

Synthesis of Some New 4,5-Substituted-4H-1,2,4-triazole-3-thiol Derivatives

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Abstract: In this study appropriate hydrazide compounds, furan-2-carboxylic acid hydrazide (**1**) and phenylacetic acid hydrazide (**2**) were converted into 1,4-substituted thiosemicarbazides **4a-e** and **5a-e** and 4-amino-5-(furan-2-yl or benzyl)-4H-1,2,4-triazole-3-thiols **7** and **10**. The 1,4-substituted thiosemicarbazides were then converted into 5-(furan-2-yl or benzyl)-4-(aryl)-4H-1,2,4-triazole-3-thiols **8a-e** and **9a-e**. In addition, the azomethines **11a-d** and **12a-d** were prepared from the corresponding arylaldehydes and the 4-amino-5-(furan-2-yl or benzyl)-4H-1,2,4-triazole-3-thiols **7** and **10**. The structures of all the synthesized compounds were confirmed by elemental analyses, IR, ¹H-NMR and ¹³C-NMR spectra.

Keywords: 4H-1,2,4-triazole-3-thiols; azomethines; thiosemicarbazides.

Introduction

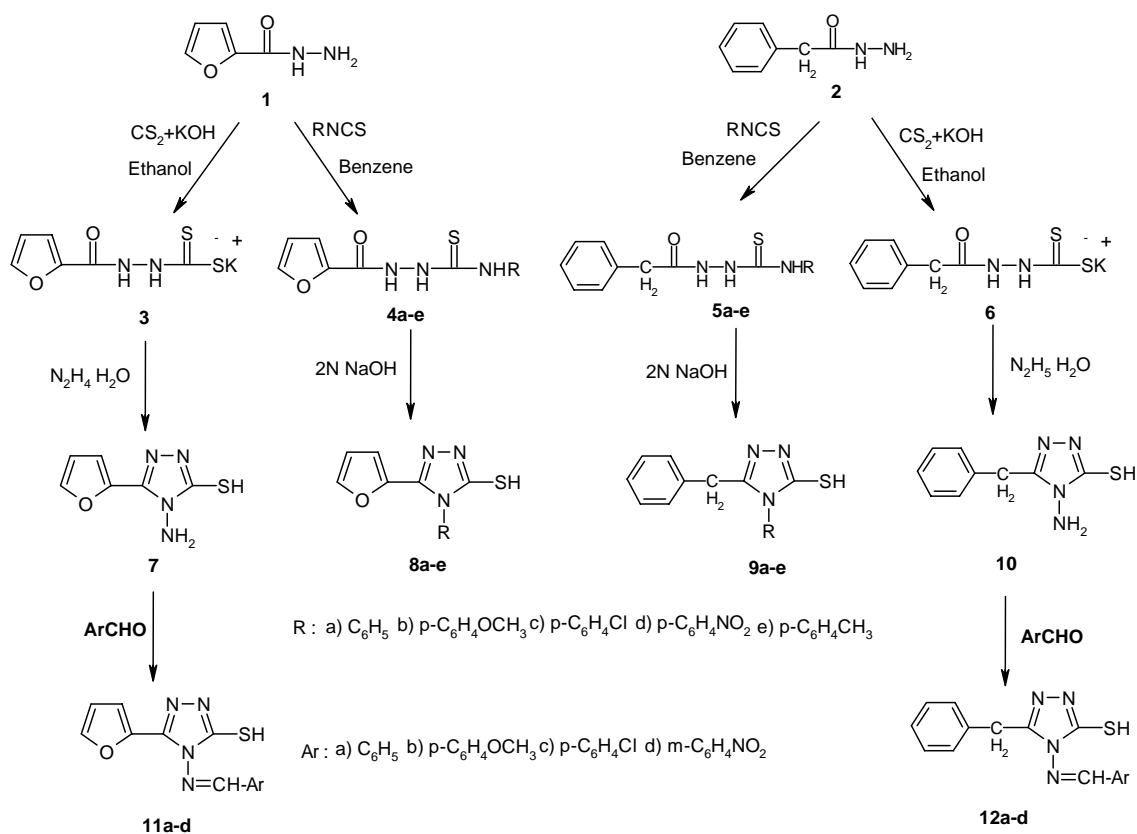
Derivatives of 1,2,4-triazole are known to exhibit anti-inflammatory [1,2], antiviral [3], analgesic [4], antimicrobial [5-7], anticonvulsant [8] and antidepressant activity [9], the latter being usually explored by the forced swim test [10,11]. Among the pharmacological profiles of 1,2,4-triazoles, their antimicrobial, anticonvulsant and antidepressant properties seem to be the best documented. New changing problems in plant protection technology have promoted research to discover more efficient pesticides. In particular the development of herbicides, now an unavoidable means to selectively control

