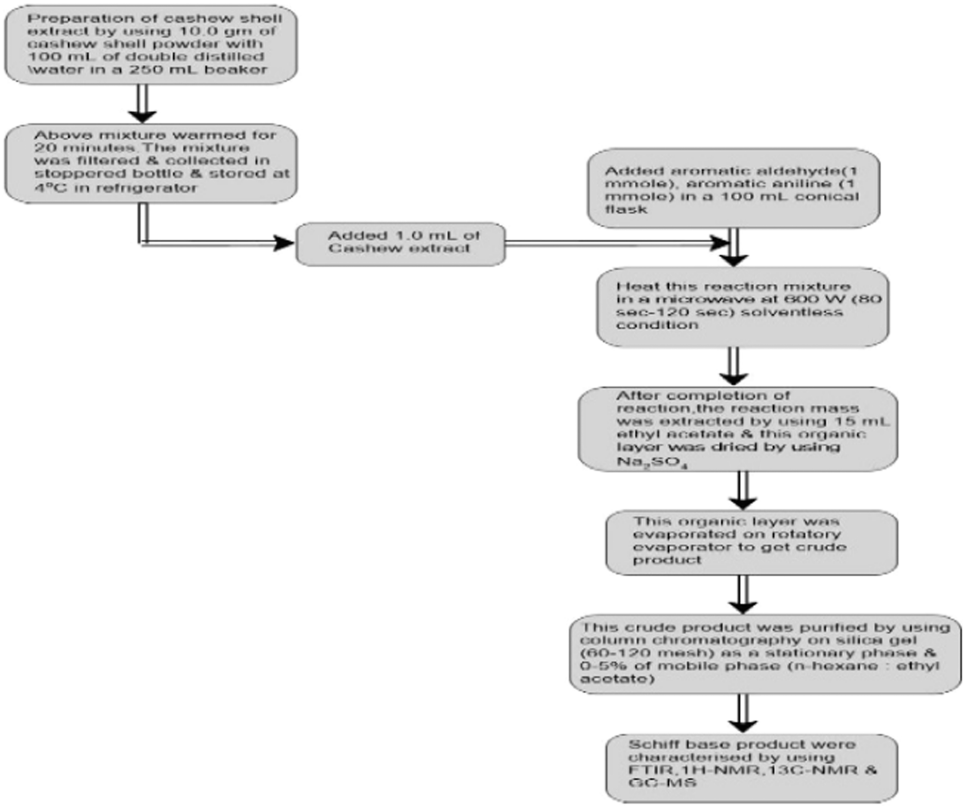


Figure 1. Flow chart of synthesis procedure of Schiff Bases.

Cashew nut shells were obtained from the cashew nut processing industry. The peeled-off shells are thrown into the environment. This biowaste is very hazardous to the environment. These cashew nut shells have an anacardic acid phenolic compound and cardanol.[23] Schiff base preparation using this methodology has a faster reaction rate, shorter time, easy workup, and good yield. These beneficial points make this methodology more interesting and attractive.

2. MATERIAL AND METHODS

All of the chemicals were purchased from HiMedia, Ratnagiri, Maharashtra, India, and used without purification. Solvents were dried by standard methods to use for reactions. A microwave energy source (model: Panasonic microwave) was used for carrying out microwave irradiation reactions. TLC was carried out with Merck silica gel 60-F_{254} plates, and column chromatography was performed over silica gel (60−120 mesh) obtained from commercial suppliers. All of the yields given in this work are referred to as an isolated yield. ^{1}H and ^{13}C nuclear magnetic resonance (NMR) spectra were recorded on a Bruker Advance III spectrometer (400 MHz, Switzerland) using $CDCl_3$ as a solvent and tetramethylsilane as an internal standard. GC−MS spectra were recorded on a Shimadzu spectrometer, Singapore. The Fourier transform infrared (FTIR) spectrum was obtained using the KBr water technique on a 3000 Hyperion microscope with vertex 80 FTIR system from Bruker, Germany.

