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THREE-COMPONENT SYNTHESIS OF NEW SUBSTITUTED *BIS*[2-IMINO-3-(SUBSTITUTED)-4-PHENYL-*3H*-THIAZOLE] DERIVATIVES AND EVALUATION OF THEIR ANTIBACTERIAL ACTIVITY

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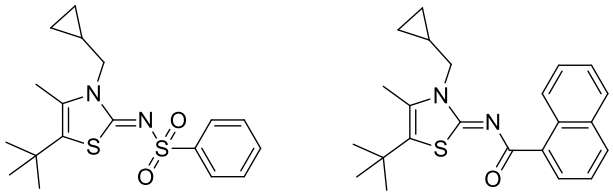
Abstract– Several new derivatives of 2,2'-(4,4'-ethylenebiphenyl)*bis*[2-imino-3-(substituted)-4-phenyl-3*H*-thiazole], 2,2'-(4,4'-biphenylsulfone)*bis*[2-imino-3-(substituted)-4-phenyl-3*H*-thiazole], 2,2'-(4,4'-methylenebiphenyl)*bis*[2-imino-3-(substituted)-4-phenyl-3*H*-thiazole] and 2,2'-(1,4-phenylene)*bis*[2-imino-3-(substituted)-4-phenyl-3*H*-thiazole] derivatives were synthesized by the condensation reaction of various isothiocyanates, diamines, and phenacyl bromide. The one-pot, three-component synthesis of new iminothiazole-containing heterocyles were conducted using catalytic amounts of triethylamine. Furthermore, the target compound **8b** was further determined by X-ray crystallographic analysis. The antimicrobial activity of the synthesized compounds was evaluated against *Salmonella enterica, Micrococcus luteus, Bacillus subtilis* and *Pseudomonas aeruginosa.*

Multicomponent reactions (MCRs) have emerged simple and powerful tools for the synthesis of heterocyclic compounds owing to a wide range of advantages including the formation of multiple bonds in one operation, saving solvents, atom economy, time saving, and simplistic work-up.[1] Thiazoline derivatives exhibit interesting biological characteristics, such as antimicrobial activity,[2] melanin-reducing

activity (KHG22394, whitening agent),[3] antiinflammatory,[4] inhibition of p53-mediated apoptosis and p53-dependent gene transcription (pifithrin-α),[5,6] as well as antifungal activity.[7] For example, iminothiazoline derivative **1** acted as a potent CB_2 receptor agonist (IC_{50}, EC_{50}) and compound **2** high affinity for the human CB_2 receptor (CB_2 IC_{50} = 16 nM) (Figure 1).[8]