the growth of weeds, resulted in a whole range of azoles exhibiting high levels of activity, application flexibility, crop tolerance and low levels of toxicity to mammals. Triazoles play an important role among this class of heterocycles. A series of 1,2,4-triazole derivatives [11] have been patented and extensively employed in agriculture. We now report the synthesis of 20 original compounds derived from furan-2-carboxylic acid hydrazide and phenylacetic hydrazide with the purpose of investigating in the future their possible antibacterial and antifungal activity.

Results and Discussion

The new derivatives were prepared following the reaction sequences depicted in Scheme 1. Initial compounds were prepared from available furan-2-carboxylic acid hydrazide (**1**), and phenylacetic acid hydrazide (**2**). Potassium 3-(2-furoyl) or (phenylacetyl) dithiocarbazates **3**, **6** were prepared by reaction of compounds **1** and **2** with carbon disulfide in ethanolic potassium hydroxide. 1-(2-Furoyl or phenylacetyl)-4-substituted thiosemicarbazides **4a-e** and **5a-e** were prepared in yields ranging from 88 to 95% by the condensation of **1** and **2** with arylisothiocyanates. Ring closure of arylthiosemicarbazides in an alkaline medium is a well known method for the synthesis of 1,2,4-triazoles, and 5-(furan-2-yl or benzyl)-4-(aryl)-4H-1,2,4-triazole-3-thiols **8a-e** and **9a-e** were obtained in 62-79% yields from the respective **4a-e**, **5a-e** by this method. Compounds **7** and **10** were obtained from the reaction of **3** and **6** with hydrazide hydrate under reflux in solution. When an arylaldehyde was added to **7** or **10** in ethanol, the reactions gave **11a-d**, **12a-d**.

Scheme 1



The IR spectra of the 1,4-substituted-thiosemicarbazide derivatives **4a-e**, **5a-e** have C=O stretching bands at 1687-1672 cm^{-1} and C=S stretching bands at 1290-1250 cm^{-1} . The N-H protons of **4a-e**, **5a-e** were observed at 9.20-10.15 ppm, (O=C-NH-NH-C=S) and 8.00-8.25 ppm (S=C-NH-Ar). Compounds **7**, **8a-e**, **9a-e**, **10**, **11a-d**, **12a-d** exist as thiol-thione tautomers as indicated by their IR spectra which showed a band due to SH and four bands due to N-C=S I, II, III, IV. The azomethine derivatives **11a-d**, **12a-d** were characterized by the presence of the methine protons (N=CH) at 9.18-10.33 ppm. The data of all the compounds are given in the Experimental section.

Experimental

General

Melting points were determined in open capillary tubes on a digital Gallenkamp melting point apparatus and are uncorrected. The IR spectra were recorded for KBr disks with a Mattson 1000 FT-IR spectrometer. $^1\text{H-NMR}$ spectra were recorded on a FX 90 JEOL 90 MHz NMR, spectrometer in CDCl_3 + DMSO-d_6 with TMS as an internal standard. Elemental analyses were done on a LECO-CHNS-938. Starting materials were obtained from Fluka or Aldrich.

General Procedure for Preparation of Potassium 3-(2-furoyl) or (phenylacetyl)dithiocarbazates **3** and **6**.

Carbon disulfide (0.15 mole) was added to a solution of potassium hydroxide (0.15 mole), absolute ethanol (200 mL) and the appropriate furan-2-carboxylic acid hydrazide (**1**) or phenylacetic acid hydrazide (**2**) (0.10 mole). This mixture was diluted with absolute ethanol (150 mL) and agitated for 12-18 hours. It was then diluted with dry ether (250 mL) and the products were filtered off and vacuum dried at 65 °C. The salts prepared as described above were obtained in nearly quantitative yields and were used without further purification.

Potassium-3-(2-furoyl)dithiocarbazate (3): m.p. 222-225 °C; IR ν (cm^{-1}): 3450, 3310 (N-H), 1639 (C=O), 1270 (C=S), 1248 (C-O-C).

Potassium-3-(Phenylacetyl)dithiocarbazate (6): m.p. 212-255 °C; IR ν (cm^{-1}): 3375, 3225 (N-H), 1670 (C=O), 1275 (C=S), 1250 (C-O-C).

