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ARTICLE

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Synthesis, characterization, and antioxidant activity of heterocyclic Schiff bases

Hakan Kizilkaya[1] | **Beşir Dag**[1] | **Tarik Aral**[1] | **Nusret Genc**[2] | **Ramazan Erenler**[2]

[1]Department of Chemistry, Faculty of Arts and Sciences, Batman University, Batman, Turkey

[2]Department of Chemistry, Faculty of Arts and Sciences, Tokat Gaziosmanpasa University, Tokat, Turkey

Correspondence
Ramazan Erenler, Department of Chemistry, Faculty of Arts and Sciences, Tokat Gaziosmanpasa University, 60250 Tokat, Turkey.
Email: rerenler@gmail.com

Abstract

Schiff base derivatives have gained great importance due to revealing a great number of biological properties. Schiff bases were synthesized by treatment of 4-amino-1,5-dimethyl-2-phenyl-1H-pyrazol-3(2H)-one (**1**) with various aldehydes in methanol at reflux. In addition, diamine was reacted with an aldehyde to yield the corresponding Schiff bases. The structures of synthesized Schiff bases were elucidated by spectroscopic methods such as microanalysis, ^{1}H-NMR, ^{13}C-NMR, and FTIR. Antioxidant activities of synthesized Schiff bases were carried out using different antioxidant assays such as 1,1-diphenyl-2-picryl-hydrazyl free radical (DPPH$^{\bullet}$) scavenging, 2,2′-azino-bis (3-ethylbenzthiazoline-6-sulfonic acid) (ABTS) radical scavenging, and reducing power activity. (*E*)-4-((1H-indol-3-yl)methyleneamino)-1,5-dimethyl-2-phenyl-1H-pyrazol-3(2H)-one (**3**), (*E*)-1,5-dimethyl-4-((2-methyl-1H-indol-3-yl) methyleneamino)-2-phenyl-1H-pyrazol-3(2H)-one (**5**), (*E*)-1,5-dimethyl-2-phenyl-4-(thiophen-2-ylmethyleneamino)-1H-pyrazol-3(2H)-one (**7**), (*E*)-1,5-dimethyl-2-phenyl-4-(quinolin-2-ylmethyleneamino)-1H-pyrazol-3(2H)-one (**9**), (1S,2S, N1,N2)-N1,N2-bis((1H-indol-3-yl)methylene)cyclohexane-1,2-diamine (**11**), and (1S,2S,N1,N2)-N1,N2-bis((2-methyl-1H-indol-3-yl)methylene)cyclohexane-1,2-diamine (**12**) were synthesized in high yields. Compound **5** displayed a good ABTS$^{\bullet+}$ activity. Compound **3** revealed the outstanding activity in all assays. Compound **7** has the best-reducing power ability in comparison to other synthesized compounds. Although compounds **5, 11, 12** are new, compounds **3, 7, 9** are known. Due to revealing a good antioxidant activity, the synthesized compounds (**3, 5, 7**) have the potential to be used as synthetic antioxidant agents.

KEYWORDS

antioxidant activity, chromatography, heterocyclic, Schiff base, spectroscopy, synthesis

1 | INTRODUCTION

The synthesis of aromatic compounds is of great importance due to the wide variety of uses.[1–8] The Schiff bases (SBs) have gained great interest owing to the wide range of their applications nowadays. The SBs, defined by an imine or azomethine (−CH = N−) group, are mostly synthesized by the condensation reaction of carbonyl compounds (aldehyde or ketone) with compounds consisting of amine moiety.[9] Due to the electron-donating ability,

SBs could be used in the field of coordination chemistry extensively.[10] SBs are among the most chiefly used organic compounds, revealing a wide range of applications, such as electroluminescent effects,[11] fluorescence properties,[12] nonlinear optical properties,[13] chemosensory.[14] In addition, SBs and their metal complexes have showed a large variety of biological activity in recent research, including anticancer, antioxidant,[15] antibacterial, antibiofilm, anti-inflammatory, hemocompatibility, cytotoxic,[16] pesticidal, nematicidal activities.[17] Due to the flexible and stereoelectronic structures, most SBs are attractive ligants to form stable complexes with most transition metals[18]. SBs complexes reveal considerable catalytic activities for many organic transformations.[19]