1 **2**

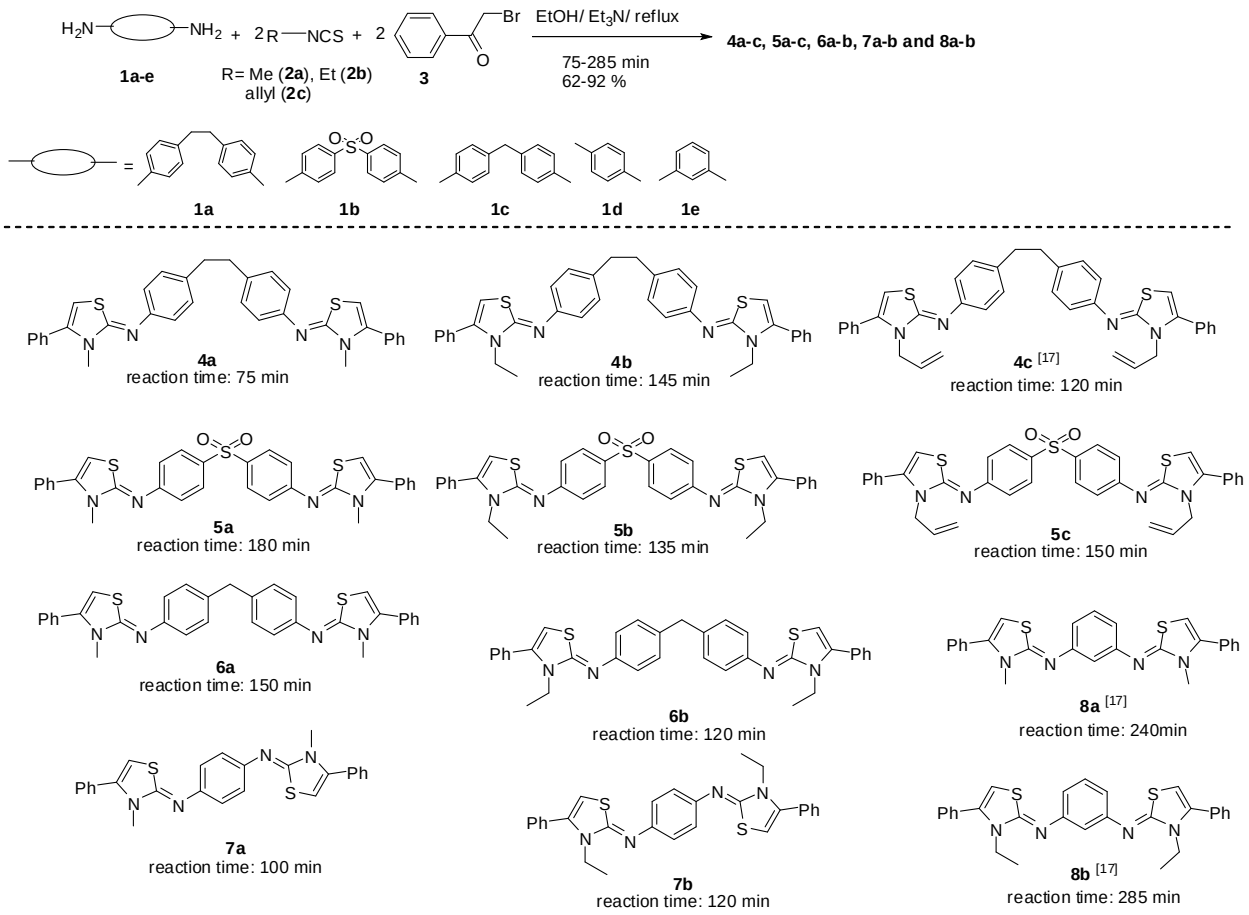
Figure 1. Examples of compounds containing iminothiazole moiety with the human CB_2 receptor activity

The first report on the synthesis of 2-amino-1,3-thiazolines applied the Hantzsch condensation reaction of α-haloketones with thiourea as starting materials.[9,10] In the literature, several alternative methods for the synthesis of thiazolidines and thiazolines have been developed, which include, interamolecular cyclization of *N*-(2-hydroxyethyl)thiourea derivatives in the presence of diethyl azodicarboxylate,[11] potassium thiocyanate with an *α*-bromoketimine,[12] the condensation of carbonyl compounds with thiourea and 1,3-disubstituted thiourea using 1,1'-(ethane-1,2-diyl)dipyridinium bistribromide (EDPBT) as brominating agent,[13] reaction of benzoyl-3-phenyl-thioureas with bromine and either acetone or enolizable ketones in the presence of triethylamine,[14] and solid-phase strategy.[15] Ghorab et al. reported the application of dapsone in syntheses of sulfonylbiscompounds.[16,17] Roussel and co-workers reported a study on atropisomerism in the 2-arylimino-*N*-(2-hydroxyphenyl)thiazoline derivatives and influence of hydrogen bonding on the racemization process.[18] Also, De Kimpe et al. reported the efficient synthesis of 2-imino-1,3-thiazolidines and 2-imino-1,3-thiazolines by ring transformation of 2-(thiocyanomethyl)-aziridines upon treatment with a catalytic amount of titanium (IV) chloride.[19]

To the best of our knowledge, limited attention has been paid to *bis*- heterocyclic compound.[20-22] It seems that *bis*-structure of compounds enhanced pharmacological and biological attributes because of carrying two moieties display greater biological activity than these carrying single moiety. On this basis, we decided to combine two active moieties into one molecule to produce symmetrical *bis*-heterocyclic compounds with ability exhibit enhanced antibacterial activities.[23-25] Recently, we reported a method for the synthesis of 3-allyl-2-(substituted imino)-4-phenyl-3*H*-thiazole and 2,2'-(1,3-phenylene)bis(3-substituted-2-imino-4-phenyl-3*H*-thiazole) derivatives *via* a two-step reaction.[26]