2.1. Preparation of Cashew Shell Extract. The cashew shells were collected from the cashew nut industry, MIDC, Mirjole, Ratnagiri, Maharashtra, India. These cashew shells were sun-dried for 4 days and powdered using a grinder. Then, 10.0 g of cashew shell powder was added to a 250 mL beaker with 100 mL of double-distilled water. The mixture was warmed for 20 min. This warmed mixture was filtered and collected in a glass stoppered bottle. This filtrate was stored in a refrigerator at 4 °C and is designated as a cashew shell extract.

2.2. General Procedure for the Synthesis of Schiff Bases under Microwave Irradiation. Aromatic aldehyde (mmol), aromatic amine (1 mmol), and cashew shell extract (1 mL) were added to a 100 mL conical flask. This conical flask was covered with aluminum foil. The reaction mixture was kept in a microwave at 600 W. The time required to prepare Schiff bases under microwave irradiation varies between 80 and

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120 s for all entries of Table 3. This reaction was carried out without any solvent. The reactions were monitored by TLC (Scheme 1). After the completion of reaction, the reaction mass was obtained using ethyl acetate (15 mL). This was kept for 3 min. Then, this organic layer was dried using Na_2SO_4. This organic layer was evaporated on a rotatory evaporator to obtain the crude product. This crude product was purified by column chromatography on silica gel (60−120 mesh) as a stationary phase and a mobile phase of 0−5% *n*-hexane/ethyl acetate. The purified Schiff base derivative was characterized by FTIR, ^{1}H NMR, ^{13}C NMR, and GC−MS. All of the prepared Schiff bases are known, and their spectral data matches with the reported literature values.[19] These spectral data are provided in the Supporting Information. Figure 1 shows the flow chart for the synthesis of Schiff bases.

3. RESULTS AND DISCUSSION

The improvement of reaction conditions served as a validation for this methodology. The optimization reaction condition was validated for the model reaction of salicylaldehyde (1 mmol) and aniline (1 mmol). Using conventional heating, the practical yield of the reaction was examined. Salicylaldehyde (1 mmol) and aniline (1 mmol) were mixed together for this reaction and agitated at room temperature for 45 min without the addition of cashew shell extract. The Schiff base derivative product was not produced by this reaction (Table 1, entry 1).

Table 1. Optimization Studies Using Salicylaldehyde and Aniline under Conventional Heating

entry	catalyst (cashew shell extract in mL)	temp (°C)	time (min)	% yield
1	0	RT	45	
2	0	70	180	
3	1	RT	45	trace
4	1	70	45	trace

After that, for 3 h at 70 °C, the same model reaction was conducted. Still, the Schiff base derivative product that was anticipated does not develop (Table 1, entry 2). After stirring for 45 min at room temperature and the addition of cashew shell extract (1 mL), the production of the Schiff base derivative product was examined, and only a trace quantity of Schiff base derivative product yield was obtained (Table 1, entry 3). If the model reaction took place at 70 °C for 45 min, trace amounts of the product were produced (Table 1, entry 4). The model reaction's optimization was then verified in a microwave environment. This model reaction was exposed to microwave radiation at 600 W for 80 s without a solvent or cashew shell extract (Table 2, entry 1). When the model reaction (Table 2, entry 2) was performed without a solvent, without cashew shell extract, and with microwave irradiation for 80 s at 400 W, the Schiff base product yield observed was 70%. When an identical reaction (Table 2, entry 3) was conducted at 600 W for 80 s with the addition of cashew shell extract, the yield for the Schiff base products was 88.04%. By employing cashew shell extract, the percentage yield of Schiff base derivative products increased in a consistent manner. This process yields the resultant product quickly. The efficacy of this technology was tested for various aromatic amines and aromatic aldehydes. This procedure for various aromatic amines and aromatic aldehydes using microwave energy results in excellent to good yield (Table 3). As shown in Table 3, a slight reduction in the practical yield for Schiff base was observed when an electron-withdrawing group, such as $-NO_2$, is present on the aromatic system. The table shows that microwave irradiation results in a quicker reaction time and a larger yield of Schiff base products. Figure 2 depicts a possible mechanism of this process.