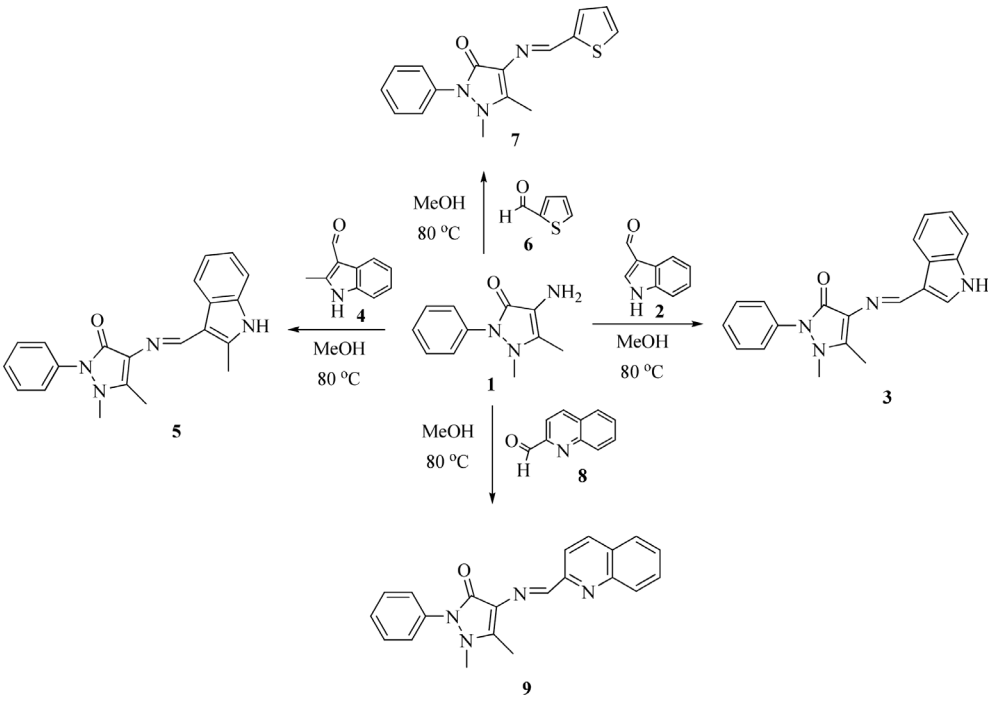
Reactive oxygen species (ROS) are free radicals produced during the oxidative metabolism. ROS can attack the nucleic acid, lipids, proteins, polyunsaturated fatty acids, and carbohydrate and induce their oxidation that may lead to oxidative damage such as protein change, membrane dysfunction, enzymatic inactivation, and break of DNA strains. Hence, ROS should be scavenged by cellular constituents. An antioxidant can inhibit or delay the oxidation of other molecules. Antioxidants are capable of inhibiting the formation of free radicals as well as delaying the lipid peroxidation leading to the deterioration of food and pharmaceutical products while processing and storage stage. Antioxidants can protect the human body from ROS. Antioxidants have been extensively used for food to prevent radical chain reactions causing the deterioration of food.[20–22]