Synthesis and characterization

Although, the synthesis of *N,N'-bis*-1,3-thiazoles have been reported,[27,28] the synthesis of *bis*-(thiazol-2-imine) derivatives *via* one-pot, three-component reaction has not been reported. In the present study, we carried out a one-pot, three component synthesis of novel substituted *bis*(thiazol-2-imine) derivatives by cyclocondensation of diamines (4,4'-ethylenedianiline **1a**, 4,4'-diaminodiphenylsulfone **1b**, 4,4'-methylenedianiline **1c**, 1,4-phenylenediamine **1d**), various substituted isothiocyanates (**2a-c**), and 2-bromoacetophenone (3) under reflux conditions (Scheme **1**). The reaction of diamines **1a-d** (1 mmol), alkyl isothiocyanate **2a-c** (2 mmol) and 2-bromoacetophenone **3** (2 mmol) in the presence of a catalytic amount of Et_3N in refluxing absolute ethanol as solvent for 45-180 min produced 2,2'-(4,4'-ethylenebiphenyl)*bis*[2-imino-3-(substituted)-4-phenyl-3*H*-thiazole] (**4a-c**), 2,2'-(4,4'-biphenylsulfone)*bis*[2-imino-3-(substituted)-4-phenyl-3*H*-thiazole] (**5a-c**), 2,2'-(1,4-phenylene)-*bis*[2-imino-3-(substituted)-4-phenyl-3*H*-thiazole] (**6a-b**), and 2,2'-(4,4'-methylenebiphenyl)*bis*[2-imino-3-(substituted)-4-phenyl-3*H*-thiazole] (**7a-b**).



Scheme 1. One-pot three-component synthesis of bis[2-imino-3-(substituted)-4-phenyl-3*H*-thiazole] derivatives

In order to obtain the optimum reaction conditions, initially, the reaction of 4,4'-ethylenedianiline (**1a**), methyl isothiocyanate (**2a**), and phenacyl bromide (**3**) in absolute ethanol in the presence of catalytic amount of triethylamine (20 mol%) under reflux condition was used as a model reaction. These conditions yielded **4a** in 73% after 75 min. Implementation of the model reaction at room temperature results in the formation of **4a** in 40% yield for 3 h. Satisfactory results were not obtained when the catalytic amounts of triethylamine were used as varying it from 5 mol% to 25 mol%. Derivatives **4-8** were synthesized under the optimized condition. It is very important to note that the corresponding bis-3*H*-thiazoles were obtained in high yields and good regioselectivities. All the compounds shown in Scheme 1 were novel and characterized by spectroscopic methods (IR, ^{1}H NMR and ^{13}C NMR) and elemental analyses. Cyclocondensation was confirmed by the appearance of a singlet in the region of 5-6 ppm for the 3*H*-thiazole moiety in the ^{1}H NMR spectra which correspond to the hydrogen at the 3-position of the thiazole ring. For instance, the characteristic features of the ^{1}H NMR in $CDCl_3$ spectra of **4a** and **7b** were the appearance of singlet at δ 5.81 and 5.76 ppm for hydrogen of the thiazole rings, respectively, indicating a ring closure of thiazole ring.

The structure of **8b** was also confirmed by single-crystal X-ray investigation.[29] The compound crystallized in monoclinic system with space group P 2_1/c, a = 18.3241(15), b = 17.7525(15), c = 7.3532(5) Å, β = 92.331(3)°, Z = 4 and V = 2390.0(3) Å^3. The detailed crystal system and refinement parameters are shown in Table 1.

Table 1. Crystal data of compound **8b**

Crystal system	Monoclinic
Formula	$C_{28}H_{26}N_4S_2$
Formula weight	482.65
Crystal colour	Colorless needle
Wavelength	0.71073 Å
D_{calc}	1.341 Mg/m^3
Crystal size	0.490 × 0.160 × 0.100 mm^3
μ	0.248 mm^{-1}
F	1016
Diffractometer, scan mode	Bruker SMART APEX2 CCD , φ/ω
Absorption correction: (multi-scan)	*SADABS*; Bruker, 2000
Completeness to θ	25.242º
Reflections collected	88745
Independent reflections	4681 [R(int) = 0.3018]
$N(param)_{refined}$:	309
S	1.151
$\Delta\rho_{max}$ e. Å^{-3}	0.300
$\Delta\rho_{min}$	- 0.286
Program	SHELXTL

The molecular structure with the numbering scheme of the compound is shown in Figure 2. The molecule is discrete. The two thiazol-benzene wings attached to the central benzene ring are not symmetrical. The five-membered thiazol rings C7/S1/C8/C9/N2 and C17/S2/C19/C20/N4 make dihedral angle of 45.88(17)°. The two benzene rings (C12-C17) and (C23-C28) are almost perpendicular with each other at an angle of 85.4(2)°. The central benzene ring (C1-C6) makes dihedral angle with the thiazoleC7/S1/C8/C9/N2 and C17/S2/C19/C20/N4 of 56.65(17) and 53.6(2)°, respectively. The azomethine N1-C7 and N3-C18 bond lengths are 1.278(4) and 1.275(4)Å, respectively. Other bond lengths and angles are in normal ranges.