Table 2. Optimization Studies Using Salicylaldehyde and Aniline under a Microwave Energy Source

entry	catalyst (cashew shell extract in mL)	microwave energy (W)	time (s)	% yield
1	0	600	80	
2	1	400	80	65.00
3	1	600	80	88.04

3.1. 2-[(*E*)-(Phenylimino)methyl]phenol (Table 3, Entry 1). Salicylaldehyde (2.44 gm), aniline (1.825 mL), and cashew shell extract (3 mL) were used. 2-[(*E*)-(Phenylimino)methyl]phenol is obtained as a pale yellow solid. MP = 52 °C (R_f = 0.65, *n*-hexane/ethyl acetate). FTIR: 3064.42 cm^{-1} for aromatic −OH stretching, 2886.47 cm^{-1} for aromatic −C−H stretching, 1682.11 and 1616.42 cm^{-1} for −N═CH− stretching, 1484.53 cm^{-1} for Ar−C═C− stretching. ^{1}H NMR δ 7.35 (m, 5H), δ 8.65 (s, 1H), δ 6.76 (d, 1H), δ 7.12 (dd, 1H), δ 6.85 (dd, 1H), δ 7.45 (d, 1H). ^{13}C NMR δ 119.07, δ 153.2, δ 130.1, δ 127.3, δ 160.1, δ 118.5, δ 132.28, δ 161.13, δ 162.68, δ 116.0, δ 132.5, δ 121.5, δ 130.6. GC−MS molecular formula: $C_{13}H_{11}NO$, molecular weight: 197, mass fragment (*m*/*z*): 197, 180, 167, 151, 139, 120, 104, 91, 78, 77, 65, 51, 50, 39.

3.2. (*E*)-*N*-(4-Nitrobenzylidene)benzenamine (Table 3, Entry 2). 4-Nitrobenzaldehyde (3.02 g), aniline (1.825 mL), and cashew shell extract (3 mL) were used. (*E*)-*N*-(4-Nitrobenzylidene)benzenamine was obtained as a yellow solid. MP = 70 °C (R_f = 0.55, *n*-hexane/ethyl acetate). FTIR: 3077.78 cm^{-1} for aromatic −C−H stretching, 2879.78 cm^{-1} for aliphatic −C−H stretching, 1682.17 and 1626.54 cm^{-1} for −N═CH− stretching, 1517.76 cm^{-1} for Ar−C═C− stretching, 1347.01 and 1315.83 cm^{-1} for $-NO_2$ stretching. ^{1}H NMR δ 7.3 (m, 5H), δ 8.39 (s, 1H), δ 7.56 (d, 1H), δ 8.40 (d, 1H). ^{13}C NMR δ 127.3, δ 130.1, δ 120.96, δ 150.91, δ 157.37, δ 130.1, δ 141.56, δ 121.2, δ 150.91. GC−MS molecular formula: $C_{13}H_{10}N_2O_2$, molecular weight: 226, mass fragment (*m*/*z*): 226, 195, 179, 167, 152, 140, 127, 115, 104, 90, 77, 76, 63, 51, 39, 28.