General procedure for Preparation of **4a-e**, **5a-e**.

A mixture of **1** (or **2**) (0.01 mole) and the appropriate aryl isothiocyanate (0.01 mole) in dry C_6H_6 was refluxed for 6 hours. The solid material obtained on cooling was filtered off and recrystallized from methanol.

1-(2-furoyl)-4-Phenylthiosemicarbazide (4a): From phenylisothiocyanate, yield 92%; m.p. 184-185 °C; IR ν (cm^{-1}): 3365, 3315 (N-H), 1672 (C=O), 1274 (C=S), 1251 (C-O-C); $^1\text{H-NMR}$ δ (ppm): 6.68-7.20 (m, 3H, furan), 7.42-7.92 (m, 5H, Ar-H), 8.11-8.19 (br, 1H, -NH-Ar), 9.20-9.92 (br, 2H, 2xNH). Calcd. for $\text{C}_{12}\text{H}_{11}\text{N}_3\text{O}_2\text{S}$ (261); (%): C, 55.16; H, 4.24; N, 16.08; S, 12.27; found (%): C, 55.27; H, 4.11, N, 15.97; S, 12.13.

1-(2-furoyl)-4-(4-methoxyphenyl)thiosemicarbazide (4b): From *p*-methoxyphenylisothiocyanate, yield 93%; m.p. 162-163 °C; IR ν (cm^{-1}): 3355, 3320 (N-H), 1678 (C=O), 1271 (C=S), 1253 (C-O-C); $^1\text{H-NMR}$ δ (ppm): 3.79 (s, 3H, -O-CH₃), 5.90-6.20 (m, 3H, furan), 6.55-6.90 (m, 4H, Ar-H), 8.21-8.25 (br, 1H, -NH-Ar), 9.21-9.92 (br, 2H, 2xNH). Calcd. for $\text{C}_{13}\text{H}_{13}\text{N}_3\text{O}_3\text{S}$ (291); (%): C, 53.60; H, 4.50; N, 14.42; S, 11.01; found (%): C, 53.45; H, 4.51, N, 14.47; S, 10.98.

1-(2-furoyl)-4-(4-chlorophenyl)thiosemicarbazide (4c): From *p*-chlorophenylisothiocyanate, yield 90%; m.p. 188-189 °C; IR ν (cm^{-1}): 3354, 3321 (N-H), 1673 (C=O), 1268 (C=S), 1249 (C-O-C); $^1\text{H-NMR}$ δ (ppm): 6.67-7.21 (m, 3H, furan), 7.22-7.90 (m, 4H, Ar-H), 8.18-8.20 (br, 1H, -NH-Ar), 9.71-10.02 (br, 2H, 2xNH). Calcd. for $\text{C}_{12}\text{H}_{10}\text{ClN}_3\text{O}_2\text{S}$ (295); (%): C, 48.74; H, 3.41; N, 14.21; S, 10.84; found (%): C, 48.45; H, 3.43, N, 14.17; S, 10.88.

1-(2-furoyl)-4-(4-nitrophenyl)thiosemicarbazide (4d): From *p*-nitrophenylisothiocyanate, yield 95%; m.p. 210-211 °C; IR ν (cm^{-1}): 3344, 3311 (N-H), 1422 (NO₂), 1679 (C=O), 1274 (C=S), 1254 (C-O-C); $^1\text{H-NMR}$ δ (ppm): 6.70-7.28 (m, 3H, furan), 7.56-7.76 (m, 4H, Ar-H), 8.00-8.14 (br, 1H, -NH-Ar), 9.21-10.11 (br, 2H, 2xNH). Calcd. for $\text{C}_{12}\text{H}_{10}\text{N}_4\text{O}_4\text{S}$ (306); (%): C, 47.06; H, 3.29; N, 18.29; S, 10.47; found (%): C, 47.10; H, 3.23, N, 18.27; S, 10.40.

1-(2-furoyl)-4-(4-methylphenyl)thiosemicarbazide (4e): From *p*-methylphenylisothiocyanate, yield 91%; m.p. 165-167 °C; IR ν (cm^{-1}): 3449, 3321 (N-H), 1683 (C=O), 1269 (C=S), 1241 (C-O-C); $^1\text{H-NMR}$ δ (ppm): 2.28 (s, 3H, CH₃), 6.71-7.26 (m, 3H, furan), 7.54-7.72 (m, 4H, Ar-H), 8.20-8.25 (br, 1H, -NH-Ar), 9.97-10.15 (br, 2H, 2xNH). Calcd. for $\text{C}_{13}\text{H}_{13}\text{N}_3\text{O}_2\text{S}$ (275); (%): C, 56.71; H, 4.76; N, 15.26; S, 11.65; found (%): C, 56.54; H, 4.71, N, 14.97; S, 11.64.