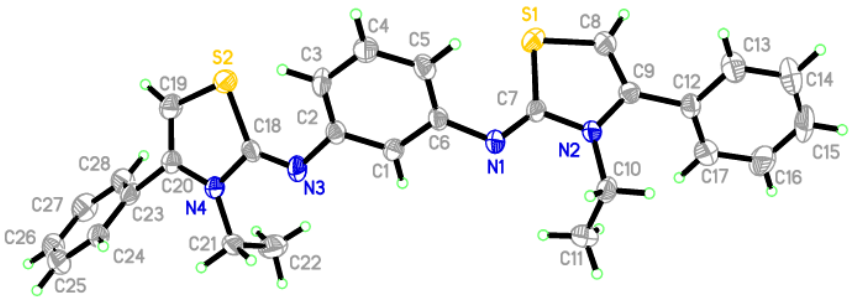


Figure 2. Molecular structure of compound **8b** with numbering scheme drawn at 50% probability ellipsoid

The bond distances d(N2 C9) = 1.394(5) A , d(S1 C7) = 1.763(4) A , d(S1 C8) = 1.732(4) A and d(C8 C9) = 1.329(5) A are in the range reported in the literature.[30,31] In addition, because of steric hindrances, two phenyl groups attached to C9 and C20 are not coplanar with thiazole ring. The ethyl groups that are attached to thiazole rings N2 and N4 atoms indicated bond length d(N2 C10) = 1.458(5) A and d(N4 C21) = 1.460 (5) A, respectively.

Determination of antibacterial activity

Bacterial isolates *Salmonella enterica, Psuedomonas aeruginosa, Bacillus subtilis* and *Micrococcus luteus* were grown on nutrient agar (Merck) plates. Single colonies were aseptically transferred to 3 mL of nutrient broth (Merck) media and allowed to incubate over-night at 37 °C for liquid cultures. The isolates (50 µL) were then inoculated in 3 mL portions of nutrient broth containing 100 µg/mL of the compound. For comparison, the isolates were also grown in the absence of the compounds. The cultures were grown at 37 °C over-night and the absorbance at 600 nm was measured for both types of culture. The effectiveness of the compounds was determined by calculating the increase or decrease in growth of

isolates in the presence or absence of the compounds in percentage terms. Tetracycline, Penicillin and Vancomycin were used as positive controls. The results are shown in Table 2.

Table 2. Percentage of bacterial growth in presence of compounds (100 μg/mL) as compared to growth in the absence of the compounds

Compound	*S. enterica*	*M. luteus*	*B. subtilis*	*P. aeruginosa*
4a	65	14	26	69
4b	57.1	12.3	47	73
4c	6	10	28	23
5a	22.4	17.3	24.5	63
5b	18.0	14.0	43	25.7
5c	14	16	13.5	24
6a	56	37	57	0
6b	44.5	9	54.6	60.5
7a	48	18	36	32.0
7b	41	22	19.5	53
8a	45	49	53	64
8b	38	56	42	49.5
Tetracycline	0	0	0	0
Penicillin	0	35	0	0
Vancomycin	0	0	68	0

Several points can be deduced from the results shown in Table 2. Firstly, Gram negative bacteria (*Salmonella enterica* and *Psuedomonas aeruginosa*) are more resistant to the compounds synthesized, and this is expected since these organisms have a two-layered phosopholipid membrane, whereas Gram positive bacteria (*Bacillus subtilis* and *Micrococcus luteus*) have one layer. Furthermore, the lipopolysaccharide layer present on the surface of Gram negative bacteria presents a barrier to efficient attachment of chemicals to the bacterial surface. Secondly, all the synthesized compounds had some effect on bacterial growth, which is significant. Thirdly, compound **4c** was the most effective chemical and inhibited bacterial growth completely against *Salmonella enterica* and *Micrococcus luteus*.