3.3. (*E*)-*N*-(4-Chlorobenzylidene)benzenamine (Table 3, Entry 3). 4-Chlorobenzaldehyde (2.81 g), aniline (1.825 mL), and cashew shell extract (3 mL) were used. (*E*)-*N*-(4-Chlorobenzylidene)benzenamine was obtained as a white solid. MP = 53 °C (R_f = 0.52, *n*-hexane/ethyl acetate). FTIR: 3081.43 cm^{-1} for aromatic −C−H stretching, 2983.48 cm^{-1} for aliphatic −C−H stretching, 1654.06 and 1621.27 cm^{-1} for −N═CH− stretching, 1584.48 cm^{-1} for Ar−C═C− stretching, 828.23 cm^{-1} for Ar−Cl stretching. ^{1}H NMR δ 7.3 (m, 5H), δ 8.45 (s, 1H), δ 7.56 (d, 2H), δ 7.50 (d, 2H). ^{13}C NMR δ 122.3, δ 153.2, δ 130.1, δ 127.3, δ 131.9, δ 130.6, δ 129.0, δ 136.6. GC−MS molecular formula: $C_{13}H_{10}NCl$, molecular weight: 214, mass fragment (*m*/*z*): 214, 200, 180, 152, 126, 112, 104, 89, 77, 63, 51.

3.4. (*E*)-*N*-(4-Chlorobenzylidene)-4-nitrobenzenamine (Table 3, Entry 4). 4-Chlorobenzaldehyde (2.81 g), 4-nitroaniline (2.76 g), and cashew shell extract (3 mL) were used. (*E*)-*N*-(4-Chlorobenzylidene)-4-nitrobenzenamine was

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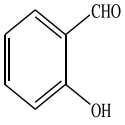
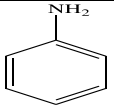
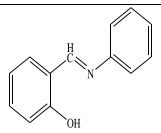
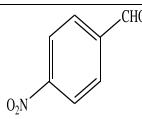
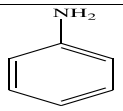
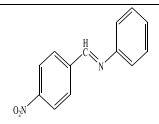
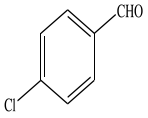
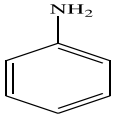
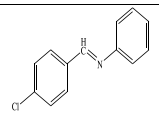
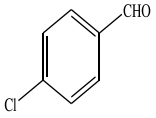
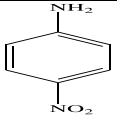
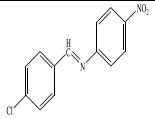
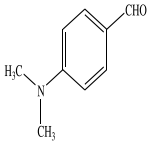
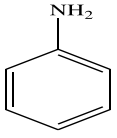
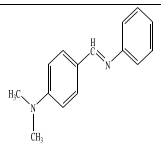
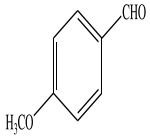
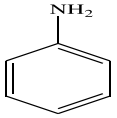
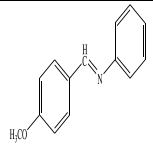
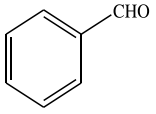
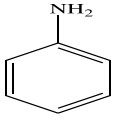
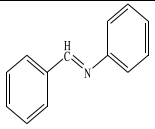
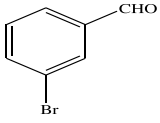
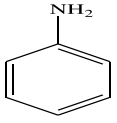
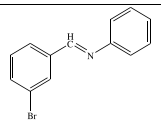
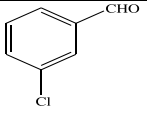
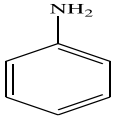
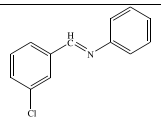
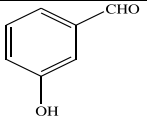
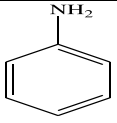
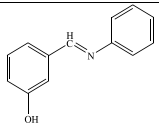
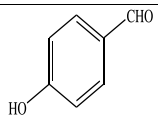
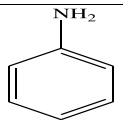
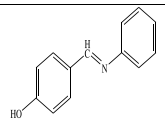
Table 3. Microwave-Assisted Synthesis of Schiff Bases in the Presence of Cashew Shell Extract