1-Phenylacetyl-4-phenylthiosemicarbazide (5a): From phenylisothiocyanate, yield 94%; m.p. 160-161 °C; IR ν (cm^{-1}): 3450, 3310 (N-H), 1687 (C=O), 1290 (C=S); $^1\text{H-NMR}$ δ (ppm): 3.35 (s, 2H, CH₂), 7.30-7.44 (m, 10H, Ar-H), 8.21-8.23 (br, 1H, -NH-Ar), 9.95-10.11 (br, 2H, 2xNH). Calcd. for $\text{C}_{15}\text{H}_{15}\text{N}_3\text{OS}$ (285); (%): C, 63.13; H, 5.30; N, 14.72; S, 11.24; found (%): C, 63.09; H, 5.35, N, 14.67; S, 11.19.

1-Phenylacetyl-4-(4-methoxyphenyl)thiosemicarbazide (5b): From *p*-methoxyphenylisothiocyanate, yield 92%; m.p. 157-159 °C; ν (cm^{-1}): 3452, 3312 (N-H), 1686 (C=O), 1274 (C=S); $^1\text{H-NMR}$ δ (ppm): 3.39 (s, 2H, CH₂), 4.25 (s, 3H, -O-CH₃), 6.77-7.30 (m, 9H, Ar-H), 8.11-8.13 (br, 1H, -NH-Ar),

9.98-10.13 (br, 2H, 2xNH). Calcd. for C₁₆H₁₇N₃O₂S (315); (%): C, 60.93; H, 5.43; N, 13.32; S, 10.47; found (%): C, 61.01; H, 5.25, N, 13.32; S, 10.49.

1-Phenylacetyl-4-(4-chlorophenyl)thiosemicarbazide (5c): From *p*-chlorophenylisothiocyanate, yield 90%; m.p. 164-165 °C; IR ν (cm⁻¹): 3482, 3317 (N-H), 1675 (C=O), 1267 (C=S); ¹H-NMR δ (ppm): 3.40 (s, 2H, CH₂), 7.31-7.44 (m, 9H, Ar-H), 8.13-8.17 (br, 1H, -NH-Ar), 10.11-10.13 (br, 2H, 2xNH). Calcd. for C₁₅H₁₄ClN₃OS (319); (%): C, 56.33; H, 4.41; N, 13.14; S, 10.03; found (%): C, 56.21; H, 4.39, N, 13.12; S, 9.99.

1-Phenylacetyl-4-(4-nitrophenyl)thiosemicarbazide (5d): From *p*-nitrophenylisothiocyanate, yield 93%; m.p. 187-188 °C; IR ν (cm⁻¹): 3451, 3322 (N-H), 1672 (C=O), 1266 (C=S); ¹H-NMR δ (ppm): 3.74 (s, 2H, CH₂), 7.37-7.87 (m, 9H, Ar-H), 8.19-8.22 (br, 1H, -NH-Ar), 10.13-10.15 (br, 2H, 2xNH). Calcd. for C₁₅H₁₄N₄O₃S (330); (%): C, 54.54; H, 4.27; N, 16.96; S, 9.71; found (%): C, 54.41; H, 4.29, N, 17.01; S, 9.69.

1-Phenylacetyl-4-(4-methylphenyl)thiosemicarbazide (5e): From *p*-methylphenylisothiocyanate, yield 88%; m.p. 160-161 °C; IR ν (cm⁻¹): 3450, 3329 (N-H), 1678 (C=O), 1250 (C=S); ¹H-NMR δ (ppm): 2.28 (s, 3H, CH₃), 3.53 (s, 2H, CH₂), 7.30-7.45 (m, 9H, Ar-H), 8.17-8.24 (br, 1H, -NH-Ar), 10.13-10.15 (br, 2H, 2xNH). Calcd. for C₁₆H₁₇N₃OS (299); (%): C, 64.19; H, 5.72; N, 14.03; S, 10.71; found (%): C, 64.11; H, .69, N, 14.01; S, 10.59.

General Procedure for the Preparation of Compounds 7 and 10.