2 | RESULTS AND DISCUSSION

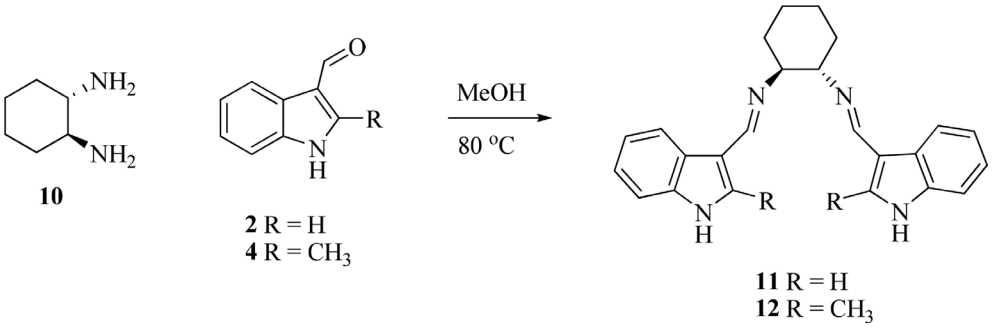
2.1 | Synthesis and characterization

The synthetic pathways for the synthesis of corresponding compounds were given (3, 5, 7, 9) in Schemes 1 and 2 (11, 12). The treatment of 4-amino-1,-5-dimethyl-2-phenyl-1H-pyrazol-3(2H)-one (1) with indole-3-carbaldehyde (2) at 80°C in MeOH yielded the corresponding compound 1,5-dimethyl-4-[(3-indoleyl)-methyleneamino]-2- phenyl-1H-pyrazol-3(2H)-one (3).[23] IR spectrum indicated the vibration bands for C═O at 1,624 cm^{-1} and for NH at 3,135 cm^{-1} confirmed the corresponding structure. In the ^{1}H NMR spectrum, the NH signal was observed at 11.60 ppm as a singlet. Olefinic proton gave the signal at 9.78 ppm as a singlet due to the lack of neighbor proton. Because of the deshielding effect, olefinic proton shifted downfield. Aromatic proton signal at indole ring appeared at 8.45 ppm as a doublet with a coupling constant of 8.0 Hz and other aromatic protons gave the signals between 7.87 and 7.18 ppm. The methyl groups bounded to nitrogen and carbon gave the signals at 3.10 and 2.48 ppm, respectively. In the ^{13}C NMR spectrum, observation of 18 peaks confirmed the proposed structure. The carbonyl peak appeared at 160.9 ppm. The methyl carbon bonded to nitrogen and carbon gave the signals at 36.5 ppm and 10.5 ppm, respectively.

Treatment of 4-aminopyridine (**1**) with methylindole-3-caroboxaldehyde (**4**) in methanol at 80°C resulted in the formation of 1,5-dimethyl-4-((2-methyl-1H-indol-3-yl)



SCHEME 1 The synthesis of Schiff bases



SCHEME 2 The synthesis of Schiff bases by treatment of diamine with aldehydes

methyleneamino)-2-phenyl-1H-pyrazol-3(2H)-one (**5**). Spectroscopic analyses revealed the proposed compound. In the IR spectrum, the NH vibration band was observed at 3,240 cm^{-1}. C═O signal was observed at 1,636 cm^{-1}. In the ^1H NMR spectrum, the integration of protons as well as chemical shifts accord with the structure. The signal observed at δ 11.49 ppm belonged to the NH. The olefinic proton displayed the signal at 9.85 ppm as a singlet. The chemical shifts of aromatic protons accord with the structure. The methyl groups resonated at δ 3.10 ppm, δ 2.54 ppm, δ 2.47 ppm. Nineteen peaks in the ^{13}C NMR spectrum confirmed the proposed structure **5**.

Treatment of 4-aminopyridine (**1**) with thiophene-2-carbaldehyde (**6**) in methanol at 80°C resulted in the formation of 1,5-dimethyl-2-phenyl-4-(thiophen-2-ylmethyleneamino)-1H-pyrazol-3(2H)-one (**7**).[24] In the IR spectrum, the carbonyl signal appeared at 1,636 cm^{-1}. In the ^1H NMR spectrum, the signal of the olefinic proton was observed at 9.88 ppm as a singlet. The other protons gave the signals at the expected location. Fourteen peaks in the ^{13}C spectrum confirmed the proposed structure (**7**).