Entry	Aromatic aldehydes	Aromatic amines	Schiff base derivatives	% yield	Time in second	Observed M.P/B.P (°C)
1				88.04	80	52
2				84.95	120	70
3				88.27	80	53
4				85.10	80	136
5				86.38	80	62
6				82.91	80	50
7				81.49	120	50
8				81.00	120	256
9				80.00	80	278
10				82.35	80	66
11				82.78	80	210

obtained as a yellow solid. MP = 136 °C (R_f = 0.52, *n*-hexane/ethyl acetate). FTIR: 3477.92−3361.09 cm^{-1} for $-NH_2$ stretching, 3093.43 cm^{-1} for aromatic −C−H stretching, 2919.74 cm^{-1} for aliphatic −C−H stretching, 1686.87 cm^{-1} for −N═CH− stretching, 1582.21 and 1506.57 cm^{-1} for Ar−C═C− stretching, 1334.50 cm^{-1} for aromatic $-NO_2$ stretching,

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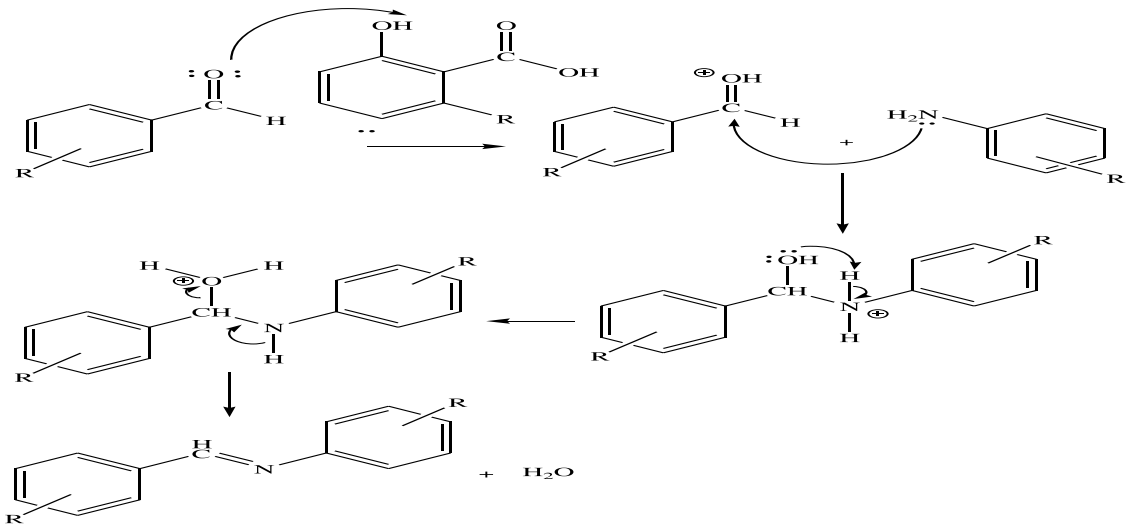

Figure 2. Possible mechanism of preparation of Schiff base derivative in the presence of cashew shell extract.

1169.15 cm^{-1} aliphatic −C−C− stretching, 850.43 cm^{-1} for Ar−Cl stretching. ^{1}H NMR δ 8.2 (d, 2H), δ 7.5 (d, 2H), δ 8.39 (s, 1H), δ 7.56 (d, 2H), δ 7.30 (d, 2H). ^{13}C NMR δ 151.65, δ 120.85, δ 126.2, δ 158.84, δ 137.38, δ 131.9, δ 130.6, δ 129.0, 136.6. GC−MS molecular formula: $C_{13}H_9ClN_2O_2$, molecular weight: 260, mass fragment (m/z): 260, 244, 230, 213, 201, 178, 167, 152, 139, 103, 89, 76, 63, 50.