A suspension of the potassium salt **3** (or **6**) (20 mmoles), 95 % hydrazine (40 mmoles) and water (2 mL) was refluxed with stirring for 0.5 to 1 hours. The color of the reaction mixture changed to green, hydrogen sulfide was evolved and a homogeneous solution resulted. A white solid was precipitated by dilution with cold water (100 mL) and acidification with concentrated hydrochloric acid. This product was filtered, washed with cold water (2x30 mL) and recrystallized from ethanol or ethanol-water.

4-Amino-5-furan-2-yl-4H-1,2,4-triazole-3-thiol (7): Yield 45%; m.p. 202-203 °C; IR ν (cm⁻¹): 3329 (N-H), 2775 (SH), 1618 (C=N), 1238 (C-O-C), 1533, 1262, 1051, 952 (N-C=S, amide I, II, III and IV bands); ¹H-NMR δ (ppm): 5.80 (s, 2H, NH₂), 6.70-7.91 (m, 3H, furan), 13.89 (s, 1H, SH); ¹³C-NMR δ : 111.89, 11398, 139.90, 142.83, 145.20, 156.54. Calcd. for C₆H₆N₄OS (182); (%): C, 39.55; H, 3.32; N, 30.75; S, 17.60; found (%): C, 39.49; H, 3.39, N, 31.01; S, 17.59.

4-Amino-5-benzyl-4H-1,2,4-triazole-3-thiol (10): Yield 53%; m.p. 207-209 °C; IR ν (cm⁻¹): 3337 (N-H), 2350 (SH), 1620 (C=N), 1535, 1260, 1050, 950 (N-C=S, amide I, II, III and IV bands); ¹H-NMR δ (ppm): 5.01 (s, 2H, NH₂), 5.41 (s, 2H, CH₂), 6.72-7.02 (m, 5H, Ar-H), 13.01 (s, 1H, SH); ¹³C-NMR δ : 35.41,

111.89, 113.98, 125.71, 127.91, 128.31, 139.90, 141.54, 142.83, 145.20, 156.54. Calcd. for C₉H₁₀N₄S (206); (%): C, 52.41; H, 4.89; N, 27.16; S, 15.54; found (%): C, 52.49; H, 4.87, N, 27.25.01; S, 15.59.

General Procedure for the Preparation of Compounds **8a-e** and **9a-e**.

A stirring mixture of compound **4a** (or **4b-e**, **5a-e**) (1 mmole) and sodium hydroxide (40 mg, 1 mmole, as a 2N solution) was refluxed for 4 hours. After cooling, the solution was acidified with hydrochloric acid and the precipitate was filtered. The precipitate was then crystallized from ethanol.

5-Furan-2-yl-4-phenyl-4H-1,2,4-triazole-3-thiol (8a): Yield 68%; m. p. 210-212 °C; IR ν (cm⁻¹): 3321, 3250 (N-H), 2575 (SH), 1604 (C=N), 1249 (C-O-C), 1535, 1260, 1054, 948 (N-C=S, amide I, II, III and IV bands); ¹H-NMR δ (ppm): 5.97-6.34 (m, 3H, furan), 7.45-7.55 (m, 5H, Ar-H), 13.04 (s, 1H, SH). Calcd. for C₁₂H₉N₃OS (243); (%): C, 59.24; H, 3.73; N, 17.27; S, 13.18; found (%): C, 58.99; H, 3.69, N, 17.25; S, 13.19.

5-Furan-2-yl-4-(4-methoxyphenyl)-4H-1,2,4-triazole-3-thiol (8b): Yield 78%; m. p. 245-246 °C; IR ν (cm⁻¹): 3331, 3258 (N-H), 2564 (SH), 1618 (C=N), 1250 (C-O-C), 1538, 1259, 1048, 948 (N-C=S, amide I, II, III and IV bands); ¹H-NMR δ (ppm): 3.88 (s, 3H, OCH₃), 5.95-6.38 (m, 3H, furan), 7.09-7.55 (m, 4H, Ar-H), 14.00 (s, 1H, SH). Calcd. for C₁₃H₁₁N₃O₂S (273); (%): C, 57.13; H, 4.06; N, 15.37; S, 11.73; found (%): C, 57.19; H, 3.99, N, 15.25; S, 11.79.

4-(4-Chlorophenyl)-5-Furan-2-yl)-4H-1,2,4-triazole-3-thiol (8c): Yield 72%; m. p. 264-265 °C; IR ν (cm⁻¹): 3351, 3288 (N-H), 2564 (SH), 1625 (C=N), 1250 (C-O-C), 1535, 1260, 1050, 950 (N-C=S, amide I, II, III and IV bands); ¹H-NMR δ (ppm): 6.16-6.50 (m, 3H, furan), 7.45-7.78 (m, 4H, Ar-H), 13.98 (s, 1H, SH). Calcd. for C₁₂H₈ClN₃OS (273); (%): C, 51.90; H, 2.90; N, 15.13; S, 11.54; found (%): C, 51.88; H, 2.99, N, 15.15; S, 11.49.