The presence of the allyl group is probably a contributing factor, although determination of the interaction between the chemical and the bacterial surface requires detailed studies. Fifth, total inhibition of *Psuedomonas aeruginosa* growth by compounds **6a** and **6c** is significant and merits further investigation, mainly due to the fact that this bacterium is one of the more resistant bacteria present in nature.

In conclusion, we have described one-pot, three-component synthesis of substituted *bis*(thiazol-2-imine) derivatives *via* a regioselective cyclocondensation reaction of diamine, phenacyl bromide, and various isothiocyantes in the presence of Et_3N as catalyst under refluxing conditions. Compound **4c** exhibited efficient antibacterial effects against *Salmonella enterica* and *Micrococcus luteus*. It is probable that these new and valuable products will exhibit other types of biological activities. The regioselectivity of reaction was also confirmed by X-ray structure of compound **8b**.

EXPERIMENTAL

Material and methods

Chemicals were purchased from Fluka, Merck and Aldrich Chemical companies. All commercially available chemicals and reagents were used without further purification. Melting points were determined with an Electrothermal model 9100 apparatus and are uncorrected. FT-IR spectra were recorded on a Shimadzu 8400S spectrophotometer. The NMR spectra were recorded on a Bruker AVANCE DMX400 spectrometer, operating at 400 MHz (^{1}H NMR) and 100 MHz (^{13}C NMR). The chemical shift values are expressed in ppm relative to TMS as an internal standard. Elemental analyses were recorded with a CHN model 2400 Perkin-Elmer and agreed with the calculated values. The antimicrobial activity of the synthesized compounds was evaluated on *Salmonella enterica, Micrococcus luteus, Bacillus subtilis* and *Pseudomonas aeruginosa.*

General procedure for the synthesis of 4-8. To a mixture of diamine (1 mmol) and isothiocyanate (2 mmol) in EtOH (5 mL) under reflux, phenacyl bromide (2 mmol) and (0.2 mmol) of Et_3N were added. After completion of the reaction, as indicated by TLC, the mixture was cooled to room temperature and was poured into ice bath. The synthesized solid was filtered and washed with EtOH, and then crystallized from EtOH-H_2O (1:1) to obtain the pure products **4-8**. The physical and spectral data of the purified compounds are as follows.

2,2'-(4,4'-Ethylenebiphenyl)bis(3-methyl-2-imino-4-phenyl-3*H*-thiazole) (4a): Yield 73%; yellow solid; mp 214-216 °C; FT-IR (KBr) (ν_{max}/cm^{-1}): 3062, 2991, 2932, 2856, 2830, 1618, 1595, 1512, 1419, 1366, 1240, 1028, 838, 702. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ 2.93 (s, 4H), 3.39 (s, 6H), 5.81 (s, 2H), 7.05 (d,

4H, *J* = 8.0 Hz), 7.16 (d, 4H, *J* = 8.0 Hz), 7.41 (t, 4H, *J* = 4.8 Hz), 7.46 (d, 6H, *J* = 4.8 Hz); ^{13}C-NMR ($CDCl_3$, 100 MHz): δ 33.5, 37.6, 95.5, 1214, 128.6, 128.7, 129.0, 129.2, 131.5, 136.7, 140.5, 149.2, 160.7 ppm; Anal. Calcd for $C_{34}H_{30}N_4S_2$ (558.76) C, 73.08; H, 5.41; N, 10.02. Found: C, 73.05; H, 5.45; N, 10.05%.

2,2'-(4,4'-Ethylenebiphenyl)bis(3-ethyl-2-imino-4-phenyl-3*H*-thiazole) (4b): Yield 89%; yellow solid; mp 169-171 °C; FT-IR (KBr) (ν_{max}/cm^{-1}): 3058, 3029, 3003, 2922, 2851, 1616, 1520, 1448, 1319, 1223, 1001, 819, 686. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ 1.22 (t, 6H, *J* = 7.2 Hz), 3.90 (q, 4H, *J* = 7.2 Hz), 4.64 (s, 4H), 5.68 (s, 2H), 7.03(d, 4H, *J* = 8.0 Hz), 7.17 (d, 4H, *J* = 8.0 Hz), 7.40-7.48 (m, 10H); ^{13}C-NMR ($CDCl_3$, 100 MHz): δ 13.5, 37.7, 40.3, 95.6, 121.3, 128.6, 129.0, 129.5, 132.0, 136.5, 140.1, 149.6, 159.4 ppm; Anal. Calcd for $C_{36}H_{34}N_4S_2$ (586.82) C, 73.68; H, 5.84; N, 9.54. Found: C, 73.64; H, 5.87; N, 9.58%.