3.5. (*E*)-*N*-[4-(Dimethylamino)benzylidene]-benzenamine (Table 3, Entry 5). 4-(Dimethylamino)-benzaldehyde (2.98 g), aniline (1.825 mL), and cashew shell extract (3 mL) were used. (*E*)-*N*-[4-(Dimethylamino)-benzylidene]benzenamine was obtained as a blackish-brown solid. MP = 62 °C (R_f = 0.50, *n*-hexane/ethyl acetate). FTIR: 2950 cm^{-1} for aromatic −C−H stretching, 2819.95 cm^{-1} for aromatic −C−H stretching, 1661.59 and 1600.89 cm^{-1} for −N═CH− stretching, 1550.83 and 1527.93 cm^{-1} for Ar−C═C− stretching. ^{1}H NMR δ 7.35 (m, 5H), δ 8.33 (s, 1H), δ 7.39 (d, 2H), δ 6.70 (d, 2H), δ 3.091 (s, 6H). ^{13}C NMR δ 127.3, δ 130.49, δ 125, δ 154.33, δ 160.2, δ 120.94, δ 130.1, 110.98, δ 152.5, δ 40.18. GC−MS molecular formula: $C_{15}H_{16}N_2$, molecular weight: 224, mass fragment (m/z): 223, 207, 179, 145, 120, 102, 91, 77, 63, 51, 42.

3.6. (*E*)-*N*-(4-Methoxybenzylidene)benzenamine (Table 3, Entry 6). 4-Methoxybenzaldehyde (2.72 g), aniline (1.825 mL), and cashew shell extract (3 mL) were used. (*E*)-*N*-(4-Methoxybenzylidene)benzenamine is obtained as a red solid. MP = 50 °C (R_f = 0.52, *n*-hexane/ethyl acetate). FTIR: 3050.49 and 2962.28 cm^{-1} for aromatic −C−H stretching, 2880.32 cm^{-1} for aliphatic −C−H stretching, 1684.32 and 1621.28 cm^{-1} for −N═CH− stretching, 1573.88 and 1507.88 cm^{-1} for Ar−C═C− stretching, 1073.49 and 1030.43 cm^{-1} for −C−O−C ether linkage. ^{1}H NMR δ 7.37 (m, 5H), δ 8.39 (s, 1H), δ 7.42 (d, 2H), δ 6.98 (d, 2H), δ 3.87 (s, 3H). ^{13}C NMR δ 120.9, δ 130.5, δ 125.5, δ 152.3, δ 159.7, δ 126.1, δ 130.2, 114.2, δ 162.2, δ 55.43. GC−MS molecular formula: $C_{14}H_{13}NO$, molecular weight: 211, mass fragment (m/z): 211, 195, 179, 167, 151, 134, 115, 104, 90, 77, 63, 51, 39, 27, 15.

3.7. (*E*)-*N*-Benzylidenebenzenamine (Table 3, Entry 7). Benzaldehyde (2.03 mL), aniline (1.825 mL), and cashew shell extract (3 mL) were used. (*E*)-*N*-(*E*)-*N*-Benzylidene-benzenamine was obtained as a brownish solid. MP = 50 °C (R_f = 0.54, *n*-hexane/ethyl acetate). FTIR: 3060 and 2886 cm^{-1} for aromatic −C−H stretching, 1624 and 1583 cm^{-1} for −N═CH− stretching, 1734 cm^{-1} for Ar−C═C− stretching. ^{1}H NMR δ 7.27 (m, 5H), δ 8.50 (s, 1H), δ 7.94 (d, 2H), δ 7.40 (dd, 3H). ^{13}C NMR δ 115.1, δ 153.2, δ 130.1, δ 128.7, δ 160.45, δ 131.4, δ 129.3, δ 128.8, δ 131.4. GC−MS molecular formula: $C_{13}H_{11}N$, molecular weight: 181, mass fragment (m/z): 181, 152, 140, 127, 115, 104, 89, 77, 74, 63, 51, 38, 27.