4-(4-Nitrophenyl)-5-Furan-2-yl)-4H-1,2,4-triazole-3-thiol (8d): Yield 62%; m. p. 187-188 °C; IR ν (cm⁻¹): 3341, 3280 (N-H), 2580 (SH), 1625 (C=N), 1250 (C-O-C), 1528 (NO₂), 1537, 1263, 1057, 952 (N-C=S, amide I, II, III and IV bands); ¹H-NMR δ (ppm): 5.91-6.95 (m, 3H, furan), 7.51-8.08 (m, 4H, Ar-H), 12.98 (s, 1H, SH). Calcd. for C₁₂H₈N₄O₃S (288); (%): C, 50.00; H, 2.80; N, 19.43; S, 11.12; found (%): C, 50.08; H, 2.89, N, 19.50; S, 11.15.

5-Furan-2-yl-4-(4-methylphenyl)-4H-1,2,4-triazole-3-thiol (8e): Yield 79%; m. p. 257-258 °C; IR ν (cm⁻¹): 3351, 3285 (N-H), 2576 (SH), 1621 (C=N), 1250 (C-O-C), 1534, 1258, 1050, 951 (N-C=S, amide I, II, III and IV bands); ¹H-NMR δ (ppm): 2.46 (s, 3H, CH₃), 5.94-6.36 (m, 3H, furan), 7.31-7.47 (m, 4H, Ar-H), 14.01 (s, 1H, SH). Calcd. for C₁₃H₁₁N₃OS (257); (%): C, 60.68; H, 4.31; N, 16.33; S, 12.46; found (%): C, 60.65; H, 4.39, N, 16.50; S, 12.42.

5-Benzyl-4-phenyl-4H-1,2,4-triazole-3-thiol (9a): Yield 73%; m. p. 197-198 °C; IR ν (cm^{-1}): 3344, 3282 (N-H), 2548 (SH), 1620 (C=N), 1535, 1263, 1050, 951 (N-C=S, amide I, II, III and IV bands); $^1\text{H-NMR}$ δ (ppm): 3.81 (s, 2H, CH_2), 7.10-7.45 (m, 10H, Ar-H), 13.81 (s, 1H, SH). Calcd. for $\text{C}_{15}\text{H}_{13}\text{N}_3\text{S}$ (267); (%): C, 67.39; H, 4.90; N, 15.72; S, 11.99; found (%): C, 67.38; H, 4.87, N, 15.65; S, 12.09.

5-Benzyl-4-(4-methoxyphenyl)-4H-1,2,4-triazole-3-thiol (9b): Yield 79%; m.p. 177-178 °C; IR ν (cm^{-1}): 3344, 3282 (N-H), 2570 (SH), 1606 (C=N), 1538, 1260, 1050, 950 (N-C=S, amide I, II, III and IV bands); $^1\text{H-NMR}$ δ (ppm): 3.80 (s, 2H, CH_2), 3.88(s, 3H, OCH_3), 6.95-7.25 (m, 9H, Ar-H), 13.06 (s, 1H, SH). Calcd. for $\text{C}_{16}\text{H}_{15}\text{N}_3\text{OS}$ (297); (%): C, 64.62; H, 5.08; N, 14.13; S, 10.78; found (%): C, 64.58; H, 4.97, N, 14.09; S, 10.72.

5-Benzyl-4-(4-chlorophenyl)-4H-1,2,4-triazole-3-thiol (9c): Yield 73%; m.p. 187-188 °C; IR ν (cm^{-1}): 3354, 3292 (N-H), 2580 (SH), 1606 (C=N), 1535, 1260, 1050, 950 (N-C=S, amide I, II, III and IV bands); $^1\text{H-NMR}$ δ : 3.84 (s, 2H, CH_2), 6.94-7.42 (m, 9H, Ar-H), 12.96 (s, 1H, SH). Calcd. for $\text{C}_{15}\text{H}_{12}\text{ClN}_3\text{OS}$ (301); (%): C, 59.70; H, 4.01; N, 13.92; S, 10.62; found (%): C, 59.58; H, 4.07, N, 14.00; S, 10.62.