The reaction of 4-aminopyridine (**1**) with quinoline-2-carbaldehyde (**8**) in MeOH at 80°C afforded the 1,5-dimethyl-2-phenyl-4-(quinolin-2-ylmethyleneamino)-1H-pyrazol-3(2H)-one (**9**).[25] IR spectrum displayed the strong vibration bands for C═O at 1,649 cm^{-1}. In the ^1H NMR spectrum, the chemical shifts were observed at the expected location. The observation of 19 peaks in the ^{13}C NMR spectrum accords with the structure.

The treatment of indole-3-carbaldehyde (**2**) with *trans*-cyclohexane-1,2-diamine (**10**) in ethanol at 80°C yielded the (1S,2S,N1,N2)-N1,N2-bis((1H-indol-3-yl) methylene)cyclohexane-1,2-diamine (**11**). In the IR spectrum, the NH vibration band was observed at 2,925 cm^{-1}. ^1H- and ^{13}C-NMR spectra revealed that the molecule has C2 symmetry. In the ^1H NMR spectrum, the signal observed at δ: 11.31 belonged to the NH protons. The other chemical shifts were observed at expected values that accorded to the structure **11**. The observation of 12 peaks in the ^{13}C NMR spectrum suited with the structure.

The reaction of 2-methyl-indole-3-carbaldehyde (4) with (1S,2S)-cyclohexane-1,2-diamine (10) afforded the (1S,2S,N1,N2)-N1,N2-bis((2-methyl-1H-indol-3-yl) methylene)cyclohexane-1,2-diamine (12). NH vibration band was observed at 2,931 cm^{-1} in the IR spectrum. In the ^1H NMR spectrum, the NH signal appeared at δ 11.15 as a singlet. The appearance of 10 protons signals at aromatic regions accorded to the structure. The aliphatic 10 protons resonated at upfield due to the strong shielding effect. The methyl groups gave the peak at δ 2.32 as a singlet. In the ^{13}C NMR spectrum, signals of four quaternary carbons, five methine carbons, and two methylene carbons supported the proposed symmetric structure.

2.2 | Antioxidant activity

Antioxidant activity of synthesized compounds was investigated using the 1,1-diphenyl-2-picryl-hydrazyl free radical ($DPPH^{\bullet}$) scavenging, 2,2′-azino-bis (3-ethylbenzthiazoline-6-sulfonic acid) (ABTS) radical scavenging, and reducing power activity. The compound 3 revealed the most DPPH activity (48.49 ± 0.13) among the compounds. In addition, it displayed the excellent ABTS (15.09 ± 0.15) scavenging activity. The compound 5 (17.89 ± 0.1), RA5 (27.97 ± 0.15) showed the considerable ABTS scavenging effect also. In concerning reducing power, the compound 7 (4.55 ± 0.02) and compound 3 (4.084 ± 0.015) have significant reducing power effect compared to the standards BHA (9.035 ± 0.186) (Table 1).

3 | EXPERIMENTAL

3.1 | General procedure

NMR spectra were recorded on a Bruker spectrometer with ^1H NMR at 400 MHz, ^{13}C NMR at 100 MHz. The ^1H NMR chemical shifts were measured relative to $CDCl_3$ as the internal reference ($CDCl_3$: δ 7.26, DMSO-d6: δ 2.5).

TABLE 1 Antioxidant activity of synthesized compounds

Compounds	DPPH[a]	ABTS[a]	FRAP[b]
3	48.49 ± 0.13	15.09 ± 0.15	4.084 ± 0.015
5	91.83 ± 0.28	17.89 ± 0.1	3.355 ± 0.024
7	616.36 ± 2.04	32.03 ± 0.16	4.55 ± 0.02
9	724.79 ± 2.06	27.97 ± 0.15	3.535 ± 0.204
11	591.62 ± 3.16	45.53 ± 0.17	0.227 ± 0.007
12	593.66 ± 3.54	44.23 ± 0.28	0.328 ± 0.007
BHT	11.81 ± 0.42	10.34 ± 0.07	5.288 ± 0.187
BHA	5.19 ± 0.08	7.14 ± 0.09	9.035 ± 0.186
Trolox	5.34 ± 0.06	6.92 ± 0.04	-

[a]IC_{50} (μg/ml).
[b]mmol TE/g compound.