3.8. (*E*)-*N*-(3-Bromobenzylidene)benzenamine (Table 3, Entry 8). 3-Bromobenzaldehyde (2.34 mL), aniline (1.825 mL), and cashew shell extract (3 mL) were used. (*E*)-*N*-(3-Bromobenzylidene)benzenamine was obtained as a brownish liquid. BP = 256 °C (R_f = 0.54, *n*-hexane/ethyl acetate). FTIR: 3060.99 and 3029.58 cm^{-1} for aromatic −C−H stretching, 2873.81 cm^{-1} for aliphatic −C−H stretching, 1700 and 1627 cm^{-1} for −N═CH− stretching, 1563.40−1591.70 cm^{-1} for Ar−C═C− stretching, 784.17−694.25 cm^{-1} for Ar−Br stretching. ^{1}H NMR δ 7.29 (m, 5H), δ 8.39 (s, 1H), δ 7.59 (d, 1H), δ 7.22 (dd, 1H), δ 7.44 (d, 1H), δ 7.79 (d, 1H). ^{13}C NMR δ 120.9, δ 151.4, δ 130.1, δ 127.6, δ 158.5, δ 138.1, δ 130.3, δ 129.2, 131.1, δ 134.0, δ 123.0, δ 131.2. GC−MS molecular formula: $C_{13}H_{10}NBr$, molecular weight: 259, mass fragment (m/z): 259, 182, 155, 152, 127, 102, 90, 76, 63, 50, 39.

3.9. (*E*)-*N*-(3-Chlorobenzylidene)benzenamine (Table 3, Entry 9). 3-Chlorobenzaldehyde (2.26 mL), aniline (1.825 mL), and cashew shell extract (3 mL) were used. (*E*)-*N*-(3-Chlorobenzylidene)benzenamine was obtained as a brownish-red liquid. BP = 278 °C (R_f = 0.53, *n*-hexane/ethyl acetate). FTIR: 3062.84 and 3028.98 cm^{-1} for aromatic −C−H stretching, 2874 cm^{-1} for aliphatic −C−H stretching, 1701.51 and 1627.99 cm^{-1} for −N═CH− stretching, 1592.55 and 1568.59 cm^{-1} for Ar−C═C− stretching, 1096.83 and 1074.34 cm^{-1} for −C−O−C− stretching, 838.59 cm^{-1} for Ar−Cl stretching. ^{1}H NMR δ 7.3 (m, 5H), δ 8.40 (s, 1H), δ 7.48 (d, 1H), δ 7.23 (dd, 1H), δ 7.30 (d, 1H), δ 7.75 (s, 1H). ^{13}C NMR δ 120.9, δ 151.4, δ 130.1, δ 127.2, δ 126.4, δ 158.6, δ 135.2, δ 130, 131.2, δ 138, δ 129.3. GC−MS molecular formula: $C_{13}H_{10}NCl$, molecular weight: 215, mass fragment (m/z): 215, 200, 180, 151, 126, 112, 104, 89, 77, 63, 51, 40.

3.10. 3-[(*E*)-(Phenylimino)methyl]phenol (Table 3, Entry 10). 3-Hydroxybenzaldehyde (2.44 g), aniline (1.825

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mL), and cashew shell extract (3 mL) were used. 3-[(*E*)-(Phenylimino)methyl]phenol was obtained as a red solid. MP = 66 °C (R_f = 0.52, *n*-hexane/ethyl acetate). FTIR: 3052.39 cm^{-1} for aromatic −OH stretching, 2916.25 cm^{-1} for aromatic −C−H stretching, 1622.12 cm^{-1} for −N=CH− stretching, 1586.41 cm^{-1} for Ar−C=C− stretching. ^{1}H NMR δ 7.33 (m, 5H), δ 8.37 (s, 1H), δ 7.22 (d, 1H), δ 7.20 (dd, 1H), δ 6.95 (d, 1H), δ 7.09 (s, 1H), δ 5.41 (s, 1H). ^{13}C NMR δ 122.3, δ 151.4, δ 130.1, δ 127.3, δ 161, δ 137.2, δ 122.2, δ 130.1, 119.3, δ 156.3, δ 114.3. GC−MS molecular formula: $C_{13}H_{11}NO$, molecular weight: 197, mass fragment (*m*/*z*): 197, 180, 167, 151, 139, 120, 104, 91, 78, 77, 65, 51, 50, 39.