5-Benzyl-4-(4-nitrophenyl)-4H-1,2,4-triazole-3-thiol (9d): Yield 63%; m.p. 210-211 °C; IR ν (cm^{-1}): 3354, 3291 (N-H), 2550 (SH), 1616 (C=N), 1535, 1260, 1050, 950 (N-C=S, amide I, II, III and IV bands); $^1\text{H-NMR}$ δ (ppm): 3.90 (s, 2H, CH_2), 6.92-8.29 (m, 9H, Ar-H), 14.01 (s, 1H, SH). Calcd. for $\text{C}_{15}\text{H}_{12}\text{NO}_2\text{S}$ (312); (%): C, 57.68; H, 3.87; N, 17.94; S, 10.27; found (%): C, 57.58; H, 3.87, N, 18.00; S, 10.27.

5-Benzyl-4-(4-methylphenyl)-4H-1,2,4-triazole-3-thiol (9e): Yield 71%; m.p. 182-183 °C; IR ν (cm^{-1}): 3358, 3290 (N-H), 2550 (SH), 1605 (C=N), 1538, 1262, 1050, 950 (N-C=S, amide I, II, III and IV bands); $^1\text{H-NMR}$ δ (ppm): 2.42 (s, 3H, CH_3), 3.81 (s, 2H, CH_2), 6.97-7.29 (m, 9H, Ar-H), 12.91 (s, 1H, SH). Calcd. for $\text{C}_{16}\text{H}_{15}\text{N}_3\text{S}$ (312); (%): C, 68.30; H, 5.37; N, 14.93; S, 11.40; found (%): C, 63.38; H, 5.37, N, 15.00; S, 11.47.

General Procedure for the Preparation of Compounds 11a-d and 12a-d.

A mixture of **7** (or **10**) (0.01 mole) and the corresponding aryl aldehyde (0.01 mole) in ethanol (25 mL) was treated with concentrated HCl (0.5 mL) and refluxed for 2 hours. The reaction mixture on cooling was filtered and recrystallized from ethanol.

4-(Benzylideneamino)-5-furan-2-yl-4H-1,2,4-triazole-3-thiol (11a): Prepared from benzaldehyde, yield 59%; m.p. 197-198 °C; IR ν (cm^{-1}): 3329 (N-H), 2625 (SH), 1630 (C=N), 1238 (C-O-C), 1535, 1262, 1051, 952 (N-C=S, amide I, II, III and IV bands); $^1\text{H-NMR}$ δ (ppm): 6.57-7.23 (m, 3H, furan), 7.55-7.97 (m, 5H, Ar-H), 10.18 (s, 1H, N=CH), 13.19 (s, 1H, SH). Calcd. for $\text{C}_{13}\text{H}_{10}\text{N}_4\text{OS}$ (270); (%): C, 57.76; H, 3.73; N, 20.73; S, 11.86; found (%): C, 57.69; H, 3.71, N, 20.69; S, 11.89.

5-furan-2-yl-4-[(4-methoxybenzylidene)amino]-4H-1,2,4-triazole-3-thiol (11b): Prepared from *p*-methoxybenzaldehyde, yield 53%; m.p. 205-206 °C; IR ν (cm⁻¹): 3339 (N-H), 2525 (SH), 1630 (C=N), 1238 (C-O-C), 1545, 1262, 1050, 950 (N-C=S, amide I, II, III and IV bands); ¹H-NMR δ (ppm): 3.87 (s, 3H, OCH₃), 5.57-6.74 (m, 3H, furan), 7.07-7.97 (m, 4H, Ar-H), 9.18 (s, 1H, N=CH), 12.99 (s, 1H, SH). Calcd. for C₁₄H₁₂N₄O₂S (300); (%): C, 55.99; H, 4.03; N, 18.65; S, 10.68; found (%): C, 56.01; H, 3.99, N, 18.69; S, 10.67.

4-[(4-Chlorobenzylidene)amino]-5-furan-2-yl-4H-1,2,4-triazole-3-thiol (11c): Prepared from *p*-chlorobenzaldehyde, yield 59%; m.p. 225-226 °C; IR ν (cm⁻¹): 3359 (N-H), 2558 (SH), 1633 (C=N), 1238 (C-O-C), 1535, 1260, 1050, 950 (N-C=S, amide I, II, III and IV bands); ¹H-NMR δ (ppm): 5.71-6.84 (m, 3H, furan), 7.06-7.98 (m, 4H, Ar-H), 9.98 (s, 1H, N=CH), 13.99 (s, 1H, SH). Calcd. for C₁₃H₉ClN₄OS (304); (%): C, 51.24; H, 2.98; N, 18.38; S, 10.52; found (%): C, 51.19; H, 3.00, N, 18.41; S, 10.55.