TLC was carried out on alumina plates ($60F_{254}$). UV-260 Shimadzu spectrometer was used for UV analysis. Silica gel (Kiesegel 60, 0.063–0.200 mm, Merck) was used for column chromatography. Melting points were determined with a Biichi B-540 apparatus and were uncorrected. IR analyses were executed on Jasco FT/IR47700 spectrometer. All chemicals and solvents for reactions and antioxidant assays were supplied from E. Merck (Darmstadt, Germany).

3.1.1 | Synthesis of 4-(1H-Indol-3-ylmethyleneamino)-1,5-dimethyl-2-phenyl-1H-pyrazol-3(2H)-one (3)

A solution of 4-amino-1,5-dimethyl-2-phenyl-1H-pyrazol-3(2H)-one (**1**) (2.03 g, 0.010 mol) in methanol (20 ml) was prepared and started to reflux, indole-3-carbaldehyde (**2**) (1.45 g, 0.010 mol) was added to this solution for 72 min during the 4 min periods. After the completion of the reaction, solid product was filtered and dried. Yield: 2.65 g, 80%; mp: 280–282°C. Anal. Calcd for $C_{20}H_{18}N_4O$: C, 72.71; H, 5.49. Found: C, 72.77; H, 5.51. FTIR: υ/cm^{-1} 3,135, 3,104, 3,037, 2,976, 2,920, 2,878, 1,624, 1,599, 1,583, 1,571, 1,524, 1,496, 1,482, 1,455, 1,437, 1,378, 1,359, 1,303, 1,284, 11,244, 1,141, 1,115, 1,003, 962, 934, 884, 862, 785 (Figure S5). ^{1}H NMR (400 MHz, DMSO-d6) δ: 11.60 (s, 1H, NH), 9.78 (s, 1H), 8.45 (d, J = 8.0 Hz, 1H), 7.86 (d, J = 4.0 Hz, 1H), 7.52 (t, J = 8.0 Hz, 2H), 7.46 (d, J = 8.0 Hz, 1H), 7.41 (d, J = 8.0 Hz, 2H), 7.34 (t, J = 8.0 Hz, 1H), 7.20 (m, 2H), 3.10 (s, 3H), 2.48 (s, 3H) (Figure S1). ^{13}C NMR (100 MHz, DMSO-d6) δ: 160.9, 152.9, 151.4, 137.8, 135.5, 132.0, 129.5, 126.8, 125.2, 124.4, 123.0, 122.6, 121.1, 119.0, 116.4, 112.3, 36.5, 10.5 (Figure S3).

3.1.2 | Synthesis of 1,5-dimethyl-4-[(2-methyl-1H-indol-3-yl) methyleneamino]-2-phenylpyrazol-3-one (5)