3.11. 4-[(*E*)-(Phenylimino)methyl]phenol (Table 3, Entry 11). 4-Hydroxybenzaldehyde (2.44 g), aniline (1.825 mL), and cashew shell extract (3 mL) were used. 4-[(*E*)-(Phenylimino)methyl]phenol was obtained as a brownish solid. MP = 210 °C (R_f = 0.51, *n*-hexane/ethyl acetate). FTIR: 3169.89 cm^{-1} for aromatic −OH stretching, 2921.74 and 2858.83 cm^{-1} for aromatic −C−H stretching, 1671.60 cm^{-1} for −N=CH− stretching, 1578.04 and 1512.93 cm^{-1} for Ar−C=C− stretching. ^{1}H NMR δ 7.26 (m, 5H), δ 8.39 (s, 1H), δ 7.41 (d, 1H), δ 6.96 (d, 1H), δ 6.9 (s, 1H). ^{13}C NMR δ 120.9, δ 153.2, δ 129.2, δ 127.3, δ 126.4, δ 132.3, δ 115.9, δ 161.3. GC−MS molecular formula: $C_{13}H_{11}NO$, molecular weight: 197, mass fragment (*m*/*z*): 197, 178, 167, 141, 120, 104, 89, 77, 65, 51, 39, 28.

This Schiff base derivative is all documented. Using the agar well-diffusion method, the 2-[(*E*)-(phenylimino)methyl]-phenol antibacterial activity was evaluated against bacillus Gram-positive bacteria, which demonstrates a successful zone of inhibition.

4. CONCLUSIONS

In this work, we have developed a green methodology for the synthesis of Schiff base derivatives. The reaction was carried out without solvent in a conical flask. The anacardic acid present in the cashew shell extracts acts as a catalyst. It is observed that Schiff base derivative product yield is excellent to good (88.27−80.00%). The reaction shows a higher percent yield of Schiff base derivatives in a shorter period of time. The reactions were completed in a shorter period of time, i.e., 80−120 s, under microwave irradiation. The spectral data (FTIR, ^{1}H NMR, ^{13}C NMR, and GC−MS) of Schiff base derivative in the presence of cashew shell extract as a natural acid catalyst is provided in the Supporting Information. Compared with the traditional pathway, this pathway is solvent-free, easy, cleaner, and safe. This pathway does not employ any toxic side product, and it is simple to workup with maximum efficiency for the formation of Schiff base derivatives. This cashew shell will help to prepare those Schiff bases that have a core bioactive nucleus of drug molecules.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acsomega.2c05187.

Flow chart of the synthesis procedure of Schiff bases; possible mechanism of preparation of Schiff bases; zone of inhibition of 2-[(*E*)-(phenylimino)methyl]phenol; scheme of Schiff base derivatives prepared under microwave irradiation; table of optimization studies using salicylaldehyde and aniline under conventional heating; table of optimization studies using salicylaldehyde and aniline under a microwave energy source; table of microwave-assisted synthesis of Schiff bases in the presence of cashew shell extract; ^{1}H NMR and ^{13}C NMR spectra and GC−MS analysis of the Schiff bases. (PDF)

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Author Contributions

S.B.M. and R.K.M. designed the research; R.K.M., K.S.M., P.P.M., and S.S.D. performed the experiments; K.S.M. and R.K.M. wrote the manuscript; S.B.M. and S.S.D. corrected and edited the manuscript; and S.B.M. created the TOC graphic, and it is original. All authors have read and agreed that the present version of the manuscript is suitable for publication. All authors have seen and approved the manuscript for submission.

Notes

The authors declare no competing financial interest.

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