4-[(3-Nitrobenzylidene)amino]-5-furan-2-yl-4H-1,2,4-triazole-3-thiol (11d): Prepared from *m*-nitrobenzaldehyde, yield 51%; m.p. 165-166 °C; IR ν (cm⁻¹): 3369 (N-H), 2563 (SH), 1631 (C=N), 1238 (C-O-C), 1535, 1260, 1050, 950 (N-C=S, amide I, II, III and IV bands); ¹H-NMR δ (ppm): 2.40 (s, 3H, CH₃), 5.82-6.72 (m, 3H, furan), 7.40-8.71 (m, 4H, Ar-H), 10.08 (s, 1H, N=CH), 13.97 (s, 1H, SH). Calcd. for C₁₃H₉N₅O₃S (315); (%): C, 49.52; H, 2.88; N, 22.21; S, 10.17; found (%): C, 49.59; H, 3.00, N, 22.29; S, 10.25.

5-Benzyl-4-(benzylideneamino)-4H-1,2,4-triazole-3-thiol (12a): Prepared from benzaldehyde, yield 43%; m.p. 177-178 °C; IR ν (cm⁻¹): 3350 (N-H), 2558 (SH), 1610 (C=N), 1535, 1260, 1050, 950 (N-C=S, amide I, II, III and IV bands); ¹H-NMR δ (ppm): 4.18 (s, 2H, CH₂), 7.28-7.90 (m, 10H, Ar-H), 10.31 (s, 1H, N=CH), 12.99 (s, 1H, SH). Calcd. for C₁₆H₁₄N₄S (294); (%): C, 65.28; H, 4.79; N, 19.03; S, 10.89; found (%): C, 65.30; H, 4.81, N, 18.99.; S, 10.84.

5-Benzyl-4-[(4-methoxybenzylidene)amino]-4H-1,2,4-triazole-3-thiol (12b): Prepared from *p*-methoxybenzaldehyde, yield 53%; m.p. 191-192 °C; IR ν (cm⁻¹): 3354 (N-H), 2566 (SH), 1605 (C=N), 1535, 1260, 1050, 950 (N-C=S, amide I, II, III and IV bands); ¹H-NMR δ (ppm): 4.16 (s, 2H, CH₂), 4.21 (s, 3H, OCH₃), 6.93-7.86 (m, 9H, Ar-H), 10.02 (s, 1H, N=CH), 12.79 (s, 1H, SH). Calcd. for C₁₇H₁₆N₄S (324); (%): C, 62.94; H, 4.97; N, 17.27; S, 9.88; found (%): C, 63.00; H, 4.96, N, 17.29.; S, 9.86.

5-Benzyl-4-[(4-chlorobenzylidene)amino]-4H-1,2,4-triazole-3-thiol (12c): Prepared from *p*-chlorobenzaldehyde, yield 58%; m.p. 205-206 °C; IR ν (cm⁻¹): 3355 (N-H), 2561 (SH), 1625 (C=N), 1533, 1261, 1050, 950 (N-C=S, amide I, II, III and IV bands); ¹H-NMR δ (ppm): 4.17 (s, 2H, CH₂), 7.27-7.96 (m, 9H, Ar-H), 10.33 (s, 1H, N=CH), 13.79 (s, 1H, SH). Calcd. for C₁₆H₁₃ClN₄S (328); (%): C, 58.44; H, 3.98; N, 17.04; S, 9.75; found (%): C, 58.39; H, 3.96, N, 17.09.; S, 9.71.

5-Benzyl-4-[(3-nitrobenzylidene)amino]-4H-1,2,4-triazole-3-thiol (**12d**): Prepared from *m*-nitrobenzaldehyde, yield 69%; m.p. 181-182 °C; IR ν (cm⁻¹): 3359 (N-H), 2563 (SH), 1621 (C=N), 1538, 1260, 1050, 950 (N-C=S, amide I, II, III and IV bands); ¹H-NMR δ (ppm): 2.44 (s, 3H, CH₃), 4.15 (s, 2H, CH₂), 7.27-7.96 (m, 9H, Ar-H), 10.33 (s, 1H, N=CH), 13.91 (s, 1H, SH). Calcd. for C₁₆H₁₃N₅S (339); (%): C, 56.63; H, 3.86; N, 20.64; S, 9.45; found (%): C, 56.69; H, 3.96; N, 20.69.; S, 9.41.

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