To a solution of 4-aminopyridine (**1**) (2.0 g, 10.0 mmol) in dry methanol (30 ml) was added a solution of 2-methylindole-3-caroboxaldehyde (**4**) (1.6 g, 10.0 mmol) in dry methanol (20 ml) slowly for 100 min via micropipette. The reaction mixture was stirred for overnight at reflux temperature. The reaction progress was monitored by TLC. After cooling to room temperature, the solid part was filtered by filtering flask under vacuum by adding cold methanol to yield the desired solid product (**5**) (2.8 g, 82%). Mp: 267–268°C. Anal. Calcd for $C_{21}H_{20}N_4O$: C, 73.23; H, 5.85. Found: C, 73.21; H, 5.82. FTIR: υ/cm^{-1} 3,240, 3,053, 2,900, 1,636, 1,591, 1,571, 1,491, 1,469, 1,452, 1,432, 1,360, 1,347, 1,279, 1,243, 1,132, 1,099, 1,068, 1,018, 962, 928, 903, 870, 851, 764, 745, 720, 692 (Figure S10). ^{1}H NMR (400 MHz, DMSO-d6) δ 11.49 (s, 1H, NH), 9.85 (s, 1H), 8.35 (t, J = 4.8 Hz, 1H), 7.52 (t, J = 7.2 Hz, 2H), 7.41 (d, J = 8.2 Hz, 2H), 7.34 (t, J = 6.2 Hz, 2H), 7.12 (t, J = 4.8 Hz, 2H), 3.10 (s, 3H), 2.54 (s, 3H), 2.47 (s, 3H) (Figure S6). ^{13}C NMR (100 MHz, DMSO-d6) δ: 161.0, 152.2, 151.2, 141.6, 136.3, 135.5, 129.5, 126.7, 126.3, 124.3, 122.1, 121.6, 120.9, 119.5, 111.9, 111.3. 36.5, 12.0, 10.5 (Figure S9).

3.1.3 | Synthesis of (E)-1,5-dimethyl-2-phenyl-4-(thiophen-2-ylmethyleneamino)-1H-pyrazol-3(2H)-one (7)

A solution of 4-aminopyridine (**1**) (2.0 g, 10.0 mmol) in dry methanol (10 ml) was started to reflux. A solution of thiophene-2-carbaldehyde (**6**) (1.12 g, 10 mmol) in MeOH (10 ml) was added to this reflux solution every 4 min and addition was completed for 80 min. After completion of the reaction for 12 hr, the reaction mixture was cooled to room temperature then the solid product was filtered and dried (2.60 g, 87%). Mp: 170–171°C. Anal. Calcd for $C_{16}H_{15}N_3OS$: C, 64.62; H, 5.08. Found: C, 64.67; H, 5.11. FTIR: υ/cm^{-1} 3,066, 2,958, 1,898, 1,814, 1,636, 1,573, 1,560, 1,514, 1,485, 1,454, 1,422, 1,410, 1,376, 1,340, 1,306, 1,211, 1,126, 1,074, 1,048, 1,024, 950, 932, 915, 867, 849, 765, 754, 743, 704, 691 (Figure S14). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 9.88 (s, 1H), 7.49 (m, 2H), 7.41 (m, 3H), 7.38 (d, 3.6 Hz, 1H), 7.33 (t, J = 7.3 Hz, 1H), 7.09 (dd, J = 3. 6 Hz, 4.9 Hz), 3.15 (s, 3H, N-CH_3), 2.47 (s, 3H, Me) (Figure S11). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 160.9, 151.7, 150.8, 145.1, 134.8, 130.4, 129.2, 128.4, 127.7, 126.9, 124.4, 118.4, 35.9, 10.1 (Figure S13).

3.1.4 | Synthesis of (*E*)-1,5-dimethyl-2-phenyl-4-(quinolin-2-ylmethyleneamino)-1H-pyrazol-3(2H)-one (9)

A solution of 4-aminopyridine (**1**) (2.0 g, 10.0 mmol) in dry methanol (10 ml) was started to reflux. A solution of quinoline-2-carbaldehyde (**8**) (1.57 g, 10 mmol) in MeOH (10 ml) was added to this reflux solution every 4 min and addition was completed for 100 min. After completion of the reaction for 12 hr, the reaction mixture was cooled to room temperature then the solid product was filtered and dried (1.91 g, 56%). Mp: 220–221°C. Anal. Calcd for $C_{21}H_{18}N_4O$: C, 73.67; H, 5.30. Found: C, 73.69; H, 5.33. FTIR: υ/cm^{-1} 3,040, 2,929, 1,948, 1,650, 1,588, 1,563, 1,481, 1,453, 1,411, 1,376, 1,356, 1,300, 1,231, 1,131, 1,113, 1,072, 1,037, 1,020, 954, 891, 863, 826, 763, 700 (Figure S19). ^{1}H NMR (400 MHz, DMSO-d6) δ: 9.75 (s, 1H), 8.42 (d, J = 8.5 Hz, 1H), 8.30 (d, J = 8.6 Hz, 1H), 8.06 (d, J = 8.5 Hz, 1H), 8.01 (d, J = 8.1 Hz, 1H), 7.80 (m, 1H), 7.64 (t, J = 7.2 Hz, 1H), 7.58 (m, 2H), 7.43 (m, 3H), 3.27 (s, 3H), 2.56 (s, 3H) (Figure S15). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 159.6, 156.8, 154.4, 152.9, 148.0, 136.8, 134.8, 130.4, 129.7, 129.5, 128.5, 128.4, 127.9, 127.6, 125.8, 117.6, 115.9, 35.4, 10.2 (Figure S17).