2,2'-(4,4'-Biphenylsulfone)bis(3-methyl-2-imino-4-phenyl-3*H*-thiazole) (5a): Yield 65%; yellow solid; mp 193-195 °C; FT-IR (KBr) ($\nu_{max/cm-1}$): 3100, 2910, 1619, 1591, 1577, 1500, 1420, 1360, 1292, 1140, 1100, 980, 815, 760, 698. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ 3.38 (s, 6H), 5.89 (s, 2H), 7.20 (d, 4H, *J* = 7.6 Hz), 7.38 (t, 4H, *J* = 3.2 Hz), 7.48 (d, 6H, *J* = 3.2 Hz), 7.85 (d, 4H, *J* = 7.6 Hz); ^{13}C-NMR ($CDCl_3$, 100 MHz): δ_c: 33.5, 95.9, 114.1, 119.1, 121.8, 128.8, 128.9, 129.6, 131.1, 140.6, 150.6 ppm; Anal. Calcd for $C_{32}H_{26}N_4S_3O_2$ (594.77) C, 64.62; H, 4.40; N, 9.41. Found: C, 64.59; H, 4.37; N, 9.45%.

2,2'-(4,4'-Biphenylsulfone)bis(3-ethyl-2-imino-4-phenyl-3*H*-thiazole) (5b): Yield 69%; yellow solid; mp 182-183 °C; FT-IR (KBr) ($\nu_{max/cm-1}$): 3096, 3059, 2960, 2926, 2856, 1627, 1593, 1500, 1437, 1382, 1280, 1142, 1103, 1071, 1004, 830, 694. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ 1.20 (t, 6H, *J* = 6.8 Hz), 3.88 (q, 4H, *J* = 6.8 Hz), 5.83 (s, 2H), 7.19 (d, 4H, *J* = 7.8 Hz), 7.38-7.48 (m, 10H), 7.85 (d, 4H, *J* = 7.8 Hz) ppm; Anal. Calcd for $C_{34}H_{30}N_4S_3O_2$ (622.82) C, 65.56; H, 4.85; N, 8.99. Found: C, 65.59; H, 4.87; N, 8.95%.

2,2'-(4,4'-Biphenylsulfone)bis(3-allyl-2-imino-4-phenyl-3*H*-thiazole) (5c): Yield 64%; yellow solid; mp 119-121 °C; FT-IR (KBr) ($\nu_{max/cm-1}$): 3068, 2960, 2918, 1619, 1595, 1439, 1382, 1280, 1147, 1098, 1075, 833, 698. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ 4.44 (m,4H), 5.01 (d, 2H, *J* = 17.2 Hz), 5.16 (d, 2H, *J* = 10.4 Hz), 5.86 (s, 2H), 5.90-5.98 (m, 2H), 7.18 (d, 4H, *J* = 10.8 Hz), 7.54-7.70 (m, 10H), 7.86 (d, 4H, *J* = 10.8 Hz) ppm; Anal. Calcd for $C_{36}H_{30}N_4S_3O_2$ (646.85) C, 66.84; H, 4.67; N, 8.66. Found: C, 66.80; H, 4.72; N, 8.63%.

2,2'-(4,4'-Methylenebiphenyl)bis(3-methyl-2-imino-4-phenyl-3*H*-thiazole) (6a): Yield 62%; yellow solid; mp 158-159 °C; FT-IR (KBr) (ν_{max}/cm^{-1}): 3057, 2918, 1685, 1616, 1577, 1560, 1521, 1446, 1355, 1002, 752, 686. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ 3.82 (s, 6H), 4.61 (s, 4H), 5.36 (s, 2H), 6.67 (d, 4H, *J* = 7.6 Hz), 7.06 (d, 4H, *J* = 7.6 Hz), 7.50-7.61 (m, 10H); ^{13}C-NMR ($CDCl_3$, 100 MHz): δ 20.6,, 40.1, 96.5, 113.2,

126.0, 128.5, 128.9, 129.7, 131.3, 133.8, 134.9, 145.2, 158.0 ppm; Anal. Calcd for $C_{33}H_{28}N_4S_2$ (544.73) C, 72.76; H, 5.18; N, 10.28. Found: C, 72.73; H, 5.21; N, 10.30%.