3.1.5 | Synthesis of (1S,2S,N1,N2)-N1,N2-bis((1H-indol-3-yl)methylene)cyclohexane-1,2-diamine (11)

To a solution of indole-3-carbaldehyde (**2**) (3.19 g, 22 mmol) in dried methanol (20 ml) was added a solution of *trans*-cyclohexane-1,2-diamine (**10**) (1.26 g, 11.0 mmol) in methanol (10 ml) slowly via micropipette for 120 min at 80°C. The reaction mixture was stirred overnight at reflux temperature. The reaction progress was monitored by TLC. After cooling to room temperature, the solvent was removed under reduced pressure to yield the viscous oil, which was boiled in hexane (20 ml) then chloroform (10 ml) was added to the solution to yield the yellow solid (3.16 g, 78%). Mp: 199–201°C (decompose). Anal. Calcd for $C_{24}H_{24}N_4$: C, 78.23; H, 6.57. Found: C, 78.19; H, 6.55. FTIR: (υ/cm^{-1}) 2,925, 2,853, 1,622, 1,577, 1,527, 1,499, 1,446, 1,387, 1,340, 1,325, 1,312, 1,294, 1,236, 1,132, 1,121, 1,090, 1,054, 1,006, 9 25, 866, 822, 735 (Figure S22). ^{1}H NMR (400 MHz, DMSO-d6) δ: 11.31 (s, 2H, 2NH), 8.42 (s, 2H), 8.22 (d, J = 8.0 Hz, 2H), 7.54 (s, 2H), 7.34 (d, J = 8.0 Hz, 2H), 7.17–7.00 (m, 4H), 3.25 (d, J = 8.7 Hz, 2H), 1.84 (d, J = 8.0 Hz, 4H), 1.72 (d, J = 8.8 Hz, 2H), 1.50 (t, J = 8.8 Hz, 2H) (Figure S20). ^{13}C NMR (100 MHz, DMSO-d6) δ 154.8, 137.3, 130.4, 125.6, 122.6, 122.3, 120.5, 115.1, 112.0, 74.8, 33.9, 24.8 (Figure S21).

3.1.6 | (1S,2S,N1,N2)-N1,N2-bis((2-methyl-1H-indol-3-yl)methylene)cyclohexane-1,2-diamine (12)