2,2'-(4,4'-Methylenebiphenyl)bis(3-ethyl-2-imino-4-phenyl-3*H*-thiazole) (6b): Yield 71%; yellow solid; mp 169-171 °C; FT-IR (KBr) (ν_{max}/cm^{-1}): 3057, 2920, 1685, 1616, 1521, 1560, 1521, 1446, 1355, 1002, 752, 686. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ 1.51 (t, 6H, *J* = 7.4 Hz), 3.82 (q, 4H, *J* = 7.4 Hz), 4.62 (s, 4H), 5.36 (s, 2H), 6.68 (d, 4H, *J* = 6.8 Hz), 7.06 (d, 4H, *J* = 6.8 Hz), 7.51-7.61 (m, 10H) ppm; Anal. Calcd for $C_{35}H_{32}N_4S_2$ (572.79) C, 73.39; H, 5.63; N, 9.78. Found: C, 73.42; H, 5.59; N, 9.80%.

2,2'-(1,4-Phenylene)bis(3-methyl-2-imino-4-phenyl-3*H*-thiazole) (7a): Yield 85%; yellow solid; mp 267-269 °C; FT-IR (KBr) ($\nu_{max/cm-1}$): 3068, 2924, 1608, 1574, 1566, 1496, 1417, 1365, 1240, 1056, 981, 883, 700, 495. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ 3.39 (s, 6H), 5.81 (s, 2H), 7.13 (s, 4H), 7.40-7.48 (m, 10H) ppm; Anal. Calcd for $C_{26}H_{22}N_4S_2$ (454.61) C, 68.69; H, 4.87; N, 12.32. Found: C, 68.74; H, 4.90; N, 12.27%.

2,2'-(1,4-Phenylene)bis(3-ethyl-2-imino-4-phenyl-3*H*-thiazole) (7b): Yield 92%; yellowish solid; mp 254-256 °C; FT-IR (KBr) ($\nu_{max/cm-1}$): 3072, 2931, 1615, 1577, 1560, 1498, 1382, 1321 1236, 1076, 1004, 881, 763, 698. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ 1.24 (t, 6H, *J* = 7.2 Hz), 3.91 (q, 4H, *J* = 7.2 Hz), 5.76 (s, 2H), 7.12 (s, 4H), 7.41-7.49 (m, 10H); ^{13}C-NMR ($CDCl_3$, 100 MHz): δ 13.6, 40.4, 95.7, 122.5, 128.7, 128.9, 129,0, 132.1, 140.1, 147.2, 159.4 ppm; Anal. Calcd for $C_{28}H_{26}N_4S_2$ (482.66) C, 69.67; H, 5.42; N, 11.60. Found: C, 69.64; H, 5.44; N, 11.63%.

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29. *X-Ray data for* ***8b***: ($C_{28}H_{26}N_4S_2$), M = 482.65 g/mol, monoclinic system, space group P $2_1/c$, a = 18.3241(15) Å, b = 17.7525(15) Å, c = 7.3532(5) Å, β = 92.331(3)°, V = 2390.0(3) $Å^3$, Z = 4, D_c= 1.341 Mg/m^3, μ = 0.248 mm^{-1}, Crystal size = 0.490 × 0.160 × 0.100 mm^3. The structure was solved by using SHELXS. The structural refinement was carried out with SHELXL. The

non-hydrogen atoms were refined anisotropically by full-matrix least-squares on F^2 values to final R_1 = 0.0949, wR_2 = 0.1267and S = 1.151 with 309 parameters using 4681 independent reflection (θ range = 3.001 to 26.000°). Reflections collected were 88745. The hydrogen atoms were placed in calculated positions. No decomposition was observed during data collection. All hydrogen atoms were refined isotropically in riding model with $U_{iso}(H) = 1.2\ U_{eq}(C)$. Crystallographic data for the structural determination has been deposited with the Cambridge Crystallographic Data Centre, CCDC No 1019271. This information may be obtained free of charge at http://www.ccdccam.ac.uk/const/retrieving.html or from the Cambridge Crystallographic Centre (CCDC), 12 Union Road, Cambridge CB2, 1EZ, UK. Fax: +44 1223 336033 or e-mail: deposite@ccdc.cam.ac.uk.

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