To a solution of 2-methylindoline-3-carbaldehyde (**4**) (3.2 g, 20 mmol) in dry methanol (15 ml) was added trans-1,2-cyclohexane diamine **10** (1.1 g, 10 mmol) in dried methanol (10 ml) slowly via micropipette for 120 min. The reaction mixture was stirred for overnight at reflux temperature. The reaction progress was monitored by TLC for consumption of the starting material. After cooling to room temperature, the mixture was kept in the fridge for 2 hr at +4°C. The yellow solid was filtered under vacuum and washed with cold methanol to yield the product (2.60 g, 68%). mp: 205–206°C. Anal. Calcd for $C_{26}H_{28}N_4$: C, 78.75; H, 7.12. Found: C, 78.77; H, 7.09.FTI R: υ/cm^{-1} 3,393, 2,931, 2,913, 2,856, 2,808, 2,159, 1,633, 1,577, 1,555, 1,488, 1,466, 1,435, 1,382, 1,304, 1,243, 1,179, 1,157, 1,137, 1,096, 1,034, 968, 940, 920, 862, 851, 839, 814, 742 (Figure S27). ^{1}H NMR (400 MHz, DMSO-d6) δ: 11.15 (s, 2H, 2NH), 8.44 (s, 2H), 8.16 (d, J = 4.0 Hz, 2H), 7.22 (d, J = 8.0 Hz, 2H), 7.02 (m, 4H), 3.20 (d, J = 4.0 Hz, 2H), 2.32 (s, 6H), 1.87 (brs, 4H), 1.74 (brs, 2H), 1.50 (brs, 2H) (Figure S23). ^{13}C NMR (100 MHz, DMSO-d6) δ: 154.4, 140.0, 135.8, 126.8, 121.7, 121.5, 120.2, 110.9, 110.4, 75.0, 49.1, 33.9, 24.9 (Figure S26).

4 | ANTIOXIDANT ASSAYS

4.1 | $ABTS^{+\bullet}$ scavenging assay

The treatment of ABTS (2 mM) with potassium persulfate (2.45 mM) yielded the formation of ABTS radical cation, which was kept for 6 hr in dark at room temperature. Afterward, $ABTS^{\bullet+}$ (1.0 ml) was treated with each compound (3.0 ml) at different concentrations. The inhibition was calculated for each concentration relative to a blank absorbance. $ABTS^{\bullet+}$ capacity was calculated by the given equation:

$$ABTS^{\bullet+} \text{ scavenging effect } (\%) = [(A_1 - A_2)/A_1] \times 100$$

in which, A_1 is $ABTS^{\bullet+}$ initial concentration and A_2 is $ABTS^{\bullet+}$ remaining concentration in the sample. The results were calculated as IC_{50}.[26]

4.2 | $DPPH^{\bullet}$ free radical assay

$DPPH^{\bullet}$ scavenging effect of compounds was carried out by the reported procedure.[27] $DPPH^{\bullet}$ solution (0.26 mM, 1.0 ml) was treated with the different concentrations of compounds (3 ml, 2.0–60 μg/ml). The reaction was

carried out at room temperature for 30 s. The absorbance measurement was executed at 517 nm on a spectrophotometer. The DPPH$^{\bullet}$ scavenging activity was calculated using the equation:

$$\text{DPPH}^{\bullet}\text{ scavenging effect}\,(\%) = [(A_1 - A_2)/A_1] \times 100$$

A_1 is the absorbance of the control and A_2 is the absorbance of the sample. The results were calculated as IC_{50}.

4.3 | Reducing power

Initially, Sodium phosphate buffer (0.2 M, pH 6.7) was prepared. Potassium ferricyanide $[K_3Fe(CN)_6]$ (1.25 ml, 1%) was reacted with compounds at different concentrations at 50°C for 30 min and the total volume was completed to 2.5 ml with sodium phosphate buffer solution. The reaction mixture was stirred for 20 min. Trichloroacetic acid (1.25 ml, 10%) and $FeCl_3$ (0.25 ml, 0.1%) were added to the reaction flask. The absorbance measurement was carried out at 700 nm with a spectrophotometer. The high absorbance value of the reaction mixture indicated a high reducing capability.[28]

5 | CONCLUSIONS

Three new (**5, 11, 12**) and three known (**3, 7, 9**) SBs were synthesized efficiently in high yields. The addition of aldehyde slowly into the reaction medium is important for product yield. Due to revealing a good antioxidant activity, the synthesized compounds (**3, 5, 7**) have the potential to be used as synthetic antioxidant agents. Due to the easy synthesis of corresponding compounds, further physical and medicinal properties of corresponding compounds should be investigated.

ORCID

Ramazan Erenler https://orcid.org/0000-0002-0505-3190

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SUPPORTING INFORMATION

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